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# AQUATIC BIOLOGICAL ASSESSMENT

## OF THE

# RED RIVER, NEW MEXICO, IN THE VICINITY OF THE QUESTA MOLYBDENUM MINE

April 1997

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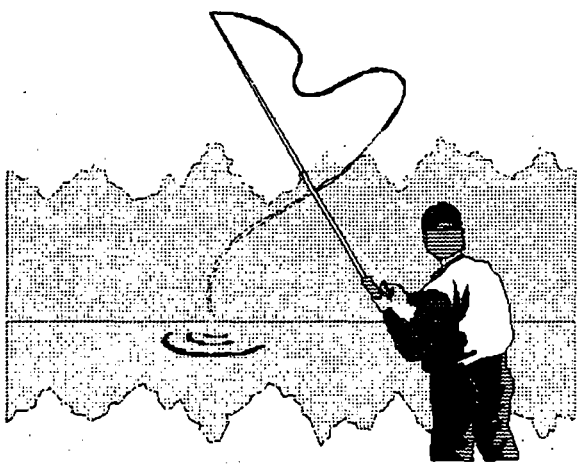
**CHADWICK ECOLOGICAL CONSULTANTS, INC.**

# AQUATIC BIOLOGICAL ASSESSMENT

## OF THE

# RED RIVER, NEW MEXICO, IN THE VICINITY OF THE QUESTA MOLYBDENUM MINE

Prepared for:

MOLYCORP, Inc.
Questa, New Mexico

April 1997

Prepared by:

CHADWICK ECOLOGICAL CONSULTANTS, INC.
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Littleton, Colorado 80120

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## INTRODUCTION

The purpose of this report is to assess the aquatic biological conditions in the Red River in the vicinity of the Molycorp, Inc. Questa Molybdenum Mine. More specifically, the objective is to evaluate the impact of the open pit mine and waste rock piles on the fish and benthic invertebrate populations of the Red River.

The Questa Molybdenum Mine began operations in 1919, using underground mining methods (Schilling 1990). Late in 1965 the mine initiated open pit mining operations, and continued until 1983 (Slifer 1996). Tailings from the mill are piped down the valley to tailings ponds near Questa (Fig. 1). Waste rock was deposited near the open pit on Molycorp property in areas drained by Spring Gulch, Sulphur Gulch, Goathill Gulch, and Capulin Canyon. Claims have been made that the open pit mining operations and waste rock dumps have had a detrimental effect on the aquatic biota of the Red River adjacent to and downstream of this portion of the Molycorp property (Slifer 1996). The focus of this report is to evaluate whether the open pit mine and waste rock dumps have in the past, or are now, actually causing a measurable negative impact to the fish and benthic invertebrate populations in this section of the Red River.

The approach taken in this report is to review all available historical data on the fish and benthic invertebrate populations of the Red River, from upstream of the Town of Red River downstream to its confluence with the Rio Grande River (Fig. 1). In addition, fish population sampling in the Red River was conducted by Chadwick Ecological Consultants, Inc., on March 31 through April 3, 1997. This recent information is also included in this report.

The scope of this report is limited to the interpretation of the available aquatic biological data relative to assessing the impacts of the open pit and the waste rock dumps. For the purposes of this report, the baseline period refers to the period prior to 1966. Fish data collected in 1960 by the New Mexico Department of Game and Fish (NMDGF 1960) and benthic invertebrate data collected in 1965 by the U.S. Department of Health, Education and Welfare (USDHEW 1966) provide "baseline" data for temporal comparisons to evaluate the potential impacts of the open pit mining operations.

The most recent data, defining "present" conditions, include the fish data collected during March 31 through April 3, 1997, by Chadwick Ecological Consultants, Inc. (presented in this report), and benthic invertebrate data collected in December, 1995, by New Mexico Environmental Department (NMED) personnel and analyzed for Molycorp by Woodward-Clyde (1996). These two sets of data represent present conditions as defined in this report.

The most recent data are compared to the baseline data to evaluate the present day impact of the inactive open pit mine and waste rock piles on the aquatic biota. Data from the intervening years was used to further evaluate longitudinal trends in the aquatic biota, to assess past impacts of open pit mining operations, and to aid in the explanation of temporal trends between the 1960's and the 1990's.

The historic and present data indicate that trout species comprise the vast majority of fish in the Red River. Therefore, trout species are the focus of this report. Potential impacts to trout populations can be grouped into two general categories: physical impacts to habitat, and chemical impacts to water quality. Physical impacts indirectly affect trout by rendering the habitat of a river more, or less, suitable for trout, through channel alterations such as channelization, widening of a channel, disruption of the substrate, the addition of sediment, etc. In the case of the Red River, the most likely physical impact appears to be sedimentation and increased total suspended solids (TSS). Sedimentation involves the introduction of fine-grained soil particles into a stream (sand, silt, clay). In addition, particulate metal precipitate can also settle on the stream bottoms. These small particles and precipitate clog the interstitial spaces between larger rock particles (gravel, cobble, boulders) causing the larger rock particles to become "embedded." This renders the substrate unsuitable for the incubation of trout eggs, and can also render the substrate unsuitable for trout food—benthic invertebrates (Waters 1995). Turbid water (due to suspended solids or precipitate) also may reduce the visibility and impair the ability of trout to feed and may result in other sub-lethal effects (Johnson *et al.* 1987, McLeay *et al.* 1987, Farnworth *et al.* 1979, Rosenberg and Snow 1975, Gammon 1970, Wallen 1951). In effect, sedimentation may not be toxic to trout themselves, but may limit the suitability of the habitat for sustaining trout.

Water quality may affect trout populations through direct toxicity to individual trout. In less severe cases, sub-lethal effects of water quality may also occur, resulting in reduced reproduction, reduced health

of individual trout, and avoidance by trout of sections of river that have elevated levels of chemical constituents (Atchison *et al.* 1987, Giattina *et al.* 1982, Sprague 1968).

Benthic invertebrates are excellent indicators of water quality in a river. Benthic invertebrate populations have characteristics that render them very useful in interpreting the magnitude and form of water quality impacts (Rosenberg and Resh 1993, Heliövaara and Väisänen 1993, DeShon 1995, Bode and Novak 1995). For example, benthic invertebrate populations are commonly comprised of several dozen different taxa, each with different tolerances to water quality constituents. The presence or absence of individual taxa allows an interpretation of the source of a water quality impact. Also, invertebrates are not very mobile and must endure the short-term water quality changes that occur in a section of river, unlike fish which can migrate long distances in a short period to avoid water quality changes. Also, invertebrates commonly have a life cycle of one to two years; their populations and community structure integrate the water quality history that occurs over this period. Finally, invertebrates are relatively easy to sample and identify, making them suitable for field studies, replicate sampling, and statistical evaluations.

Benthic invertebrates are commonly used to monitor stream systems where man-made disturbance has the potential to degrade water quality (Chadwick *et al.* 1986, Chutter 1969, Nelson and Roline 1993). Common responses to these disturbances can include decreased total abundance, decreased number of species, and a shift from a community of sensitive species to a community of tolerant species (Chutter 1969, Clements 1994). Sensitive species in mountain stream communities include mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), which are referred to as the "EPT" taxa (Plafkin *et al.* 1989). Tolerant stream species can include some species of midges (Chironomidae) and segmented worms (Oligochaeta).

Physical impacts directly affect benthic invertebrates by precluding their survival in the substrate of the river bottom. Physical impacts that directly affect invertebrates include sedimentation, high flows, high TSS, desiccation, disruption of the substrate, etc. In the case of the Red River, the most likely physical impact appears to be sedimentation. Benthic invertebrates generally live in the interstitial spaces between larger sized bottom substrate particles (gravel, cobble, boulders). As these interstitial spaces become filled with sediment (sand, silt, clay, precipitate), the substrate is no longer suitable for sustaining many species

of benthic invertebrates (Waters 1995). Sediment impacts to benthic invertebrate populations usually result in lower density of invertebrates (Waters 1995, Culp *et al.* 1986, Rosenberg and Snow 1975), but the number and diversity of taxa sometimes remains relatively high (Farnworth *et al.* 1979). The number of taxa may remain high because there are usually a few interstitial spaces that remain open, especially in faster-flowing riffle sections of a river, which can support invertebrates.

Water quality may also directly affect benthic invertebrate populations through toxicity to individual invertebrates. Water quality impacts usually result in lower density, and possibly lower number of taxa, of invertebrates; although in some cases where dissolved metals are elevated, diversity indices can remain relatively high (Chadwick and Canton 1984, Chadwick *et al.* 1986). Impacts to water quality can also reduce the number of sensitive EPT taxa (Clements 1994).

## HISTORICAL DATA SOURCES

### Fish Data

Listed below are the available historical fish data sources included in this report. The list includes the year of data collection, a brief description of the document, and the literature citation of the document. The majority of the fish data were collected by NMDGF.

| Date | Topic | Citation |
|---|---|---|
| 1960 | Stream Survey Forms | NMDGF (1960) |
| 1974 | Memo to R.L. Brashears, dated 24 October 1974 | Patterson (1974) |
| 1975 | Memo to Bob Patterson, dated 10 November 1975 | Parish (1975a) |
| 1976 | Memo to Red River File, dated 19 July 1976 | Parish (1976a) |
| | Memo to Red River File, dated 8 September 1976 | Parish (1976b) |
| 1977 | Memo to Jim Yarbrough, dated 22 April 1977 | Parish (1977a) |
| | Memo to Jim Yarbrough, dated 9 May 1977 | Parish (1977b) |
| 1978 | Memo to Bob Patterson, dated 19 July 1978 | Parish (1978a) |
| | Memo to Bob Patterson, dated 13 September 1978 | Parish (1978b) |
| 1979 | Memo to Herb Garn, dated December 3, 1979 | Parish (1979) |
| 1980 | U.S. EPA Water Quality Assessment | Melancon *et al.* (1982) |
| 1981 | Memo to Mike Hatch, dated 29 October 1984 | Akroyd (1984) |

| Date | Topic | Citation |
|---|---|---|
| 1983 | Memo to Dick McCleskey, dated 20 September 1983 | Patterson (1983) |
| 1984 | Memo to Dick McCleskley, dated 29 February 1984 | Patterson (1984) |
| 1984 | Memo to Mike Hatch, dated 29 October 1984 | Akroyd (1984) |
| 1985 | Memo to Mike Hatch, dated 21 August 1985 | Akroyd (1985) |
| 1986 | Memo to Mike Hatch, dated 5 January 1987 | Akroyd (1987a) |
| 1987 | Memo to Mike Hatch, dated 6 October 1987 | Akroyd (1987b) |
| 1988 | Memo to Michael Hatch, dated 29 November 1988 | Akroyd (1988) |
| 1995 | New Mexico Dept. of Game and Fish Performance Report | Akroyd (1996) |
| 1996 | New Mexico Dept. of Game and Fish Performance Report | Akroyd (1997) |

**Benthic Invertebrate Data**

Listed below are the available historical benthic invertebrate data sources included in this report. The list includes the year of data collection, a brief description of the document, and the literature citation. The benthic invertebrate data sources include a variety of different agencies and organizations.

| Date | Topic | Citation |
|---|---|---|
| 1960 | Stream Survey Forms | NMDGF (1960) |
| 1965 | Water Quality Survey | USDHEW (1966) |
| 1970 | Water Quality Survey | USEPA (1971) |
| 1971 | Limnological Report to Molycorp | Pennak (1972) |
| 1976 | Limnological Report to Molycorp | Pennak (1976) |
| 1977 | Limnological Report to Molycorp, March | Pennak (1977a) |
| | Limnological Report to Molycorp, October | Pennak (1977b) |
| 1978 | Limnological Report to Molycorp | Pennak (1978) |
| 1979 | Limnological Report to Molycorp | Pennak (1979) |
| 1980 | Site Specific Water Quality Assessment | Melancon *et al.* (1982) |
| 1981 | Limnological Report to Molycorp | Pennak (1981) |
| 1982 | Limnological Report to Molycorp | Pennak (1983) |
| 1983 | Limnological Report to Molycorp | Pennak (1984) |
| 1984 | Intensive Survey of the Red River | Jacobi and Smolka (1984) |
| 1985 | Intensive Survey of the Red River | Smolka and Jacobi(1986) |
| 1986 | Intensive Survey of the Red River | Smolka and Tague (1987) |
| 1988 | Aquatic EcoSystem Survey | ENSR (1988) |
| 1988 | Intensive Survey of the Red River | Smolka and Tague (1989) |
| 1992 | Special Water Quality Survey | Smolka (1993) |

## STUDY AREA

The study area of this report includes the Red River from its headwaters to the confluence with the Rio Grande. The Molycorp Questa Molybdenum Mine is adjacent to the north bank of the Red River in its middle reaches, between the towns of Red River and Questa (Fig. 1).

### Reach Descriptions

In order to organize the available historical fish and benthic invertebrate data, the Red River has been segmented into six reaches (Fig. 1). These reaches are used to group data for historical sampling sites into distinct, biologically significant parts of the river which contain roughly similar characteristics of channel morphology, habitat, potential impacts, etc. This allows a more focused interpretation of the historical data. Descriptions of the six reaches that follow are based on several field trips in March 1997 by Chadwick Ecological Consultants, Inc. personnel.

#### Upstream of Red River

This reach the Red River includes its headwaters downstream to the Town of Red River. There is some residential development in this portion of the river, in the form of vacation homes (e.g. Valley of the Pines subdivision) and commercial lodges, but not to the extent present in the Town of Red River. Stream shading from coniferous trees and shrubs is extensive in this reach. Stream flows are lower compared to downstream reaches, and the water is clear (Fig. 2). We observed that the stream substrate in this reach exhibited little accumulation of fine silt and sand, with low embeddedness. Water depths are variable in this reach, with a mixture of shallow riffle areas and deeper runs and pools (Fig. 3). This reach provides good habitat for the different age classes of trout. For example, young trout require the shallow areas to feed and to escape predators. The older, larger trout, in contrast, require deeper water for cover and to maintain position in the stream. The reach upstream of the Town of Red River provides this habitat variability.

**FIGURE 2:** Red River just upstream of the Town of Red River, New Mexico, March 18, 1997.

**FIGURE 3:** Red River at upstream end of the Town of Red River, March 18, 1997.

Red River to Hansen Creek

This reach extends from the Town of Red River downstream to just upstream of the confluence with Hansen Creek. Field observations in March 1997 indicated that this section begins to exhibit a reduction in water clarity and an increase in sediment deposition. Bitter Creek contains historical mining operations and natural hydrothermal scars, which apparently contribute sediment to the Red River. Channelization in some areas in the Town of Red River straightens the stream channel and decreases the variability in stream depths (Fig. 4). Water is still reasonably clear in the portion of this reach in town. Downstream of the Town of Red River, water clarity decreases (Fig. 5), due to factors which include non-point source runoff from the Town of Red River, erosion from highway banks and other disturbed areas, the outfall of the town's sewage treatment facility, and runoff from the natural hydrothermal scar drained by Hot-n-Tot Creek (Fig. 6). The substrate in the portion of this reach downstream of town becomes more embedded compared to the uppermost reach, apparently due to these natural and man-made impacts. Downstream of the Town of Red River, water depths become more variable compared to sections in town, providing potential habitat for the various age classes of trout. Shading from trees is limited in the section of the river near town, but increases in the section downstream of town.

**FIGURE 4:** Red River in the downstream end of the Town of Red River, March 5, 1997.

**FIGURE 5:** Red River just downstream of the Town of Red River, March 26, 1997.

**FIGURE 6:** Culvert under Highway 38 for Hot-n-Tot Creek, March 18, 1997.

Hansen Creek to Molycorp Boundary

This reach extends from the confluence with Hansen Creek downstream to the eastern edge of the Molycorp property boundary. Observations indicated a further reduction in water clarity in this reach. Water depths are variable, providing a mix of shallow riffle areas and deeper runs and pocket pools. Shading in this reach is comparable to the reach upstream of the Town of Red River. The major characteristic of this reach is the inflow of Hansen Creek, which drains a large area of hydrothermal scarring (Fig. 7). Runoff from this scarring carries sediment into the Red River, creating a relatively large alluvial fan (Fig. 8). We observed that the introduced sediment dramatically increases embeddedness and decreases water clarity, essentially covering many of the larger substrate particles in areas of reduced water velocities immediately downstream of Hansen Creek (Figs. 9 and 10).

In addition to sediment inputs from Hansen Creek, Hansen Spring also apparently introduces substances to the Red River in this reach. This spring is located in an overflow channel adjacent to the Red River, and appeared to input directly into the Red River. Its channel contained a very evident white precipitate (Fig. 11).

**FIGURE 7:** Hansen Creek and hydrothermal scar upstream of Highway 38, March 18, 1997.

**FIGURE 8:** Hansen Creek alluvial fan at confluence with Red River, March 18, 1997.

**FIGURE 9:** Red River just downstream of Hansen Creek, March 5, 1997.

**FIGURE 10:** Red River downstream of Hansen Creek near Hansen Spring, March 18, 1997.

**FIGURE 11:** Hansen Spring in overflow channel of Red River, March 18, 1997.

Molycorp Boundary to Capulin Canyon

This reach extends from the eastern Molycorp property boundary downstream to just upstream of the confluence with Capulin Canyon. Water depths in this reach are a combination of shallow riffles and deeper runs and plunge pools. Substrate particles are larger in this reach compared to upstream reaches, being dominated by large cobble. Observations of the stream channel indicated embeddedness is considerably higher than in the reach upstream of town, but not as high as in the reach just downstream from Hansen Creek. Similar to the next two upstream reaches, water clarity is reduced (Fig. 12). The discolored appearance of the water observed in the reach below Hansen Creek and Hansen Spring is also evident in this reach.

This reach contains the confluence with Columbine Creek, which joins the Red River from the south side of the valley. Columbine Creek is a small, clear stream (Fig. 13) that apparently acts to dilute the compounds present in the Red River.

**FIGURE 12:** Red River at Goathill Campground downstream of Columbine Creek, March 5, 1997.

**FIGURE 13:** Columbine Creek upstream of confluence with Red River, March 25, 1997.

Capulin Canyon to Questa

This reach extends from the confluence with Capulin Canyon downstream to just upstream of the confluence with Cabresto Creek, near the town of Questa. As with the reach from Hansen Creek to the Molycorp eastern property boundary, a major feature in this reach is a natural hydrothermal scar; in this case, the one drained by Capulin Canyon. Field observations in March 1997 indicated that the mouth of Capulin Canyon is similar to Hansen Creek in appearance, with loose sediment deposited in the channel. Capulin Springs also enter the Red River in this reach. These seeps also apparently introduce substances to the Red River, including those producing white precipitate.

Water in this reach continues to exhibit reduced clarity (Figs. 14 and15). The predominantly cobble substrate exhibits sedimentation in the channel, but not as much as the two reaches immediately upstream. Water depths provide a mix of shallow and deeper areas, and cover consisting of overhanging banks and pocket water is present. Stream shading is provided by willows and pines along this reach.

**FIGURE 14:** Red River 0.5 mi downstream of Capulin Springs, upstream of the Questa Ranger Station, March 5, 1997.

**FIGURE 15:** Red River just upstream of Cabresto Creek, March 5, 1997.

Questa to Rio Grande

This reach extends from the confluence with Cabresto Creek, near the town of Questa, downstream to the confluence of the Red River and the Rio Grande. At the upper end of this reach, Cabresto Creek (Fig. 16) adds clear, diluting flows to the Red River. The river valley widens at Questa, and portions of this reach through Questa have areas of unstable stream banks (Fig. 17), which contribute to less variability in water depths compared to downstream portions of this reach. The cobble substrate exhibits less embeddedness compared to the other reaches downstream of the Town of Red River. The river valley subsequently narrows again upstream of the state fish hatchery, and remains a narrow canyon down to the Rio Grande.

Water clarity near the fish hatchery appeared to be somewhat better than the reaches immediately upstream, with less of a milky white color. The outfall from the hatchery also acts as a dilution effect to the Red River (Fig. 18).

Water depths are more variable, with deeper pool habitat in the section of this reach from just upstream of the hatchery downstream to the Rio Grande. Although shading from trees is less than that of upstream reaches, the steep canyon walls in the lower half of this section provide shading.

**FIGURE 16:** Cabresto Creek upstream of the Red River, March 5, 1997.

**FIGURE 17:** Red River downstream of the Highway 522 bridge, March 25, 1997.

**FIGURE 18:** Red River at the Red River Fish Hatchery, March 5, 1997.

**Site Descriptions**

Fish collection study sites sampled by Chadwick Ecological Consultants, Inc., in the spring of 1997 are described below and are included in Fig. 19. Study sites from historical fish studies are also briefly described below. Due to the large number of historical study sites, they are not individually shown on the figures, but have been grouped into the distinct, biologically significant reaches of river as shown (Figs. 1 and 19).

1997 Fish Data Collection

Elevations for the portion of the Red River sampled in the present study ranged from approximately 8,900 feet upstream from the Town of Red River down to approximately 7,120 feet, at a point 0.3 miles upstream from the diversion for the Red River fish hatchery. Stream gradients within the study reach are highest upstream from the Town of Red River, moderate from the Town of Red River downstream to Questa, and lowest from the town of Questa downstream to near the fish hatchery.

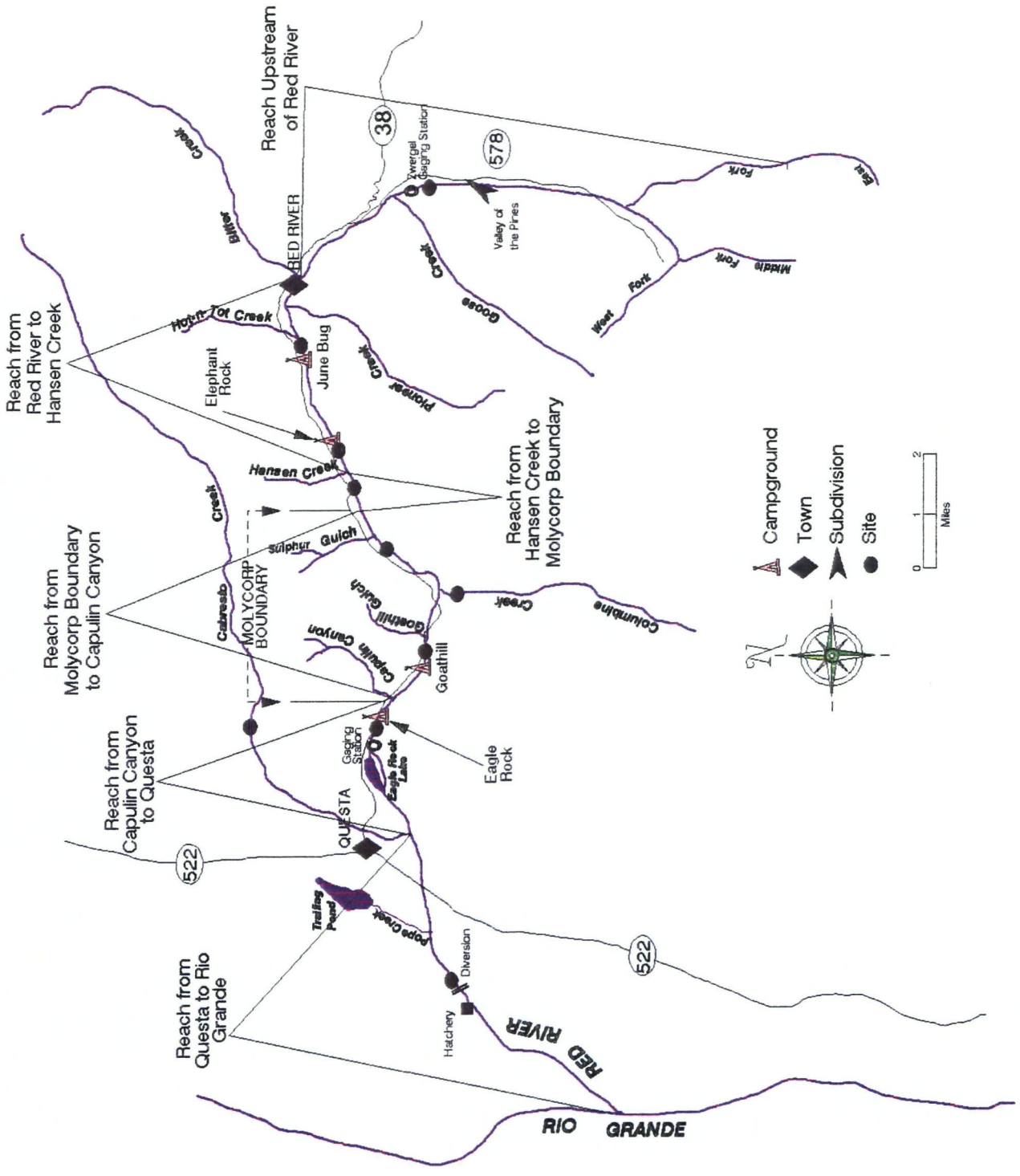


**FIGURE 19:** Chadwick Ecological Consultants, Inc. spring 1997 fish sampling sites.

During fish population sampling for the present study, water clarity was variable between study sites. The water was very clear at the study site upstream from the Town of Red River, and moderately stained with a blush-white color roughly halfway between the Town of Red River and the Molycorp Mine property boundary. This staining was greater downstream at the U.S. Forest Service Questa Ranger Station. Water clarity near the fish hatchery increased to levels similar to the reach of the Red River upstream of the Molycorp property.

Overall channel morphology and gross habitat features relative to the suitability of the Red River for sustaining trout are similar from the upper reaches of the river downstream to the Rio Grande. Although specific habitat characteristics of the river, such as gradient, sinuosity, width, etc., vary along the river, a similar riffle-run-pool character is present along its entire length. Cover consisted of pocket water, undercut banks, snags, overhanging vegetation, and pools throughout.

Study site locations for spring 1997 fish sampling are as follows:

***Red River***

| | |
|---|---|
| Upstream of Town of Red River | Located approximately 0.6 miles upstream from Goose Creek, 0.2 miles upstream from the gaging station at an elevation of approximately 8,900 feet. |
| June Bug Campground | Located near the upstream end of June Bug Campground at an elevation of approximately 8,530 feet. |
| Downstream of Elephant Rock Campground, upstream from Hansen Creek | Located 0.4 miles downstream from Elephant Rock Campground at an elevation of approximately 8,360 feet. |
| Downstream of Hansen Creek, upstream of mill | Located 0.8 miles upstream from mill access road, 0.7 miles downstream from Hansen Creek, at an elevation of approximately 8,200 feet. This site corresponds to the "Bobita Campground" site of the New Mexico Game and Fish Department. |
| Downstream of mill, upstream of Columbine Creek | Located 1.1 miles downstream from mill access road at an elevation of approximately 8,100 feet. |
| Goathill Campground | Located at the upstream end of Goathill Campground at an elevation of approximately 7,670 feet. |

| | |
|---|---|
| Upstream of Questa Ranger Station | Located 0.4 miles upstream from ranger station access road, just upstream from where tailings pipes cross over the Red River. The elevation of this site was approximately 7,480 feet. |
| Upstream of hatchery diversion | Located 0.3 miles upstream of the Red River fish hatchery diversion, at an elevation of approximately 7,120 feet. |
| ***Tributaries*** | |
| Columbine Creek | Located approximately 400 yards upstream from its confluence with the Red River, at an elevation of approximately 7,880 feet. |
| Cabresto Creek | Located 1.6 miles upstream of the Carson National Forest boundary, at an elevation of approximately 7,640 feet. |

1995 Benthic Invertebrate Data Collection

Study site locations for benthic invertebrate sampling by NMED in December 1995 (Woodward-Clyde 1996) on the Red River (Fig. 20) are as follows:

| | |
|---|---|
| Upstream of Red River | Red River upstream of confluence with Bitter Creek (Site RRB-1). |
| Downstream of Red River | Downstream of the confluence with Pioneer Creek (Site RRB-3). |
| Near Elephant Rock Campground | Downstream of confluence with Hot-n-Tot Creek (Site RRB-5). |
| Downstream of Hansen Creek, upstream of Sulphur Gulch. | Red River between Hansen Creek and Sulphur Gulch (RRB-7). |
| Just downstream of Columbine Creek | Downstream of Columbine Creek (Site RRB-10A). |
| Upstream of Goathill Gulch | Downstream of Columbine Creek, upstream of Goathill Gulch (Site RRB-11). |
| Upstream of Capulin Canyon | Downstream of Goathill Gulch, upstream of Capulin Canyon (Site RRB-13). |

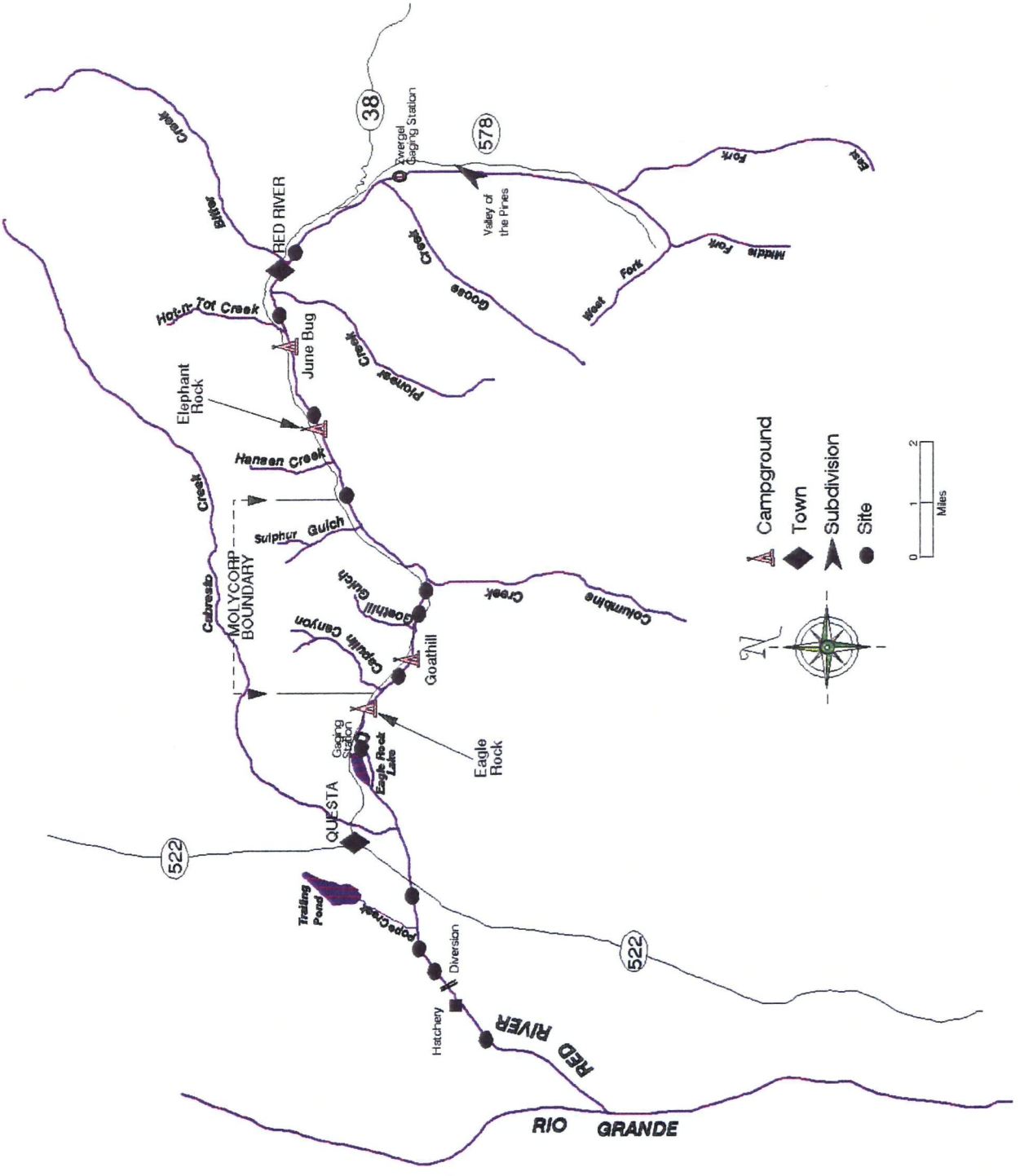


**FIGURE 20:** NMED December 1995 benthic invertebrate sampling sites (Woodward-Clyde 1996).

| | |
|---|---|
| Near Questa Ranger Station | Downstream of USGS gaging station #0826500, near the Questa Ranger Station (Site RRB-16). |
| Downstream of Highway 522 Bridge | Just downstream of bridge, downstream of Cabresto Creek (Site LRB-1). |
| Downstream of Pope Creek | Downstream of tailings pond discharge outfall #002 (Site LRB-11A). |
| Upstream of hatchery diversion | At new spring water control boxes for fish hatchery (Site LRB-16). |
| Downstream of fish hatchery | Downstream of USGS gaging station #0266820, downstream of hatchery (Site LRB-21). |

Historical Fish and Benthic Invertebrate Data Collection

The historical fish and benthic invertebrate data collection sites are described below. These sites have been grouped into the six reaches of the Red River in order to allow a more focused interpretation of the data.

***Upstream of Red River***

| | |
|---|---|
| East Fork at Blue Lake Trail | 3 miles upstream of confluence of east and west forks. |
| Just downstream of the Forks | Site just downstream of confluence of the east and west forks of the Red River. |
| 2.0 mi. downstream of the Forks | 2 miles downstream of the east and west forks of the Red River. |
| 2.9 mi. downstream of the Forks | Located 2.9 miles downstream of confluence of the east and west forks of the Red River. |
| Downstream of Valley of the Pines | Upstream of the Zwergel Gaging Station, downstream of the Valley of the Pines subdivision. |
| Zwergel Gaging Station | Located 2.2 miles upstream of the Town of Red River. |
| Upstream of Bitter Creek | 800 feet upstream of confluence with Bitter Creek and Red River. |
| Downstream of Bitter Creek | Just downstream of the confluence of Bitter Creek with Red River. |

***Red River to Hansen Creek***

| | |
|---|---|
| June Bug Campground | Located at June Bug Campground one mile west of the Town of Red River. |
| Elephant Rock Campground | At Elephant Rock Campground approximately 0.8 miles upstream from confluence of Hansen Creek and Red River. |

***Hansen Creek to Molycorp Boundary***

| | |
|---|---|
| Upstream of Molycorp property boundary. | 0.5 mile stretch of Red River upstream of Molycorp property boundary; includes the Bobita Campground site sampled by NMDGF in 1995 and 1996. |

***Molycorp Boundary to Capulin Canyon***

| | |
|---|---|
| Upstream of Columbine Creek | Located just upstream of Columbine Creek, 6 miles east of Questa. |
| Downstream of Columbine Creek | 500 feet downstream of confluence of Columbine Creek and Red River. |
| Upstream of Goathill Gulch | Approximately 0.8 miles feet upstream of confluence of Goathill Gulch and Red River. |
| Goathill Campground | Near confluence of Goathill Gulch and Red River approximately 1.8 miles upstream from USGS Gaging Station #08265000. |

***Capulin Canyon to Questa***

| | |
|---|---|
| Near Mouth of Bear Canyon | Located in the Red River at the mouth of Bear Canyon just downstream of Capulin Canyon; 1.2 miles upstream of head of Eagle Rock Lake. |
| Eagle Rock Campground | Located approximately 0.25 miles upstream from USGS Gaging Station #08265000. |
| Questa Ranger/Gaging Station | Site located near the USGS Gaging Station #08265000 near Questa Ranger Station. |
| Head of Eagle Rock Lake | Site located approximately 0.4 miles upstream from USGS Gaging Station #08265000, near Eagle Rock Lake Diversion. |

***Questa to Rio Grande***

| | |
|---|---|
| SH 522 Bridge (Formerly SH3) | Bridge where Highway 522 (formerly Highway 3) crosses Red River approximately 2.8 miles downstream from USGS Gaging Station #08265000. |
| Upstream of Pope Creek | Approximately 150 feet upstream of Pope Creek's confluence with Red River. |
| Upstream of hatchery diversion | A 0.5 mile stretch upstream of the Red River State Fish Hatchery, approximately 2 miles downstream of the bridge at SH 522. |
| Downstream of hatchery diversion | Just downstream of hatchery diversion and upstream of the Red River State Fish Hatchery. |
| Downstream of hatchery | Just downstream of the Red River State Fish Hatchery. |
| Between hatchery and El Aujae Campground | Several sampling sites in the 1.5 mile section of the Red River in the canyon downstream of the fish hatchery and upstream of the campground. |
| El Aujae Campground | Located approximately 1.5 miles downstream from the hatchery. |
| La Junta Point | La Junta point recreation site located about 3 miles downstream of the state hatchery. |

## METHODS

### 1997 Data Fish Collection

Fish populations were quantitatively sampled at ten sites during the week of March 31 through April 3, 1997. Sampling provided data on species composition, abundance, biomass, and the size structure of the fish community. The section of stream sampled at each site was chosen to be representative of the habitat present in that reach of stream, in terms of pool/riffle ratio, shading, bank stability, etc. Sites were of sufficient length to ensure a representative section of the available habitat features: 270 to 345 feet in length in the Red River, 128 feet in Cabresto Creek, and 208 feet in Columbine Creek.

Sampling was conducted by making three sampling passes through a representative section of stream using either bank or backpack electrofishing gear. Bank electrofishing equipment consisted of a 4,000 watt generator, a Coffelt voltage regulator (VVP-15), and two electrodes. Backpack electrofishing equipment consisted of a Coffelt Mark-10 CPS unit with one electrode. At all sites, sample sections were blocked with 50 ft seines (1¼ mesh) to reduce the potential for fish to enter or leave the study section during sampling.

Fish captured from each pass were kept separate to allow estimates of population density of each species using a maximum likelihood estimator and the "MicroFish" program developed by the U.S. Forest Service (Van Deventer and Platts 1983, 1986). All fish sampled were identified, counted, weighed, and released. This sampling provides species lists, estimates of abundance (#/mile, #/acre), and biomass (lbs/acre).

### 1995 Benthic Invertebrate Data Collection

Benthic invertebrates were quantitatively sampled at 12 sites by NMED personnel on December 20 and 21, 1995. Five replicate Hess samples were taken from riffle areas at each site. A full discussion of methods and the presentation of the data are found in Woodward-Clyde (1996).

**Historical Fish and Benthic Invertebrate Data Collection**

Fish

The historical fish data from the Red River were collected in most cases by the NMDGF. The majority of this sampling was done using a single pass electrofishing technique. Some of the more recent fish data were collected using a three pass electrofishing technique. In order to compare the data from the different studies, it was necessary to standardize the data to make comparisons appropriate. For all historical data collection (prior to 1997), fish collected on the first electrofishing pass are included in this report. For the data collected by Chadwick Ecological Consultants, Inc., in the spring of 1997, the data are presented based on the results of all three passes. However, comparisons to the historical data are made using only the first pass data collected in 1997, in order to be directly comparable.

In the NMDGF sampling summaries, it was often mentioned that they were working in turbid waters making fish observations difficult. A common pattern was to sample within one week after the river was stocked with trout. How the fish were identified or how length measurements were obtained were generally not mentioned in the reports; however, at least on some occasions, the collection crew would not actually collect the fish in a net, but would estimate the species and size of the fish as they floated by during electrofishing (R. Akroyd, NMDGF, personal communication). In some cases, the species of fish was not determined and was recorded as "Unknown."

Benthic Invertebrates

The early historical invertebrate surveys were conducted primarily by Dr. Robert Pennak, University of Colorado, Boulder. Later surveys were done by a variety of groups including NMED, US EPA, ENSR, and the New Mexico Surface Water Quality Bureau. A variety of sampling equipment was used, including Surber samplers, kick nets, delta frame dipnets and Hess samplers. Because there were different sampling methods, the data are presented in a variety of ways including number of taxa, density, biomass, and several different biotic indices.

In mountain streams, such as those near the Molycorp Molybdenum Mine, the presence of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa (referred to as the EPT taxa) can be used as an indicator of water quality. These insect groups are considered to be sensitive to a wide range of pollutants (Weiderholm 1989, Plafkin *et al.* 1989, Klemm *et al.* 1990, Lenat and Penrose 1996, Wallace *et al.* 1996). Stress to aquatic systems can be evaluated by comparing the number of EPT taxa (expressed as the percent of EPT taxa relative to the total taxa) between unimpacted and potentially impacted sites. Impacted sites would be expected to have fewer EPT taxa (lower percent EPT taxa) compared to unimpacted sites.

Another useful biological indicator of water quality is the Shannon-Weaver Diversity Index (H'), which the EPA recommends as a measure of the effects of stress on invertebrate communities (Klemm *et al.* 1990). This index generally has values ranging from 0-4, with values from 2.5-4.0 indicative of a healthy invertebrate community (Klemm *et al.* 1990, Wilhm 1970).

## RESULTS AND DISCUSSION

### Water Quality Summary

With regard to the potential for harm to aquatic life, water quality data from 1988 through 1996 were reviewed, as provided by Molycorp (Vail Engineering 1993, 1995, 1997) and in reports by Smolka and Tague (1987, 1989), Smolka (1993), and Slifer (1996). This included data on flow (cfs), pH, and a number of constituents. From the perspective of aquatic life, it appears that three parameters are of potential concern: pH, zinc, and aluminum. Concentrations of these constituents were compared to applicable EPA water quality criteria (EPA 1986, 1987, 1988) and standards developed by the State of New Mexico.

Over the period from 1988 to 1996, pH throughout the Red River was generally in the range of 6.5 to 8.5 units. The pH did exhibit a general decrease from upstream to downstream, with the decrease beginning downstream of the hydrothermal scars on the Hot-n-Tot and Hansen Creek drainages. However,

even though the pH decreased slightly, the values were predominately in the range that is considered safe for aquatic life (EPA 1986). Periods of lower pH values are associated with storm events eroding the thermal scars (Slifer 1996).

When considering the potential harm to aquatic biota from metals, it is important to consider the dissolved form. This is the form that is considered to most closely approximate the bioavailable (i.e. toxic) fraction of the metal (Bergman and Dorward-King 1997), and is the form preferred by the EPA with respect to water quality criteria (May 4, 1995, Federal Register 60:86 @ 22229-22237). This is also the form used for criteria developed by the State of New Mexico.

The zinc data that are available indicate a slight increase through the study area from less than 50 µg/L upstream of Red River to values around 70 to 100 µg/L downstream of the Questa Ranger Station (ENSR 1988, Vail Engineering 1993, 1995, 1996). To determine potential for harm, it is necessary to know the hardness since the zinc criteria are hardness based (EPA 1986. State of New Mexico, 20 NMAC 6.1, Sec. 3101, January 23, 1995, pp. 44-46, Standards Applicable to Attainable or Designated Uses). Smolka (1993) measured hardness monthly during 1992. Mean hardness during this time period increased from approximately 90 mg/L $CaCO_3$ near the Town of Red River to 176 mg/L at the Questa Ranger Station. Based on the most current New Mexico and EPA zinc criteria equation (EPA 1986, 1987. State of New Mexico, 20 NMAC 6.1, Sec. 3101, January 23, 1995, pp. 44-46, Standards Applicable to Attainable or Designated Uses) as modified for dissolved values (May 4, 1995, Federal Register 60:86 @ 22229-22237), these hardness values would result in chronic zinc criteria of 95 µg/L and 169 µg/L, respectively. The reported dissolved zinc values were well below these values in their respective reaches, indicating that neither chronic nor acute toxicity from dissolved zinc would be expected to occur in the Red River. Smolka and Tague (1989) also noted that during storm events, water quality in the Red River resulted in total metal concentrations that appeared to exceed water quality standards; however, when dissolved metals were considered, the criteria were not violated.

Aluminum has been shown to be toxic to aquatic biota a concentrations well less than 1 mg/L (Sparling and Lowe 1996), especially at pH values near 5.0 or lower. Fish are generally considered to be more sensitive than aquatic insects (Sparling and Lowe 1996, Heliövaara and Väisänen 1993). The toxicity

of aluminum is reduced at pH values of 6.5 or higher. In the range of pH observed in the Red River, aluminum would be highly insoluble (Hem 1985). In addition, aluminum is prone to form colloidal hydroxides that can pass through a 0.45 μm pore filter (the filter used to determine dissolved metals). As such, the colloids will be reported as "dissolved" aluminum (Hem 1985), although they would not be bioavailable.

Concentrations of *total* aluminum increase from generally less than 1 mg/L upstream of the Town of Red River to values greater than 10 mg/L at the Questa Ranger Station (Vail Engineering 1993, 1995, 1997, Smolka and Tague 1987, 1989). Reported *dissolved* aluminum values are considerably lower, ranging from 48 μg/L (0.048 mg/L) to over 2,000 μg/L (2 mg/L) through the river (Fig. 21). With regard to potential for harm to aquatic life, EPA and the State of New Mexico have a criterion for dissolved aluminum, with 87 μg/L for the chronic criterion (EPA 1988, State of New Mexico, 20 NMAC 6.1, Sec. 3101, January 23, 1995, pp. 44-46, Standards Applicable to Attainable or Designated Uses). As is apparent from the data (Fig. 21), this chronic criterion is exceeded from the reaches upstream of the Molycorp property to the reach downstrem of Capulin Canyon. It is important to note that much of this reported "dissolved" aluminum may actually be in colloidal form and, thus, not bioavailable (i.e., not toxic). Nonetheless, these data would suggest a potential for toxicity to aquatic life from dissolved aluminum in the reaches of the river downstream of the Town of Red River to Questa (Fig. 21).

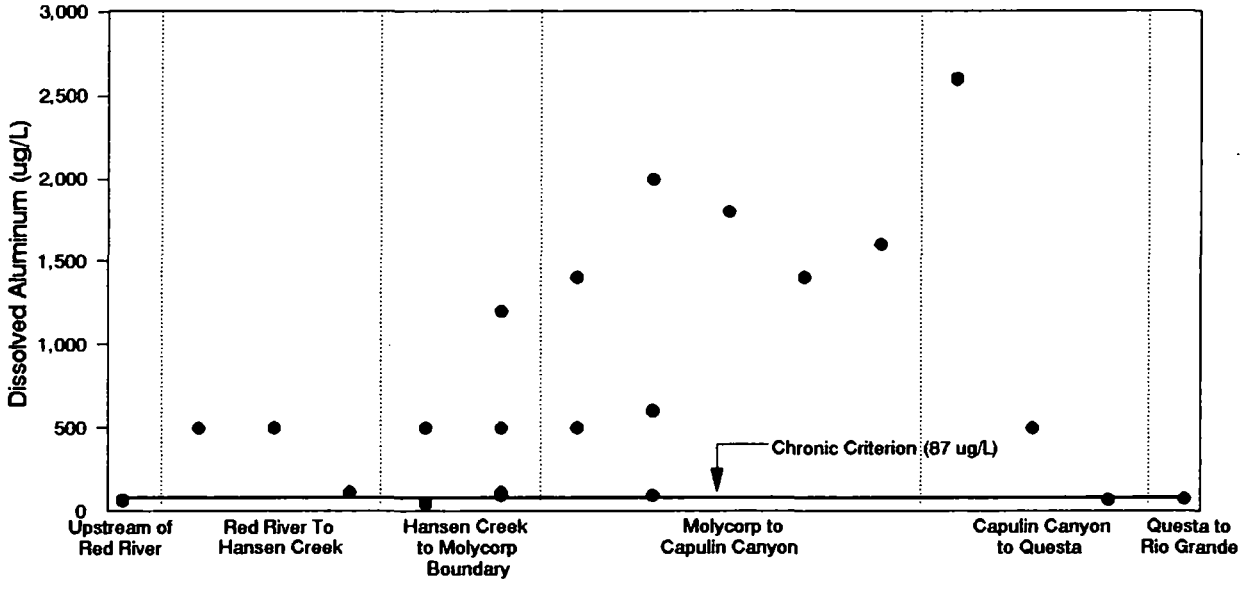


**FIGURE 21:** Dissolved aluminum concentrations in the six reaches of the Red River, New Mexico, (Smolka and Tague, 1988, South Pass Resources, Inc. 1995, Slifer 1996, Steffen Robertsen and Kirsten, Inc. 1995).

**Present Fish Populations**

A total of four different trout species were collected in the Red River and its tributaries during sampling on March 31 through April 3, 1997 (Table 1). Brown trout were the most common at eight of the ten sampled sites. Upstream of Red River, cutthroat trout were the most abundant species. In Cabresto Creek, a hybrid between rainbow and cutthroat trout were the most common.

Based on the size distribution of collected fish and past stocking records, it appears that cutthroat, brook, and brown trout are self-sustaining in the Red River and the two tributary streams. The size classes of fish collected indicate the presence of multiple size/age groups of these three species, indicating natural reproduction of these three species is occurring in the Red River and tributaries.

**TABLE 1:** Fish population parameters for collection sites on the Red River and tributaries. Data collected during March 31-April 3, 1997, by Chadwick Ecological Consultants, Inc. Data from three electrofishing passes (CUT = cutthroat trout, BRK = brook trout, RBT = rainbow trout, BRN = brown trout).

| | | | Density | | Biomass |
|---|---|---|---|---|---|
| Site, Date | Species | # Collected | #/Mile | #/Acre | Lbs./Acre |
| **Red River** | | | | | |
| Upstream of Town of Red River, 4/2/97 | CUT | 34 | 551 | 261 | 19.1 |
| | BRK | 19 | 291 | 138 | 5.9 |
| | RBT | 5 | 76 | 36 | 14.1 |
| | BRN | 5 | 199 | 94 | 8.4 |
| | **Total** | 63 | 1,117 | 529 | 47.5 |
| June Bug Campground, 4/2/97 | BRK | 2 | 33 | 15 | 0.4 |
| | RBT | 8 | 133 | 60 | 14.5 |
| | BRN | 23 | 433 | 194 | 5.7 |
| | HYBRID | 10 | 200 | 90 | 8.1 |
| | **Total** | 43 | 799 | 359 | 28.7 |
| Downstream of Elephant Rock Campground, upstream of Hansen Creek, 4/2/97 | RBT | 1 | 19 | 7 | 2.9 |
| | BRN | 28 | 570 | 220 | 16.5 |
| | **Total** | 29 | 589 | 227 | 19.4 |
| Downstream of Hansen Creek, upstream of mill, 4/1/97 | BRN | 3 | 34 | 13 | 2.4 |
| Downstream of mill, upstream of Columbine Creek, 4/1/97 | RBT | 1 | 19 | 9 | 3.3 |
| | BRN | 6 | 116 | 55 | 9.7 |
| | **Total** | 7 | 135 | 64 | 13.0 |
| Goathill Campground, 4/1/97 | BRN | 13 | 243 | 107 | 6.8 |
| Upstream of Questa Ranger Station, 4/1/97 | NO FISH | -- | -- | -- | -- |
| Upstream of hatchery diversion, 3/31/97 | RBT | 20 | 395 | 164 | 43.1 |
| | BRN | 50 | 934 | 388 | 21.3 |
| | **Total** | 70 | 1,329 | 552 | 64.4 |
| **Tributaries** | | | | | |
| Columbine Creek, 4/3/97 | BRN | 22 | 426 | 474 | 27.3 |
| Cabresto Creek, 4/3/97 | CUT | 2 | 82 | 56 | 5.5 |
| | BRK | 4 | 165 | 111 | 5.1 |
| | RBT | 3 | 124 | 83 | 28.4 |
| | HYBRID | 18 | 784 | 528 | 35.4 |
| | **Total** | 27 | 1,155 | 778 | 74.4 |

All of the rainbow trout collected were larger than 7.5 inches, with most in the 8-11 inch size range. This is the size of fish commonly stocked in the river by NMDGFP over the last two decades, and are the target of the fisheries management efforts in the basin (R. Akroyd, NMDGF, personal communication). In the 1970's, it appears that small rainbow trout fry (several inches long) was stocked instead of the "catchable" size being stocked at present. The Town of Red River also apparently stocks rainbow trout, some of which are up to 20 inches in length. Rainbow trout are commonly stocked throughout the western United States. It has been our experience that stocked rainbow trout do not sustain populations through natural reproduction. Although a limited amount of natural reproduction may occur, this is uncommon. The rainbow trout levels in the Red River are probably maintained almost exclusively by stocking, and not natural reproduction. Within a few months of being stocked, most rainbow trout are no longer in the river, having died, migrated, or been caught by anglers. This is the typical pattern for stocked rainbow trout and is assumed throughout the remainder of this report when evaluating the available fish collection information for 1997 and for the historical data.

The hybrid fish collected at the site at June Bug Campground and in Cabresto Creek appeared to have characteristics of both cutthroat and rainbow trout. These two species are known to hybridize throughout the western U.S. (Behnke 1992). The small size of the collected hybrids suggests that these were the result of natural reproduction, not stocking.

Fish collection in the spring of 1997 was conducted prior to the stocking of rainbow trout at all sites except near the fish hatchery diversion, the most downstream site. Brown trout were the most common species of fish collected at most sites. Rainbow trout were not the most common species of trout collected at any of the ten sampling sites (Table 1). This directly contrasts with much of the historical data discussed in the remainder of this report (see Historical Fish Populations section). The reason for this is apparently that much of the historical data were collected during the stocking season for rainbow trout in the Red River. The significance of the 1997 data, prior to the stocking of rainbow trout, is that stocked rainbow trout are less of a confounding factor in interpreting the fish data and evaluating the suitability of the different reaches of the Red River for sustaining resident trout populations.

Winter, with low flows and cold temperatures, represents a difficult time for trout. The trout remaining in the Red River in spring allow a more direct interpretation of the ability of the reaches of the river to sustain trout through the most difficult season.

The fish collection data from the spring of 1997 indicates a very clear pattern (Fig. 22). Relative to the fish populations upstream of the Town of Red River, populations consistently decrease at each site within each reach to very low levels at the site below Hansen Creek and upstream of the Molycorp mill (Table 1). There is an approximately 30-40% decrease in fish populations parameters from the site upstream of the Town of Red River to the June Bug Campground Site (Table 1). The physical habitat of the Red River in this reach appears similar in suitability to the reach of the river upstream of the Town of Red River. This suggests that activities in or near the Town of Red River have a detrimental effect on trout populations. There is a further 25-40% decrease in trout population parameters between the June Bug and Elephant Rock Campground sites (Table 1). Again, the suitability of the physical habitat at these two sites appears to be similar. These two sites bracket the confluence of Hot-n-Tot Creek and a wastewater treatment plant outlet. Hot-n-Tot Creek drains runoff from a hydrothermal scar. These two factors appear to further impact the trout populations of the Red River.

Fish population parameters decrease an additional 90% between the Elephant Rock Campground site and the site downstream of Hansen Creek (Table 1). Hansen Creek also drains an extensive hydrothermal scar, forming a delta of fine sediment at its confluence with the Red River (Fig. 8). In addition, there is a spring just downstream of Hansen Creek that appears to provide a source of aluminum hydroxide precipitate into the Red River (Fig. 11).

Comparing the data from the site upstream of the Town of Red River to the site downstream of Hansen Creek, there is a 95% reduction in fish collected, a 97% reduction in the number of fish/mile, a 98% reduction in density (number of fish/acre), and a 95% reduction in biomass (lbs/acre). Therefore, the cumulative effect of the impacts to the Red River trout populations extending from the Town of Red River to a point upstream of the Molycorp property is a more than 95% reduction in fish populations.

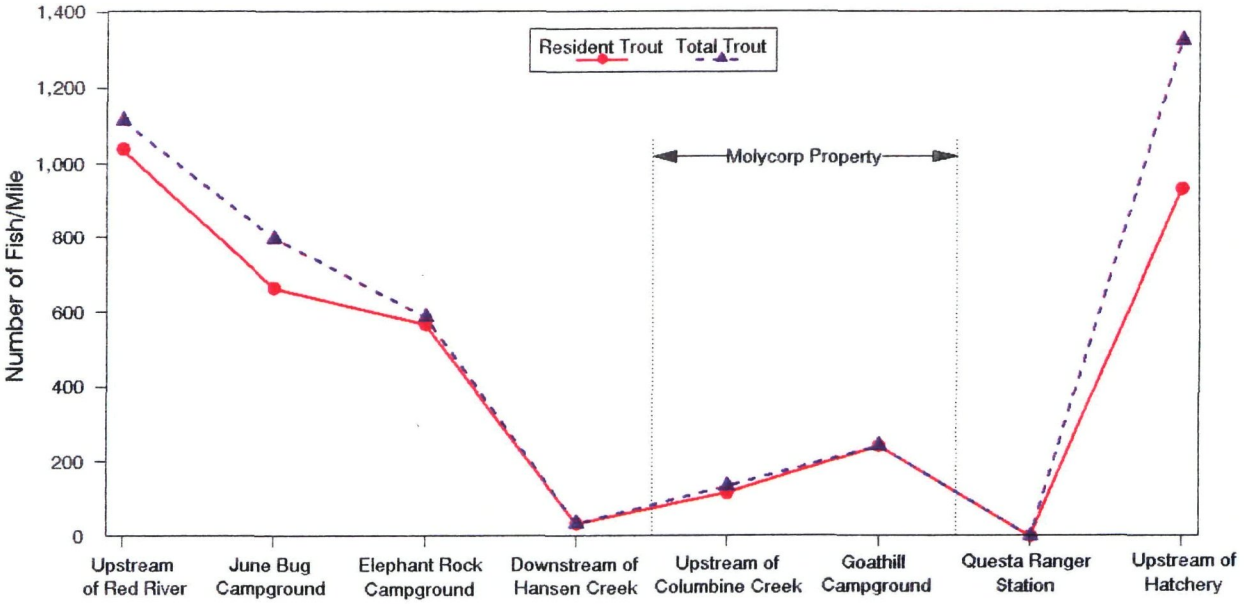


**FIGURE 22:** Trend in the number of fish per mile for data collected in spring, 1997. Data represent results of three electrofishing passes. Resident trout excludes stocked rainbow trout.

The single most important negative impact in this section appears to be the effects of Hansen Creek. Hansen Creek introduces substantial amounts of sediment, possibly with elevated levels of metals, to the Red River. The levels of sediment alone appear to render the section of the Red River downstream of the confluence unsuitable for maintaining all but a few trout. Water quality data indicate that during stable flow conditions, levels of zinc downstream of Hansen Creek do not appear to be toxic to fish, although aluminum may be. In addition, the possibility exists that short-term increased levels of metals, low pH, or sediment occurring during storm events may be toxic to fish. These factors would limit the suitability of the Red River to sustain trout in this reach of the river downstream of Hansen Creek.

Recent habitat ratings using the EPA's Rapid Bioassessment Protocol (RBP) method (Plafkin *et al.* 1989) were collected in 1995 and 1996 at four sites in the Red River (Akroyd 1996, 1997). The RBP method includes an estimation of substrate embeddedness. Embeddedness at the Bobita Campground sampling site (just downstream of Hansen Creek) was estimated to be 60% during both 1995 and 1996. In contrast, embeddedness at the site upstream of the Town of Red River was 25% and 35% in 1995 and 1996,

respectively. This information indicates a substantial increase in the amount of sediment in the Red River downstream of Hansen Creek.

At the two collection sites adjacent to the Molycorp mine property, the site upstream of Columbine Creek, and the site at Goathill Campground, trout population parameters increase to a small extent, but remain low (Table 1, Fig. 22). Columbine Creek appears to improve conditions in the Red River to a small extent. The number of fish collected and fish density increase at the site downstream of Columbine Creek (the Goathill Campground Site) as compared to the site upstream of Columbine Creek. Columbine Creek itself supports a population of brown trout. These trout appear to be self-sustaining, based on the presence of multiple-size/age classes in this tributary to the Red River.

The short-term additions of water with high levels of sediment and metals, which may be occurring from Hansen Creek during storm runoff events, apparently do not occur in the reach of the river adjacent to the mine. Stormwater controls are apparently in place at the mine site to prevent this stormwater runoff (Slifer 1996). However, degraded water quality from Hanson Creek during storm events may still effect this reach of the Red River.

The site upstream of the Questa Ranger Station contained no fish when sampled in the spring of 1997 (Table 1). This site is downstream of the confluence with Capulin Canyon. This may be at least partially due to increased sedimentation in this reach of the river. Habitat data from Akroyd (1996, 1997) indicate a substrate embeddedness of 75% in this reach. This level of embeddedness would represent a substantial reduction in the suitability of the river to support fish.

Trout population parameters at the site upstream of the hatchery diversion are comparable to those at the site upstream of the Town of Red River (Table 1, Fig. 22). This is true even taking into account the rainbow trout recently stocked in this section. The recovery of the Red River to conditions that can sustain relatively high trout population levels may be due, in part, to the influence of Cabresto Creek. Cabresto Creek contained three species of trout and total trout biomass of Cabresto Creek was higher than at any other site sampled (Table 1).

**Present Benthic Invertebrate Populations**

The most recent benthic invertebrate data were collected in December 1995 by NMED personnel. The data were contained in a report by Woodward-Clyde Consultants (1996). This effort included replicate sampling at 12 sites along the Red River from upstream of the Town of Red River downstream to a point near the USGS gaging station (Station No. 0266820), downstream of the Red River State Fish Hatchery. This information is used to characterize the present status of the benthic invertebrate populations in the Red River.

The highest density and number of taxa occur at the sampling site upstream of the Town of Red River. Both the number of taxa and density decline at downstream sites (Table 2). This suggests impacts to the benthic invertebrate populations are beginning at the Town of Red River.

**TABLE 2:** Benthic invertebrate population parameters for collection sites on the Red River. Data collected during December 20-21, 1995, by NMED (Woodward Clyde 1996).

| Site | #/m$^2$ | # of Taxa | # EPT Taxa | EPT Taxa as % Total Taxa | Diversity Index |
|---|---|---|---|---|---|
| Upstream of Red River | 10,121 | 48 | 23 | 48 | 2.80 |
| Downstream of Red River | 2,616 | 40 | 21 | 53 | 3.67 |
| Near Elephant Rock Campground | 4,030 | 34 | 18 | 53 | 3.40 |
| Downstream of Hansen Creek, upstream of Sulphur Gulch | 1,177 | 26 | 15 | 58 | 3.62 |
| Just downstream of Columbine Creek | 1,614 | 36 | 23 | 64 | 3.54 |
| Upstream of Goathill Gulch | 600 | 18 | 14 | 78 | 2.01 |
| Upstream of Capulin Canyon | 319 | 17 | 11 | 65 | 3.26 |
| Near Questa Ranger Station | 456 | 16 | 11 | 69 | 2.49 |
| Downstream of Highway 522 Bridge | 2,605 | 22 | 12 | 55 | 2.39 |
| Downstream of Pope Creek | 3,891 | 29 | 16 | 55 | 2.44 |
| Upstream of hatchery diversion | 4,449 | 34 | 14 | 41 | 2.08 |
| Downstream of fish hatchery | 6,012 | 45 | 23 | 51 | 2.42 |

At the site downstream of the Town of Red River, benthic invertebrate density decreased by 75% and was significantly lower (Analysis of Variance, ANOVA, $p = 0.0003$) than at the upstream site (Table 2, Fig. 23). This indicates impacts to benthic invertebrate populations are occurring near the Town of Red River. The number of taxa decreased by 17%, but the percent of EPT taxa was comparable at both sites. The impact in this reach of the river is probably a physical impact, such as a moderate increase in fine sediment input. Increased sediment at low levels has been shown to reduce the density of invertebrates in streams (Culp *et al.* 1986, Farnworth 1979, Rosenberg and Snow 1975, Gammon 1970) without necessarily resulting in substantial decreases in the number of taxa present.

Near the Elephant Rock Campground site, invertebrate density increased compared to the previous site, but was still significantly less than the site upstream of Red River (ANOVA, $p < 0.05$). This may reflect a slight enrichment effect of the wastewater treatment plant. While the percentage of EPT taxa and diversity index are comparable between the two sites, the total number of taxa decreased an additional 15% and the number of EPT taxa was 22% lower than the site upstream of Red River. This suggests that the impacts to the benthic invertebrate population seen at the site downstream of Red River are continuing at the Elephant Rock Campground.

Downstream of Hansen Creek, density of benthic invertebrates is reduced by over 70% and was significantly lower than the Elephant Rock Campground site (ANOVA, $p < 0.0001$). The number of taxa is reduced by an additional 23%, and the number of EPT taxa is reduced by an additional 17%. However, the percentage of EPT taxa and the diversity index are higher than at the Elephant Rock Campground Site. The continued presence of EPT taxa (although in lower numbers) combined with the significantly lower density would tend to indicate a physical impact; probably the negative impact of sediment input from Hansen Creek. Habitat ratings by Akroyd (1996, 1997) indicate an embeddedness of 60% in this reach of the river, which would support this position.

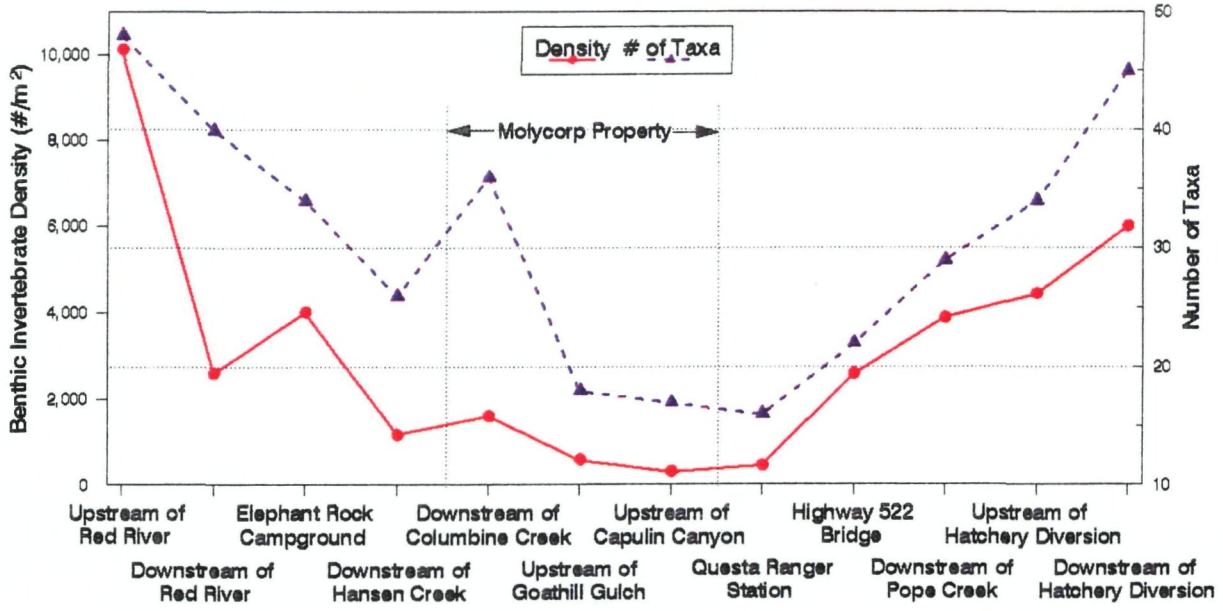


**FIGURE 23:** Trend in benthic invertebrate density and number of taxa for data collected in 1995.

Comparing the data from the site upstream of the Town of Red River to the site downstream of Hansen Creek, there is an 88% reduction in benthic invertebrate density, a 46% reduction in the total number of taxa, and a 35% reduction in the number of EPT taxa. These reductions are, in part, a result of fewer heptageniid mayflies, and capniid and nemourid stoneflies (Woodward-Clyde 1996). These organisms are often considered intolerant of stress (DeShon 1995, Klemm *et al.* 1990). Heptageniid mayflies have been identified as sensitive to input of metals, whereas stoneflies are often considered less sensitive to metals (Clements 1994). Both mayflies and stoneflies are sensitive to sediment input (Hynes 1970), and prefer coarse gravel/riffle substrates (Ward 1975, Hynes 1970). Therefore, the data do not clearly indicate the causes of the reductions observed.

At the next site downstream, the site just downstream of Columbine Creek, there are slight increases in the number of taxa and density. These increases are not significant; however, they suggest that Columbine Creek is having a positive effect on the Red River, possibly through the input of drifting benthic invertebrates (Hynes 1970, Allan 1995).

The next three downstream sites (upstream of Goathill Gulch, upstream of Capulin Canyon, and near the Questa Ranger Station) all indicate that impacts to benthic invertebrate populations are occurring (Table 2, Fig. 23). At all three of these sites, density is significantly lower (ANOVA, $p < 0.05$) than at the two sites bracketing Columbine Creek (the sites downstream of Hansen Creek and downstream of Columbine Creek). The low density and the approximately 50% reduction in number of taxa and EPT taxa, as compared to the site just downstream of Columbine Creek, could suggest either water quality and/or physical impacts to the population. The habitat ratings by Akroyd (1996, 1997) indicate an embeddedness of 75% in this reach of the river. This would indicate that sediment is having a substantial effect on invertebrate populations.

The next site downstream at the Highway 522 Bridge is also downstream of Cabresto Creek. As compared to the Questa Ranger Station site, the Highway 522 Bridge site has significantly higher density (ANOVA, $p = 0.006$). The number of taxa also increased substantially, although EPT taxa did not exhibit a significant increase. Much of the increase in density can be attributed to higher numbers of the sensitive mayfly group (Woodward-Clyde 1996). The population parameters indicate a significant improvement in the suitability of the Red River to support invertebrates downstream of Cabresto Creek.

The three sites downstream of Questa (downstream of Pope Creek, upstream of hatchery diversion, downstream of fish hatchery) shows an increasing trend in the number of taxa and density (Table 2, Fig. 23). These parameters indicate that the suitability of the Red River to support benthic invertebrates is becoming more similar to that found upstream of the Town of Red River, exhibiting the same overall trend seen in the trout populations (Fig. 22).

**Historical Fish Populations**

Upstream of Red River

The reach of the Red River upstream of the Town of Red River has historically contained the most diverse fish populations in the river. Over the period from 1960 to the present, cutthroat, brook, brown, and rainbow trout have been collected. In most cases, rainbow trout were the most abundant species present

(Appendix A, Table A1). Rainbow trout populations appear to be sustained by stocking. Cutthroat, brook, and brown trout populations are apparently sustained by natural reproduction.

The baseline data in this reach of the Red River, based on the results of sampling in 1960, indicate that cutthroat and brook trout were present. The abundance of fish was 352 fish per mile in 1960 (Table 3).

**TABLE 3:** Historical fish collection data for the reach of Red River upstream of the Town of Red River. First pass data only.

| Site, Date | Total # Collected | Total #/Mile | % RBT |
|---|---|---|---|
| **East Fork at Blue Lake Trail** | | | |
| June/Aug. 1960 | 20 | 352 | 0 |
| **Just downstream of the Forks** | | | |
| Nov. 1975 | 35 | 700 | 91 |
| May 1977 | 112 | 1,120 | 96 |
| July 1978 | 96 | 960 | 99 |
| Sept. 1978 | 24 | 480 | 100 |
| **2.0 mi. downstream of the Forks** | | | |
| Nov. 1975 | 27 | 540 | 59 |
| May 1977 | 86 | 860 | 94 |
| July 1978 | 56 | 560 | 96 |
| Sept. 1978 | 13 | 260 | 100 |
| **2.9 mi. downstream of the Forks** | | | |
| Nov. 1975 | 37 | 740 | 62 |
| May 1977 | 148 | 1,480 | 95 |
| July 1977 | 66 | 660 | 94 |
| **Downstream of Valley of the Pines** | | | |
| Aug. 1995 | 45 | 724 | 20 |
| **Zwergel Gaging Station** | | | |
| May 1977 | 51 | 510 | 75 |
| July 1978 | 73 | 730 | 55 |
| Sept. 1978 | 30 | 600 | 20 |
| Sept. 1980 | 28 | 493 | 18 |
| Sept. 1988 | 23 | 371 | 70 |
| Aug. 1996 | 95 | 1,529 | 6 |

During the 1970's and the 1980's, the abundance of fish has varied widely, from 371 fish/mile to over 1,500 fish/mile. Stocked rainbow trout comprised the majority of this abundance in most years at most sites (Table 3). During the early to mid-1970's, the rainbow trout were apparently stocked as fry, fish of several inches in size. The fish collection data for these sites (Appendix A, Table A1) indicates that the conditions in this reach of the Red River were suitable to allow some of these fish to grow to average lengths of up to 8-10 inches.

The fish collection data indicate that water quality and habitat conditions during baseline conditions (1960 data), at present (1997 data), and in the intervening years were suitable to sustain healthy trout populations upstream of the Town of Red River. Without the stocking of rainbow trout, populations of cutthroat, brook, and brown trout would continue to sustain healthy populations.

Red River to Hansen Creek

Rainbow and brown trout were the most common species of trout in the section of the Red River downstream of the Town of Red River and upstream of Hansen Creek (Appendix A, Table A1). Rainbow trout appear to have been maintained by stocking; brown trout were probably self-sustaining through natural reproduction or immigration. Cutthroat and brook trout were occasionally present, but in low numbers, and probably represent fish that had migrated downstream from the reach upstream of Red River. One white sucker was present in 1975.

The abundance of fish varies considerably in this reach of the Red River (Table 4). The baseline (1960) abundance was a total of 632 trout/mile in the upper portion of this reach. However, two-thirds of these fish were stocked rainbow trout. During the 1970's and the 1980's, the majority of the fish were stocked rainbow trout, with brown trout maintaining abundance of up to 150 fish/mile. In some years, abundance of both brown and rainbow trout was low, less than a few hundred fish/mile. In 1983, at the Elephant Rock Campground site, no fish were found. This is in contrast to the trout populations in the reach upstream of the Town of Red River, which usually exhibited higher trout densities than those found in the reach of the river downstream of the Town of Red River. As previously noted, the suitability of the physical habitat to support trout in these two reaches of the Red River appears to be similar.

**TABLE 4:** Historical fish collection data for the reach of the Red River from the Town of Red River downstream to Hansen Creek. First pass data only.

| Site, Date | Total # Collected | Total #/Mile | % RBT |
|---|---|---|---|
| **June Bug Campground** | | | |
| Oct. 1960 | 20 | 632 | 65 |
| Nov. 1975 | 18 | 180 | 11 |
| May 1977 | 53 | 530 | 89 |
| July 1978 | 96 | 960 | 76 |
| Sept. 1980 | 30 | 1,072 | 97 |
| Sept. 1983 | 14 | 280 | 71 |
| **Elephant Rock Campground** | | | |
| Nov. 1975 | 5 | 50 | 80 |
| May 1977 | 23 | 230 | 96 |
| July 1978 | 20 | 200 | 100 |
| Sept. 1983 | 0 | 0 | 0 |
| Sept. 1988 | 6 | 97 | 16 |

The relatively low trout density in this reach of the river, as compared to the reach of the river upstream of the Town of Red River, combined with the apparent continued decrease from June Bug to Elephant Rock Campgrounds, suggest that there have been impacts to the trout fishery in this section of the river over time. These impacts probably include activities in the Town of Red River, erosion from disturbed areas (i.e. the thermal scar on Hot-n-Tot Creek), septic and underground storage tank leaks, development, etc. (Chadwick Ecological Consultants, Inc., personal obervation, Slifer 1996).

The fish collection data suggest that the reach of the Red River from the Town of Red River downstream to Hansen Creek can support trout. However, the suitability of this reach of the river is lower than that of the reach upstream of the Town of Red River.

Hansen Creek to Molycorp Boundary

The reach of the Red River downstream of the confluence with Hansen Creek contains very few trout (Table 5). Nearly all of the fish collected in this reach were rainbow trout, with few brown trout collected (Appendix A, Table A1). As discussed earlier, the rainbow trout were probably maintained by stocking.

The brown trout were probably maintained by immigration downstream from more abundant trout populations in upstream sections of the river. Baseline conditions were probably similar, although there was apparently no sampling site in this reach of the river in 1960, or prior to the initiation of open pit mining.

**TABLE 5:** Historical fish collection data for the reach of the Red River from Hansen Creek downstream to the Molycorp property boundary. First pass data only.

| Site, Date | Total # Collected | Total #/Mile | % RBT |
|---|---|---|---|
| **Upstream of Molycorp property boundary** | | | |
| Nov. 1975 | 2 | 40 | 100 |
| July 1978 | 2 | 20 | 100 |
| Sept. 1980 | 4 | 143 | 100 |
| Aug. 1995 | 10 | 162 | 50 |
| Aug. 1996 | 7 | 113 | 29 |

The input of sediment from Hansen Creek appears to be the major impact to the trout fishery in the section of the Red River downstream from Hansen Creek, although increased concentrations of dissolved aluminum may contribute. Hansen Creek drains a hydrothermal scar that is apparently the source of the sediment. Increased sediment can induce stress in trout in a number of ways, leading to a reduced suitability of the reach of river to sustain fish (Johnson *et al.* 1987, McLeay *et al.* 1987, Farnworth *et al.* 1979, Rosenberg and Snow 1975, Wallen 1951). In addition, Hansen Creek and the spring just downstream of Hansen Creek periodically input increased levels of metals, TSS, and metal precipitate, as well as low pH levels following storm events.

Molycorp Boundary to Capulin Canyon

Rainbow trout comprise the majority of the fish collected in the reach of the Red River adjacent to the Molycorp mine property. Cutthroat and brown trout were also occasionally present at the sites in this reach (Appendix A, Table A1). The rainbow trout were probably maintained by stocking; the brown trout have probably been maintained by immigration from upstream populations or from the population in Columbine Creek. The few cutthroat trout present were probably migrants from upstream populations, as cutthroat trout are generally inhabitants of smaller, higher elevation stream segments.

Abundance of trout was generally low and comprised predominantly of stocked rainbow trout (Table 6). The single site sampled in this reach of river in 1960 (upstream of Columbine Creek) indicates that the baseline conditions included 281 trout/mile, with approximately two-thirds of this amount being stocked rainbow trout. This abundance level is somewhat higher than that found in the reach of the Red River upstream of the Molycorp boundary in the 1970's (Table 5), although no site was sampled in that reach during 1960.

**TABLE 6:** Historical fish collection data for the reach of the Red River from the Molycorp property boundary downstream to Capulin Canyon. First pass data only.

| Site, Date | Total # Collected | Total #/Mile | % RBT |
|---|---|---|---|
| **Upstream of Columbine Creek** | | | |
| Oct. 1960 | 16 | 281 | 69 |
| **Downstream of Columbine Creek** | | | |
| Nov. 1975 | 12 | 240 | 42 |
| Sept. 1980 | 11 | 195 | 100 |
| **Upstream of Goathill Gulch** | | | |
| May 1977 | 0 | 0 | 0 |
| **Goathill Campground** | | | |
| Nov. 1975 | 11 | 220 | 55 |
| April 1977 | 74 | 740 | 93 |
| July 1978 | 12 | 120 | 92 |
| Sept. 1980 | 12 | 430 | 100 |
| Sept. 1983 | 2 | 40 | 100 |

There is some evidence that the input of water from Columbine Creek has a positive influence on trout populations or may provide a source of colonizing trout. At the sites downstream of the confluence with Columbine Creek, abundance was sometimes higher than at the 1960 site upstream of Columbine Creek (Table 6), or in the reach of the river upstream of the Molycorp property boundary (Table 5). However, this positive influence is slight. Throughout the length of this reach of river, there appears to be little increase in trout abundance from the low levels found in the reach between Hansen Creek and the Molycorp boundary.

Capulin Canyon to Questa

In the reach of the Red River from Capulin Canyon downstream to Questa, rainbow and brown trout and a few white suckers have been collected (Appendix A, Table A1). Most of the trout caught were stocked rainbow trout (Table 7). The brown trout were apparently sustained by immigration from adjacent sections of the river.

Abundance of trout was consistently low at the Questa Ranger Station site. In the 1970's, stocked rainbow trout were present at the most downstream section of this reach, at the Head of Eagle Rock Lake sampling site.

No sampling site was located in this reach of the Red River in 1960, and sampling was not initiated in this reach until the mid 1970's. The baseline trout populations in this reach are uncertain, but probably exhibited a low abundance of trout. This is evident from the low abundance in upstream reaches in 1960, and the low abundance present in the 1970's and 1980's.

**TABLE 7:** Historical fish collection data for the reach of the Red River from Capulin Canyon downstream to Questa. First pass data only.

| Site, Date | Total # Collected | Total #/Mile | % RBT |
|---|---|---|---|
| **Near Mouth of Bear Canyon** | | | |
| Nov. 1975 | 2 | 40 | 100 |
| April 1977 | 0 | 0 | 0 |
| July 1978 | 14 | 140 | 86 |
| **Eagle Rock Campground** | | | |
| July 1976 | 17 | 228 | 76 |
| **Questa Ranger/Gaging Station** | | | |
| Sept. 1988 | 0 | 0 | 0 |
| Aug. 1995 | 0 | 0 | 0 |
| Aug. 1996 | 2 | 32 | 0 |
| **Head of Eagle Rock Lake** | | | |
| Nov. 1975 | 10 | 200 | 50 |
| July 1976 | 35 | 700 | 46 |
| April 1977 | 12 | 120 | 0 |

This reach of the river appears to have low suitability to maintain trout populations. The most apparent reason for this low suitability appears to be excessive sediment conditions (both physical sediment and particulate precipitate). In addition, some effects of chemical stress may be present from dissolved aluminum. The influence of Capulin Canyon appears to preclude improvements in the suitability of this reach of the river for trout.

Questa to Rio Grande

The reach of the Red River from Questa downstream to the confluence with the Rio Grande consistently supported rainbow and brown trout (Appendix A, Table A1). The abundance of these two species has been evenly mixed over the years (Table 8). A few white suckers and two chubs were also collected. The rainbow trout were probably maintained by stocking; brown trout were probably maintained by natural reproduction.

**TABLE 8:** Historical fish collection data for the reach of the Red River from Questa downstream to the Rio Grande. First pass data only.

| Site, Date | Total # Collected | Total #/Mile | % RBT |
|---|---|---|---|
| **SH 522 Bridge** | | | |
| Sept. 1980 | 46 | 815 | 78 |
| **Upstream of hatchery diversion** | | | |
| Oct. 1960 | 6 | 317 | 0 |
| July 1976 | 32 | 640 | 69 |
| Sept. 1980 | 23 | 405 | 26 |
| Nov. 1986 | 28 | 687 | 65 |
| Sept. 1987 | 12 | 316 | 8 |
| Sept. 1988 | 49 | 1,293 | 27 |
| Sept. 1995 | 29 | 424 | 55 |
| Aug. 1996 | 100 | 1,609 | 14 |
| **Downstream of hatchery diversion** | | | |
| July 1976 | 32 | 640 | 69 |
| April 1977 | 126 | 1,260 | 64 |
| Nov. 1986 | 47 | 1,241 | 36 |
| Sept. 1987 | 36 | 950 | 8 |
| Sept. 1988 | 71 | 1,875 | 34 |
| **Downstream of hatchery** | | | |
| June 1981 | 29 | 290 | 55 |
| Sept. 1984 | 37 | 370 | 38 |

**TABLE 8:** Continued.

| Site, Date | Total # Collected | Total #/Mile | % RBT |
|---|---|---|---|
| Aug. 1985 | 16 | 160 | 6 |
| Nov. 1986 | 230 | 2,300 | 47 |
| Sept. 1987 | 59 | 590 | 37 |
| Sept. 1988 | 130 | 1,300 | 11 |
| **Between hatchery and El Aujae Campground** | | | |
| Oct. 1974 | 371 | 2,474 | 89 |
| Nov. 1979 | 34 | 680 | 24 |
| June 1981 | 70 | 350 | 66 |
| Feb. 1984 | 8 | 80 | 0 |
| Sept. 1984 | 75 | 375 | 19 |
| Aug. 1985 | 40 | 200 | 3 |
| Nov. 1986 | 224 | 1,120 | 7 |
| Sept. 1987 | 120 | 600 | 11 |
| Sept. 1988 | 243 | 1,215 | 0 |
| **El Aujae Campground** | | | |
| Sept. 1976 | 55 | 1,100 | 44 |
| June 1981 | 57 | 570 | 81 |
| Sept. 1984 | 22 | 220 | 9 |
| Aug. 1985 | 17 | 170 | 6 |
| Nov. 1986 | 74 | 740 | 7 |
| Sept. 1987 | 58 | 580 | 7 |
| Sept. 1988 | 126 | 1,260 | 1 |
| **La Junta Point** | | | |
| Nov. 1979 | 37 | 740 | 16 |
| June 1981 | 37 | 370 | 49 |
| Sept. 1984 | 34 | 340 | 9 |
| Aug. 1985 | 47 | 470 | 43 |

A baseline abundance of 317 brown trout/mile was present during sampling in 1960 (Table 8). This abundance of fish was exceeded during almost all subsequent sampling periods at all sites. On many occasions, brown trout abundance, alone, exceeds this level, without the stocked rainbow trout. Brown trout populations in this section of the Red River appear to be healthy and self-sustaining. Abundance levels equal or exceed those that were found in the headwater reach of the river, upstream of the Town of Red River.

**Historical Benthic Invertebrate Populations**

Upstream of Red River

In the Red River upstream of the Town of Red River, benthic invertebrate sampling indicates the presence of healthy, diverse populations (Table 9; Appendix B, Table B1). Density was consistently higher than 1,000 invertebrates/$m^2$ at most sites, and the diversity indices were consistently higher than 3.0. The number of taxa varied substantially over the years. However, this may be the result of differing methods employed among the different studies.

Baseline conditions in 1965 indicate just over 1,000 invertebrates/$m^2$ and 20-22 taxa were present at the two sites in this reach (Table 9). Most of the taxa were EPT taxa, indicating suitable water quality and substrate conditions.

**TABLE 9:** Historical benthic invertebrate collection data for the reach of the Red River upstream of the Town of Red River.

| Site, Date | # of Taxa | % EPT Taxa | #/$m^2$ | g/$m^2$ | Diversity Index |
|---|---|---|---|---|---|
| **East Fork at Blue Lake Trail** | | | | | |
| June 1960 | 9 | 78 | 542 | -- | -- |
| **Zwergel Gaging Station** | | | | | |
| Sept. 1980 | 27 | 59 | K | -- | -- |
| April 1985 | 27 | 63 | 2,501 | -- | 3.60 |
| Aug. 1986 | 16 | 69 | 1,567 | -- | 3.03 |
| Sept. 1988 | 28 | 61 | 2,038 | -- | 3.77 |
| April 1992 | 31 | 64 | 2,765 | -- | 3.64 |
| **Upstream of Bitter Creek** | | | | | |
| Nov. 1965 | 22 | 77 | 1,044 | -- | -- |
| Nov. 1970 | 17 | -- | 3,548 | -- | -- |
| April 1992 | 29 | 59 | 3,090 | -- | 3.45 |
| **Downstream of Bitter Creek** | | | | | |
| Nov. 1965 | 20 | 90 | 1,267 | -- | -- |
| Nov. 1970 | 16 | -- | 2,971 | -- | -- |
| April 1992 | 26 | 65 | 2,551 | -- | 3.46 |

K = kick sample (qualitative)

Red River to Hansen Creek

In the reach of the river downstream of the Town of Red River, most population indices still indicate healthy invertebrate populations. However, a slight impairment from the conditions upstream of the Town of Red River is apparent. For example, densities are lower in many cases than in the reach upstream (Table 10), with several density values less than 1,000/m$^2$. Three of the eight calculated diversity indices are less than 3.0. These population parameters suggest some historical impairment near the Town of Red River. There was no baseline sampling location in 1965 in this reach of the Red River.

**TABLE 10:** Historical benthic invertebrate collection data for the reach of the Red River from the Town of Red River downstream to Hansen Creek.

| Site, Date | # of Taxa | % EPT Taxa | #/m$^2$ | g/m$^2$ | Diversity Index |
|---|---|---|---|---|---|
| **June Bug Campground** | | | | | |
| Sept. 1980 | 25 | 68 | K | -- | -- |
| Jan. 1984 | 22 | 68 | 2,071 | -- | 3.13 |
| Aug. 1986 | 21 | 71 | 1,145 | -- | 3.33 |
| Sept. 1988 | 14 | 64 | 771 | -- | 2.59 |
| April 1992 | 20 | 65 | 1,835 | -- | 3.13 |
| **Elephant Rock Campground** | | | | | |
| Nov. 1970 | 17 | -- | 1,152 | -- | -- |
| Sept. 1980 | 27 | 67 | K | -- | -- |
| April 1985 | 21 | 67 | 916 | -- | 3.79 |
| Aug. 1986 | 23 | 70 | 2,090 | -- | 3.15 |
| Sept. 1988 | 16 | 62 | 997 | -- | 2.92 |
| April 1992 | 18 | 72 | 1,407 | -- | 2.71 |

K = kick sample (qualitative)

Hansen Creek to Molycorp Boundary

Downstream of Hansen Creek the historical data indicate that invertebrate density was relatively low, compared to sites upstream of Red River. Density levels in this reach of the Red River are less than a few hundred invertebrates/m$^2$ in many cases (Table 11). This contrasts with levels of nearly 800/m$^2$ to over 2,000/m$^2$ in the reach immediately upstream (Table 10). The number of taxa is also substantially lower in this reach. For baseline conditions in 1965, this reach exhibited a significant (ANOVA, $p < 0.05$) 20% reduction in abundance, and a 37% decrease in number of taxa compared to the river upstream of the Town

of Red River (Tables 9 and 11). These 1965 USDHEW data appear to contradict the conclusions of the report by USDHEW (1966), and the reiteration of these conclusions in Slifer (1996), which state that "the water is clean at all stations sampled in the study area." This USDHEW conclusion appears to have been directed toward the amount of organic pollution in the river as based on the biotic indices. In fact, the USDHEW population parameters indicate substantial impacts to invertebrate population levels downstream of Hansen Creek, even under baseline conditions.

**TABLE 11:** Historical benthic invertebrate collection data for the reach of the Red River from Hansen Creek downstream to the Molycorp property boundary.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Diversity Index |
|---|---|---|---|---|---|
| **Upstream of Molycorp property boundary** | | | | | |
| Nov. 1965 | 17 | 71 | 337 | -- | -- |
| May 1971 | 5 | 60 | 99 | 1.7 | -- |
| June 1971 | 9 | 78 | 210 | 4.2 | -- |
| July 1971 | 9 | 89 | 109 | 4.0 | -- |
| Sept. 1971 | 9 | 78 | 90 | 2.7 | -- |
| Oct. 1971 | 4 | 100 | 29 | 0.8 | -- |
| Nov. 1971 | 10 | 70 | 160 | 2.9 | -- |
| Oct. 1976 | -- | -- | 562 | 6.0 | -- |
| March 1977 | -- | -- | 787[a] | 1.7 | -- |
| Oct. 1977 | -- | -- | 56 | 0.7 | -- |
| March 1978 | -- | -- | 959 | 7.3 | -- |
| Aug. 1979 | -- | -- | -- | 1.6 | -- |
| Sept. 1979 | -- | -- | -- | 0.4 | -- |
| Sept. 1980 | 18 | 72 | K | -- | -- |
| July 1981 | -- | -- | -- | 26.5 | -- |
| Oct. 1982 | -- | -- | -- | 4.4 | -- |
| Oct. 1983 | -- | -- | -- | 2.7 | -- |
| Sept. 1988 | 16 | 62 | 1,275 | -- | 2.82 |
| Oct. 1988 | 10 | 90 | 230 | -- | 2.92 |
| April 1992 | 13 | 62 | 1,594 | -- | 2.41 |

K = kick sample (qualitative)
[a] = published value miscalculated as 112/m²

The percent EPT taxa is relatively high in the samples from 1971 and in the late 1980's and early 1990's (Table 11). This suggests a physical impact to the population, such as the input of sediment from Hansen Creek. Increased sediment levels can reduce the density of invertebrates (Culp *et al.* 1986,

Farnworth *et al.* 1979, Rosenberg and Snow 1975, Gammon 1970). However, periodic influx of storm flows from Hansen Creek, which would contain elevated metal levels, as well, may also be affecting this reach.

Molycorp Boundary to Capulin Canyon

The data available for the reach of the Red River from the Molycorp property boundary downstream to Capulin Canyon are very limited (Table 12). However, in most cases densities are similar to those in the reach of the river just downstream of Hansen Creek. The number of taxa appears to be slightly higher than in the reach upstream. As all of these samples were collected downstream of Columbine Creek; this suggests some improvement to the water quality and/or sediment due to Columbine Creek or through colonization by drifting invertebrates from this tributary.

**TABLE 12:** Historical benthic invertebrate collection data for the reach of the Red River from the Molycorp property boundary downstream to Capulin Canyon.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Diversity Index |
|---|---|---|---|---|---|
| **Downstream of Columbine Creek** | | | | | |
| Sept. 1980 | 26 | 70 | K | -- | -- |
| **Upstream of Goathill Gulch** | | | | | |
| Nov. 1965 | 14 | 71 | 402 | -- | -- |
| Nov. 1970 | 11 | -- | 933 | -- | -- |
| **Goathill Campground** | | | | | |
| Oct. 1976 | -- | -- | 808[a] | 6.5 | -- |
| March 1977 | -- | -- | 211 | 4.5 | -- |
| Oct. 1977 | -- | -- | 43 | 0.3 | -- |
| March 1978 | -- | -- | 1,677 | 32.3 | -- |
| July 1978 | -- | -- | 443 | 5.2 | -- |
| Aug. 1979 | -- | -- | -- | 0.6 | -- |
| Sept. 1979 | -- | -- | -- | 0.6 | -- |
| Sept. 1980 | 20 | 75 | K | -- | -- |
| July 1981 | -- | -- | -- | 3.0 | -- |
| Oct. 1982 | -- | -- | -- | 1.9 | -- |
| Oct. 1983 | -- | -- | -- | 1.5 | -- |
| Oct. 1988 | 6 | 83 | 79 | -- | 1.96 |

K = kick sample (qualitative)
[a] = published value miscalculated as 763/m²

Baseline conditions in 1965 indicate number of taxa, percent EPT taxa, and density are similar to those in the reach downstream of Hansen Creek (Table 11). The density levels at these two sites from 1965 were not significantly different. This indicates no substantial differences in the limited suitability of these two reaches of the Red River to support invertebrates in 1965, which again appears to contradict the conclusions in USDHEW (1966), which was the source of the baseline data.

Capulin Canyon to Questa

In the reach of the Red River downstream of Capulin Canyon, low number of taxa and low density of invertebrates have historically been present (Table 13). The densities are comparable to the two reaches just upstream: the reaches downstream of Hansen Creek and on the reach adjacent to the Molycorp property. However, the number of taxa in the reach downstream of Capulin Canyon appear to be somewhat lower than in the reaches upstream. This suggests additional impacts to the invertebrate populations are occurring in this reach, possibly due to the influences of Capulin Canyon. The percent EPT taxa is comparable to all upstream reaches of the river.

Baseline conditions in 1965 indicate low number of taxa and low density (Table 13). The density at the Questa Ranger Station site in 1965 was significantly lower (ANOVA, $p < 0.02$) than that at the adjacent site upstream on the Molycorp property. This indicates that this reach of the river historically was significantly less suitable for supporting benthic invertebrates than the reach of river adjacent to the Molycorp property. These data again contradict the conclusion that biological conditions in the Red River in 1965 were of high quality (USDHEW 1966).

**TABLE 13:** Historical benthic invertebrate collection data for the reach of the Red River from Capulin Canyon to Questa.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Diversity Index |
|---|---|---|---|---|---|
| **Eagle Rock Campground** | | | | | |
| May 1971 | 5 | 80 | 31 | 2.9 | -- |
| June 1971 | 5 | 40 | 74 | 1.1 | -- |
| July 1971 | 8 | 50 | 59 | 2.9 | -- |
| Sept. 1971 | 6 | 67 | 50 | 1.3 | -- |
| Oct. 1971 | 8 | 88 | 149 | 3.5 | -- |
| Nov. 1971 | 7 | 71 | 50 | 2.3 | -- |
| Oct. 1976 | -- | -- | 170 | 1.4 | -- |
| March 1977 | -- | -- | 555[a] | 7.8 | -- |
| Oct. 1977 | -- | -- | 82 | 2.4 | -- |
| March 1978 | -- | -- | 52 | 0.5 | -- |
| July 1978 | -- | -- | 490 | 16.3 | -- |
| Aug. 1979 | -- | -- | -- | 0.2 | -- |
| Sept. 1979 | -- | -- | -- | 1.0 | -- |
| July 1981 | -- | -- | -- | 1.5 | -- |
| Oct. 1982 | -- | -- | -- | 1.4 | -- |
| Oct. 1983 | -- | -- | -- | 2.4 | -- |
| **Questa Ranger/Gaging Station** | | | | | |
| Nov. 1965 | 9 | 67 | 83 | -- | -- |
| Nov. 1970 | 11 | -- | 448 | -- | -- |
| Sept. 1988 | 6 | 100 | 171 | -- | 2.06 |
| Oct. 1988 | 3 | 100 | 108 | -- | 1.30 |
| April 1992 | 10 | 60 | 490 | -- | 1.18 |

K = kick sample (qualitative)
[a] = calculated value approximately 112/m²

Questa to Rio Grande

The historical data in the reach of the Red River downstream of Questa suggest some improvement in conditions for benthic invertebrates, compared to the reach of the river just upstream of Questa. Density of invertebrates was almost always greater than 100/m², and in many cases was at least several hundred/m² (Table 14). The number of taxa also is greater in most cases in the reach downstream of Questa, relative to the reach upstream of Questa. These improvements are probably due, at least in part, to the positive influence of the input of water from Cabresto Creek.

**TABLE 14:** Benthic Invertebrate collection data for the reach of the Red River from Questa downstream to the Rio Grande.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Diversity Index |
|---|---|---|---|---|---|
| **SH 522 Bridge** | | | | | |
| Nov. 1965 | 6 | 67 | 108 | -- | -- |
| Nov. 1970 | 10 | -- | 818 | -- | -- |
| Sept. 1980 | 22 | 73 | K | -- | -- |
| April 1985 | 17 | 59 | 388 | -- | 3.48 |
| Aug. 1986 | 17 | 71 | 607 | -- | 3.34 |
| April 1992 | 13 | 69 | 535 | -- | 2.43 |
| **Upstream of Pope Creek** | | | | | |
| May 1971 | 11 | 82 | 290 | 7.14 | -- |
| June 1971 | 5 | 40 | 216 | 3.78 | -- |
| July 1971 | 8 | 75 | 326 | 5.04 | -- |
| Sept. 1971 | 8 | 75 | 82 | 0.84 | -- |
| Oct. 1971 | 8 | 88 | 147 | 2.10 | -- |
| Nov. 1971 | 8 | 88 | 617 | 3.36 | -- |
| Oct. 1976 | -- | -- | 765 | 6.6 | -- |
| March 1977 | -- | -- | 2,018 | 17.3 | -- |
| Oct. 1977 | -- | -- | 159 | 1.1 | -- |
| March 1978 | -- | -- | 907 | 6.2 | -- |
| July 1978 | -- | -- | 211 | 1.8 | -- |
| Aug. 1979 | -- | -- | -- | 2.4 | -- |
| Sept. 1979 | -- | -- | -- | 2.0 | -- |
| July 1981 | -- | -- | -- | 6.7 | -- |
| Oct. 1982 | -- | -- | -- | 14.0 | -- |
| Oct. 1983 | -- | -- | -- | 6.9 | -- |
| Oct. 1988 | 11 | 64 | 362 | -- | 2.68 |
| **Upstream of hatchery diversion** | | | | | |
| June 1960 | 12 | 67 | 1,650 | -- | -- |
| Nov. 1965 | 10 | 50 | 291 | -- | -- |
| Nov. 1970 | 16 | -- | 2,759 | -- | -- |
| May 1971 | 9 | 78 | 299 | 10 | -- |
| June 1971 | 7 | 71 | 479 | 16 | -- |
| July 1971 | 8 | 62 | 199 | -- | -- |
| Sept. 1971 | 6 | 50 | 571 | -- | -- |
| Oct. 1971 | 5 | 60 | 479 | 10.9 | -- |
| Nov. 1971 | 7 | 57 | 84 | -- | -- |
| Oct. 1976 | -- | -- | 632 | 5.8 | -- |

**TABLE 14:** Continued.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Diversity Index |
|---|---|---|---|---|---|
| March 1977 | -- | -- | 1,875 | 51.6 | -- |
| Oct. 1977 | -- | -- | 224 | 2.5 | -- |
| March 1978 | -- | -- | 1,402 | 18.5 | -- |
| July 1978 | -- | -- | 2,207 | 21.1 | -- |
| Aug. 1979 | -- | -- | -- | 3.4 | -- |
| Sept. 1979 | -- | -- | -- | 1.0 | -- |
| July 1981 | -- | -- | -- | 4.9 | -- |
| Oct. 1982 | -- | -- | -- | 2.8 | -- |
| Oct. 1983 | -- | -- | -- | 6.9 | -- |
| Oct. 1988 | 11 | 64 | 495 | -- | 2.56 |
| **Downstream of Hatchery** | | | | | |
| April 1992 | 19 | 63 | 1,423 | -- | 3.19 |
| **Between hatchery and El Aujae Campground** | | | | | |
| Nov. 1965 | 20 | 50 | 344 | -- | -- |
| Nov. 1970 | 19 | -- | 3,523 | -- | -- |
| Aug. 1979 | -- | -- | -- | 1.7 | -- |
| Sept. 1979 | -- | -- | -- | 1.4 | -- |
| July 1981 | -- | -- | -- | 6.7 | -- |
| Oct. 1982 | -- | -- | -- | 9.8 | -- |
| Oct. 1983 | -- | -- | -- | 6.0 | -- |
| April 1985 | 20 | 75 | 2,047 | -- | 2.29 |
| Aug. 1986 | 17 | 65 | 1,836 | -- | 2.70 |
| Oct. 1988 | 12 | 58 | 1,973 | -- | 1.66 |
| **La Junta Point** | | | | | |
| Oct. 1988 | 10 | 70 | K | -- | -- |

K = kick sample (qualitative)

There is also some information that indicates conditions have improved over the last three decades. The baseline conditions at the two sites in this reach sampled in 1965 (State Highway 522 Bridge, above the hatchery diversion) indicate low numbers of taxa and low densities (Table 14). The 1965 densities in this reach were not significantly different from those in the reach upstream of Questa. However, the data from 1965 at the two sites in this reach clearly represent low densities relative to the data collected in this reach in the 1970's and 1980's.

## TEMPORAL PATTERNS OF AQUATIC BIOTA

### Fish

Fish collection data from 1960 were collected prior to the initiation of open pit mining, and represent baseline data. Fish collection in the spring of 1997 provide the most recent data available and allow a comparison of baseline and present conditions with which to evaluate the effects of open pit mining on the fish populations of the Red River. Also, data collected during the intervening period can be compared to investigate the trend over time.

USGS gaging records for the Red River were briefly examined for the period from 1958-1996. As fish populations can be impacted by extreme high and low flows, the flow records were evaluated in order to determine if fish collection data for the baseline period (1960) or the present (1997) were affected to any unusual degree by extremely high runoff flows or extremely low winter flows. It appears that, for several years prior to data collection in 1960, both high and low flows were not unusually extreme, and would probably not have affected resident fish populations to an unusual degree. Similarly, the flow levels over the past few years apparently have not affected fish populations sampled in 1997 to an unusual degree.

In order to make the data sets from the different periods comparable, only first pass electrofishing data were used. Also, since rainbow trout are maintained by stocking, and are not directly controlled by habitat and water quality conditions as are resident fish, rainbow trout numbers have been omitted from the comparison. The intervening period was defined as 1974 through 1988. The year 1974 represents the first available data collected after the initiation of open pit mining. Data collected in 1995 and 1996 by NMDGF were omitted from the intervening period as these two years are probably more representative of present conditions than the period between baseline and the present. All data were presented as the number of fish collected on the first pass per mile of river. For the intervening years (1974-1988), all collection sites within a reach of the river were averaged; at sites with only rainbow trout present, or with no fish collected, a value of 0 fish per mile was used in the calculations.

The Red River apparently experiences a relatively high level of recreational fishing pressure (Akroyd, R.F. 1997, personal communication). This fishing pressure is apparently dispersed throughout the length of the river from the reach upstream of Red River downstream to near the fish hatchery. Recreational fishing commonly has a substantial influence in the fish present in a reach of river, and this is probably also the case in the Red River. However, we have no information that indicates that one reach of the Red River is affected to a larger degree than others in the past or at present. Therefore, we assume that fishing pressure is affecting the different reaches of the Red River at roughly equal levels.

It has been our experience that stocked rainbow trout are more vulnerable to being caught by anglers; the resident brown trout are considerably less vulnerable. Rainbow trout commonly absorb the brunt of the fishing pressure. This was the case in the Red River based on data from 1959-1974 (Pacific 1979). Data from this period indicated that rainbow trout comprised 97% of the total fish caught by anglers; slightly less than 3% of the catch were brown trout, with a few cutthroat and brook trout also caught (Pacific 1979). Thus, the elimination of rainbow trout from the data comparisons, below, helps minimize the effects of fishing pressure in evaluating the trends in fish data discussed below.

The longitudinal trends in fish density (number of fish/mile) show a similar trend for baseline conditions (1960 data), the period during operation of the open pit mine (1974-1988 data), and present conditions (1997 data). The trends all indicate a substantial decrease in trout density downstream of the Town of Red River (Fig. 24). However, an even more dramatic decrease in trout density is evident downstream of Hansen Creek. This pattern is evident for baseline (1960) data, prior to the initiation of open pit mining, as well as the later sampling periods. The data for all three periods also show a substantial increase in trout density downstream of Questa.

A direct comparison between the data from 1960 and 1997 indicate that at all four reaches where corresponding data were collected in both years (upstream of Red River, Red River to Hansen Creek, the Molycorp property between the Molycorp property boundary and Capulin Creek, and Questa to the Rio Grande), the fish density in 1997 is higher than in 1960 (Fig. 24). Although the collection methods utilized in 1997 may have been more efficient, the higher fish densities in 1997 indicate that the Red River is at least as suitable for sustaining trout in 1997 as it was in 1960.

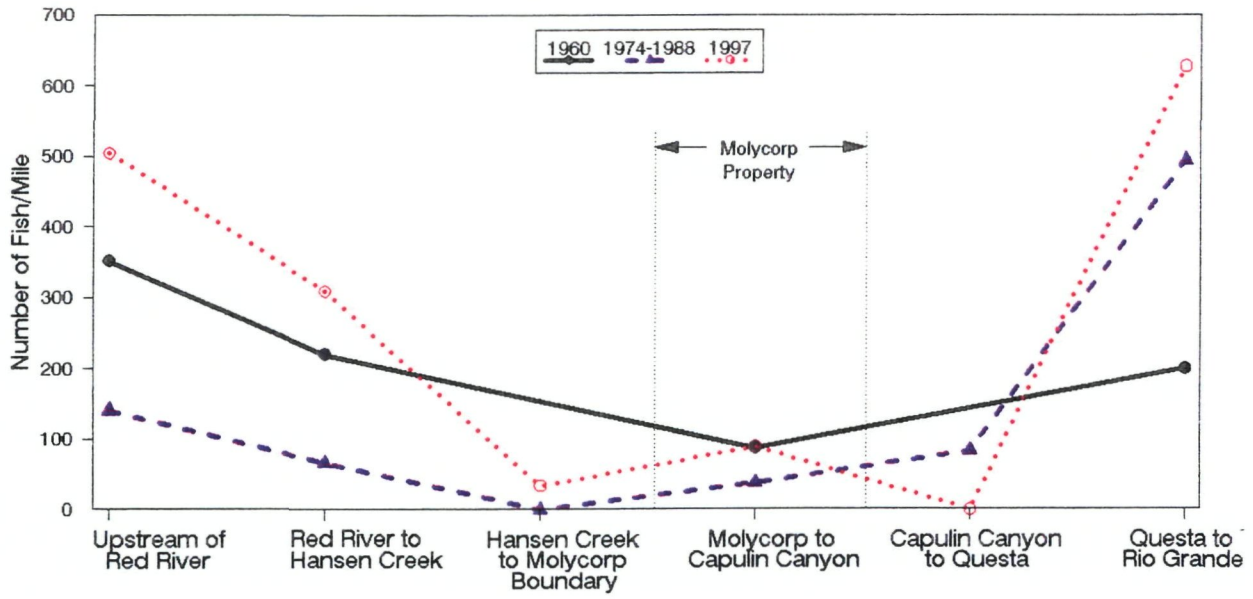


**FIGURE 24:** Longitudinal trends in fish density (no./mile) for baseline conditions (1960 data), open pit mine operation (1974-1988 data), and the present (1997 data). First pass data only, rainbow trout excluded.

In the reach of the Red River downstream of Capulin Canyon and upstream of Questa (the Questa Ranger Station Site), no fish were found in 1997 (Table 1), or in 1988 and 1995. In 1996, only two brown trout were collected at this site. No corresponding site was sampled in this reach of the river in 1960, or apparently prior to 1988. Therefore, no direct comparison is possible between baseline and present conditions at this site.

The direct comparison found in Slifer (1996), indicating that trout density has decreased from 572 fish per mile down to 0 fish per mile between 1960 and 1988, is an inaccurate comparison. First of all, the fish per mile figure used in Slifer (1996) from 1960 is actually data for the 1960 site located *upstream* of Columbine Creek. The 1988 data referred to by Slifer (1996) as having no fish is from a site located at the Questa Ranger Station, approximately 4.5 miles downstream of the 1960 site. As the influences of both Columbine Creek, Capulin Canyon, and other point and non-point sources of potential changes to the river occur between the location of the 1960 site and the 1988 Questa Ranger Station site, the comparison in Slifer

(1996) is misleading and inaccurate. In fact, there are no matching sites between the 1960 and 1988 studies that would allow such a comparison as made in Slifer (1996).

In addition, the 572 fish per mile reportedly collected at the 1960 site (upstream of Columbine Creek) is actually 88 fish per mile, excluding stocked rainbow trout. In 1960 (October), a single electrofishing pass was made through 300 feet of stream, and 11 rainbow and 5 brown trout were collected, for a total of 16 fish per 300 feet of stream, or 282 fish per mile actually captured. However, this number was expanded by more than 100% in an attempt to account for poor visibility at the time of sampling (Parish 1975b). The expanded number of 572 simply represents a wild guess as to the number of fish present, and is an inappropriate way to treat field data. This conclusion was also reached by NMDGF (Parish 1975b). As discussed above, for purposes of comparing resident fish rather than recently stocked fish, only the brown trout numbers actually collected were considered in this report. If this is done, the actual number is 88 fish per mile in 1960.

More importantly, the trend in trout density in 1960, 1974-1988, and 1997 data all indicate negative impacts to the trout beginning in the reach immediately downstream of the Town of Red River. A more substantial negative impact occurs downstream of Hansen Creek. The cumulative effects of these impacts reduce trout density to very low levels prior to the reach of river adjacent to the Molycorp property. Adjacent to the mine, slight increases in trout density are found. This is probably due, in part, to the positive impact on the Red River due to the input of water or migrating fish from Columbine Creek. Downstream of Capulin Canyon, the trout density is reduced even further. Downstream of Questa, the suitability of the Red River to support trout is more comparable to that found upstream of the Town of Red River.

**Benthic Invertebrates**

Benthic invertebrate data from early November 1965 were apparently collected prior to the initiation of open pit mining, and represent baseline data. Benthic invertebrate data collected in December 1995 represent the most recent data available and allow a comparison of baseline and present conditions with which to evaluate the effects of open pit mining on the benthic invertebrate populations of the Red River. Data available from the intervening period can also be used to investigate the long-term trend in populations.

In order to make appropriate comparisons between the data sets, the two population parameters of density (no./$m^2$) and number of taxa are used. These two parameters are common to most of the available data sets. Also, these two parameters are useful and commonly used in evaluating physical and chemical impacts to benthic invertebrate populations.

The longitudinal trend in benthic invertebrate density shows a general decrease from the reach upstream of Red River downstream to near Questa (Fig. 25). This trend is evident for baseline conditions (1965 data), the period during the operation of the open pit mine (1970-1992 data), and for present conditions (1995 data).

For all data sets, there is a decrease in invertebrate density downstream of the Town of Red River. There is a further decrease in density downstream of Hansen Creek. All three data sets reach their lowest density in the reach of the Red River between Capulin Canyon and Questa. Downstream of Questa all three data sets indicate a substantial increase in benthic invertebrate density. This pattern was clearly established in benthic invertebrate populations in 1965, prior to open pit mining, and continues to present.

The trend in number of taxa among the three data sets shows decreases from upstream of Red River downstream to near Questa (Fig. 26). The trend for all data sets show a substantial decrease in taxa in the reach downstream of Hansen Creek, upstream of the Molycorp mine. The decrease continues, with lowest number of taxa in the reach downstream of Capulin Canyon for the 1995 and 1970-1992 data sets. For the 1965 data set, the reach downstream of Questa exhibited the lowest number of taxa.

In all six reaches of the Red River, the present benthic invertebrate density and number of taxa are substantially higher than those of the baseline period (1965) and the period of open-pit mine operation (1970-1992 data). Although the collection and analysis methods varied between the various studies, this information suggests that the Red River is at least as suitable for sustaining benthic invertebrates at present as it was prior to open pit mining operations.

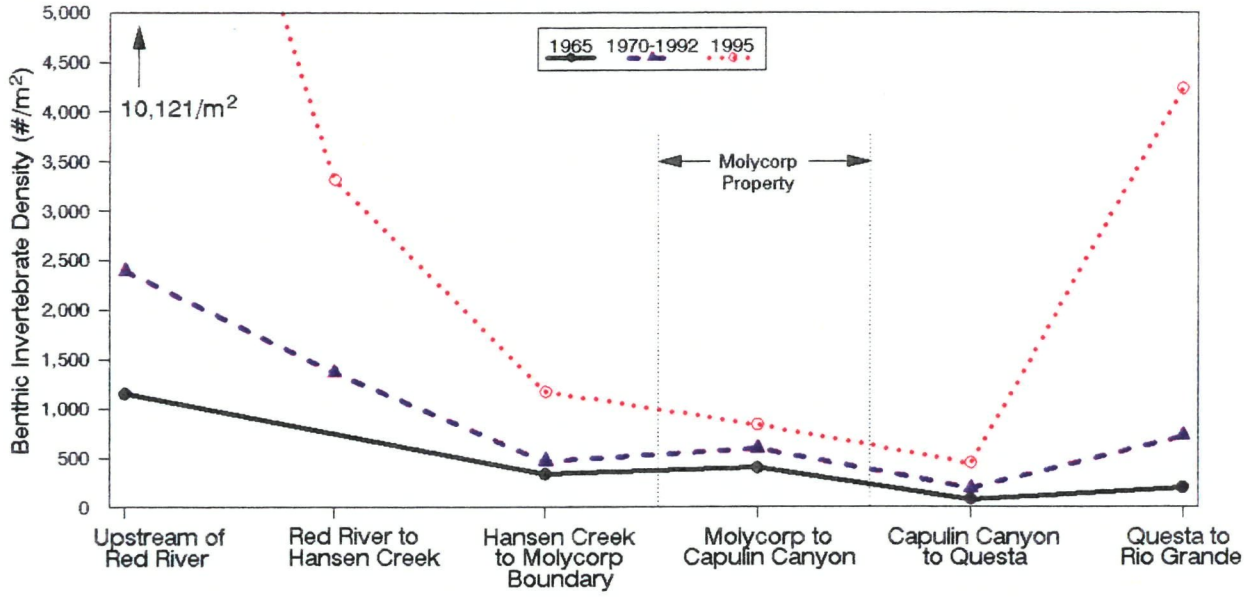


**FIGURE 25:** Longitudinal trends in benthic invertebrate density (no./$m^2$) for baseline conditions (1965 data), open pit mine operation (1970-1992), and the present (1995).

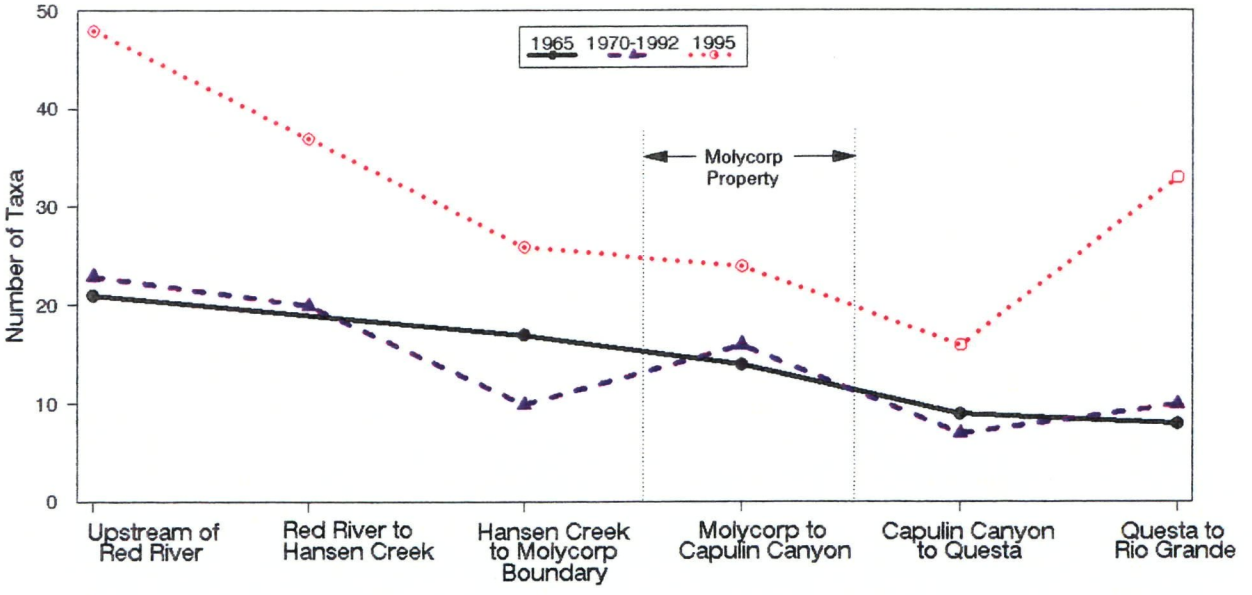


**FIGURE 26:** Longitudinal trends in the number of benthic invertebrate taxa for baseline conditions (1965 data), open pit mine operation (1970-1992 data), and the present (1995 data).

## CONCLUSIONS

Fish data were collected during three separate periods. Baseline data were collected in 1960; recent data were collected in 1997; data during the operation of the Questa Molybdenum Mine were collected during 1974-1988. The three sets of data indicate a similar pattern of fish density along the length of the Red River.

All three data sets indicate that negative impacts to fish populations occur in the reach downstream of the Town of Red River. These impacts appear to be the result of increased sedimentation of the river. All three data sets also indicate that a more substantial impact to fish populations occurs downstream of Hansen Creek. Apparently, this is due to increased sedimentation of the Red River from the input of sediment from Hansen Creek, although periodic inputs of elevated metals and reduced pH from the thermal scars during storm events may contribute to the decrease. This trend was established in 1960, prior to the initiation of open pit mining at the Questa Mine.

The baseline data indicate that the lowest fish population levels in the Red River occurred in 1960 at the site adjacent to the future open-pit mine (the site sampled upstream of Columbine Creek). The data from 1974-1988 and 1997 also indicate low fish population levels in this reach of the river. However, these two data sets exhibited lower fish density at the sites just downstream of Hansen Creek, upstream of the mine.

The three data sets also indicate increasing fish densities at sites downstream of Questa. This is apparently due to improvements in the sediment levels, and perhaps water quality at sites in this reach of the river.

The similarity in the longitudinal trend in fish density between the three data collection periods (1960, 1974-1988, 1997) indicates that the relative suitabilities of the distinct reaches of the Red River to sustain fish populations has not changed substantially over this period. This trend is apparently independent of open pit mining activities, including the creation of the waste rock piles at the Questa Molybdenum Mine.

Comparisons between baseline fish densities and present conditions indicate that, at all corresponding sampling sites between 1960 and 1997, there are higher densities of resident trout (excluding stocked rainbow trout) at present than during baseline conditions. Although sampling methods between the two periods were different, this indicates that the suitability of the Red River to sustain trout likely has improved over this period.

The present trend in trout density (1997 data) indicates impacts to the fishery occur near the Town of Red River. A much more substantial impact occurs downstream of Hansen Creek, upstream of the Questa Mine. In this reach of the river, fish population parameters have decreased by over 95% as compared to the reach upstream of the Town of Red River. Downstream of Capulin Canyon, the trout density is reduced to zero, apparently as a result of the impact of sediment on the fishery. The suitability of the Red River to support trout downstream of Questa improves to levels comparable to that found upstream of Red River.

Benthic invertebrate data collection parallels that of fish data collection, with baseline data collected in 1965, recent data collected in 1995, and data collected during the operation of the open pit mine during the years of 1970-1992. The three sets of benthic invertebrate data indicate a similar pattern of invertebrate population parameters along the length of the Red River.

All three data sets indicate a substantial reduction in benthic invertebrate density and number of taxa in the reach from the Town of Red River to the reach downstream of Hansen Creek. Apparently this is due to the increased sedimentation of this reach of the river, although periodic input of metals and lower pH during storm flows may contribute to the trend. This trend was established in 1965, prior to the initiation of open pit mining.

The baseline data indicate lowest benthic invertebrate density occurred in the reaches of the Red River from Hansen Creek downstream to Questa. This pattern is also evident from data collected in 1970-1992 and from data collected in 1995. All three data sets indicate increasing density at sites downstream of Questa. This is apparently due to improvements in sediment levels and/or water quality at the sites in this reach of the river. The number of taxa follows a similar longitudinal trend, with decreasing numbers of taxa in reaches downstream of the Town of Red River. However, in contrast to the density data, the number of

taxa continues to decline for all three data sets down to lowest levels in the reach downstream of Capulin Canyon.

The similarity in the longitudinal trend in benthic invertebrate population parameters for all three data collection periods (1965, 1970-1992, 1995) indicates that the relative suitabilities of the reaches of the Red River to support invertebrates has not changed substantially over this period. The reaches of the Red River from Hansen Creek downstream to Questa have supported reduced populations of benthic invertebrates in the past, and at present. This trend is independent of open pit mining activities at the Questa Molybdenum Mine.

Present invertebrate population levels are higher than for baseline conditions. Although sampling methods between the two periods were different, this suggests that there may have been improvements in the suitability of the Red River to support invertebrates over the period from 1965 to 1995.

The present trend in benthic invertebrate populations indicates impacts occur downstream of the Town of Red River. As was the case with fish populations, a much more substantial impact occurs downstream of Hansen Creek, but upstream of the Questa Mine. Through the reaches of the river adjacent to the mine, and downstream of Capulin Canyon, there are further decreases in invertebrate population levels. Downstream of Questa, the populations improved substantially.

The trends for both fish and benthic invertebrates indicate that the cumulative impacts of sediment from a number of sources, and possibly decreased water quality, substantially decrease the suitability of the Red River to sustain aquatic biota in the reaches upstream of the Molycorp Questa Mine. This pattern was evident during both baseline and present conditions. In the reaches of the river adjacent to the mine and downstream of Capulin Canyon, the suitability of the river to sustain aquatic biota does not improve. This pattern was established prior to open pit mining during baseline conditions and continues to the present. The open pit mine and waste rock piles do not appear to have measurably impacted the suitability of the Red River to support aquatic biota.

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# APPENDIX A

# FISH DATA

**TABLE A1:** Historical fish population data for sites on the Red River, New Mexico. Fist pass data only.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **East Fork at Blue Lake Trail** | | | | | | | | | | | | |
| June/Aug. 1960 | CUT | 17 | 299 | 186 | 16.7 | 407 | 36.6 | 176 | 90 | 1 (70%) | 300 | NMDGF (1960) |
| | BRK | 3 | 53 | 33 | 2.9 | 72 | 6.4 | 165 | 89 | 1 (70%) | 300 | NMDGF (1960) |
| **Just Downstream of the Forks** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 32 | 640 | 398 | 46.3 | 687 | 80.0 | 434 | 229 | 1 | 264 | Parish (1975a) |
| | BRK | 3 | 60 | 37 | 1.2 | 64 | 2.0 | 154 | 32 | 1 | 264 | Parish (1975a) |
| May 1977 | RBT | 107 | 1,070 | 665 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | CUT | 2 | 20 | 12 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | BRK | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | Hybrid | 2 | 20 | 12 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| July 1978 | RBT | 95 | 950 | 590 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | UNK | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| Sept. 1978 | RBT | 24 | 480 | 298 | -- | -- | -- | * | -- | 1 (70%) | 264 | Parish (1978b) |
| **2.0 Mi. Downstream of the Forks** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 16 | 320 | 199 | -- | 408 | -- | 186 | -- | 1 | 264 | Parish (1975a) |
| | CUT | 4 | 80 | 50 | 2.7 | 102 | 5.5 | 116 | 54 | 1 | 264 | Parish (1975a) |
| | BRK | 3 | 60 | 37 | 0.5 | 77 | 1.1 | 145 | 14 | 1 | 264 | Parish (1975a) |
| | BRN | 1 | 20 | 12 | -- | 26 | -- | 200 | -- | 1 | 264 | Parish (1975a) |
| | UNK | 3 | 60 | 37 | -- | 77 | -- | * | -- | 1 | 264 | Parish (1975a) |
| May 1977 | RBT | 81 | 810 | 503 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | BRK | 3 | 30 | 19 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | CUT | 2 | 20 | 12 | | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| July 1978 | RBT | 54 | 540 | 336 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | UNK | 2 | 20 | 12 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| Sept. 1978 | RBT | 13 | 260 | 162 | -- | -- | -- | * | -- | 1 | 264 | Parish (1978b) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2.9 Mi. Downstream of the Forks** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 23 | 460 | 286 | -- | 426 | -- | 214 | -- | 1 | 264 | Parish (1975a) |
| | CUT | 14 | 280 | 174 | 11.9 | 259 | 17.7 | 184 | 68 | 1 | 264 | Parish (1975a) |
| May 1977 | RBT | 141 | 1,410 | 876 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | CUT | 7 | 70 | 43 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| July 1977 | RBT | 63 | 630 | 391 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | CUT | 3 | 30 | 19 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| **Downstream of Valley of the Pines** | | | | | | | | | | | | |
| Aug. 1995 | CUT | 2 | 32 | 20 | 3.3 | 24 | 3.9 | 225 | 163 | 3 | 328 | Akroyd (1996) |
| | HYB | 3 | 48 | 30 | 3.8 | 36 | 4.6 | 203 | 127 | 3 | 328 | Akroyd (1996) |
| | RBT | 9 | 145 | 90 | 19.8 | 110 | 24.2 | 254 | 220 | 3 | 328 | Akroyd (1996) |
| | BRK | 10 | 161 | 100 | 2.9 | 122 | 3.6 | 89 | 29 | 3 | 328 | Akroyd (1996) |
| | BRN | 21 | 338 | 210 | 19.7 | 256 | 24.1 | 157 | 94 | 3 | 328 | Akroyd (1996) |
| **Zwergel Gaging Station** | | | | | | | | | | | | |
| May 1977 | RBT | 38 | 380 | 236 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | BRK | 5 | 50 | 31 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| | CUT | 8 | 80 | 50 | -- | -- | -- | * | -- | 1 (90%) | 528 | Parish (1977b) |
| July 1978 | RBT | 40 | 400 | 248 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | CUT | 9 | 90 | 56 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | BRK | 21 | 210 | 130 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | UNK | 3 | 30 | 19 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| Sept. 1978 | RBT | 6 | 120 | 74 | -- | -- | -- | * | -- | 1 | 264 | Parish (1978b) |
| | CUT | 11 | 220 | 137 | -- | -- | -- | * | -- | 1 | 264 | Parish (1978b) |
| | BRK | 12 | 240 | 149 | -- | -- | -- | * | -- | 1 | 264 | Parish (1978b) |
| | BRN | 1 | 20 | 12 | -- | -- | -- | * | -- | 1 | 264 | Parish (1978b) |
| Sept. 1980 | CUT | 13 | 229 | 142 | 8.9 | -- | -- | 172 | 63 | n.s. | 300 | Melancon *et al.* (1982) |
| | BRK | 10 | 176 | 109 | 6.8 | -- | -- | 159 | 62 | n.s. | 300 | Melancon *et al.* (1982) |
| | RBT | 5 | 88 | 55 | 7.9 | -- | -- | 237 | 144 | n.s. | 300 | Melancon *et al.* (1982) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 1988 | RBT | 16 | 258 | 160 | 16.4 | 258 | 26.4 | 206 | 102 | 3 | 328 | Akroyd (1988) |
| | CUT | 7 | 113 | 70 | 3.3 | 113 | 5.3 | 148 | 47 | 3 | 328 | Akroyd (1988) |
| Aug. 1996 | BRN | 7 | 113 | 70 | 9.0 | 146 | 18.7 | 217 | 128 | 3 | 328 | Akroyd (1997) |
| | RBT | 6 | 96 | 60 | 9.0 | 125 | 18.8 | 226 | 150 | 3 | 328 | Akroyd (1997) |
| | CUT | 29 | 467 | 290 | 1.0 | 630 | 2.3 | 60 | 4 | 3 | 328 | Akroyd (1997) |
| | BRK | 53 | 853 | 530 | 12.5 | 1,104 | 26.2 | 90 | 24 | 3 | 328 | Akroyd (1997) |
| **June Bug Campground** | | | | | | | | | | | | |
| Oct. 1960 | RBT | 13 | 411 | 255 | -- | -- | -- | 211 | -- | 1 (50%) | 170 | NMDGF (1960) |
| | BRN | 7 | 221 | 137 | -- | | -- | 161 | -- | 1 (50%) | 170 | NMDGF (1960) |
| Nov. 1975 | RBT | 2 | 20 | 12 | 0.5 | 20 | 0.9 | 159 | 45 | 1 | 528 | Parish (1975a) |
| | BRN | 15 | 150 | 93 | 2.9 | 153 | 4.7 | 133 | 31 | 1 | 528 | Parish (1975a) |
| | WS | 1 | 10 | 6 | 0.5 | 10 | 0.9 | 203 | 90 | 1 | 528 | Parish (1975a) |
| May 1977 | RBT | 47 | 470 | 292 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977b) |
| | BRN | 3 | 30 | 19 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977b) |
| | CUT | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977b) |
| | BRK | 2 | 20 | 12 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977b) |
| July 1978 | RBT | 73 | 730 | 454 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | BRN | 11 | 110 | 68 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | BRK | 4 | 40 | 25 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | UNK | 8 | 80 | 50 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| Sept. 1980 | BRN | 1 | 35 | 22 | 0.9 | -- | -- | 149 | 41 | n.s. | 150 | Melancon *et al.* (1982) |
| | RBT | 29 | 1,037 | 644 | 79.2 | -- | -- | 223 | 123 | n.s. | 150 | Melancon *et al.* (1982) |
| Sept. 1983 | RBT | 10 | 200 | 124 | -- | -- | -- | -- | -- | 1 | 264 | Patterson (1983) |
| | BRN | 4 | 80 | 50 | -- | -- | -- | -- | -- | 1 | 264 | Patterson (1983) |
| **Elephant Rock Campground** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 4 | 40 | 25 | 2.6 | 58 | 5.9 | 196 | 102 | 1 | 528 | Parish (1975a) |
| | BRN | 1 | 10 | 6 | 0.2 | 14 | 0.5 | 121 | 35 | 1 | 528 | Parish (1975a) |
| May 1977 | RBT | 22 | 220 | 137 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977b) |
| | BRN | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977b) |
| July 1978 | RBT | 20 | 200 | 124 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 1983 | No fish | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | 1 | 528 | Patterson (1983) |
| Sept. 1988 | BRN | 5 | 81 | 50 | 1.8 | 93 | 3.4 | 143 | 36 | 3 | 328 | Akroyd (1988) |
| | RBT | 1 | 16 | 10 | 0.7 | 18 | 1.4 | 199 | 74 | 3 | 328 | Akroyd (1988) |
| **Upstream of Molycorp property boundary** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 2 | 40 | 25 | -- | 54 | -- | * | -- | 1 | 264 | Parish (1975a) |
| July 1978 | RBT | 2 | 20 | 12 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| Sept. 1980 | RBT | 4 | 143 | 89 | 12.7 | -- | -- | 236 | 143 | n.s. | 150 | Melancon *et al.* 1982 |
| Aug. 1995 | RBT | 5 | 81 | 50 | 10.7 | 56 | 12.0 | 263 | 215 | 3 | 328 | Akroyd (1996) |
| | BRN | 5 | 81 | 50 | 4.5 | 56 | 5.0 | 150 | 89 | 3 | 328 | Akroyd (1996) |
| Aug. 1996 | RBT | 2 | 32 | 20 | 2.5 | 29 | 3.6 | 231 | 125 | 3 | 328 | Akroyd (1997) |
| | BRN | 5 | 81 | 50 | 4.5 | 71 | 6.1 | 175 | 86 | 3 | 328 | Akroyd (1997) |
| **Upstream of Columbine Creek** | | | | | | | | | | | | |
| Oct. 1960 | RBT | 11 | 193 | 120 | 17.0 | -- | -- | 234 | 142 | 1 | 300 | NMDGF (1960) |
| | BRN | 5 | 88 | 55 | 2.8 | -- | -- | 164 | 51 | 1 | 300 | NMDGF (1960) |
| **Downstream of Columbine Creek** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 5 | 100 | 62 | 6.7 | 88 | 9.6 | 216 | 109 | 1 | 264 | Parish (1975a) |
| | CUT | 5 | 100 | 62 | 1.3 | 88 | 1.8 | 126 | 21 | 1 | 264 | Parish (1975a) |
| | UNK | 2 | 40 | 25 | -- | 36 | -- | * | -- | 1 | 264 | Parish (1975a) |
| Sept. 1980 | RBT | 11 | 195 | 121 | 18.9 | -- | -- | 241 | 156 | n.s. | 300 | Melancon *et al.* (1982) |
| **Upstream of Goathill Gulch** | | | | | | | | | | | | |
| May 1977 | No fish | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | 1 | 528 | Parish (1977b) |
| **Goathill Campground** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 6 | 120 | 74 | -- | -- | -- | * | -- | 1 | 264 | Parish (1977a) |
| | CUT | 5 | 100 | 62 | -- | -- | -- | * | -- | 1 | 264 | Parish (1977a) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April 1977 | BRN | 4 | 40 | 25 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977a,b) |
| | RBT | 69 | 690 | 429 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977a,b) |
| | CUT | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977a,b) |
| July 1978 | RBT | 11 | 110 | 68 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | UNK | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| Sept. 1980 | RBT | 12 | 430 | 267 | 33.9 | -- | -- | 229 | 127 | n.s. | 148 | Melancon *et al.* (1982) |
| Sept. 1983 | RBT | 2 | 40 | 25 | -- | -- | -- | -- | -- | 1 | 264 | Patterson (1983) |
| **Near Mouth of Bear Canyon** | | | | | | | | | | | | |
| Nov. 1975 | RBT | 2 | 40 | 25 | 2.8 | 28 | 3.1 | 222 | 110 | 1 | 264 | Parish (1975a, 1977a) |
| April 1977 | No fish (2 dead RBT) | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | 1 | 528 | Parish (1977a,b) |
| July 1978 | RBT | 12 | 120 | 74 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | WS | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| | UNK | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (70%) | 528 | Parish (1978a) |
| **Eagle Rock Campground** | | | | | | | | | | | | |
| July 1976 | RBT | 13 | 174 | 108 | -- | -- | -- | * | -- | 1 | 396 | Parish (1976a) |
| | BRN | 2 | 27 | 17 | -- | -- | -- | * | -- | 1 | 396 | Parish (1976a) |
| | UNK | 2 | 27 | 17 | -- | -- | -- | * | -- | 1 | 396 | Parish (1976a) |
| **Questa Ranger/ Gaging Station** | | | | | | | | | | | | |
| Sept. 1988 | No fish | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | 3 | 328 | Akroyd (1988) |
| Aug. 1995 | No fish | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | 3 | 328 | Akroyd (1996) |
| Aug. 1996 | BRN | 2 | 32 | 20 | 0.1 | 29 | 0.2 | 90 | 5 | 3 | 328 | Akroyd (1997) |
| **Head of Eagle Rock Lake** | | | | | | | | | | | | |
| Nov. 1975 | BRN | 4 | 80 | 50 | 4.7 | 56 | 5.2 | 224 | 93 | 1 | 264 | Parish (1975a) |
| | RBT | 5 | 100 | 62 | 9.8 | 70 | 11.1 | 258 | 158 | 1 | 264 | Parish (1975a) |
| | WS | 1 | 20 | 12 | -- | 14 | -- | -- | -- | 1 | 264 | Parish (1975a) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July 1976 | RBT | 16 | 320 | 199 | -- | -- | -- | * | -- | 1 | 264 | Parish (1976a, 1977a) |
| | BRN | 5 | 100 | 62 | -- | -- | -- | * | -- | 1 | 264 | Parish (1976a, 1977a) |
| | WS | 11 | 220 | 137 | -- | -- | -- | * | -- | 1 | 264 | Parish (1976a, 1977a) |
| | UNK | 3 | 60 | 37 | -- | -- | -- | * | -- | 1 | 264 | Parish (1976a, 1977a) |
| April 1977 | WS | 12 | 120 | 74 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977a,b) |
| **SH 522 Bridge** | | | | | | | | | | | | |
| Sept. 1980 | RBT | 36 | 638 | 396 | 42.8 | -- | -- | 212 | 108 | n.s. | 300 | Melancon *et al.* (1982) |
| | BRN | 8 | 142 | 88 | 7.9 | -- | -- | 187 | 90 | n.s. | 300 | Melancon *et al.* (1982) |
| | WS | 2 | 35 | 22 | 1.7 | -- | -- | 185 | 75 | n.s. | 300 | Melancon *et al.* (1982) |
| **Upstream of hatchery diversion** | | | | | | | | | | | | |
| Oct. 1960 | BRN | 6 | 317 | 197 | -- | -- | -- | 311 | -- | 1 (20%) | 100 | NMDGF (1960) |
| July 1976 | RBT | 22 | 440 | 273 | -- | -- | -- | * | -- | 1 | 264 | Parish (1976a)(conflicting site location) |
| | BRN | 10 | 200 | 124 | -- | -- | -- | * | -- | 1 | 264 | Parish (1976a)(conflicting site location) |
| Sept. 1980 | BRN | 17 | 299 | 186 | 16.7 | -- | -- | 162 | 90 | n.s. | 300 | Melancon *et al.* (1982) |
| | RBT | 6 | 106 | 66 | 4.5 | -- | -- | 180 | 68 | n.s. | 300 | Melancon *et al.* (1982) |
| Nov. 1986 | BRN | 9 | 238 | 148 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987a) |
| | RBT | 17 | 449 | 279 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987a) |
| Sept. 1987 | BRN | 11 | 290 | 180 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987b) |
| | RBT | 1 | 26 | 16 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987b) |
| Sept. 1988 | BRN | 36 | 950 | 590 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1988) |
| | RBT | 13 | 343 | 213 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1988) |
| Sept. 1995 | RBT | 16 | 234 | 145 | 14.1 | 132 | 12.8 | 206 | 97 | 3 | 361 | Akroyd (1996) |
| | BRN | 13 | 190 | 118 | 5.8 | 107 | 5.2 | 138 | 49 | 3 | 361 | Akroyd (1996) |
| Aug. 1996 | BRN | 86 | 1,384 | 860 | 16.0 | 988 | 18.4 | 107 | 19 | 3 | 328 | Akroyd (1997) |
| | RBT | 14 | 225 | 140 | 13.9 | 161 | 16.0 | 201 | 99 | 3 | 328 | Akroyd (1997) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Downstream of hatchery diversion** | | | | | | | | | | | | |
| July 1976 | BRN | 10 | 200 | 124 | -- | -- | -- | * | -- | 1 | 264 | Parish (1977a)(conflicting |
| | RBT | 22 | 440 | 273 | -- | -- | -- | * | -- | 1 | 264 | site location) |
| | | | | | | | | | | | | Parish (1977a)(conflicting site location) |
| April 1977 | BRN | 45 | 450 | 280 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977a) |
| | RBT | 81 | 810 | 503 | -- | -- | -- | * | -- | 1 | 528 | Parish (1977a) |
| Nov. 1986 | BRN | 30 | 792 | 492 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987a) |
| | RBT | 17 | 449 | 279 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987a) |
| Sept. 1987 | BRN | 33 | 871 | 541 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987b) |
| | RBT | 3 | 79 | 49 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1987b) |
| Sept. 1988 | BRN | 47 | 1,241 | 771 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1988) |
| | RBT | 24 | 634 | 394 | -- | -- | -- | * | -- | 1 | 200 | Akroyd (1988) |
| **Downstream of hatchery** | | | | | | | | | | | | |
| June 1981 | BRN | 13 | 130 | 81 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| | RBT | 16 | 160 | 99 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| Sept. 1984 | BRN | 23 | 230 | 143 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| | RBT | 14 | 140 | 87 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| Aug. 1985 | BRN | 11 | 110 | 68 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |
| | RBT | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |
| | UNK | 4 | 40 | 25 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |
| Nov. 1986 | BRN | 122 | 1,220 | 758 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987a) |
| | RBT | 108 | 1,080 | 671 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987a) |
| Sept. 1987 | BRN | 37 | 370 | 230 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987b) |
| | RBT | 22 | 220 | 137 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987b) |
| Sept. 1988 | BRN | 108 | 1,080 | 671 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1988) |
| | RBT | 14 | 140 | 87 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1988) |
| | UNK | 8 | 80 | 50 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1988) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Between hatchery and El Aujae Campground** | | | | | | | | | | | | |
| Oct. 1974 | RBT | 331 | 2,207 | 1,371 | -- | -- | -- | * | -- | 1 (50%) | 792 | Patterson (1974) |
| | BRN | 36 | 240 | 149 | -- | -- | -- | * | -- | 1 (50%) | 792 | Patterson (1974) |
| | WS | 4 | 27 | 17 | -- | -- | -- | * | -- | 1 (50%) | 792 | Patterson (1974) |
| Nov. 1979 | RBT | 8 | 160 | 99 | -- | -- | -- | * | -- | 1 (50%) | 264 | Parish (1979) |
| | BRN | 25 | 500 | 311 | -- | -- | -- | * | -- | 1 (50%) | 264 | Parish (1979) |
| | UNK | 1 | 20 | 12 | -- | -- | -- | * | -- | 1 (50%) | 264 | Parish (1979) |
| June 1981 | BRN | 46 | 230 | 143 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1984) |
| | RBT | 24 | 120 | 75 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1984) |
| Feb. 1984 | BRN | 7 | 70 | 43 | -- | -- | -- | * | -- | 1 | 528 | Patterson (1984) |
| | UNK | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 | 528 | Patterson (1984) |
| Sept. 1984 | BRN | 60 | 300 | 186 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1984) |
| | RBT | 14 | 70 | 43 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1984) |
| | UNK | 1 | 5 | 3 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1984) |
| Aug. 1985 | BRN | 32 | 160 | 99 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1985) |
| | RBT | 1 | 5 | 3 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1985) |
| | UNK | 7 | 35 | 22 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1985) |
| Nov. 1986 | BRN | 209 | 1,045 | 649 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1987a) |
| | RBT | 15 | 75 | 47 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1987a) |
| Sept. 1987 | BRN | 101 | 505 | 314 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1987b) |
| | RBT | 13 | 65 | 40 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1987b) |
| | UNK | 6 | 30 | 19 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1987b) |
| Sept. 1988 | BRN | 241 | 1,205 | 749 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1988) |
| | UNK | 2 | 10 | 6 | -- | -- | -- | * | -- | 1 (50%) | 1,056 | Akroyd (1988) |
| **El Aujae Campground** | | | | | | | | | | | | |
| Sept. 1976 | RBT | 24 | 480 | 298 | -- | -- | -- | * | -- | 1 (75%) | 264 | Parish (1976b) |
| | BRN | 31 | 620 | 385 | -- | -- | -- | * | -- | 1 (75%) | 264 | Parish (1976b) |
| June 1981 | BRN | 11 | 110 | 68 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| | RBT | 46 | 460 | 286 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |

**TABLE A1:** Continued.

| Site, Year | Species | # Collected | #/mi | #/km | Kg/km | #/ha | Kg/ha | Average Length (mm) | Average Weight (g) | # of Passes (efficiency) | Site Length (ft) | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 1984 | BRN | 20 | 200 | 124 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| | RBT | 2 | 20 | 12 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| Aug. 1985 | BRN | 16 | 160 | 99 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |
| | RBT | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |
| Nov. 1986 | BRN | 69 | 690 | 429 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987a) |
| | RBT | 5 | 50 | 31 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987a) |
| Sept. 1987 | BRN | 54 | 540 | 336 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987b) |
| | RBT | 4 | 40 | 25 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1987b) |
| Sept. 1988 | BRN | 121 | 1,210 | 752 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1988) |
| | RBT | 1 | 10 | 6 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1988) |
| | UNK | 4 | 40 | 25 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1988) |
| **La Junta Point** | | | | | | | | | | | | |
| Nov. 1979 | RBT | 6 | 120 | 74 | -- | -- | -- | * | -- | 1 (40%) | 264 | Parish (1979) |
| | BRN | 18 | 360 | 224 | -- | -- | -- | * | -- | 1 (40%) | 264 | Parish (1979) |
| | WS | 11 | 220 | 137 | -- | -- | -- | * | -- | 1 (40%) | 264 | Parish (1979) |
| | Chub | 2 | 40 | 25 | -- | -- | -- | * | -- | 1 (40%) | 264 | Parish (1979) |
| June 1981 | BRN | 19 | 190 | 118 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| | RBT | 18 | 180 | 112 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| Sept. 1984 | BRN | 29 | 290 | 180 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| | RBT | 3 | 30 | 19 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| | UNK | 2 | 20 | 12 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1984) |
| Aug. 1985 | BRN | 22 | 220 | 137 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |
| | RBT | 20 | 200 | 124 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |
| | UNK | 5 | 50 | 31 | -- | -- | -- | * | -- | 1 (50%) | 528 | Akroyd (1985) |

*Divided into 2-3" size classes.
n.s. = not specified.
Data from Akroyd (1988, 1996, 1997) includes only 1st pass.

# APPENDIX B

# BENTHIC INVERTEBRATE DATA

**TABLE B1:** Historical benthic invertebrate population data for sites on the Red River, New Mexico.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Biotic Indices | Reference |
|---|---|---|---|---|---|---|
| **East Fork at Blue Lake Trail** | | | | | | |
| June 1960 | 9 | 78 | 542 | -- | 1.47 $cm^3/m^2$ | NMDFG (1960) |
| **Zwergel Gaging Station** | | | | | | |
| Sept. 1980 | 27 | 59 | K | -- | -- | Melancon *et al.* (1982) |
| April 1985 | 27 | 63 | 2,501 | -- | H' = 3.60<br>$CTQ_a$ = 48<br>BCI = 104 | Smolka & Jacobi (1986) |
| Aug. 1986 | 16 | 69 | 1,567 | -- | H' = 3.03<br>$CTQ_a$ = 44<br>BCI = 112 | Smolka & Tague (1987) |
| Sept. 1988 | 28 | 61 | 2,038 | -- | H' = 3.77<br>$CTQ_a$ = 48<br>BCI = 104 | Smolka & Tague (1989) |
| April 1992 | 31 | 64 | 2,765 | -- | H' = 3.64<br>$CTQ_a$ = 46<br>BCI = 110 | Smolka (1993) |
| **Upstream of Bitter Creek** | | | | | | |
| Nov. 1965 | 22 | 77 | 1,044 | -- | -- | USFWPCA (1966) |
| Nov. 1970 | 17 | -- | 3,548 | -- | BBI = 30 | USEPA (1971) |
| April 1992 | 29 | 59 | 3,090 | -- | H' = 3.45<br>$CTQ_a$ = 45<br>BCI = 111 | Smolka (1993) |
| Dec. 1995 | 48 | 48 | 10,121 | -- | EPT/Chiron = 19.3<br>HBI = 2.72<br>H' = 2.80<br>% scrapers = 35.2<br>% filterers = 1.6 | Woodward-Clyde (1996) |
| **Downstream of Bitter Creek** | | | | | | |
| Nov. 1965 | 20 | 90 | 1,267 | -- | -- | USFWPCA (1966) |
| Nov. 1970 | 16 | -- | 2,971 | -- | BBI = 31 | USEPA (1971) |
| April 1992 | 26 | 65 | 2,551 | -- | H' = 3.46<br>$CTQ_a$ = 47<br>BCI = 107 | Smolka (1993) |
| **Downstream of Red River** | | | | | | |
| Dec. 1995 | 40 | 53 | 2,616 | -- | EPT/Chiron. = 7.3<br>HBI = 3.83<br>H' = 3.67<br>% scrapers = 17.8<br>% filterers = 12.5 | Woodward-Clyde (1996) |

**TABLE B1:** Continued.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Biotic Indices | Reference |
|---|---|---|---|---|---|---|
| **June Bug Campground** | | | | | | |
| Sept. 1980 | 25 | 68 | K | -- | -- | Melancon *et al.* (1982) |
| Jan. 1984 | 22 | 68 | 2,071 | -- | H' = 3.13<br>$CTQ_a$ = 36 | Jacobi & Smolka (1984) |
| Aug. 1986 | 21 | 71 | 1,145 | -- | H' = 3.33<br>$CTQ_a$ = 41<br>BCI = 125 | Smolka & Tague (1987) |
| Sept. 1988 | 14 | 64 | 771 | -- | H' = 2.59<br>$CTQ_a$ = 41<br>BCI = 123 | Smolka & Tague (1989) |
| April 1992 | 20 | 65 | 1,835 | -- | HBI = 2.14<br>H' = 3.13<br>$CTQ_a$ = 49<br>BCI = 103 | Smolka (1993) |
| **Elephant Rock Campground** | | | | | | |
| Nov. 1970 | 17 | -- | 1,152 | -- | BBI = 29 | USEPA (1971) |
| Sept. 1980 | 27 | 67 | K | -- | -- | Melancon *et al.* (1982) |
| April 1985 | 21 | 67 | 916 | -- | H' = 3.79<br>$CTQ_a$ = 37<br>BCI = 136 | Smolka & Jacobi (1986) |
| Aug. 1986 | 23 | 70 | 2,090 | -- | H' = 3.15<br>$CTQ_a$ = 43<br>BCI = 118 | Smolka & Tague (1987) |
| Sept. 1988 | 16 | 62 | 997 | -- | H' = 2.92<br>$CTQ_a$ = 42<br>BCI = 135 | Smolka & Tague (1989) |
| April 1992 | 18 | 72 | 1,407 | -- | HBI = 2.48<br>H' = 2.71<br>$CTQ_a$ = 44<br>BCI = 113 | Smolka (1993) |
| Dec. 1995 | 34 | 53 | 4,030 | -- | EPT/Chiron = 2.6<br>HBI = 4.48<br>H' = 3.40<br>% scrapers = 12.4<br>% filterers = 8.0 | Woodward-Clyde (1996) |
| **Upstream of Molycorp property boundary** | | | | | | |
| Nov. 1965 | 17 | 71 | 337 | -- | -- | USFWPCA (1966) |
| May 1971 | 5 | 60 | 99 | 1.7 | -- | Pennak (1972) |
| June 1971 | 9 | 78 | 210 | 4.2 | -- | Pennak (1972) |
| July 1971 | 9 | 89 | 109 | 4.0 | -- | Pennak (1972) |
| Sept. 1971 | 9 | 78 | 90 | 2.7 | -- | Pennak (1972) |
| Oct. 1971 | 4 | 100 | 29 | 0.8 | -- | Pennak (1972) |

**TABLE B1:** Continued.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Biotic Indices | Reference |
|---|---|---|---|---|---|---|
| Nov. 1971 | 10 | 70 | 160 | 2.9 | -- | Pennak (1972) |
| Oct. 1976 | -- | -- | 562 | 6.0 | -- | Pennak (1976) |
| Mar. 1977 | -- | -- | 787[a] | 1.7 | -- | Pennak (1977a) |
| Oct. 1977 | -- | -- | 56 | 0.7 | -- | Pennak (1977b) |
| Mar. 1978 | -- | -- | 959 | 7.3 | -- | Pennak (1978) |
| Aug. 1979 | -- | -- | -- | 1.6 | -- | Pennak (1979) |
| Sept. 1979 | -- | -- | -- | 0.4 | -- | Pennak (1979) |
| Sept. 1980 | 18 | 72 | K | -- | -- | Melancon *et al.* (1982) |
| July 1981 | -- | -- | -- | 26.5 | -- | Pennak (1981) |
| Oct. 1982 | -- | -- | -- | 4.4 | -- | Pennak (1983) |
| Oct. 1983 | -- | -- | -- | 2.7 | -- | Pennak (1984) |
| Sept. 1988 | 16 | 62 | 1,275 | -- | H' = 2.82<br>$CTQ_a$ = 42<br>BCI = 119 | Smolka & Tague (1989) |
| Oct. 1988 | 10 | 90 | 230 | -- | H' = 2.92<br>$CTQ_a$ = 29<br>BCI = 172 | ENSR. (1988) |
| April 1992 | 13 | 62 | 1,594 | -- | HBI = 2.59<br>H' = 2.41<br>$CTQ_a$ = 52<br>BCI = 97 | Smolka (1993) |
| **Downstream of Hansen Creek, Upstream of Sulphur Gulch** | | | | | | |
| Dec. 1995 | 26 | 58 | 1,177 | -- | EPT/Chiron. = 5.9<br>HBI = 4.77<br>H' = 3.62<br>% scrapers = 11.1<br>% filterers = 24.0 | Woodward-Clyde (1996) |
| **Downstream of Columbine Creek** | | | | | | |
| Sept. 1980 | 26 | 70 | K | -- | -- | Melancon *et al.* (1982) |
| Dec. 1995 | 36 | 64 | 1,614 | -- | EPT/Chiron. = 6.0<br>HBI = 4.01<br>H' = 3.54<br>% scrapers = 17.1<br>% filterers = 28.5 | Woodward-Clyde (1996) |
| **Upstream of Goathill Gulch** | | | | | | |
| Nov. 1965 | 14 | 71 | 402 | -- | -- | USFWPCA (1966) |
| Nov. 1970 | 11 | -- | 933 | -- | BBI = 21 | USEPA (1971) |

**TABLE B1:** Continued.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Biotic Indices | Reference |
|---|---|---|---|---|---|---|
| Dec. 1995 | 18 | 78 | 600 | -- | EPT/Chiron. = 0.7<br>HBI = 7.02<br>H' = 2.01<br>% scrapers = 1.3<br>% filterers = 14.1 | Woodward-Clyde (1996) |
| **Goathill Campground** | | | | | | |
| Oct. 1976 | -- | -- | 808[b] | 6.5 | -- | Pennak (1976) |
| Mar. 1977 | -- | -- | 211 | 4.5 | -- | Pennak (1977a) |
| Oct. 1977 | -- | -- | 43 | 0.3 | -- | Pennak (1977b) |
| Mar. 1978 | -- | -- | 1,677 | 32.3 | -- | Pennak (1978) |
| July 1978 | -- | -- | 443 | 5.2 | -- | Pennak (1978) |
| Aug. 1979 | -- | -- | -- | 0.6 | -- | Pennak (1979) |
| Sept. 1979 | -- | -- | -- | 0.6 | -- | Pennak (1979) |
| Sept. 1980 | 20 | 75 | K | -- | -- | Melancon *et al.* (1982) |
| July 1981 | -- | -- | -- | 3.0 | -- | Pennak 1981 |
| Oct. 1982 | -- | -- | -- | 1.9 | -- | Pennak (1983) |
| Oct. 1983 | -- | -- | -- | 1.5 | -- | Pennak (1984) |
| Oct. 1988 | 6 | 83 | 79 | -- | H' = 1.96<br>$CTQ_a$ = 31<br>BCI = 164 | ENSR. (1988) |
| **Upstream of Capulin Canyon** | | | | | | |
| Dec. 1995 | 17 | 65 | 319 | -- | EPT/Chiron. = 14.3<br>HBI = 3.83<br>H' = 3.26<br>% scrapers = 14.8<br>% filterers = 13.8 | Woodward-Clyde (1996) |
| **Eagle Rock Campground** | | | | | | |
| May 1971 | 5 | 80 | 31 | 2.9 | -- | Pennak (1972) |
| June 1971 | 5 | 40 | 74 | 1.1 | -- | Pennak (1972) |
| July 1971 | 8 | 50 | 59 | 2.9 | -- | Pennak (1972) |
| Sept. 1971 | 6 | 67 | 50 | 1.3 | -- | Pennak (1972) |
| Oct. 1971 | 8 | 88 | 149 | 3.5 | -- | Pennak (1972) |
| Nov. 1971 | 7 | 71 | 50 | 2.3 | -- | Pennak (1972) |
| Oct. 1976 | -- | -- | 170 | 1.4 | -- | Pennak (1976) |
| Mar. 1977 | -- | -- | 555[c] | 7.8 | -- | Pennak (1977a) |
| Oct. 1977 | -- | -- | 82 | 2.4 | -- | Pennak (1977b) |
| Mar. 1978 | -- | -- | 52 | 0.5 | -- | Pennak (1978) |
| July 1978 | -- | -- | 490 | 16.3 | -- | Pennak (1978) |
| Aug. 1979 | -- | -- | -- | 0.2 | -- | Pennak (1979) |
| Sept. 1979 | -- | -- | -- | 1.0 | -- | Pennak (1979) |
| July 1981 | -- | -- | -- | 1.5 | -- | Pennak (1981) |
| Oct. 1982 | -- | -- | -- | 1.4 | -- | Pennak (1983) |
| Oct. 1983 | -- | -- | -- | 2.4 | -- | Pennak (1984) |

**TABLE B1:** Continued.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Biotic Indices | Reference |
|---|---|---|---|---|---|---|
| **Questa Ranger/ Gaging Station** | | | | | | |
| Nov. 1965 | 9 | 67 | 83 | -- | -- | USFWPCA (1966) |
| Nov. 1970 | 11 | -- | 448 | -- | BBI = 19 | USEPA (1971) |
| Sept. 1988 | 6 | 100 | 171 | -- | H' = 2.06<br>$CTQ_a$ = 32 | Smolka & Tague (1989) |
| Oct. 1988 | 3 | 100 | 108 | -- | H' = 1.30<br>$CTQ_a$ = 31<br>BCI = 161 | ENSR. (1988) |
| April 1992 | 10 | 60 | 490 | -- | HBI = 1.26<br>H' = 1.18<br>$CTQ_a$ = 46<br>BCI = 108 | Smolka (1993) |
| Dec. 1995 | 16 | 69 | 456 | -- | EPT/Chiron. = 6.8<br>HBI = 4.56<br>H' = 2.49<br>% scrapers = 4.0<br>% filterers = 6.1 | Woodward-Clyde (1996) |
| **SH 522 Bridge** | | | | | | |
| Nov. 1965 | 6 | 67 | 108 | -- | -- | USFWPCA (1966) |
| Nov. 1970 | 10 | -- | 818 | -- | BBI = 19 | USEPA (1971) |
| Sept. 1980 | 22 | 73 | K | -- | -- | Melancon *et al.* (1982) |
| April 1985 | 17 | 59 | 388 | -- | H' = 3.48<br>$CTQ_a$ = 45<br>BCI = 112 | Smolka & Jacobi (1986) |
| Aug. 1986 | 17 | 71 | 607 | -- | H' = 3.34<br>$CTQ_a$ = 42<br>BCI = 119 | Smolka & Tague (1987) |
| April 1992 | 13 | 69 | 535 | -- | HBI = 2.60<br>H' = 2.43<br>$CTQ_a$ = 50<br>BCI = 100 | Smolka (1993) |
| Dec. 1995 | 22 | 55 | 2,605 | -- | EPT/Chiron = 4.9<br>HBI = 6.32<br>H' = 2.39<br>% scrapers = 1.5<br>% filterers = 3.8 | Woodward-Clyde (1996) |
| **Upstream of Pope Creek** | | | | | | |
| May 1971 | 11 | 82 | 290 | 7.14 | -- | Pennak (1972) |
| June 1971 | 5 | 40 | 216 | 3.78 | -- | Pennak (1972) |
| July 1971 | 8 | 75 | 326 | 5.04 | -- | Pennak (1972) |
| Sept. 1971 | 8 | 75 | 82 | 0.84 | -- | Pennak (1972) |
| Oct. 1971 | 8 | 88 | 147 | 2.10 | -- | Pennak (1972) |
| Nov. 1971 | 8 | 88 | 617 | 3.36 | -- | Pennak (1972) |
| Oct. 1976 | -- | -- | 765 | 6.6 | -- | Pennak (1976) |

**TABLE B1:** Continued.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Biotic Indices | Reference |
|---|---|---|---|---|---|---|
| Mar. 1977 | -- | -- | 2,018 | 17.3 | -- | Pennak (1977a) |
| Oct. 1977 | -- | -- | 159 | 1.1 | -- | Pennak (1977b) |
| Mar. 1978 | -- | -- | 907 | 6.2 | -- | Pennak (1978) |
| July 1978 | -- | -- | 211 | 1.8 | -- | Pennak (1978) |
| Aug. 1979 | -- | -- | -- | 2.4 | -- | Pennak (1979) |
| Sept. 1979 | -- | -- | -- | 2.0 | -- | Pennak (1979) |
| July 1981 | -- | -- | -- | 6.7 | -- | Pennak (1981) |
| Oct. 1982 | -- | -- | -- | 14.0 | -- | Pennak (1983) |
| Oct. 1983 | -- | -- | -- | 6.9 | -- | Pennak (1984) |
| Oct. 1988 | 11 | 64 | 362 | -- | H' = 2.68<br>$CTQ_a$ = 61<br>BCI = 82 | ENSR. (1988) |
| **Downstream of Pope Creek** | | | | | | |
| Dec. 1995 | 29 | 55 | 3,891 | -- | EPT/Chiron = 6.5<br>HBI = 6.26<br>H' = 2.44<br>% scrapers = 2.4<br>% filterers = 4.3 | Woodward-Clyde (1996) |
| **Upstream of hatchery diversion** | | | | | | |
| June 1960 | 12 | 67 | 1,650 | -- | 28.6 $cm^3/m^2$ | NMDFG (1960) |
| Nov. 1965 | 10 | 50 | 291 | -- | -- | USFWPCA (1966) |
| Nov. 1970 | 16 | -- | 2,759 | -- | BBI = 27 | USEPA (1971) |
| May 1971 | 9 | 78 | 299 | 10 | -- | Pennak (1972) |
| June 1971 | 7 | 71 | 479 | 16 | -- | Pennak (1972) |
| July 1971 | 8 | 62 | 199 | -- | -- | Pennak (1972) |
| Sept. 1971 | 6 | 50 | 571 | -- | -- | Pennak (1972) |
| Oct. 1971 | 5 | 60 | 479 | 10.9 | -- | Pennak (1972) |
| Nov. 1971 | 7 | 57 | 84 | -- | -- | Pennak (1972) |
| Oct. 1976 | -- | -- | 632 | 5.8 | -- | Pennak (1976) |
| Mar. 1977 | -- | -- | 1,875 | 51.6 | -- | Pennak (1977a) |
| Oct. 1977 | -- | -- | 224 | 2.5 | -- | Pennak (1977b) |
| Mar. 1978 | -- | -- | 1,402 | 18.5 | -- | Pennak (1978) |
| July 1978 | -- | -- | 2,207 | 21.1 | -- | Pennak (1978) |
| Aug. 1979 | -- | -- | -- | 3.4 | -- | Pennak (1979) |
| Sept. 1979 | -- | -- | -- | 1.0 | -- | Pennak (1979) |
| July 1981 | -- | -- | -- | 4.9 | -- | Pennak (1981) |
| Oct. 1982 | -- | -- | -- | 2.8 | -- | Pennak (1983) |
| Oct. 1983 | -- | -- | -- | 6.9 | -- | Pennak (1984) |
| Oct. 1988 | 11 | 64 | 495 | -- | H' = 2.56<br>$CTQ_a$ = 59<br>BCI = 84 | ENSR. (1988) |

**TABLE B1:** Continued.

| Site, Date | # of Taxa | % EPT Taxa | #/m² | g/m² | Biotic Indices | Reference |
|---|---|---|---|---|---|---|
| Dec. 1995 | 34 | 41 | 4,449 | -- | EPT/Chiron = 13.5<br>HBI = 6.22<br>H' = 2.08<br>% scrapers = 1.1<br>% filterers = 5.5 | Woodward-Clyde (1996) |
| **Downstream of hatchery** | | | | | | |
| April 1992 | 19 | 63 | 1,423 | -- | H' = 3.19<br>$CTQ_a$ = 53<br>BCI = 93 | Smolka (1993) |
| **Between hatchery and El Aujae Campground** | | | | | | |
| Nov. 1965 | 20 | 50 | 344 | -- | -- | USFWPCA (1966) |
| Nov. 1970 | 19 | -- | 3,523 | -- | BBI = 26 | USEPA (1971) |
| Aug. 1979 | -- | -- | -- | 1.7 | -- | Pennak (1979) |
| Sept. 1979 | -- | -- | -- | 1.4 | -- | Pennak (1979) |
| July 1981 | -- | -- | -- | 6.7 | -- | Pennak (1981) |
| Oct. 1982 | -- | -- | -- | 9.8 | -- | Pennak (1983) |
| Oct. 1983 | -- | -- | -- | 6.0 | -- | Pennak (1984) |
| April 1985 | 20 | 75 | 2,047 | -- | H' = 2.29<br>$CTQ_a$ = 51<br>BCI = 98 | Smolka & Jacobi (1986) |
| Aug. 1986 | 17 | 65 | 1,836 | -- | H' = 2.70<br>$CTQ_a$ = 43<br>BCI = 117 | Smolka & Tague (1987) |
| Oct. 1988 | 12 | 58 | 1,973 | -- | H' = 1.66<br>$CTQ_a$ = 50<br>BCI = 99 | ENSR. (1988) |
| Dec. 1995 | 45 | 51 | 6,012 | -- | EPT/Chiron = 15.1<br>HBI = 6.40<br>H' = 2.42<br>% scrapers = 1.3<br>% filterers = 8.0 | Woodward-Clyde (1996) |
| **La Junta Point** | | | | | | |
| Oct. 1988 | 10 | 70 | K | -- | -- | ENSR. (1988) |

EPT/Chiron. = ratio of EPT taxa to Chironomidae taxa
HBI = Hilsenhoff Biotic Index
H' = Shannon-Weiner Diversity Index
$CTQ_a$ = Community Tolerance Quotient ($CTQ_p$ for all sites = 50)
BCI = Biotic Condition Index
BBI = Beck Biotic Index
K = kick sample (qualitative)
[a] Published value miscalculated as 112/m²
[b] Published value miscalculated as 763/m²
[c] Calculated value approximately 112/m²

TRC Environmental Solutions Inc.

NM
22306

# QUESTA MINE SITE EXPERT REPORT

*Prepared by*

**Ian P.G. Hutchison**

April 23, 1997

# QUESTA MINE SITE
# EXPERT REPORT BY IAN P.G. HUTCHISON

I, Ian P.G. Hutchison, Senior Vice President of TRC Environmental Solutions, Inc., have been retained to provide the following expert report in *Amigos Bravos and New Mexico Citizens for Clean Air vs. Molycorp, Inc.* (D.N.M. No. CIV 95-1497 [JP/DJS]).

## 1.0 SUMMARY OF QUALIFICATIONS

### 1.1 GENERAL QUALIFICATIONS

- Senior Vice President of TRC Environmental Solutions, Inc., with general responsibilities for mining environmental, and Superfund remediation projects.
- Over 25 years of experience in dealing with water quality issues at a large number of mining and industrial sites in the United States, Canada, South America and Africa.
- Ph.D. in Civil Engineering and Graduate Diploma (M.S. equivalent) in Hydraulic and Soil Mechanics from the University of the Witwatersrand, South Africa, and a B.S. in Civil Engineering from the University of Cape Town, South Africa.
- Experience on over 50 mining environmental projects throughout the United States, Canada, South America and Africa.
- Registered Professional Engineer in eight states, including New Mexico.
- Resume is provided in Attachment A.

### 1.2 PUBLICATIONS

- Senior editor and author of a textbook entitled "Mine Waste Management" published in 1992, Lewis Publishers.
- Other publications in the last 10 years include:
  - *Introduction to Evaluation, Design and Operation of Precious Metal Heap Leaching Projects*, Editor and Author of Chapter on "Surface Water Balance," 1988.
  - *Management for Hazardous Waste Liability at Mining Sites.* Colorado State University Symposium, January 1991.
  - *Summitville Mine - Remedial Alternatives Identification and Evaluation.* I.P. Hutchison, Michael L. Leonard, Sr. and David P. Cameron. Summitville Forum 95: A Forum held in Conjunction with Tailings and Mine 1995, Colorado State University, Fort Collins, Colorado, January 1995.

### 1.3 CASES IN THE LAST FOUR YEARS

- Involved as an expert witness and provided deposition or trial testimony on the following cases in the last four years:
  - *IMACC vs. Dorothy Myers Warburton, et al.*
  - *Penny Newman et al. versus State of California, Riverside County, et al.* regarding the Stringfellow site, California, 1993.

### 1.4 COMPENSATION

- My hourly rate is $160/hour.

## 2.0 SUMMARY OF OPINIONS

1. My major opinions deal with the diffuse nature of the sources of constituents, the seepage and ground water flow conditions at the mine site, and the surface water quality conditions in Red River. Naturally occurring alteration minerals occur within bedrock dispersed throughout the fractured bedrock area, are exposed on the surface in weathered bedrock (referred to as natural scar areas), and are dispersed within the colluvium and alluvium, and throughout most, but not all, of the excavated overburden pile material. Oxidization and weathering primarily of one of the minerals present, i.e., pyrite, can cause acidic conditions (i.e., low pH) and contribute dissolved constituents, which include a range of salts and metals, to surface or ground water flow that comes into contact with the weathered minerals. References in this report to "constituents" implies generally one or more substances from the range of salts and metals which typically include total dissolved solids (TDS), sulfate, aluminum, cadmium, copper, iron, manganese and zinc.

2. More specifically, my opinions are:
   - **Constituent Sources and Conveyances:** There are no discernible, confined and discrete conveyances of constituents from the overburden piles (also referred to as waste rock piles) to the Red River.
   - **Hydraulic Connection:** Conditions at the mine site are not well enough understood to determine whether there is a direct hydraulic connection between the overburden piles and Red River.

- **Red River Water Quality:** The available data does not support the conclusion that there has been a general reduction in the water quality of the Red River caused by mining activities between the mid-1960s and the mid-1990s.
- **Source of Constituents in Red River:** The available data does not allow for a determination of whether constituent loadings in Red River are derived from overburden piles, scar areas, or from alluvial deposits in tributary and Red River channels.

3. In addition to the above opinions, I have reviewed the plaintiff's expert reports and have provided comments on them.

4. The remaining sections of this report deal with the following topics:
   - 3.0 Basis for Major Opinions
   - 4.0 Summaries of Comments on Plaintiffs' Expert Reports

# 3.0 BASIS FOR MAJOR OPINIONS

## 3.1 CONSTITUENT SOURCES AND CONVEYANCES

1. There are no discernible, confined and discrete conveyances of constituents from the mine's overburden piles for the following reasons:
   - **Diffuse Sources:** Migration of water and constituents from and through the overburden piles is diffuse.
   - **Diffuse Flow Paths:** Migration of water and constituents through the alluvium and fractured bedrock, which underlie the overburden piles, is diffuse.
   - **Seepage Zones:** Migration of water and constituents into Red River, including the springs, which are actually seepage zones, is diffuse.

2. Each of these reasons is discussed in more detail below.

3.1.1 DIFFUSE SOURCES

1. The primary source of constituents in the overburden piles is the acid-generating minerals that are attached to the soil particles and boulders. Both water and oxygen are necessary to cause these minerals to oxidize or weather. This process can cause acidic conditions (i.e., low pH) and dissolves the constituents contained in the minerals. Infiltration of water during rainstorms and snowmelt migrates generally downward through the piles and dissolves the constituents. Infiltration is typically widespread over the surfaces of the piles; however, the rates of infiltration vary at different locations on the piles, depending on the surface slope and the amount of clay and silt present.

2. To the extent they represent potential sources of constituents, the overburden piles, therefore, are widespread diffuse seepage sources, with the amount of constituent loading varying within the source area.

3.1.2 DIFFUSE FLOW PATHS

1. Migration of water and constituents (or seepage) from the piles continues downward through the underlying unsaturated alluvium, natural hydrothermal scar areas, and/or fractured bedrock above the ground water table. Some lateral spreading may occur on lower permeability layers within the waste piles, or the underlying alluvium, or on low permeability bedrock surfaces. Migration of this widespread diffuse source therefore continues to be neither discernible, confined nor discrete. It is generally not discernible as it occurs as a subtle increase of moisture content on the surface of soil particles and in the large number of interconnected fractures that occur in bedrock. It is unbounded as it occurs over a widespread area, and finally, it is not discrete as it occurs in millions of pores and fractures in the soils and bedrock.

2. The alluvial material that occurs at the site is typically sandy, silty and sometimes clayey material. Ground water migration through these soils is diffuse, but rates of migration will vary locally depending on the soil types and composition.

3. After passing through the unsaturated zone, seepage from the overburden piles is mixed with ground water and then continues to migrate slowly through alluvium and fractured rock to deep bedrock below the Red River, to the Red River, or into the dewatered underground mine workings by the same diffuse flowpaths described above.

4. The geology of the area is complex, and a large number of faults and structural fractures have been identified at the site (SPRI, 1995). These include:
   - East-west trending low angle (relatively flat) faults and structural contacts dipping to the north;
   - High angle east-west, northeast and northwest trending faults;
   - Other high angle joints and fractures;
   - High and low angle fractures adjacent to magmatic intrusions.

   Typically, faults include zones of more permeable fractured rock as well as zones of low permeability rock where clayey materials can be present, where the fault zones "pinch out," or where faults are offset by younger faults cutting across older faults.

5. In addition to this largely random distribution of more permeable to less permeable zones formed by the faults described above, the bedrock between the faults is also highly fractured. Fractures occur at a large number of different orientations and typically have a large range of lengths and thicknesses. The intersection of these fractures and the faults causes the millions of migration pathways referred to in paragraph 1 above.

6. Ground water located in the fractured bedrock acts like water in a very large sponge, with a very large number of interconnected openings of varying size. Because of the random nature of the large number of faults and fractures in the bedrock, the rate of ground water migration can vary considerably from one area to the next.

7. Published ground water flow theories frequently treat flow through "fractured rock" as a diffuse flow through a continuum, which approximates flow through a porous medium (such as silt or sand) with increasing size of areas that are being analyzed. Due to the large size of

the mine facilities, and the mine site area, ground water migration could be analyzed as flow through porous media (Hubbert, 1956; Long et al., 1982; Hsieh et al., 1985).

8. As seepage containing dissolved constituents derived from the overburden piles migrates downgradient and away from the piles, the constituent concentrations are typically reduced by their contact with unmineralized alluvium and fractured bedrock, particularly if the alluvium or bedrock has the potential to neutralize acidic water. This process is referred to as attenuation and includes a combination of dilution, precipitation, adsorption and complexation. Metals are most susceptible to attenuation; however, salts can also be attenuated.

9. Furthermore, as ground water migrates through naturally acid-generating mineralized bedrock underlying the scars or alluvium that consists of eroded and redeposited scar material, additional salts and metals can be dissolved, leading to increased constituent concentrations.

10. It is evident that the concentration of constituents in ground water is not only a function of the source concentrations, but also the chemical interactions that occur within the ground water as it migrates through alluvial and fractured bedrock material. As a general rule, the further the ground water migrates from the original source of constituents, the less the constituent concentrations are dependent on that source, and the more they are dependent on the natural properties of the alluvium and fractured bedrock.

3.1.3 SEEPAGE ZONE

1. Referring to the seepage through the banks of the Red River as "springs" is inaccurate:

> *"A spring is a concentrated discharge of ground water appearing at the ground surface as a current of flowing water. To be distinguished from springs are seepage zones, which include slower movement of ground water to the ground surface."* (D.K. Todd, 1980)

2. It is more appropriate to use "seepage zones" to describe the areas along the banks of Red River, such as Capulin, Portal and Cabin Spring. This is based on my field observations and field mapping of seep areas conducted by GSi/water (GSi, 1997). It is also supported by Dr. Mink's expert report (Mink, 1997) and by deposition statements by both Dr. Mink and

Mr. Kelsey (Mink deposition, 1997; Kelsey deposition, 1997). These seepage zones have the appearance of wet soils or shallow fractured bedrock with water seeping out of the pore spaces at a varying rates throughout the seepage zone.

## 3.2 HYDRAULIC CONNECTION

1. Conditions at the mine site are not well enough understood to determine whether there is any direct hydraulic connection between the overburden piles and the Red River. It is virtually impossible to determine how much, if any, of the constituents emanating from the overburden piles migrate to the river, for the following reasons:
   - **Alternative Diffuse Migration Pathways:** There are several diffuse migration pathways for seepage derived from the overburden piles, including migration out of the general area in deep faults and fractures located well below the bed of the Red River and migration into the underground mine workings.
   - **Geochemical Processes:** The chemical reactions that take place as migration occurs alters the concentrations of the constituents and retards or eliminates the potential direct migration of constituents from the overburden piles to the Red River. As discussed below, this phenomenon is illustrated by the fact that the Red River reach along and closest to the largest overburden piles in the mine site area receives a lower mass TDS loading than river reaches adjacent to areas containing natural scars located close to the river, or adjacent to the town of Red River (Figure 6).
   - **Mixed Sources:** Because there are a large number of mining related sources (overburden piles) and nonmining related natural sources (scars, mineralized fractured bedrock, and mineralized alluvium) it is essentially impossible to distinguish whether any particular constituent loading to Red River is due to either natural or mine-related sources.

2. Each of the above reasons is discussed in more detail below.

### 3.2.1 ALTERNATIVE DIFFUSE PATHWAYS

1. As discussed above, the three potential diffuse migration pathways for seepage from the overburden piles include migration in deep bedrock faults and fractures to the west and below the Red River, migration into the underground mine, and shallow migration to the Red River.

2. While it is generally true that fractured bedrock permeability decreases with depth, the depths at which significant decreases occur vary from site to site. Evidence at the Questa Mine site indicates permeable bedrock occurs at considerable depths, and deep migration pathways are therefore very likely. This evidence includes:

   - During geologic time the area was subjected to extensive volcanism related to regional continental rifting. The major structural features, such as the high angle ring faults surrounding the caldera in which the mine is situated, are likely to be several thousands of feet deep. In addition, subsequent intrusions such as dikes and plutons derived from subterranean magma chambers and their associated fracturing, also extend to a great depth. The thickness of intra-caldera volcanic units are reported to range up to 10,000 feet in the Questa Caldera (SPRI, 1995), which would be the minimum depth of the above referenced high angle ring faults and subsequent intrusive structures. Figure 1 illustrates the typical structure for a caldera similar to the Questa caldera. Figure 2 shows the outline of the Questa caldera including the major faults that have been mapped or otherwise inferred in the area.
   - Water is observed by Molycorp personnel to seep into the deep underground mine workings through a large number of faults and fractures. The so-called "rain forest" occurs deep in the underground mine along the haulage drift at elevation 7,120 which is 600 to 700 feet below the level of the Red River and over 2,000 feet below the ground surface. Molycorp's underground mine mapping shows that extensive fracture systems are still present at this depth and represent a source of seepage into the mine (Molycorp, 1997).

3. As mentioned above, and as shown in Figure 3, the underground mine workings create a large drawdown cone in the ground water table which intercepts infiltration at the mine site, and seepage from the overburden piles. The interpretation in Figure 3 of the ground water levels in the mine area is the most reasonable given the available monitor well ground water level data; it also incorporates the Red River water levels. The mine's ground water capture zone estimated from these ground water contours is in general agreement with that determined by SPRI (SPRI, 1995, Figure 8) in that it shows capture extends from the Goathill Creek area in the west, to the area under the Sugar Shack, South Middle and Sulfur Gulch overburden piles to the east.

4. In my opinion the most realistic assessment of the average recharge from ground water in the mine area is SPRI's estimate of 0.66 cfs, or 295 gpm which is based on long term (1943 to 1955) base flow data for the general area between the Zwergle gauge upstream of Red River

and the Ranger Station gauge near Questa (SPRI, 1995, page B-6). It has been calculated for a mine site drainage/catchment area of approximately 3,200 acres, which includes portions of Capulin Canyon and Spring Gulch drainage areas that are outside of the projected capture zone for the mine. The other estimate presented in SPRI's report (SPRI) uses assumptions as to the amount of infiltration which appear to be too high, and which are not as reliable as the data-based estimate.

5. The SPRI estimate of average recharge is also appropriate for the 1980s to the 1990s. The average Red River flow at the Questa gauge was 48.6 cfs for the period 1943 to 1955, for which the above recharge estimate was performed. The flow during this period is close to the average flow at Questa during the 1980s and 1990s, i.e., 50.8 cfs for 1980 through 1993.

6. Correcting the SPRI's estimate for the area captured by the underground mine workings, which is approximately 2,300 acres (Attachment C), yields a ground water recharge rate of about 210 gpm.

7. Accounting for the increases in surface flows to the underground mine caused by the diversion of the upper portions of the Capulin Canyon and Goathill Creek Drainages (approximately 585 acres), and of surface water collecting in the open pit area (575 acres) yields approximately an additional 103 gpm (Attachment C, Table 1). This means that on the average, approximately 313 gpm, including the diversions and open pit, infiltrate in the underground mine's capture area.

8. Molycorp's reported equilibrium pumping rate from the underground workings is 270 gpm (Molycorp, 1997). To this amount should be added any seepage that occurs out of the mine through deep fractures. As the typical level of accuracy of these types of calculations is of the order of 20 percent, the over 270 gpm from the underground mine and the 313 gpm total infiltration may be treated as the same values. This indicates that virtually all the ground water flow in the mine's capture area is being pumped out of the area and does not migrate to Red River.

9. The estimated underground mine workings cone of depression captures seepage from the Capulin Canyon, Goathill Creek, and Sugar Shack West overburden piles, most of the western potions of the Sugar Shack South and Middle, and Sulfur/Spring Gulch piles and the open pit

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overburden disposal piles (Figure 3). The only overburden that appears to be outside of the capture area is the Spring Gulch pile, and the limited eastern portions of the Sugar Shack South, Middle and Sulfur/Spring Gulch piles. The potential for seepage of constituents from the Spring Gulch overburden pile to Red River is very limited, based on evaluations and testing conducted by SRK, it contains black andesite, aplite and granite; *"These materials exhibit an average net neutralization potential. The average NP/AP ratio for black andesite and aplite/granite exceeds 3:1, indicating low acid producing potential."*

10. The potential for seepage of constituents from the Sulfur/Spring Gulch pile is also very limited because the eastern portion of this pile projected outside the underground mine capture zone, contains nonacid-generating black andesite and aplite/granite (SRK, 1995, page 33). Furthermore, the potential for seepage of constituents from this pile may be further reduced by the decline, which is a downward sloping tunnel that passes under the Sulfur/Spring Gulch pile and which could be intercepting ground water seepage from that pile. SRK in their report (SRK, 1995, page 29) indicate that ground water seepage occurs into the decline. Plaintiffs' expert Dr. Mink (Mink deposition, 1997, page 135) concurs that the decline may be dewatering ground water in the vicinity of monitoring well MMW-14 and -16, along the eastern edge of Sulfur/Spring Gulch pile.

11. The potential for seepage of constituents to Red River from the eastern portions of Sugar Shack South, Middle, and Sulfur/Spring Gulch piles is further reduced because the eastern faces of these piles have been covered with nonacid-generating black andesite and aplite/granite (SRK 1995, page 33).

### 3.2.2 GEOCHEMICAL PROCESSES

1. As previously mentioned, seepage containing constituent concentrations is subject to attenuation by the alluvium and fractured bedrock through which it migrates. Evidence that a significant amount of attenuation capacity exists in the fractured bedrock is the quality of the underground mine water. As discussed by SRK (SRK, 1995, page 27 and Table 1.4), the water pumped out of the mine is characterized by neutral pH, high TDS and sulfate and reduced metal concentrations, typical changes that occur during attenuation.

2. Further support for the presence of the natural attenuation capacity of the fractured bedrock is found in the inherent characteristics of the rocks in the area. The abundance of alkaline and calc-alkaline volcanic host rocks, such as aplite, latite, and dacite, and the added presence of natural carbonate alteration products in mineralized zones, provide natural neutralization capacity for migrating acidic water. Secondary alteration minerals, such as gypsum, provide additional neutralization capacity. The erosion and deposition of these materials in the valley fill alluvial deposits as cementation agents or detritus also provide neutralization capacity.

3. While SRK (SRK, 1995) indicates the alluvium has a limited neutralization potential, its samples were limited to three locations (Nos. 86, 88 and 94, Figure 3.3, SRK, 1995). Two of these samples (i.e., 86 and 88) could have been collected from alluvial material derived at least partly from the erosion of natural scar material. None of these samples are representative of the fractured bedrock under the overburden piles, which is where most of the seepage from these piles would go, nor are they representative of the alluvium along Red River.

### 3.2.3 MIXED SOURCES

1. As discussed above, there are a number of natural and mining related sources of constituents. They not only include the scar areas and overburden piles, but also generally mineralized acid-generating areas such as the lower Capulin Creek area (SRK, 1995), and alluvium derived from eroded scar material that has been deposited in the tributary creekbeds as well as the bed and banks of the Red River. Evidence for the presence of mineralized material in the creekbeds is also provided by some of the soil samples collected by SRK (Samples 10, 69, 70, 73, 87, HC6, and HC7; SRK, 1995). Furthermore, ground water in the alluvium south of Red River (i.e., on the opposite side of the river from the mine site) has a low pH (GSi, 1997), which provides more evidence of potential acid-generating mineralized material along the Red River.

2. The alluvium was placed in the creek and Red River beds over the past three million years, i.e., during the Quarternary Period. As this has been, and continues to be, an ongoing erosional/depositional process, new acid-generating mineralized material is continually being added, as the in-situ material oxidizes and slowly dissolves.

## 3.3 RED RIVER WATER QUALITY

### 3.3.1 INTRODUCTION

1. The reasons the available data does not support the conclusion that water quality in Red River has worsened between the 1960s and the 1990s due to mining activities are as follows:
   - **Climatic Trends:** The 1960s data was collected during a much drier period than the 1980s and 1990s information and cannot, therefore, be compared to the later data as constituent loadings to the river naturally increase during wetter periods.
   - **Reductions in Migration of Constituents:** Certain aspects of the Molycorp mining activities have resulted in reductions in the migration of constituents to the Red River.

   Each of these reasons are discussed in more detail below.

### 3.3.2 CLIMATIC TRENDS

1. As shown in Figures 4 and 5, both the precipitation and the flow in Red River have increased significantly from the 1960s through the 1990s. These graphs show the five-year moving average precipitation and runoff and therefore reflect the average annual accumulation over the previous five years. This approach is commonly used to establish trends in data; it makes these trends more visible by averaging out the extreme wet and dry years.

2. Figure 5 shows that average Red River flows have increased from approximately 30 cubic feet per second (cfs) in the 1960s and 1970s to 50 cfs in the 1980s and 1990s. As a result, the catchments adjacent to the river would have been a lot wetter in the 1980s and 1990s, thereby increasing the flushing of constituents into the river. Wetter conditions result in:
   - Higher rates of infiltration through the unsaturated soils and fractured bedrock containing weathered, mineralized material above the ground water table.
   - Higher ground water levels contacting more weathered mineralized material.
   - Increased ground water flow resulting in increased rates of constituent migration into the Red River.

3.3.3 REDUCTIONS IN MIGRATION OF CONSTITUENTS

1. Several of the mining and related activities result in reductions of constituent loads to the Red River. These include:
   - The dewatered underground mine workings which intercept a large proportion of the ground water flow towards the Red River as shown in Figure 3 (see discussion in Section 3.2.1).
   - The stormwater control systems prevent surface runoff contribution of both dissolved constituents and sediment into the Red River.
   - The diversions from Capulin Canyon to Goathill Creek reduce the constituent load in seepage for the upper portion of Capulin Canyon.
   - The subsidence area, intentionally created in the Goathill drainage, captures the surface runoff and seepage from the upper portion of Goathill Creek and conveys it to the underground workings.

## 3.4 SOURCE OF CONSTITUENTS IN RED RIVER

1. The available data do not allow for determination of whether constituent loadings in Red River are derived from overburden piles, natural scar areas, or from the alluvial deposits within the tributary and Red River channels. The reasons for this are that there are a large number of processes that determine whether constituents from the overburden piles actually migrate to Red River, most of which have not been characterized. These processes include : (1) the relative loadings of overburden piles and natural scar areas which determine what the potential proportion of source constituents are due to the overburden piles; (2) the migration pathways through the unsaturated zone and then through ground water; (3) the extent of geochemical changes that occur in seepage as it migrates through alluvium and fractured bedrock; (4) the extent to which the natural alluvial material, which contains mineralized material, impacts Red River water quality; and finally (5) the extent to which the Red River water itself chemically controls the constituent levels in the water.

2. The relative TDS loading from the bottom of an overburden pile, which is not indicative of what may reach the Red River, is different and possibly much lower than from natural scars because:
   - The overburden piles contain a very large proportion of gravel and boulder-sized material which typically only provide a fraction of the constituent load compared to finer-grained materials such as sands and silts, which are the predominant composition of the scar areas.

- The scar areas are more uniformly flushed by rainfall and infiltration as they contain more uniform material. Therefore, there is an increased potential to leach out more of the constituents than in the overburden piles. Infiltration through the overburden piles tends to be varied and most of the infiltration water typically only contacts a portion of the material, thereby reducing the mass of constituents that can be leached.

3. The laboratory shake tests conducted by SRK (SRK, 1995) are not representative of the relative loadings of overburden piles and scar areas. Plaintiffs' expert Dr. Williams has concurred with the conclusion that shake tests are not representative (Williams Deposition, 1997, page 130). Shake tests are not representative because:
   - Shake tests involve an agitated mixing of the material and water. This typically results in dissolved loads much higher than in nature where precipitation trickles over or through material.
   - Infiltration through overburden piles, while diffuse, varies significantly from one area to the next and may not reach all portions of the overburden material. This infiltration pattern further reduces loads for overburden piles and cannot be taken into account in shake tests.

4. While it is known that natural scars contribute significant loadings to Red River, without knowing the relative loading of overburden versus a scar it is not possible to calculate whether loadings to Red River have changed due to mining. While mining activities have increased the area of overburden that could potentially drain to Red River, they have also captured a substantial portion of the seepage emanating from both scar and overburden areas. In some areas overburden has been placed directly on scar material and the effect of this on the residual load from this combined area is also unknown.

5. As discussed in Section 3.1, potential flow pathways from the overburden piles are extremely large in number, variable in direction and generally difficult to impossible to define.

6. As discussed in Section 3.2 above, there are a range of geochemical changes that occur as the loading emanating from the bottom of an overburden pile migrates downward and laterally. These changes can potentially increase constituent concentration if the host material is acid-generating, or reduce concentrations if the host material has attenuative capacity.

# 4.0 COMMENTS ON PLAINTIFF'S EXPERT REPORTS

## 4.1 DIRECT HYDRAULIC CONNECTION

1. Plaintiffs' experts claim that there is direct hydraulic connection between the overburden piles and Red River, and that there are sufficiently well-understood preferential flow pathways for ground water movement from the overburden piles to Red River (Kelsey, 1997, *Opinion 1*; Mink, 1997, *Opinion 1*; and Williams, 1997, *Opinions 1 and 2*). However, no evidence is presented to support these opinions, and as outlined in Section 3.0, the evidence that is available supports the contrary conclusion, i.e., that there are no discernible, confined and discrete conveyances from the mine's overburden piles to Red River.

2. Plaintiffs' experts claim that because the Red River adjacent to the mine area is gaining, i.e., it receives recharge from the adjacent land areas, and because the overburden piles are located on that adjacent land area on permeable alluvium and bedrock, a direct hydraulic connection exists (Kelsey, Page 4; Mink, Page 7). The hypothesis stated simply indicates that ground <u>water</u> can migrate from higher ground to a lower area. It does not take into account the extremely complex geology (which has a very strong influence on the direction of migration of ground water); seepage collection; underground mine dewatering; or the complex chemical reactions that occur between ground water and the alluvium and fractured bedrock, which strongly influences to what extent <u>constituents</u> in the water migrate or are attenuated.

3. Plaintiffs' general claim that the Red River is gaining is an oversimplification and specific data I was able to locate shows that the opposite may be true for large portions of the Red River reach along the mine area. The 1988 evaluation completed by USGS (USGS, 1988) indicates that the reach between the mill down to 300 feet above the mouth of Columbine Creek, loses 1 cfs (approximately 450 gpm) of flow. Furthermore, the ground water level data presented in SPRI's report (SPRI, 1995, Figure 5) and collected by the mine in the ground water wells MMW-10A, B and C and -11 (Molycorp, 1997) shows there is a gradient away from the river into the bedrock under the Sugar Shack overburden pile, which is consistent with the Red River being a losing stream in this area.

4. The significance of the above losing river segment is that it occurs in the area where some of the largest overburden piles, i.e. Sugar Shack South, Middle and Sulphur Gulch, are located

relatively close to Red River. In areas where the river is recharging ground water under these piles, there would obviously be no potential for any constituent loading to the river from these overburden pile areas. To the extent these loses persist over time, they reduce the potential loads calculated for this reach shown in Figure 6 and discussed in Section 3.3, as these calculated loads assume this is a gaining reach.

5. Plaintiffs' expert makes the general assertions that because the overburden piles are in the recharge areas, and the seepage zones are in discharge areas, and because the primary aquifer systems within the mine area are sufficiently well understood, this represents a basis for finding a direct hydraulic connection between the overburden piles and the Red River (Kelsey, 1997, page 4). This general conclusion does not take into account all the site specific facts, such as those listed below:

   - Plaintiffs' experts do not appear to take into account the important fact that before mining, the bedrock and the alluvium, including the alluvium in the tributary channels as well as Red River itself, all contained naturally mineralized material that had resulted in widespread ground and surface water impacts. SPRI accurately characterized this condition by stating: *"Naturally acidic waters have been in transit through the same system, excluding seepage barriers, for thousands of years as is evident from limonite-cemented alluvial and mudflow deposits."* (SPRI, 1995, page 6).
   - The seepage zones referred to in the references cited (SRK, 1995, pages 11-12, and 21; SPRI, 1995, page 5; NMED, 1996, pages 16 and 33), include Capulin Canyon, Highway 38, Cabin and Portal. With the exception of Portal, these seepage zones are not located in close proximity to the overburden piles, or in downgradient areas, and it cannot therefore be concluded they are discharge areas for infiltration through overburden piles (see Figure 1.6, page 12, SRK, 1995).
     - The Capulin seepage zone is located approximately 5,000 feet (1 mile) downgradient from the closest mapped natural scar area and over 8,000 feet (1.5 miles) downgradient from the Capulin overburden pile. In any event, seepage from the Capulin overburden pile is intercepted and conveyed to the underground mine workings. The Capulin seepage zone is located in a fan delta deposit of alluvium which contains naturally occurring acid-generating mineralization. Thus, the fan delta deposit itself is the most likely source of constituents in the Capulin seepage zone.

- The Highway 38 seepage zone is located approximately 2,500 feet downgradient from a portion of the Sugar Shack West overburden pile.
- The Cabin seepage zone is located downgradient from a small natural drainage area. This zone is over 1,500 feet away from a large natural scar area and the Sugar Shack South overburden pile located in an adjacent drainage to the northeast.
- The Portal seepage zone is located 500 to 1,000 feet downgradient from the large natural scar area and Sugar Shack South overburden pile.
- The Sulphur Gulch seepage zone is located close to the toe of the Sulphur Gulch overburden pile, and less than 1,000 feet downgradient from a large natural scar area. While this zone is close to an overburden pile it has among the lowest constituent loadings of all the seepage zones on Red River (SRK, 1995, Table 1.4). For example, TDS and sulfate were measured to be 540 mg/l and 260 mg/l respectively. By comparison, values for water samples in Hansen Creek are much higher (SRK, 1995, Table 3.1). The measured TDS and sulfate concentrations are 2,620 mg/L and 1,544 mg/L respectively. This further demonstrates that the available data is not amenable to identifying specific sources to Red River.

• Mr. Kelsey's reference to overburden piles being placed over natural tributary channels which drain to Red River (SPRI, 1995, page B-3) is also not necessarily an indication that infiltration of water through the overburden piles would increase constituent loads to the river. All the tributaries that drain the mine area, i.e., Capulin Canyon and Goathill, Sulphur, Blind, and Spring Gulches, contain either naturally mineralized scars, or alluvial fan deposits derived from the erosion of scars, or both. The effect of this natural mineralization on the seepage water quality has not been characterized to the extent it is possible to indicate whether the overburden piles have had any impact on Red River water quality.

6. As discussed in Section 3.2, the complex nature of the seepage system, the chemical interaction between seepage, ground water and the alluvium or fractured bedrock, and the unpredictability of any connection between seepage from the overburden piles and the Red River, are highlighted by the fact that the major contributions of TDS, sulfate and metals to the Red River does not occur in the Red River reach (from the mill site to 300 feet above the mouth of Columbian Creek, Stations 7 to 10 in Figure 6) where over 50 percent (approximately 180 million tons) of the overburden piles are located along the Red River, or necessarily in areas where the scar areas are closest to the Red River (Table 1.1 and

Figure 1.2, SRK, 1995). The highest loads occur in Cabin seepage zone and in the Town of Red River, with the next higher in the Hansen Creek and Eagle Rock campground areas. Only one of these areas is within the mine site (Figure 6).

7. As further support for direct hydraulic connection, Dr. Mink (Mink, 1997, page 7) indicates that *"data show that water from mine wastes contains significantly greater concentrations of sulfate and metals (aluminum, iron, manganese, zinc, copper, cadmium) than water from scar areas."* However, no facts are provided to substantiate this statement. While water samples collected below the Capulin overburden pile (WS-CAP1 and WS-GC1) have high concentrations, it is not evident whether these are due to the upgradient overburden or the underlying scars (Figure 1.5, SRK, 1995). By contrast, the water samples collected on top of the Sugar Shack South overburden pile (WS-SS1 and WS-SS2) have very low concentrations, lower than the concentrations below the natural scars in the Hansen Creek area.

8. Dr. Williams uses water quality data and the fact that the same constituents occur in the overburden piles as in Red River, to conclude that there is direct hydraulic connection between the overburden piles and Red River (Williams 1997, page 7). This approach is too simplistic as it does not make adjustments for constituents that are added from naturally occurring mineralized material in the alluvium, in the creek and river beds, and in the fractured bedrock, nor does it account for the attenuation of the overburden pile derived constituents in these same materials. Dr. Williams furthermore also fails to point out (Williams, 1997, page 8) that most of the water samples collected downgradient from overburden piles could also be impacted by natural scar material located under and adjacent to these overburden piles.

9. Dr. Williams makes the statement that *"seepage flows laterally downhill along low hydraulic conductivity barriers at the base of the waste rock"* (Williams, 1997, page 4). This is not substantiated by any of the data. Dr. Williams provides no evidence of any such barriers, in fact the available information, which indicates that bedrock is highly fractured and faulted, suggest that such barriers are not present. It is not clear how an estimate of the relative amount of ground water flow intercepted by the underground mine working cone of depression can be attempted when Dr. Williams has made no attempt to estimate the size of the cone of depression.

10. Dr. Williams' claim (Williams, 1997, pages 8 and 9) that the timing of the appearance of the white precipitate in Red River verifies a hydraulic connection, has no factual basis. No reliable scientific data is provided to support the sudden appearance of new seeps and springs since mining started. For one, the premining data collection efforts were much less intense than those of the late 80s and 90s. To my knowledge, there is no documented systematic seep survey that characterizes seeps over time on a scientific basis. I have also not seen any evaluations of the appearance and disappearance of seeps that takes into account the effect of natural seep fluctuations. Any references therefore to finding new seeps and springs is likely due to a large number of nonmining related factors including more intensive observation of the river banks, different observational and seep characterization skills by the various parties involved, varying precipitation conditions causing increases or decreases in seepage flow rates prior to the observations, and varying snowmelt conditions.

11. Dr. Mink furthermore claims that seepage from Capulin Canyon overburden pile potentially contributes sulfate and metals to Red River (Mink, 1997, page 8). Even if a portion of the subsurface seepage from the Capulin Canyon overburden pile bypasses the seepage collection and diversion system, there is no evidence to indicate these constituents in this seepage reach Red River. There is a large expanse of alluvium and fractured bedrock, over 1-1/2 miles long below the overburden piles that not only contains naturally occurring mineralized material derived from scar erosion, but also contains attenuation capacity which would reduce naturally the seepage and reduce the metal concentrations. It is therefore, equally likely that the quality of seepage that does get into Red River is largely dependent on the chemical properties of these natural materials. In addition, a fault traverses along the upper portion of Capulin Canyon. It likely extends to great depth, also providing a deep migration pathway into the bedrock below the Red River.

## 4.2 PREFERENTIAL FLOW PATHWAYS

1. Mr. Kelsey's claims (Kelsey, 1997, page 7) that both perched ground water conditions and the presence of fractures and faults provide preferential pathways are unsubstantiated.

2. The perching conditions referenced by Mr. Kelsey (SPRI, page 6) are stated to be speculation by SPRI themselves: *"Perched water **can** form near the base of the waste rock dumps. Perched water **can** form in zones of fractured bedrock above the main water table and above clay intervals in the valley fill. Bedrock seeps, such as the seeps at Cabin Springs, near the river, **may** be from a perched bedrock zone."* Furthermore SPRI provides no evidence or any further discussion to confirm this speculation. Finally, in an alluvium-fractured bedrock system such as the one at the mine site, widespread perching generally does not occur. Because it consists of permeable alluvium overlying permeable fractured bedrock, the ground water it contains represents a single aquifer system which fills from the bottom up. As I indicated, isolated perched conditions can occur; however, their presence would have to be identified by data, not simply by speculation.

3. The faulting and fracturing referred to by Mr. Kelsey (SPRI, 1995, Figure 3, Pages 5 and B1; Plate 2: Geologic Map of the Questa Mine Area, and Plate 1: Geologic Map and Cross Sections of the Questa Mining District) does not support his opinion on preferred pathways.
   - Figure 3 (SPRI, 1995) simply shows a geologist's conceptual definition of some of the flat lying, east-west trending faults in the area. These lines do not connote flow pathways, but merely the location of faults that are typically irregular bands of sheared and fractured rock, and that can vary in thickness up to ten or hundreds of feet. They can also include areas where the fault zone is very thin and impermeable. Furthermore, between the indicated faults there are other known and unknown faults, and between the fault zones there is fractured bedrock. All of the above fractures can convey water in a diffuse but variable pattern.
   - The other SPRI references simply contain geologic descriptions of fault systems and do not indicate preferred pathways.

## 4.3 GROUND WATER MIGRATION CAPTURE BY THE UNDERGROUND MINE

1. Plaintiffs' witnesses also claim that the ground water cone of depression created by dewatering the underground mine does not capture a significant portion of the shallow ground water within the mine area (Mink, 1997, Opinion 2; Kelsey, 1997, page 4) due to perching of ground water and low permeability bedrock in the vicinity of the underground mine. The available data indicates the contrary, i.e.:
   - As previously discussed, the referenced SPRI statements of perching water under waste dumps and along the edge of the river

(SPRI, 1995, page 6) are speculative and no supporting evidence is provided. My experience at several mines with similar geologic conditions is that widespread perching typically does not occur.

- The referenced SPRI statements regarding potential perching in the alluvium between the Sugar Shack south overburden pile and Red River in the vicinity of Monitoring Wells MMW-10A, B and C have been misinterpreted (SPRI, 1995, page 12).
  - SPRI indicates its preferred explanation for the results of the pump test conducted in the MMW-10A well in this area is that the water was not perched (SPRI, 1995, page 13). I concur with SPRI's conclusion that there is merely a lower permeability zone in the area between the two well screens in MMW-10A and -C. This is also consistent with my ground water flow analysis outlined in Chapter 3.0 which accounts for such local heterogeneities.
  - It is generally not possible to have perched water develop in alluvial deposits adjacent to rivers as these deposits are usually totally saturated up to at least the water level in the river. The suspected perched zone was indicated to be below the river's water level (SPRI, 1995, page 12) which is implausible.
  - There is reference to another potentially localized perched ground water zone in the MMW-7 well area in the SPRI report (SPRI, 1995, page 11, and Figure 8) which is interpreted by SPRI not to have any effect on the amount of water captured by the underground mine workings. As shown in their Figure 8 (SPRI, 1995) and Figure 3 attached to this report, ground water under this potentially perched area can migrate into the underground workings if the water in MMW-7 is perched.

2. The other reasons the plaintiff's experts use to imply that seepage capture by the underground mine is not significant are unconvincing. In some cases, closer examination of the data referenced in the experts' citations actually substantiates the opposite, i.e., that capture is significant. Mr. Kelsey refers (Kelsey, 1997, page 6) to the SPRI reports (SPRI, 1995, page B-7) ... incorrect conclusion, and ignores basic data in the SPRI document that shows significant capture is being achieved.

   - Because the net accretion to Red River in the mine area was measured to be the same in 1988 as it was in 1965, in spite of mine dewatering from the new underground mine that took place from the mid 1970s onwards, SPRI concluded mine dewatering did not influence or intercept any accretion to the river (SPRI, 1995, page B-7). This conclusion ignores a very well established hydrologic principal, which is that net accretion to river segments continually changes with time as it depends predominantly on both the amount and the pattern of precipitation and temperature over

the previous weeks, months and even years. Therefore, using differences in the estimated accretion in two different periods to calculate how much water is being abstracted by a mine is meaningless and could result in a wide range of values.

- Reference to Figure 8 in the same report (SPRI, 1995) clearly shows that the underground mine had a significant capture zone extending from the east near Sulphur Gulch to the west, close to Goathill Gulch, and to the south close to Red River. This significant capture zone is consistent with my own assessment of the capture achieved by the underground mine (see Figure 3 of this report).
- Both SPRI (SPRI, 1995, page B-7) and by reference Mr. Kelsey incorrectly indicate that *"most of the ground water recharge to the river may have come from the upper part of the ground water system. In other words, the deep mine was not directly in the recharge zone."* Even though there may be different hydrologic units such as alluvium, shallow fractured bedrock, and deeper bedrock, there is generally only one ground water system at the site. With the exception of possible localized perched conditions at MMW-7 and potentially other isolated areas, the ground water in the mine site area is continuous. Therefore, creating a cone of depression in an area will capture all ground water flow that occurs within the capture zone. Ground water cannot, as plaintiffs' expert implies, migrate over the top of a several-hundred-foot-deep ground water depression. The effect of dewatering the mine has been measured as far away as approximately 5,000 feet at MMW-13.

3. Dr. Williams claims that because water levels in wells MMW-10A, B and C, and MMW-11 had not responded to mine dewatering, this indicated the capture zone of the mine was limited. Review of all the available information however (Molycorp, 1997) indicates there have been significant responses in the alluvium at MMW-10A, 9.22 feet drawdown, and MMW-10C, 8.66 feet and in shallow bedrock at MWW-10B, 9.18 feet, and MMW-11, 8.34 feet over the period May 1995 through February 1997. The lack of response in MMW-7 can be attributed to the anisotropic nature of fractured bedrock systems, i.e., directional permeability and storativity variations which will affect the time response of drawdown cone development on locally perched water conditions.

## 4.4 RED RIVER WATER QUALITY

1. Both Mr. Kelsey (Kelsey, 1997, Opinion 3) and Dr. Williams (Williams, 1997, Opinions 3 and 4) claim that the mine has worsened the water quality in the Red River. Mr. Kelsey's two main reasons are: (1) his theory on hydraulic connection, which as discussed in Section 3.1 is

not substantiated by the scientific data, and (2) the water quality data from the Red River. Dr. Williams attributes her opinion to the apparent increases in constituent loadings measured in Red River.

2. Dr. Williams claims that *"sulfate and metal loadings in the reach of the Red River adjacent to Molycorp Mine is more attributable to mining activities and emplacement of waste rock piles than to natural hydrothermal scars"* (Williams, 1997, Opinion 3, Page 5). The Red River water quality data relied on does not demonstrate that constituent loads to the Red River increased from 1966 to 1992 due to mining activities. As discussed in Section 3, there are other factors that cause changes to constituent loads to the Red River.

3. Mr. Kelsey has claimed that the Moly Tunnel *"caused the subsequent emergence of Portal Spring"* (Kelsey, 1997, Page 9). This statement is unsubstantiated, and the limited data that is available suggests that the "Moly Tunnel" does not likely represent a measurable source of seepage to Red River.

4. While the Moly Tunnel drained, the limited flow was reported to have been collected and reused in the mill (Dave Schoemaker Deposition, 1996). Flow in the tunnel is reported to have been derived from ground water inflow to the historic underground mine and precipitation recharge through the open pit, both of which are located at the upper end of the Tunnel. Once the new underground mine went into production (i.e., early 1980s), water no longer flowed out of the Tunnel, but was collected and drained down into the mine via a winze (i.e., a vertical shaft internal to the mine workings). Thus the volume of water Mr. Kelsey assumed would be accumulating behind the plug actually flowed down into and is collected in the underground workings. The Tunnel mouth was plugged in 1992 to avoid surface discharges in the event the winze became plugged (David Shoemaker Deposition, 1996).

# QUESTA MINE SITE
# EXPERT REPORT BY IAN P.G. HUTCHISON
# (Continued)

5. Recent inspections of the plug by Molycorp staff (Molycorp, 1997) indicate that there has been only a small (approximately two feet) of head behind the plug. The amount of standing water is relatively small and is not likely to cause any measurable increase of seepage to Red River. The effect of this small amount of water is that of a small surface pool of water located approximately 200 feet from the Red River.

Ian P.G. Hutchison

Dated: April 23, 1997

# TABLE 1

## CALCULATION OF TOTAL AVERAGE BASEFLOW AND RUNOFF FROM MINE AREA FOR PERIOD 1980 TO 1993

- Average Streamflow for Period 1943-1955 (Gauge near Questa): 48.6 cfs

- Average Streamflow for Period 1980-1993 (Gauge near Questa): 50.8 cfs

- Average Streamflows for Common Period 1943-1964 (22 years)
  - Gauge near Red River (19.1 square miles): 17.04 cfs
  - Gauge near Questa (113.0 square miles): 44.70 cfs

  Increase: 27.66 cfs over 93.9 square miles

  = 0.295 cfs/square mile

- Average Streamflow for Common Period 1963-1973 (11 years)
  - Gauge below Zwergle Dam (25.7 square miles): 17.27 cfs
  - Gauge near Questa (113.0 square miles): 32.10 cfs

  Increase: 14.83 cfs over 87.3 square miles

  = 0.170 cfs/square mile

Average Increase in Streamflow = (22 x 0.295 + 11 x 0.170)/33 = 0.253 cfs/square mile

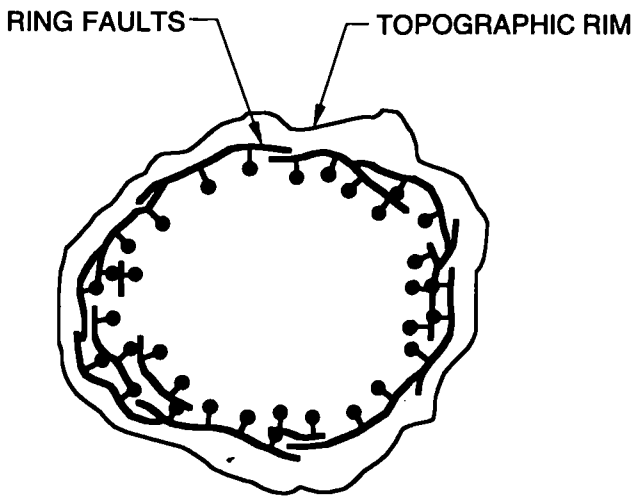
Amount of Base Flow (Recharge) Calculated by SPRI = 11.04/87.3 = 0.126 cfs/square mile

Amount of Surface Runoff Calculated by Differencing

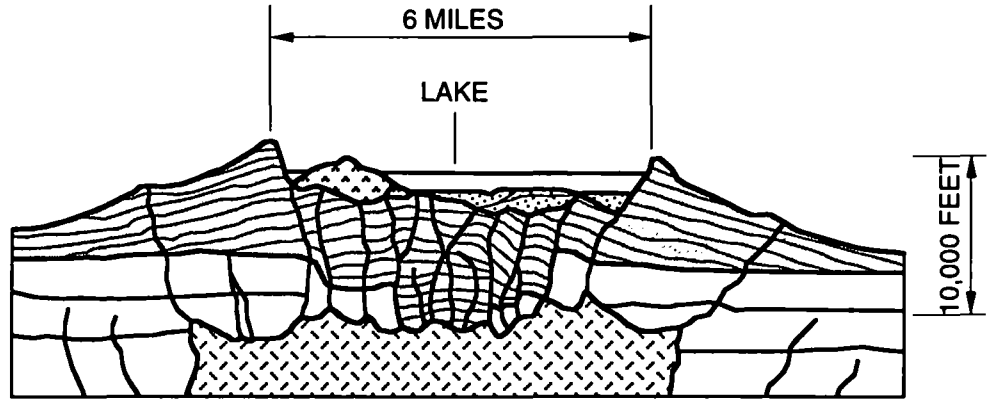
= 0.253 - 0.126
= 0.127 cfs/square mile

For 1.81 square miles (1,160 acres = 575 + 585)

= 0.230 cfs
= 103 gpm




PLAN




SECTION

FIGURE 1

**CONCEPTUAL PRESENTATION OF FAULTING IN A TYPICAL CALDERA (BASED ON CRATER LAKE, OREGON TWISS AND MOORES, 1992)**

TRC ENVIRONMENTAL SOLUTIONS, INC.

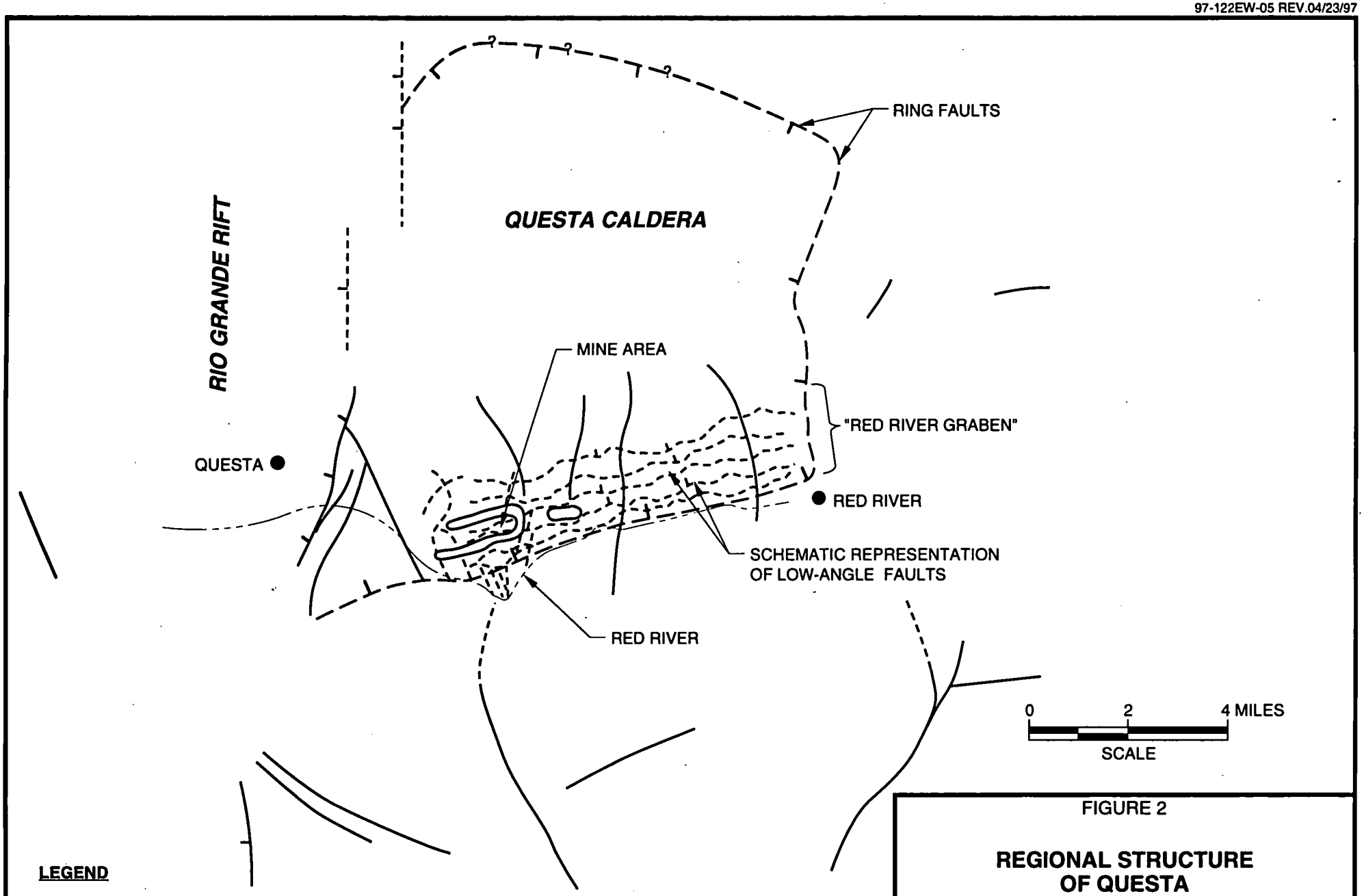
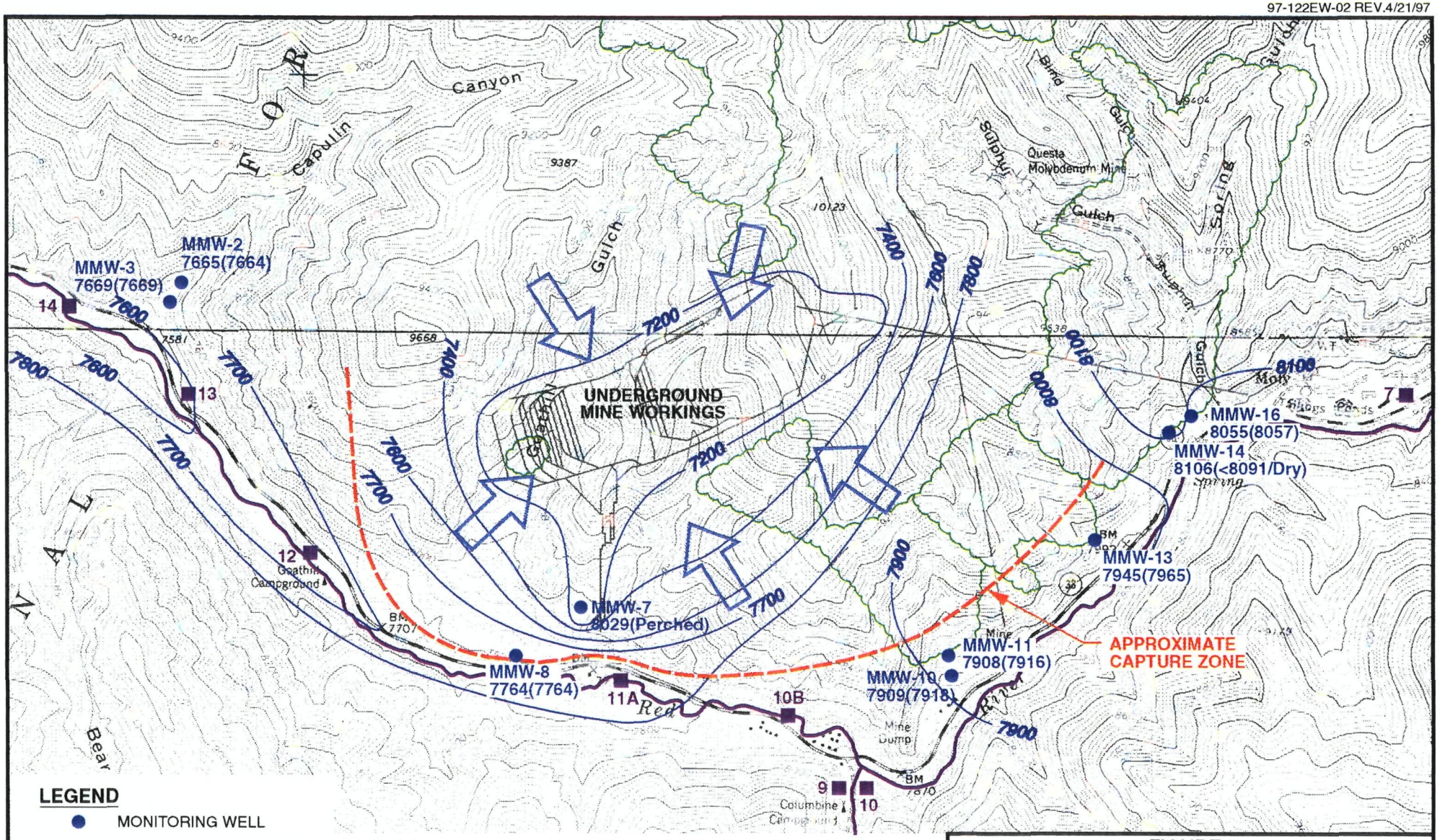



FIGURE 2

**REGIONAL STRUCTURE OF QUESTA**

**TRC ENVIRONMENTAL SOLUTIONS, INC.**

97-122EW-02 REV.4/21/97




**LEGEND**

- MONITORING WELL
- 7908 FEBRUARY 1997 ELEVATION
- (7916) JANUARY 1996 ELEVATION
- RED RIVER SAMPLE LOCATION
- GROUND WATER FLOW DIRECTION
- OVERBURDEN DISPOSAL PILES (SRK, 1995)

0 2000 4000 FEET

SCALE

REFERENCE: U.S.G.S. TOPOGRAPHIC MAPS OF QUESTA AND RED RIVER, NEW MEXICO DATED 1963.

FIGURE 3

**GROUND WATER CONE OF DEPRESSION CREATED BY DEWATERING OF THE UNDERGROUND MINE**

**TRC ENVIRONMENTAL SOLUTIONS, INC.**

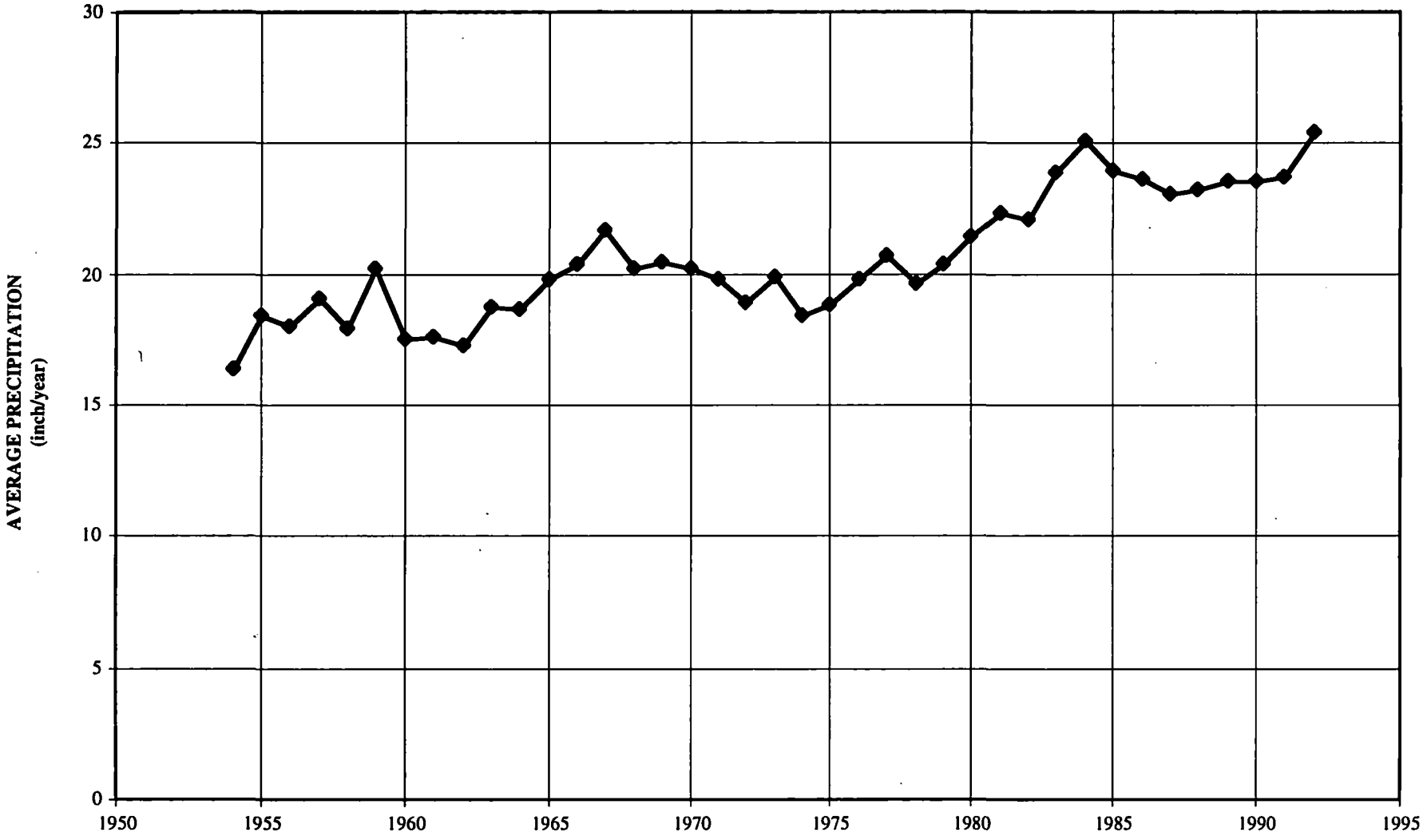



FIGURE 4

**FIVE YEAR
MOVING AVERAGE PRECIPITATION
AT RED RIVER**

TRC ENVIRONMENTAL SOLUTIONS, INC.

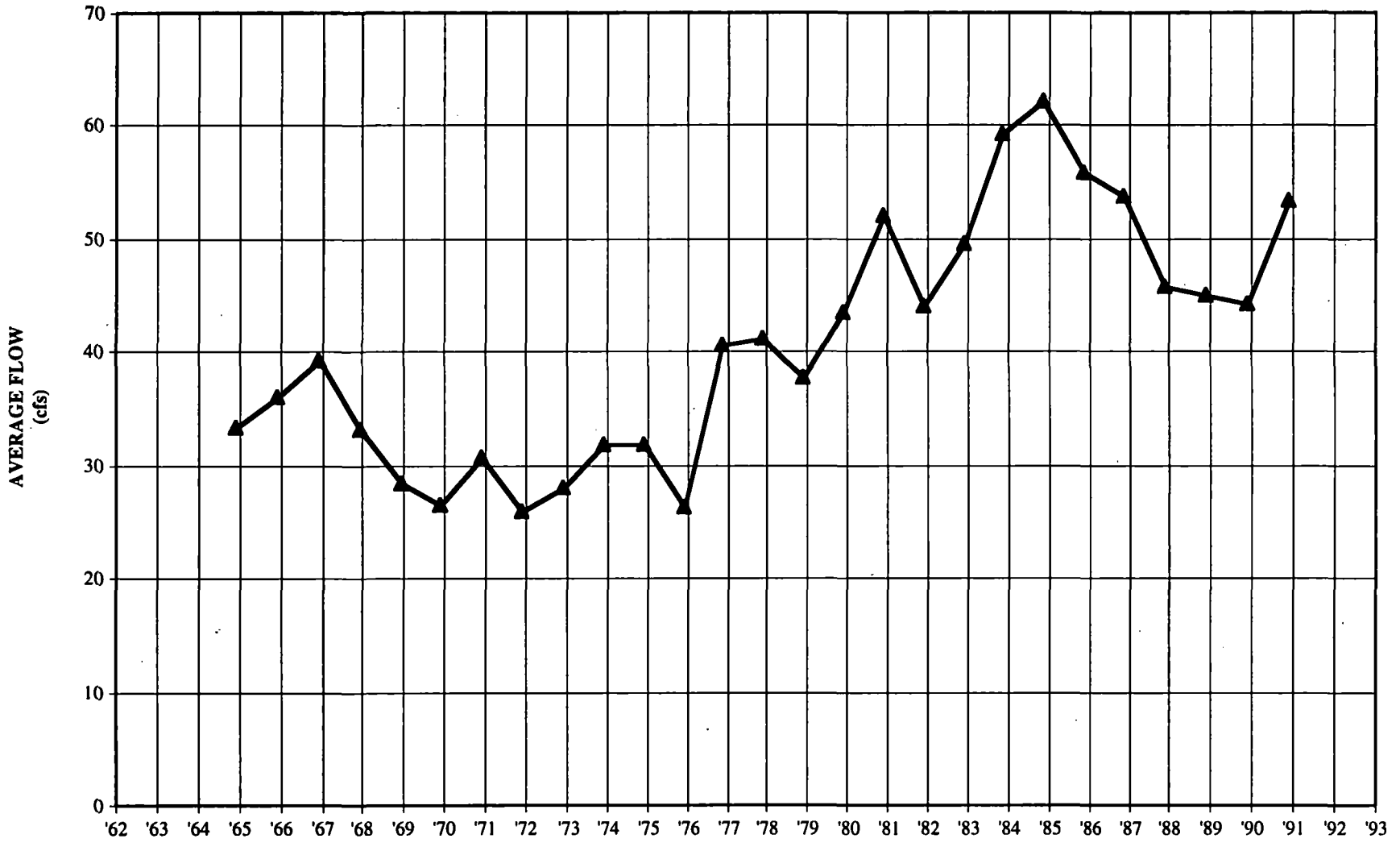
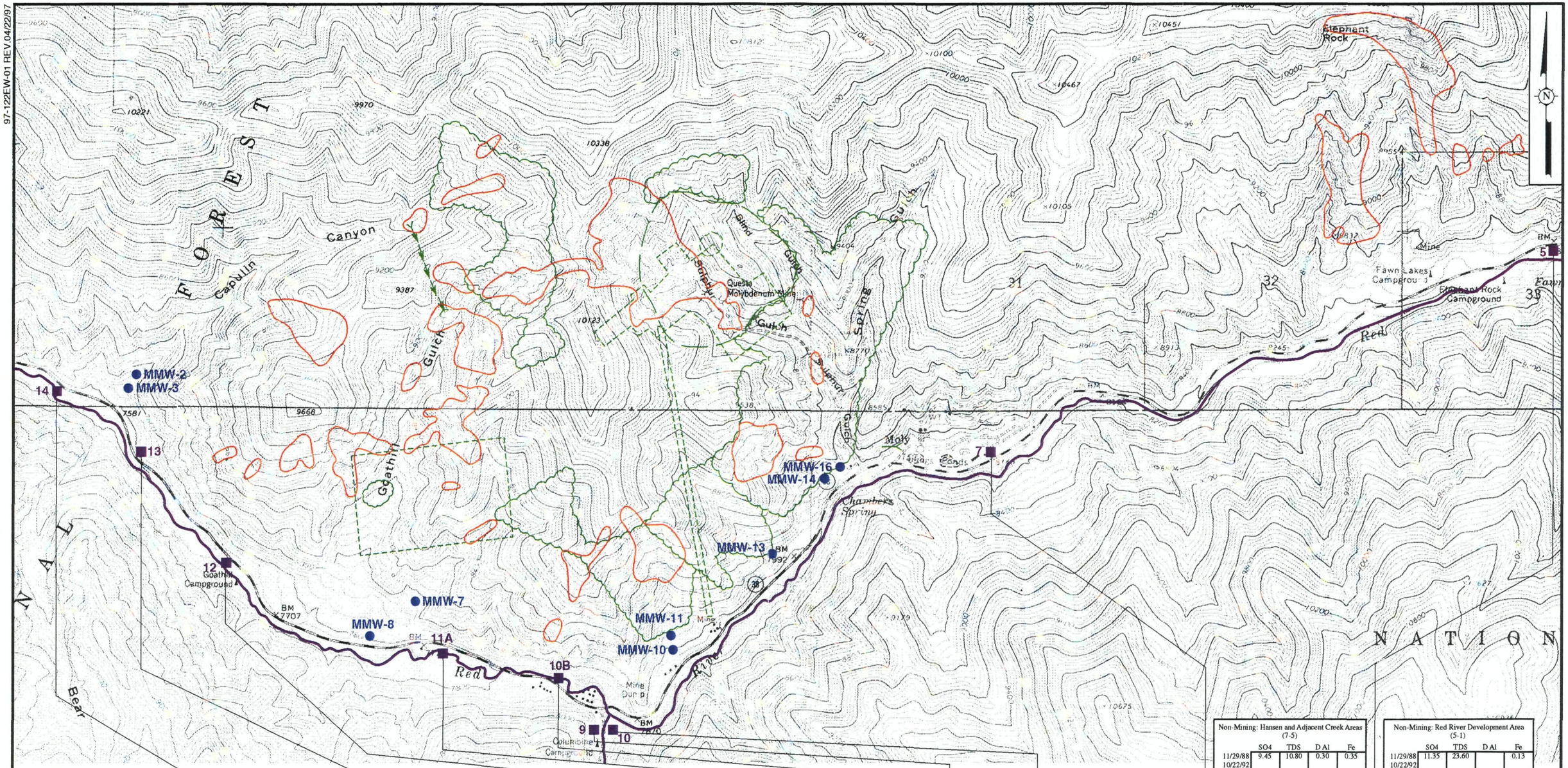



FIGURE 5

**FIVE YEAR MOVING AVERAGE**
**RED RIVER FLOW NEAR QUESTA**

**TRC ENVIRONMENTAL SOLUTIONS, INC.**

97-122EW-01 REV.04/22/97




| Non-Mining: Catchment Areas Downgradient from the Mine Site (17-14) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | 9.38 | 29.82 | 0.20 | 0.42 |
| 10/22/92 | 9.60 | 30.54 | 0.21 | -0.06 |
| 2/16/93 | | | | |
| 11/10/93 | -2.46 | 0.69 | 0.29 | 1.29 |
| 2/11/94 | | | | |
| 10/13/94 | 37.44 | 23.73 | 0.00 | 0.10 |
| 2/14/95 | 10.69 | 37.23 | -0.01 | 0.06 |
| 11/9/95 | 4.21 | -37.22 | 0.02 | -1.74 |
| 2/26/96 | 5.51 | | | |
| Average | 10.63 | 14.13 | 0.12 | 0.01 |
| Ranking: | 6 | 6 | 3 | 6 |

| Mining: Capulin Creek Area (14-13) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | -2.79 | -1.50 | 0.33 | 0.09 |
| 10/22/92 | 13.40 | 33.72 | 0.01 | 0.05 |
| 2/16/93 | 10.34 | 10.96 | 0.01 | 0.11 |
| 11/10/93 | 6.42 | 9.60 | 0.74 | 4.16 |
| 2/11/94 | 2.46 | 5.07 | 0.01 | 0.49 |
| 10/13/94 | -2.24 | 5.53 | 0.01 | 0.07 |
| 2/14/95 | 3.29 | 2.03 | 0.00 | -0.56 |
| 11/9/95 | -0.57 | 61.18 | -0.02 | 1.69 |
| 2/26/96 | 11.87 | | | |
| Average | 4.69 | 15.82 | 0.14 | 0.76 |
| Ranking: | 8 | 4 | 2 | 1 |

| Mining: Remainder of Catchment Area Adjacent to and West of Goathill Creek (13-12) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | 11.71 | 8.11 | 0.19 | -0.10 |
| 10/22/92 | -4.59 | -14.64 | -0.03 | 0.01 |
| 2/16/93 | -2.78 | 0.38 | 0.00 | 0.01 |
| 11/10/93 | 0.18 | -21.46 | 0.14 | -0.47 |
| 2/11/94 | 5.19 | 8.56 | 0.00 | -0.62 |
| 10/13/94 | 6.21 | 0.46 | 0.00 | 0.02 |
| 2/14/95 | 2.51 | 1.53 | 0.00 | 0.62 |
| 11/9/95 | 6.09 | -15.79 | 0.01 | 0.08 |
| 2/26/96 | 0.19 | | | |
| Average | 2.75 | -4.11 | 0.04 | -0.06 |
| Ranking: | 9 | 9 | 6 | 8 |

| Mining: Goathill Creek Area (12-11A) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | | | | |
| 10/22/92 | | | | |
| 2/16/93 | | | | |
| 11/10/93 | 17.07 | -0.40 | -0.11 | 0.99 |
| 2/11/94 | | | | |
| 10/13/94 | 19.27 | 22.53 | 0.01 | -0.07 |
| 2/14/95 | 18.17 | 11.07 | -0.05 | 0.46 |
| 11/9/95 | 13.35 | 25.71 | 0.01 | -2.78 |
| 2/26/96 | 8.98 | | | |
| Average | 15.37 | 14.73 | -0.04 | -0.35 |
| Ranking: | 2 | 5 | 8 | 9 |

| Mining: Remainder of Catchment Area Adjacent to and East of Goathill Creek (11A-10B) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | | | | |
| 10/22/92 | | | | |
| 2/16/93 | | | | |
| 11/10/93 | 18.76 | 33.57 | -0.13 | 0.10 |
| 2/11/94 | | | | |
| 10/13/94 | 11.72 | -4.73 | 0.00 | 0.02 |
| 2/14/95 | 2.95 | -5.57 | -0.10 | 0.08 |
| 11/9/95 | 5.86 | 1.65 | 0.02 | 2.31 |
| 2/26/96 | -1.11 | | | |
| Average | 7.64 | 6.23 | -0.05 | 0.63 |
| Ranking: | 7 | 8 | 9 | 2 |

| Mining: Catchment Area opposite Columbia Creek (10B-10-9) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | -35.95 | -84.50 | -0.72 | -0.22 |
| 10/22/92 | 13.49 | 20.15 | 0.07 | -0.04 |
| 2/16/93 | 15.92 | 36.07 | 0.06 | -0.14 |
| 11/10/93 | 6.34 | 21.72 | 0.13 | -0.03 |
| 2/11/94 | 12.97 | 22.37 | 0.05 | 0.28 |
| 10/13/94 | 34.24 | 30.65 | 0.08 | 0.00 |
| 2/14/95 | 17.10 | 14.18 | 0.08 | -0.01 |
| 11/9/95 | 12.70 | 33.66 | -0.03 | 0.35 |
| 2/26/96 | 29.00 | 0.00 | 0.00 | 0.00 |
| Average | 11.76 | 10.48 | -0.03 | 0.02 |
| Ranking: | 4 | 7 | 7 | 5 |

| Mining: Mill, Portal Spring, and the Spring Gulch, Sulfer Gulch, Middle and Sugar Shack South Overburden Disposal Pile Area (10-7) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | 13.07 | 21.98 | 0.10 | -0.30 |
| 10/22/92 | 17.58 | 14.19 | -0.09 | -0.02 |
| 2/16/93 | 10.46 | 17.25 | 0.01 | 0.10 |
| 11/10/93 | 4.13 | 20.94 | 0.46 | -0.09 |
| 2/11/94 | 16.41 | 21.39 | 0.01 | 0.20 |
| 10/13/94 | 12.33 | 19.15 | 0.10 | -0.02 |
| 2/14/95 | 3.59 | 8.38 | 0.01 | -0.06 |
| 11/9/95 | 13.18 | 13.67 | 0.00 | 0.10 |
| 2/26/96 | 6.61 | | | |
| Average | 10.82 | 17.12 | 0.07 | -0.01 |
| Ranking: | 5 | 3 | 5 | 7 |

| Non-Mining: Hansen and Adjacent Creek Areas (7-5) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | 9.45 | 10.80 | 0.30 | 0.35 |
| 10/22/92 | | | | |
| 2/16/93 | | | | |
| 11/10/93 | 8.61 | 26.01 | 0.37 | -0.05 |
| 2/11/94 | | | | |
| 10/13/94 | 20.05 | 22.69 | 0.02 | 0.12 |
| 2/14/95 | 14.99 | 18.26 | 0.01 | -0.01 |
| 11/9/95 | 15.08 | 28.41 | 0.02 | -0.05 |
| 2/26/96 | 16.09 | | | |
| Average | 14.04 | 21.23 | 0.14 | 0.07 |
| Ranking: | 3 | 2 | 1 | 4 |

| Non-Mining: Red River Development Area (5-1) | | | | |
|---|---|---|---|---|
| | SO4 | TDS | D Al | Fe |
| 11/29/88 | 11.35 | 23.60 | | 0.13 |
| 10/22/92 | | | | |
| 2/16/93 | | | | |
| 11/10/93 | 28.39 | 50.27 | 0.09 | 0.22 |
| 2/11/94 | 19.87 | 36.94 | 0.09 | 0.18 |
| 10/13/94 | 32.51 | 63.65 | 0.11 | 0.08 |
| 2/14/95 | 24.79 | 53.86 | 0.02 | 0.11 |
| 11/9/95 | 24.56 | 42.38 | 0.03 | 0.17 |
| 2/26/96 | 27.00 | | | |
| Average | 24.06 | 45.12 | 0.07 | 0.15 |
| Ranking: | 1 | 1 | 4 | 3 |

**LEGEND**

- MONITORING WELL
- RED RIVER SAMPLE LOCATION
- UNDERGROUND MINE WORKINGS AND OPEN PIT
- SCAR AREAS (SRK, 1995)
- OVERBURDEN DISPOSAL PILES (SRK, 1995)
- ADIT

REFERENCE: U.S.G.S. TOPOGRAPHIC MAPS OF QUESTA AND RED RIVER, NEW MEXICO DATED 1963.

FIGURE 6

## INCREMENTAL SURFACE WATER LOADINGS (GM/SEC)

TRC ENVIRONMENTAL SOLUTIONS, INC.

ATTACHMENT A

# Ian P. G. Hutchison

## EDUCATION

B.S., Civil Engineering, University of Capetown, South Africa, 1967.
Graduate Diploma, Hydraulic and Soils Engineering, University of the Witwatersrand, South Africa, 1974.
Ph.D., Hydrology, University of the Witwatersrand, South Africa, 1976.

## EXPERIENCE DETAIL

**1989-Present: Senior Vice President, TRC Environmental Solutions, Inc.**

- Expert witness for the following:
  - Stringfellow Superfund site, California (surface water-VOCs and metals) (Deposition and Trial Testimony 1987 through 1993).
  - Rancho California Airport site, California (ground water - hydrocarbons) (Deposition).
  - John Wayne Airport site, California (ground water - VOCs) (Expert Report, 1990).
  - Testimony to the County Supervisors on the Briggs Mine EIR, Inyo County, California (mine waste management). (Hearing Testimony, 1995).
  - Iron Mountain Mine site, California (acid drainage, metals) (Expert Review, 1994).
  - Hope Brook Gold Mine in Newfoundland, Canada (mine waste management, surface water). (Expert Report, 1995)
  - Confidential gold mine site in the southwestern United States (mine waste management, surface and ground water) (Expert Report, 1996).
  - Stanford Research Park Industrial Complex in Palo Alto, California (ground and surface VOCs) Expert Report, 1993).
  - Hattiesburg Wood Treatment Site, Mississippi (soil and ground water-wood treatment chemicals) ( In progress 1995 - 1996).
  - Meyer's Drum Reprocessing Facilities (soil and ground water PCBs, Bunker C, metals and COCs) (Expert Report and Deposition, 1996).

- Project Director or Principal-in-Charge for the following remediation projects:
  - Site characterization and remedial design for the historic Pacific Coast Pipeline Refinery/Superfund site in Fillmore, California involving heavy and light hydrocarbon fuels. Remediation included soil vapor extraction and ground water pump and treat.
  - Site characterization and remedial design for the Purity Oil Recycling Facility Superfund site which is impacted by hydrocarbons and volatile organics (VOCs). Remedial technologies included soil vapor extraction, capping and ground water pump and treat.
  - Site characterization, risk assessments and remedial planning for the large operating Unocal refinery at Wilmington. Constituents of concern included hydrocarbons and lead. Remedial technologies included capping, soil excavation and treatment, and in-situ ground water treatment.

- Site characterization and remedial design, and record of decision (ROD) changes, for the J.H. Baxter Superfund site in northern California. Constituents of concern include dense nonaqueous phase liquids (DNAPLs); i.e., creosote, polychlorinated phenols (PCP), and metals including arsenic, chromium and zinc. Remedial elements included soil excavation, ex-situ biotreatment, onsite disposal in a RCRA-equivalent cell, in-situ biotreatment, slurry wall and limited ground water extraction and treatment.
- Site characterization, remedial design, and ROD changes for the Cabot Carbon/Koppers Superfund site (Wood Treatment Plant) in Gainesville, Florida involving creosote, PCP and metals. Remedial technologies included capping and "passive" slurry wall systems.
- Site characterization and remedial design, and construction oversight for the Feather River Wood Treatment site in Oroville, California which involves creosote, PCP and metals. Remediation included soil excavation and disposal in onsite RCRA-equivalent cells.
- Site characterization and remediation planning at the Vega Alta industrial site in Puerto Rico (VOCs). Remediation included selective ground water pump and treat.
- Site characterization and remediation planning at the Boricua Wood Treatment site in Puerto Rico (arsenic). Remedial technologies included soil excavation, offsite disposal and capping.
- Site characterization, remedial planning and design, and remediation construction at a mercury mine and processing facility in California. Technologies employed included building decontamination and demolition, soil excavation stabilization and offsite disposal, and buried drum location and removal.
- Remedial design for closure of tailings piles at the Shafter Silver Mine in Texas. Closure included regrading and capping.
- Assessment of closure liability and costs including conceptual designs and cost estimates for acid mine drainage control and treatment systems at mines in Colorado, Idaho and Nevada as part of a corporate acquisition. Closure technologies included physical, chemical and wetlands (biological) treatment, regrading and capping.
- Corrective action planning and design for a RCRA wood treatment facility in Montgomery, Alabama (constituents of concern include PAHs, PCP, metals and dioxins). Corrective action technologies include a "passive" slurry wall.
- Site characterization and interim measures implementation and evaluation at the Charleston Superfund site (wood treatment plan) in South Carolina. The technology tested involved NAPL removal well systems.

• Project Director or Principal-in-Charge for the following mining projects:

- Development of closure plans for the Cactus Gold Heap Leach Mine in Lancaster, California. Closure elements included regrading and backfilling of pond areas.
- Development of closure plans for wastewater ponds and tailing impoundments, tailings impoundment corrective actions, and ground water impact characterization for the Molycorp Mountain Pass rare earth mine, California. Characterization involved demonstration of limited seepage migration from tailings impoundment, and remedial/ closure technologies included a seepage interception well system, innovative cost-effective silty material caps for landfills and tailings ponds, and improvements to the wastewater treatment system (neutralization and settling).
- Development of closure plans for an acidic waste rock disposal pile at the Homestake Mine, California. Closure technologies included short-term leachate collection and return systems and long-term control by encapsulation of the waste rock in clay cells.

- Development of closure plans and designs, and permitting of wastewater transfers at the Royal Mountain King Gold Mine, California. Operation of mine site during closure period. Technologies employed included RO treatment and solar evaporation of wastewater, regrading, soil and composite covers for tailings ponds and earthfill dam construction to contain pit lake levels.
- Planning and conceptual design of wastewater disposal systems for the Sonora Gold Mine, California. Systems permitted included land application on waste rock piles and blending and discharge under the NPDES program.
- Seepage evaluations, design of seepage control systems and a spill control dam at the Cerro Verde Mine in Peru.
- Briggs Gold Mine heap leach environmental impact report (EIR), California.
- Soledad Canyon gravel mine and site infrastructure design for TMC.
- Permitting of three copper mines and associated processing plants (heap leaching, SX/copper sulfate and EW facilities) in COREMA Region II (Atacama Desert) in Chile.
- Remediation designs and closure plan development for four lead/zinc/copper mines in the Peruvian Andes. Technologies included regrading, capping, underground mine sealing and wetlands treatment systems.
- Characterization and remedial planning for the control of acid drainage from historic mines in the Moche, Llaucano, and Parcoy River Basins in northern Peru.

• Regulatory development activities, including:

- Senior editor and author of a 650-page textbook on mine waste management.
- Preparation of industry "strawman" mine waste regulations for California.
- Senior editor and reviewer of the Arizona BADCT mine waste regulations.
- Presentation of testimony on mine waste management to State Hearing Boards in California.

• Senior Review Consultant on the following projects:

- OII municipal/industrial landfill Superfund site in California (cover design, leachate collection and treatment and ground water characterization and remediation).
- Site characterization and remedial planning at the closed Casmalia RCRA hazardous waste landfill site, California. Remediation includes ground water trench collection systems and capping.
- Design of the B-18 hazardous waste disposal cell at Kettleman Hills, California.
- Expansion plans for the McFarland-Delano Municipal Landfill, California.
- Lead-zinc mining district Superfund site RI/FS in Kansas and Missouri (Jasper County and the Baxter Springs-Treece Superfund sites).
- Development of a strategic RCRA compliance plan and designs for FMC's lithium production facility in Bessemer, North Carolina.
- Site characterization and remedial planning including technology impracticability evaluations for Bristol Meyers' Weck Industrial site in North Carolina.
- Site characterization and remedial design for two drum recycling facilities in Oakland and Emeryville, California (VOCs, PCB, heavy hydrocarbons and metals).
- San Fernando Valley Superfund Site (Glendale Operable Unit) 5,000 gpm ground water remediation project.
- Reassessment of proposed remedial ground water pumping at an industrial site in Ontario, California. Alternative proposed utilized natural attenuation to limit ground water extraction and treatment.
- Characterization of waste rock for the Mule Canyon Mine in Nevada.

**1981-1989: Managing Principal and Division Head, Water Engineering, Steffen Robertson and Kirsten**

- Responsible for the U.S. operations of the company, including several hundred projects involving waste management, water pollution control, land use and air quality permitting, and open pit mining.
- Direct technical management of solid waste disposal, hazardous waste and hydrologic work carried out by the company.
- Project principal in charge of the design and construction of mine tailings and waste rock disposal facilities in Alaska, Washington, California, Colorado, Utah, and Nevada.
- Expert witness on the Stringfellow Superfund Site.
- Technical oversight on investigations carried out on the Boulder Marshall Municipal Waste Landfill Superfund site in Colorado.
- Technical expert review work on ground and surface water and soil pollution problems on mining Superfund sites including California Gulch, Colorado, and Galena, Kansas. Development of a comprehensive approach for the development of ARARs.
- Presentation of specialist technical evidence for ground and surface water contamination problems at mine sites in California and New Mexico.
- Supervision of regional hydrologic and water balance studies for the Rio Grande River basin.
- Embankment dam design and construction in California and Washington (fill dam heights of up to 400 feet).
- Project management of the design of 100-acre waste water disposal ponds in California.
- Testimony on water quality and waste management issues at the State and Regional Water Quality Control Boards in California.

**1976-1981: Hydraulics Department Head/Project Engineer, Acres International**

- Hydrologic and hydraulic engineering aspects of all projects conducted in the United States, and maintaining a staff team to undertake the work.
- Hydroelectric projects in New York, Maine, Vermont, and Alaska, including the Susitna River project in Alaska.
- Industrial process plants and tailings disposal systems in Ohio and Colorado.
- Streamwater quality studies in New York.
- FEMA flood plain mapping studies.
- The hydrologic and hydraulic engineering associated with a wide range of irrigation, navigation, hydroelectric, and industrial projects throughout Canada, the United States, and South America.

- Irrigation schemes in the Dominican Republic and Bolivia.
- Design and construction of three ports on the Amazon River in Peru.
- Design and construction of hydroelectric generating stations in Newfoundland, Ontario, and Alberta, Canada.
- Large-scale river basin water balance studies in Alberta, Canada.
- Regional flood studies for the province of New Brunswick, Canada.

**1970-1976: Research Officer, Hydrological Research Unit, University of the Witwatersrand, Johannesburg, South Africa**

- The development and application of river basin catchment, ground water, lake and estuary computer models for the evaluation of salinity control measures of the St. Lucia Lake system.
- Provided input to the update of national design flood manuals.
- Numerous consulting assignments involving the development of surface water supplies and implementation of flood control measures for projects in South Africa, Botswana, and Lesotho.
- Conducted graduate courses in computer modeling of surface water systems and water resources project economics.
- Conducted a study tour of the United States and Canada to review available technology for the modeling of flow and water quality of surface systems.

**1968-1970: Engineer, Technical Computing Company, Johannesburg, South Africa**

- Development and application of structural analysis computer software for the design of bridge decks and pile groups, and one-dimensional tidal propagation modeling in estuaries.

## REGISTRATIONS

Professional Engineer in California and seven other states.

## PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers
American Water Resources Association
International Mine Water Association

## TECHNICAL PUBLICATIONS

Author and presenter of more than 25 publications and seminar presentations on the subjects of waste management, hydrology, and regulatory development.

*A Mathematical Model to Aid Management of Outflow from the Okavango Swamp, Botswana.* Journal of Hydrology, Vol. 19, No. 2, June 1973.

*The Okavango Delta - Ways of Evaluating the Economic and Environmental Impact of Mass Transport of Water.* Presented at the 5th Quinquennial Convention of the South African Institution of Civil Engineering, South Africa, August 1973.

*A Mathematical Sediment Model for a Sea Water Intake Basin.* Presented at the Conference on Marine and Fresh Water Research in Southern Africa, Port Elizabeth, South Africa, July 1976.

*Lake St. Lucia - Mathematical Modelling and Evaluation of Ameliorative Measures.* The Civil Engineer in South Africa, Transactions of the South African Institution of Civil Engineering, South Africa, Vol. 19, No. 4, April 1977.

*Lake St. Lucia - The Computer Points the Way.* African Wildlife, Vol. 31, No. 2, April/May 1977.

*Mathematical Modelling of Water Level and Salinity Regions in Some Southern African Lake and Estuary Systems.* Presented at the Seventeenth Congress of the International Association for Hydraulic Research (IAHR), Baden-Baden, Federal Republic of Germany, August 1977.

*Regional Flood Frequency Analysis for New Brunswick.* Presented at the Canadian Hydrology Symposium: 77-Floods, in Edmonton, Alberta, Canada, August 1977.

*A Systematic Approach to Flood Risk Mapping.* Presented at the International Symposium on Risk and Reliability in Water Resources, in Waterloo, Ontario, Canada, June 1978.

*Modelling the Water and Salt Balance in a Shallow Lake.* Ecological Modelling, Vol. 4, 1978, pp. 21-235.

*Aspects of Phosphogypsum Waste Disposal.* Presented at the Seventh Annual Madison Waste Conference, Dept. of Engineering and Applied Science, University of Wisconsin-Extension, Madison, Sept. 11-12, 1984.

*Cyanide Control Options - Lessons From Case Histories.* Presented at the Tucson Cyanide Conference, December 1985.

*Legal Allocation of Augmented Water Supply Due to Silvacultural Activity in the Upper Rio Grande River Basin.* Fourth International Hydrology Symposium on "Multivariate Analysis of Hydrologic Process: Stochastic-Deterministic," Colorado State University, Fort Collins, Colorado, July 15-17, 1985.

*Introduction to Evaluation, Design and Operation of Precious Metal Heap Leaching Projects,* Editor and Author of Chapter on "Surface Water Balance," 1988.

*Management for Hazardous Waste Liability at Mining Sites.* Colorado State University Symposium, January 1991.

*Mine Waste Management.* Editors: I.P. Hutchison and R.D. Ellison. Lewis Publishers, Inc. 1992. pp. 652.

*Summitville Mine - Remedial Alternatives Identification and Evaluation.* I.P. Hutchison, Michael L. Leonard, Sr. and David P. Cameron. Summitville Forum 95: A Forum held in Conjunction with Tailings and Mine 1995, Colorado State University, Fort Collins, Colorado, January 1995.

ATTACHMENT B

# ATTACHMENT B: REFERENCES


**GSi, 1997:** GSi/water. *Ground Water Data* . Collected in 1996. 1997.

**Hsieh et al., 1985:** Hsieh, P.A. and Neuman, S.P., "Field Determination of the Three Dimensional Hydraulic Conductivity Tensor of Aniosotropic Media". *I, Theory: Water Resources Research*, v.21. pp. 1655-1665. 1985.

**Hubbert, 1956:** Hubbert, M.K., *Darcy's Law and the Field Equations of the Flow of Underground Fluids: Trans. America. Inst. Met. Engrs.*, v.207, pp. 222-239. 1956.

**Kelsey Deposition, 1977:** Kelsey, Richard K., P.E. Deposition. Taken by Richard E. Schwartz. April 7, 1997.

**Kelsey, 1997:** Kelsey, Richard K., P.E. *Expert Report.* March 14, 1997.

**Long et al., 1982:** Long, J.L.S., and others, "Porous Media Equivalents for Networks of Discontinuous Fractures", *Water Resources Research*, v.18, pp. 645-658. 1982.

**Mink Deposition, 1997:** Mink, Leland Leroy, Ph.D., P.G. Deposition. Taken by R. Timothy McCrum. April 8, 1997.

**Mink, 1997:** Mink, Leland Leroy, Ph.D., P.G. *Expert Report.* March 13, 1997.

**Molycorp, 1997:** Molycorp, Inc. Data provided by Molycorp, Questa. 1997.

**Molycorp, Undated:** Molycorp, Inc. *Stormwater Pollution Prevention Plan.* Undated.

**Moores, 1993:** Moores, Eldrige E. and Robert Twiss. *Structural Geology.* W.H. Freeman & Company, New York, 1993.

**NMED, 1996:** Slifer, Dennis. *Red River Groundwater Investigation.* New Mexico Environment Department Surface Water Quality Bureau. March 1996.

**Shoemaker Deposition, 1997:** Shoemaker, David. Deposition. Taken by Eric Ames. January 22, 1997.

**SPRI, 1995:** South Pass Resources Inc. *Progress Report on the Geology, Hydrogeology And Water Quality of the Mine Area* . Taos County, New Mexico, 1995.

**SRK, 1995:** Steffen, Robertson and Kirsten. *Questa Molybdenum Mine: Geochemical Assessment and Preliminary Closure Plan.* April 13, 1995.

**USGS, 1988:** USGS. *Rio Grande Basin: Red River Seepage Investigation.* 1988.

**Vail, 1993:** Vail Engineering, Inc. *Interim Study of the Acidic Drainage to the Middle Red River, Taos County, New Mexico.* July 9, 1993.

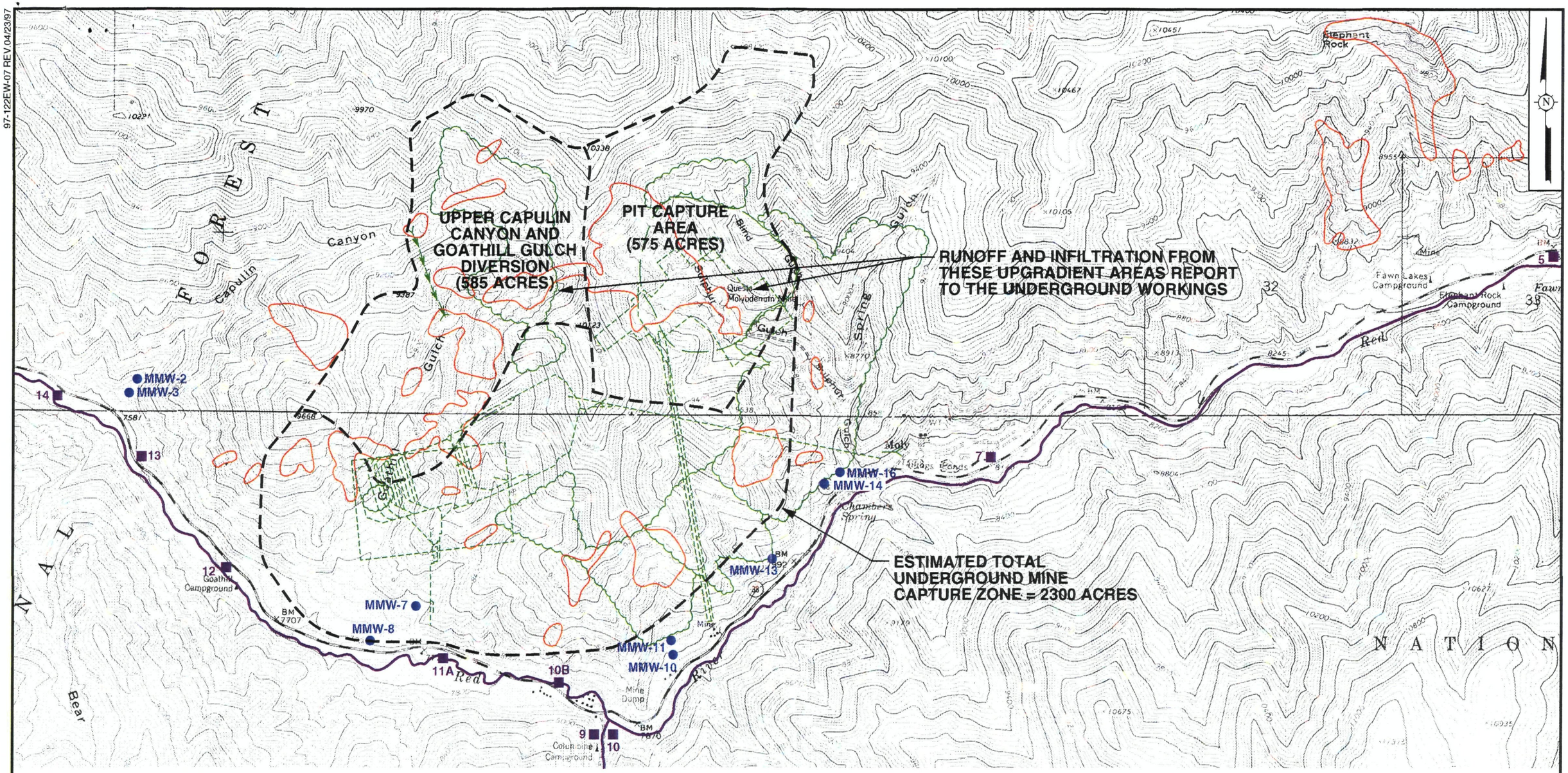
**Williams Deposition, 1997:** Williams, Barbara Cook, Ph.D., P.E. Deposition. Taken by Richard Schwartz. Volume I. April 8, 1997.

**Williams, 1997:** Williams, Barbara Cook, Ph.D., P.E. *Expert Report.* March 13, 1997.

**Woodward-Clyde, 1995:** Woodward-Clyde Consultants. *Red River Surface Water Investigation Report November 1995 Molycorp Questa Mine, Questa, New Mexico.* June 1996.

ATTACHMENT C

97-122EW-07 REV.04/23/97




**LEGEND**

- MONITORING WELL
- RED RIVER SAMPLE LOCATION
- UNDERGROUND MINE WORKINGS AND OPEN PIT
- SCAR AREAS (SRK, 1995)
- OVERBURDEN DISPOSAL PILES (SRK, 1995)
- ADIT

0 2000 4000 FEET
SCALE

REFERENCE: U.S.G.S. TOPOGRAPHIC MAPS OF QUESTA AND RED RIVER, NEW MEXICO DATED 1963.

ATTACHMENT C

**MINE AREAS**

**TRC ENVIRONMENTAL SOLUTIONS, INC.**

Expert Report – William M. Schafer, Ph.D.

DM
22306

# 1. Summary of Qualifications

## 1.1 Employment and Title

Dr. William M. Schafer is founder and President of Schafer & Associates, an environmental consulting firm specializing in mining environmental issues.

## 1.2 Qualifications, Education, Experience, and Publications

Dr. Schafer received a B.S. degree in watershed science from Colorado State University, a M.S. degree in soil science from the University of California at Davis, and a Ph.D. in soil science from Montana State University. Dr. Schafer worked at Montana State University as Research Associate and Assistant Professor from 1975 until 1985, during which time he conducted research on mined land revegetation and reclamation, mining geochemistry, and mining hydrology. As a consultant, he has been involved in over 200 projects relating to mining environmental management. He has authored or co-authored numerous papers, symposium presentations, and technical short-courses over the last ten years. Dr. Schafer's resume including a list of all articles published in the last ten years is attached.

## 1.3 Compensation

Hourly rate is $140 per hour.

Direct Hydrologic connection case in which, according to application LAC minerals lost.

## 1.4 Appeared as Witness in Past 4 years

- (Friends of Santa Fe County v LAC Minerals (USA) Inc et al. (US District Court for New Mexico): Expert witness for LAC Minerals regarding the Ortiz Mine
- Expert witness in a Montana water rights claim
- State of Montana v ARCO et al. (US District Court for Montana) Factual witness for the ARCO Clark Fork River Natural Resource Damage suit (pending)

# 2. Sources of Information

My opinion is based on a detailed review of a number of documents and reports, (listed in References Cited Section 5), detailed analysis and interpretation of selected data contained in the aforementioned reports, a visit to the Molycorp site and the surrounding vicinity including the Red River, and inspection of selected reaches of tributary basins. In addition, I reviewed the expert reports submitted by Mr. Richard Kelsey dated March 14,1997; Dr. Leland Mink dated March 13, 1997; and Ms. Barbara Williams dated March 13, 1997.

# 3. Summary

1. Flow in the Red River consists of two components; surface runoff and groundwater. Surface runoff from the mined area is controlled by the stormwater management system. As a result, the mine has reduced that portion of the natural metal and sulfate loads to the Red River that before mining were carried by surface runoff. Groundwater contributions to flow, also known as "baseflow", vary by as much as ten-fold on different days within a single year. Additionally, the average annual groundwater baseflow can vary by a factor of two or more. Baseflow contribution from the reach of the Red River adjacent to the mining area measured in November 1965 and November 1988 by United States Geological Survey (USGS) fall within the natural range of variability. Consequently, based on my review of available information, I do not believe that baseflow contribution has changed as a result of Molycorp's activities.

Says no change in base flow as a result of Molycorps activities. How can he say they have reduced metals loadings?

2. Changes in annual precipitation correspond with changes in groundwater baseflow. Consequently, increased annual precipitation for the period 1980 to present (Slifer 1996), would tend to increase groundwater baseflow, resulting in increased loads of sulfate, TDS and metals from natural hydrothermal scar areas to the Red River.

3. Despite increased precipitation from 1980 to present, available flow and chemical data from the Red River do not identify a trend for increasing

metal, total dissolved solids (TDS) or sulfate levels since development of the open pit in late 1965 through 1981. Reliable data on metal concentrations in the Red River are not available prior to the 1970's. Calculated loads and concentrations of TDS since 1965 are within normal ranges of variability and are due to changes in precipitation and other natural factors. Changes in sulfate load and concentration through time are small. In addition, sulfate loads to the Red River are contributed over a diffuse zone several miles long – starting above the mine, and continuing in the reach adjacent to the mine, and continuing downgradient of the mine. Similar proportional changes in sulfate occur both above and adjacent to the mine. Consequently, changes in sulfate cannot be shown to result from mining at the Molycorp site.

A number of complex processes may affect the metal loads in rivers including precipitation, deposition in the bed, re-suspension, and adsorption or dissolution from adsorbed phases into dissolved phases. Consequently, these processes must be considered when determining the source of metal loads. Most metal loads in the Red River increase in a downstream direction, but the pattern of load increase does not indicate that the mine area is a source of the metals. Changes in metal concentrations are more consistent with contribution from hydrothermal scars that occur over a zone starting well above and ending well below the mine area. The changes in the load of some metals, especially iron, are caused by re-suspension of precipitates in the streambed.

4. Water in contact with either mine waste rock or natural hydrothermal scars has the same geochemical "signature". Consequently, increases in the concentration of specific metals such as zinc or manganese in seeps or in the Red River adjacent to the mine do not indicate that seepage was contributed by mine waste rock sources.

5. The metal concentration in seeps adjacent to the Red River is controlled by the ambient pH of the groundwater system. Consequently, differences in the chemistry of water contacting mine waste rock or hydrothermal scars, if present, would not cause similar differences in the

chemistry of groundwater seeps. Based on the natural chemical evolution of groundwater, recharge from scar areas would be expected to have poorer chemistry than recharge through mine waste rock.

6. There is no geochemical basis for determining the location, timing or amount of acidic drainage and associated constituents, also known as acid rock drainage (ARD), contributed to the Red River by the mine waste rock.

# 4. Basis of opinion

## *4.1 Red River Flow Regime*

1. Surface water in the Red River is derived from surface runoff and from groundwater "baseflow" contributions (Dunne and Leopold 1978). In mountain streams, surface runoff occurs during seasonal snowmelt events and in response to large rainstorms. Baseflow is more continuous and accounts for all of the flow in perennial streams for most of the year. There are a number of mathematic and graphical methods for estimating groundwater recharge to streams by separating the baseflow contribution from surface runoff (Mau and Winter 1997).

   For example, flow data from the Red River gauge near Questa were used and baseflow was determined graphically for a low flow (1978, Figure 1) and a higher flow year (1984, Figure 2). The variation in estimated daily baseflow for the entire hydrologic basin just below the mine site varied from 2 to 50 cubic feet per second (cfs) in 1978, and from 10 to 100 cfs in 1984. Similar seasonal variations in baseflow would be expected for groundwater contributions from the reach adjacent to the Molycorp mine. Variations in average annual baseflow varied from of 14 to 27 cfs, or 0.14 to 0.27 feet of groundwater recharge averaged over the basin area.

   Using data collected by Vail Engineering in 1992 and 1995, Smolke and Tague in 1988, EPA in 1970, and US Public Health Service in 1965, the baseflow contribution for the reach adjacent to the mine can

be estimated by subtracting upstream and tributary flows from downstream flows. Baseflow was 4.0, 3.2 and 3.1 cfs in 1988, 1993 and 1995 respectively. In some years specific segments of the Red River near the Molycorp mine have been losing reaches. During the earlier years, Columbine Creek was not gauged, however, in 1970 (a low flow year) the reach lost 1.5 cfs of flow even without accounting for Columbine Creek. If Columbine Creek flow was assumed to be 3 cfs, then the Red River reach adjacent to the mine lost 4.5 cfs in 1970. In 1965, the reach contributed 4.3 cfs of baseflow if Columbine flow was assumed to be 5 cfs.

2. Mink and Kelsey each referred to USGS studies of the groundwater contribution to the Red River conducted in 1965 and in 1988. Mink quoted the 1988 USGS report inaccurately when he reported a groundwater seepage contribution of 4 cfs in the reach bordering Molycorp. The 4 cfs increase in flow actually occurred upstream of the mill. Actual baseflow contribution in 1988 was a loss of 1 cfs between the mill and Columbine Creek and a gain of 3.7 cfs below Columbine Creek, for a total contribution of 2.7 cfs.

3. The baseflow contribution rate for any mountain stream would be expected to vary within any year by up to ten-fold (Mau and Winter 1997). Consequently, variations in baseflow such as those observed between 1965 and 1988 in the Red River are common for any two single day measurements of baseflow collected in two different years. This observation cannot be construed as a trend indicating change in groundwater baseflow due to the Molycorp mine.

## 4.2 Geochemical Conditions in the Red River

1. The concentrations of many constituents in the Red River increase in a downstream direction. Williams attributed the increases in sulfate, TDS, and metal concentration to the waste rock piles at the Molycorp mine site. Evidence offered that the Molycorp waste rock piles were the primary source includes: (i) constituents have increased since development of the open pit; (ii) constituents are elevated in water in contact with waste rock;

and (iii) the mine has covered a large extent of hydrothermal scars, a natural source of sulfate, TDS and metal loading. Additionally, the concentrations of metals in water contacting waste rock was said to have a different "signature" than water in contact with hydrothermal scars. Specifically, she contended that water contacting mine waste rock had higher concentrations of manganese and zinc.

2. I conducted a detailed review of the sulfate, TDS and metal concentrations in the Red River. I used data from several sources to determine the "mass loads" in the Red River upgradient, adjacent to, and downgradient of the Molycorp Mine. Information sources include Public Health Service 1966, EPA 1971, Smolka and Tague 1989, Vail Engineering 1993, and Woodward Clyde 1996. These data were used because they span the available period of record, and because they came from a variety of sources. The mass loads of each constituent (grams/second) were calculated by multiplying the concentration measured in samples collected from various stations along the Red River by the measured flow rate. Mass loads were determined at several stations upgradient of the Molycorp Mine starting above the town of Red River (near Highway 38 mile marker 13) continuing to above the mill (between mile marker 7 and 8). Several monitoring stations were also sampled adjacent to the Molycorp Mine, from the mill downstream to the mouth of Capulin Canyon (near mile marker 3). Finally, several stations below the mine but above the town of Questa were sampled. In the earlier sampling events, fewer stations were monitored. Nonetheless, mass loads were calculated for total dissolved solids (TDS), sulfate, alkalinity, aluminum, iron, manganese, and zinc for all available stations (Figures 1 through 7).

3. There is significant variation in the TDS load in the river between measurements taken from 1965 to 1995 (Figure 3a and 3b). Higher TDS loads occur during periods of higher flow October 1988 and November 1995, and lower TDS occurs during low flow (such as in 1970 when flow was only 11.7 cfs at the Ranger Station). There is a relatively consistent increase in TDS in a downstream direction. During periods of high flow, the TDS load increases from 40 g/s to 100 g/s between the town of Red

River and the station just above the Molycorp mill. These increases in TDS are not caused by the mine. The sources of elevated TDS along this 5 mile reach are hydrothermal scars located mostly north of the river (South Pass 1995, SRK 1995, Vail Engineering 1994, Woodward Clyde 1996).

Along the next 4 mile reach, TDS increases by 75 grams per second (g/s). Possible sources of TDS include groundwater recharge through the Molycorp mine waste rock, runoff and groundwater flow through exposed hydrothermal scars (or debris flow fan delta deposits derived from scar areas), groundwater flow through bedrock, or groundwater flow through hydrothermal scar areas that have been buried by mine facilities. Surface water runoff from the mine facilities is prevented from directly entering the Red River.

Additionally, a significant portion of the groundwater flow to the north of this reach of the Red River is collected by mine dewatering. The groundwater intercepted by passive and active mine dewatering may intercept both mine-affected groundwater as well as groundwater with naturally elevated TDS levels. Downgradient of the Molycorp Mine, the TDS levels continue to increase. Exposed hydrothermal scars further west of the mine areas accounts for these loads. Variations in the TDS load and concentration are best explained by natural variation in rainfall and other natural factors.

4. The sulfate loads follow the same pattern as TDS (Figure 4). This is not surprising because sulfate is the primary anion dissolved in the Red River so differences in TDS should parallel those of sulfate. Differences in sulfate load are strongly affected by the flow rate, with small sulfate loads observed during periods of low flow (1970), and with higher loads occurring during periods of high flow. In 1965 (before the open pit) and in 1988, the increase in sulfate across the reach adjacent to the mine was approximately equal. In both 1992 and 1995, roughly 50% of the sulfate measured in the Red River above Questa could be attributed to the reach

adjacent to the Molycorp Mine. Potential sources of sulfate load along this reach may include either natural or mine-related flows.

5. The alkalinity measured in the Red River (Figure 5) provides an important indication of the balance of acidic and alkaline waters that have mixed together from various sources. Williams, and several literature sources (Slifer 1996) allege that acid rock drainage (ARD) from the Molycorp Mine causes an increase in metals in the Red River. If acidic water flows into a stream containing alkaline water, the stream will become less alkaline (or may even become acidic) downstream of the mixing zone. The ability of ARD to decrease stream alkalinity or to cause acidic stream chemistry has been demonstrated by a number of authors (Chapman and others 1983, Theobald and others 1962).

Alkalinity is an important aspect of overall water quality because the pH of water decreases in acidic water, the solubility of metals is increased in low pH water, metals tend to occur in a dissolved rather than in a total recoverable form at low pH which increases their bioavailability, and water quality standards for protection of aquatic life for several metals are higher in alkaline (high hardness) waters.

The total load of alkalinity (in g/s) within the Red River increases slightly in a downstream direction. Alkalinity loads have not changed between 1965 and the present. This indicates that if low pH waters are moving towards the Red River: 1) their contribution has not changed since 1965, before development of the open pit; 2) they are neutralized before they reach the river or within a mixing zone within the river; or 3) acidic flows constitute a minor proportion of the total inflow to the Red River.

There are few usable data for metal concentration and flow in the Red River available prior to development of the open pit. All metal loads described in this section were calculated for the total recoverable forms rather than the dissolved forms of metals. It should be noted that EPA recognizes that the many metals, especially zinc and aluminum, are more bioavailable in their dissolved than in the total recoverable form. In

recent analyses of Red River water, all dissolved metal concentrations are below the EPA acute standards and are below or near the EPA chronic standards for protection of aquatic life. Chronic standards for dissolved aluminum were exceeded in the Red River above the mine and in the reach adjacent to the mine in 1992 and 1995, the only years with measurements for dissolved aluminum.

Total aluminum concentrations (Figure 6) tend to increase in a downstream direction and a significant increase in aluminum occurs over a 2 mile reach just upstream of the mine (probably from Hanson Creek), adjacent to the mine, and downgradient of the mine. Aluminum increases in the Red River upgradient of the mine confirms that there are aluminum loads that are attributable to natural sources. At the pH observed in the Red River, most aluminum would be expected to occur in the form of small ("colloidal") particles of aluminum oxyhydroxide, with low levels of dissolved aluminum (Woodward Clyde 1996).

6. Total iron loads (Figure 7) do not change appreciably throughout the length of the Red River except during the highest measured flow (October, 1988 – 30 cfs). Chemical precipitates (composed of iron and aluminum oxyhydroxides) that have lodged in the stream bed gravels can be re-suspended during periods of high flow. During such high flows, this re-suspension of precipitates that previously settled out of the water can lead to the mistaken conclusion that surface water flows or seeps are contributing significant iron loads. At the pH observed in the Red River, all iron would be expected in the form of small ("colloidal") particles of iron oxyhydroxide, with no measurable dissolved iron (Woodward Clyde 1996).

7. The primary source of total manganese loads (Figure 8) in the Red River occurred downgradient of the mine in 1988 and 1992, while the reach adjacent to the mine received significant increases in load in 1995. Potential sources of manganese include natural hydrothermal scars or mine sources as discussed for TDS and sulfate loads.

8. The changes in zinc loading (Figure 9) were very similar to those for manganese and similar conclusions can be drawn about potential sources.

## 4.3 Geochemical Signatures of Potential Sources of Mass Load

1. Flow in the Red River comes from a number of sources that may differ geochemically (Table 1). In general, these potential sources can be classified as surface or groundwater contribution from unmineralized portions of the basin, surface or groundwater flow from natural hydrothermal scar areas, and surface or groundwater flow from mine waste rock sources.

2. Williams argues that the concentrations of metals and sulfate in water contacting mine waste rock and soils from hydrothermal scars provides a means of distinguishing between the two sources. Williams indicated that mine water in contact with mine waste rock has higher levels of manganese and zinc than water from hydrothermal scars. This observation was based upon comparison of standing water and runoff from 9 samples of waste rock and 8 samples of hydrothermal scar water (SRK 1995). The average composition of each group of samples was compared to see which had a higher metal concentration. While the waste rock samples had higher average concentrations of manganese, zinc and other metals, the variability of individual measurements within each group were large.

I used a statistical test to determine whether the average metal concentrations for the two groups of samples was significantly different. A non-parametric analysis of variance was used for this test (Table 2). The apparent differences in average metal contents were not significantly different at a probability of 95%.

Additional data were collected to assess any potential differences between water contacting hydrothermal scars and mine waste rock. Shaker flask tests for grab samples of scar and waste rock were obtained from SRK (1995). The mean metal concentrations from these two sets of

samples were compared and the apparent difference in the mean metal concentration was used by SRK to support the theory that some metals, especially zinc and manganese are higher in water contacting mine rock. The same statistical test was used to determine whether the average metal concentrations for the two groups of shaker tests was significantly different. The non-parametric analysis of variance showed that the apparent differences in average metal contents were not significantly different at a probability of 95% (Table 3).

Slifer (1996) compared the average total metal concentration in 4 scar samples and in 7 waste rock samples. Based on the apparent differences in the average total metal concentration, Slifer concluded that waste rock had higher total concentrations of manganese and zinc. A non-parametric analysis of variance (Table 4) indicates that the scar and waste rock samples are not significantly different in total aluminum, manganese or zinc. The hydrothermal scar samples are higher in total iron. In water contacting sediment or rock material, the concentration of the metals (iron, aluminum, manganese, and zinc) is not strongly affected by total metal content. Therefore, even if scar and waste rock samples had differed in total metals, this cannot be used to infer that water contacting these materials would differ in metal concentration.

3. All available geochemical data from scar and mine rock shaker tests, and surface water in contact with scars or mine rock, were combined with the observed chemistry of seeps, and the Red River on solubility diagrams (Figure 11 through 15). Analyses of the data from all sources indicates that the pH of the samples is the primary factor that controls the metal concentration. Metal levels are highest at low pH in water in contact with waste rock or scars; in seeps; or in the Red River. Samples of waste rock and scars had wide range of pH and metal levels from each of these sources showed significant overlap due to the range in observed pH. Differences in the concentration of zinc and manganese in water contacting waste rock or scars, even if statistically significant, would not cause water from waste rock to have higher zinc or manganese levels if it reached the Red River. Samples collected by SRK were waters in direct

contact with waste rock or scar material, and thus are representative of surface runoff. Surface water from waste rock piles that is alleged to impact the Red River would infiltrate through the waste rock, continue to migrate downward in natural sediments until it mixed with the local groundwater system. After mixing, the seepage could potentially migrate downgradient until in entered the Red River. Bedrock units near the Molycorp mine, especially andesite and aplite, contains a significant amount of carbonate material. As acidic water travels through such bedrock or alluvial sediments a number of chemical reactions occur that tend to slow the rate of travel of some constituents (especially acidity, aluminum and iron) while barely affecting the rate of flow of other constituents (like TDS). As a result, aluminum, iron and acidity that may exit a waste rock pile would not be expected to travel quickly through underlying bedrock or alluvium. The capacity of bedrock or alluvial materials to attenuate metals and acidity will be exhausted only after a great number of decades or centuries so that all constituents including metals can travel at an equal rate. Therefore, the rate of travel of metals leached from hydrothermal scars (which have existed for millennia) would be expected to be faster than from waste rock areas. Consequently, differences in the chemistry of water in contact with waste rock versus scar material do not indicate that seepage fed from these sources can be reliably distinguished based on subtle differences in metal concentration measured in the Red River.

4. Figures 11, 12 and 13 illustrate the concentrations of sulfate, aluminum and iron in the Red River, in seeps, and in waters in contact with natural scar material and with mine rock. In addition, a geochemical model (Phreeqc, Parkhurst 1995) was used to calculate the theoretical concentration of these constituents that would occur in equilibrium with particular minerals. Sulfate concentration in acidic seeps and waters contacting scars and mine rock indicate that gypsum may be present. Gypsum is not in equilibrium with Red River water since measured sulfate levels are much lower than the gypsum solubility curve. Aluminum and iron minerals (boehmite and amorphous ferrihydrite) appear to control the solubility of iron and aluminum in seeps, waters

contacting scars and mine rock, and in the Red River. This fact indicates that the pH of the surface and groundwater system determines the resulting aluminum and iron concentration. Consequently, apparent changes in dissolved aluminum and iron levels in either surface or groundwater can not identify the waste rock piles as a source of these metals. The solubility of manganese and zinc was not modeled in Phreeqc. The solubility of manganese is strongly affected by the degree of oxidation (the redox potential) and solubility varies widely over the range of redox conditions commonly observed in surface water and shallow groundwater at the Questa mine site. The solubility of zinc was not modeled because willemite, a zinc silicate, is often the least soluble mineral in natural waters. In order to predict the concentration of zinc in water in contact with willemite, the pH and dissolved silica concentrations must be known and no data are available for the dissolved silica concentration.

## *4.4 Determining the Contributions of Acidic Inflows to the Red River*

1. The change in flow and surface chemistry in the reach of Red River adjacent to the Molycorp mine can be used to back-calculate the average chemistry of influent water. Reports from Williams, Mink, and Kelsey contend that most of the water flowing into the Red River from this reach is mine-affected. Additionally, the reports argue that the mine-affected water is acidic and contains highly elevated levels of metals.

2. I used data from 1965, 1988, 1992 and 1995 to calculate the average characteristics of water inflows to the Red River adjacent to the mine (Table 5). The average pH of inflow water is near-neutral and the average inflow is moderately alkaline. Consequently, it is clear that the water flowing into the Red River in this reach is not strongly acidic. The inflow which averages 3.7 cfs is probably a mixture of alkaline and low TDS groundwater, and a small proportion of acidic water, which may explain the average total aluminum, iron, manganese and zinc calculated for water flowing into this reach. Based on proportional weighted averaging of the influent chemistry with typical acidic and non-acidic waters, acidic

water represents less than 10% of the total flow into the Red River along this reach. Natural hydrothermal scars occurring along this reach could easily contribute this amount of flow (0.37 cfs or 166 gpm). At a typical groundwater recharge rate of 0.25 feet/year, only 66 acres of scar areas would be needed to contribute this amount of flow. There are 160 acres of undisturbed hydrothermal scars in the basin along this reach of the Red River based on maps produced by SRK (1995).

3. Phreeqc (Parkhurst 1995) was used to investigate the potential contribution of acidic water to the Red River. Data from the 1995 surface water sampling (Woodward Clyde 1996) were used for this model because complete ion analyses were completed on these samples. Water sampled at the mouth of Hanson Creek and water flowing at Cabin Springs were each used as "typical" acidic waters. Hanson Creek is a natural acidic source while Cabin Springs may be either natural or mine-affected. A water sample from Red River upgradient of the town of Red River was used to represent natural runoff or seepage unaffected by either scar areas or the mine. Acid water and unaffected river water were mixed in varying percentages, and the resulting zinc and sulfate levels were compared to downgradient Red River water. The resulting graphs can be graphically interpreted to show that acidic seepage represents only 2 to 4.5% of the total flow in the Red River basin, or 0.6 to 1.35 cfs at an average flow of 30 cfs. This amount of flow would be contributed from an "acidic" area of 108 to 244 acres with an average groundwater recharge of 0.25 feet/year. The area of the basin covered by hydrothermal scars is much larger than this area, and likely accounts for the loading observed in the Red River both before and after mining.

## 4.5 Chemical Dynamics in Surface Waters Impacted by Acidic Seeps

1. Most available data used to calculate mass loads were collected during "baseflow" periods. Baseflow refers to the time when the majority of water in a stream is contributed by groundwater inflows, as opposed to the runoff period when most flow is contributed by surface runoff. Peak runoff rates occur in the Red River (Figure 10) during snowmelt or in

response to summer thunderstorms.

Large increases in mass load can occur during runoff periods, especially if the flow regime is great enough to scour the streambed and remove precipitated metals that have accumulated in the bed. Mass load and flow at the Ranger Station were measured by Smolka and Tague (1989) four times after a September, 1988 rainstorm event. As flow decreased from 140 to 30 cfs, sulfate loads decreased by 4 to 5 times. Loads of iron, manganese and zinc decreased 10 times, and aluminum loads decreased 100 times. In many streams that are biologically impaired due to metals input, the impact occurs during high flow periods when metals are flushed into the river or when precipitates are re-suspended. Fish kills on the Clark Fork River in Montana have been described after large summer thunderstorms. In 1988, Bitter Creek (4 miles above the mine) was the only station that exceeded EPA aquatic life standards for metals (Smolka and Tague 1989). If biological impairment occurs mostly due to runoff of acidic water during high flow conditions, then the impairment cannot be attributed to the mine, because surface runoff from mine facilities does not reach the Red River.

2. Changes in the mass load or concentration of constituents in water in a downstream direction (or through time) is often used a means of identifying potential sources of input (such as from a mine). Williams relied on a comparison of concentrations in the Red River measured in 1965 and in 1988 to conclude that the mine had caused an increase in loading. Other referenced reports including Slifer (1995), similarly rely on analysis of concentrations in the Red River as a means of assessing load increases.

3. A mass load model implicitly assumes that the constituents analyzed are "conservative", meaning that they are not stored at any point within the system. Similarly, flux between surface water and alluvial groundwater can complicate the analysis of mass load data. Some constituents such as TDS are chemically conservative. However, most metals, and especially iron and aluminum, often are not conservative.

4. In 1962 Theobald and others described the mixing of an acidic and an alkaline stream in Colorado. After mixing, a number of metals including iron, aluminum, and manganese were removed from the surface water system and were deposited as a sediment layer on the streambed. Large quantities of other metals were removed from solutions. Iron and manganese oxyhydroxides are well known for their ability to adsorb a wide variety of metals and scavenge them from solution. Johnson (1986) described the adsorption of copper and zinc on iron oxyhydroxides in the Carnon River in England. Chapman and others (1983) and Chapman (1982) developed models to predict the transport of metals in natural waters comprised of mixtures of acidic and alkaline water. The model describes the complex interaction of dissolved metals, bed sediments, and suspended metals in streams. Runkel and others (1996) and Bencala and others (1990) describe the transport of metals in streams affected by input of acidic water. Metals moved more slowly than predicted due to interaction with bed sediments.

All of the research cited above describe a number of complex processes that affect metal transport. Based on these studies, changes in metal concentrations within a river system can be attributed to a number of factors including deposition in the streambed, resuspension of previously deposited precipitates, adsorption onto bed sediments or dissolution from bed sediments. Consequently, changes in concentration in metals in the Red River cannot be reliably attributed to the Molycorp mine without proper consideration of these processes. When surface water data are properly interpreted, there is no indication that the Molycorp Mine currently or at any time has contributed metal loads to the Red River.

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**Table 1. Chemical characteristics of potential sources of flow to the Red River.**

| Inflow source | Surface or Groundwater | Chemical characteristics |
|---|---|---|
| *Unmineralized areas* | Surface water | neutral pH, alkaline, low TDS water similar to Columbine Creek (Woodward Clyde 1995) |
| | Groundwater | neutral pH, alkaline, low to moderate TDS water represented by baseflow above Red River |
| *Hydrothermal scars* | Surface water | variable pH, sulfate, TDS and metals presented by samples in Table 2.1 (SRK 1994) |
| | Groundwater | represented by background seep sample __ in SRK (1994), but pH, sulfate, TDS and metals are widely variable |
| *Molycorp mine* | Surface water | Surface runoff controlled by mine. |
| | Groundwater | groundwater contributions adjacent to the Red River may be affected by the mine or by hydrothermal scars. Existing data do not differentiate between these sources |

**Table 2. Analysis of variance for surface water in contact with hydrothermal scars and with mine rock (data from SRK 1995).**

## *Comparison of Dissolved Metals in Water Contacting Hydrothermal Scars (Type = 1) and Mine Rock (Type = 2)*

## *Reference SRK (1995)*

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| AL_MGPKG | 11 | 7184.5455 | 4786.2352 | 1910.00 | 18900.00 |
| FE_MGPKG | 11 | 41948.18 | 41046.46 | 7830.00 | 156000.0 |
| MN_MGPKG | 11 | 318.9273 | 289.7890 | 17.70 | 1080.00 |
| ZN_MGPKG | 11 | 92.1182 | 159.4162 | 20.80 | 569.00 |
| SITETYPE | 11 | 1.3636 | .5045 | 1.00 | 2.00 |

## Kruskal-Wallis Tests

**Ranks**

| | SITETYPE | N | Mean Rank |
|---|---|---|---|
| AL_MGPKG | 1.00 | 7 | 5.57 |
| | 2.00 | 4 | 6.75 |
| | Total | 11 | |
| FE_MGPKG | 1.00 | 7 | 4.29 |
| | 2.00 | 4 | 9.00 |
| | Total | 11 | |
| MN_MGPKG | 1.00 | 7 | 7.14 |
| | 2.00 | 4 | 4.00 |
| | Total | 11 | |
| ZN_MGPKG | 1.00 | 7 | 7.00 |
| | 2.00 | 4 | 4.25 |
| | Total | 11 | |

**Test Statistics[a,b]**

| | AL_MGPKG | FE_MGPKG | MN_MGPKG | ZN_MGPKG |
|---|---|---|---|---|
| Chi-Square | .321 | 5.143 | 2.286 | 1.750 |
| df | 1 | 1 | 1 | 1 |
| Asymp. Sig. | .571 | .023 | .131 | .186 |

a. Kruskal Wallis Test

b. Grouping Variable: SITETYPE

## *Mann Whitney Tests*

**Ranks**

| | SITETYPE | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| AL_MGPKG | 1.00 | 7 | 5.57 | 39.00 |
| | 2.00 | 4 | 6.75 | 27.00 |
| | Total | 11 | | |
| FE_MGPKG | 1.00 | 7 | 4.29 | 30.00 |
| | 2.00 | 4 | 9.00 | 36.00 |
| | Total | 11 | | |
| MN_MGPKG | 1.00 | 7 | 7.14 | 50.00 |
| | 2.00 | 4 | 4.00 | 16.00 |
| | Total | 11 | | |
| ZN_MGPKG | 1.00 | 7 | 7.00 | 49.00 |
| | 2.00 | 4 | 4.25 | 17.00 |
| | Total | 11 | | |

**Test Statistics[b]**

| | AL_MGPKG | FE_MGPKG | MN_MGPKG | ZN_MGPKG |
|---|---|---|---|---|
| Mann-Whitney U | 11.000 | 2.000 | 6.000 | 7.000 |
| Wilcoxon W | 39.000 | 30.000 | 16.000 | 17.000 |
| Z | -.567 | -2.268 | -1.512 | -1.323 |
| Asymp. Sig. (2-tailed) | .571 | .023 | .131 | .186 |
| Exact Sig. [2*(1-tailed Sig.)] | .648[a] | .024[a] | .164[a] | .230[a] |

a. Not corrected for ties.

b. Grouping Variable: SITETYPE

**Table 3. Analysis of variance for shaker test data for samples of material from hydrothermal scars and mine rock (data from SRK 1995).**

## *Comparison of Dissolved Metals in Shaker tests of Samples from Hydrothermal Scars (Type = 1) and Mine Rock (Type = 2)*

## *Reference SRK (1995)*

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| ALUMINUM | 23 | 17.16261 | 33.91286 | .02000 | 133.0000 |
| H_ION | 48 | 2.7E-04 | 5.7E-04 | 0.0E+00 | 2.3E-03 |
| IRON | 22 | 12.08318 | 46.95729 | .03000 | 221.0000 |
| MANGANESE | 23 | 3.100043 | 5.814834 | .00600 | 20.90000 |
| SULFATE | 10 | 914.7100 | 790.9921 | 68.10000 | 2830.000 |
| TDS | 47 | 564.2553 | 613.1024 | 10.00000 | 2000.000 |
| ZINC | 23 | .4275217 | .8166208 | .00500 | 3.26000 |
| TYPE | 48 | 1.583333 | .4982238 | 1.00000 | 2.00000 |

## Kruskal-Wallis Tests

**Ranks**

| | TYPE | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| ALUMINUM | 1.00000 | 11 | 10.23 | 112.50 |
| | 2.00000 | 12 | 13.63 | 163.50 |
| | Total | 23 | | |
| H_ION | 1.00000 | 20 | 27.15 | 543.00 |
| | 2.00000 | 28 | 22.61 | 633.00 |
| | Total | 48 | | |
| IRON | 1.00000 | 11 | 10.73 | 118.00 |
| | 2.00000 | 11 | 12.27 | 135.00 |
| | Total | 22 | | |
| MANGANESE | 1.00000 | 11 | 10.09 | 111.00 |
| | 2.00000 | 12 | 13.75 | 165.00 |
| | Total | 23 | | |
| SULFATE | 1.00000 | 1 | 2.00 | 2.00 |
| | 2.00000 | 9 | 5.89 | 53.00 |
| | Total | 10 | | |
| TDS | 1.00000 | 20 | 19.27 | 385.50 |
| | 2.00000 | 27 | 27.50 | 742.50 |
| | Total | 47 | | |
| ZINC | 1.00000 | 11 | 11.36 | 125.00 |
| | 2.00000 | 12 | 12.58 | 151.00 |
| | Total | 23 | | |

**Test Statistics[a,b]**

| | ALUMINUM | H_ION | IRON | MANGANESE | SULFATE | TDS | ZINC |
|---|---|---|---|---|---|---|---|
| Chi-Square | 1.466 | 1.235 | .315 | 1.671 | 1.485 | 4.140 | .186 |
| df | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Asymp. Sig. | .226 | .266 | .575 | .196 | .223 | .042 | .666 |

a. Kruskal Wallis Test

b. Grouping Variable: TYPE

## Mann Whitney Tests

**Ranks**

| | TYPE | N | Mean Rank |
|---|---|---|---|
| ALUMINUM | 1.00000 | 11 | 10.23 |
| | 2.00000 | 12 | 13.63 |
| | Total | 23 | |
| H_ION | 1.00000 | 20 | 27.15 |
| | 2.00000 | 28 | 22.61 |
| | Total | 48 | |
| IRON | 1.00000 | 11 | 10.73 |
| | 2.00000 | 11 | 12.27 |
| | Total | 22 | |
| MANGANESE | 1.00000 | 11 | 10.09 |
| | 2.00000 | 12 | 13.75 |
| | Total | 23 | |
| SULFATE | 1.00000 | 1 | 2.00 |
| | 2.00000 | 9 | 5.89 |
| | Total | 10 | |
| TDS | 1.00000 | 20 | 19.27 |
| | 2.00000 | 27 | 27.50 |
| | Total | 47 | |
| ZINC | 1.00000 | 11 | 11.36 |
| | 2.00000 | 12 | 12.58 |
| | Total | 23 | |

**Test Statistics[b]**

| | ALUMINUM | H_ION | IRON | MANGANESE | SULFATE | TDS | ZINC |
|---|---|---|---|---|---|---|---|
| Mann-Whitney U | 46.500 | 227.000 | 52.000 | 45.000 | 1.000 | 175.500 | 59.000 |
| Wilcoxon W | 112.500 | 633.000 | 118.000 | 111.000 | 2.000 | 385.500 | 125.000 |
| Z | -1.211 | -1.111 | -.561 | -1.293 | -1.219 | -2.035 | -.431 |
| Asymp. Sig. (2-tailed) | .226 | .266 | .575 | .196 | .223 | .042 | .666 |
| Exact Sig. [2*(1-tailed Sig.)] | .235[a] | | .606[a] | .211[a] | .400[a] | | .695[a] |

a. Not corrected for ties.

b. Grouping Variable: TYPE

**Table 4. Analysis of variance for total metals in samples of hydrothermal scars and mine rock (data from Slifer 1996).**

# Non Parametric Tests

## *Comparison of Total Metals in Hydrothermal Scars (Type = 1) and in Mine Rock (Type = 2)*

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| ACIDITY | 17 | 3001.412 | 3779.753 | 326.00 | 12200.00 |
| ALUMINUM | 17 | 349.12 | 495.72 | 4 | 1850 |
| EC | 17 | 4547.65 | 3213.87 | 1350 | 12300 |
| IRON | 17 | 227.24 | 305.93 | 1 | 836 |
| MANGANESE | 17 | 124.53 | 223.81 | 2 | 777 |
| SULFATE | 17 | 3747.12 | 3443.09 | 735 | 12700 |
| ZINC | 17 | 22.00 | 40.89 | 0 | 130 |
| TYPE | 17 | 1.53 | .51 | 1 | 2 |

***Reference Slifer (1995)***

## Kruskal-Wallis Tests

**Ranks**

| | TYPE | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| ACIDITY | 1 | 8 | 9.38 | 75.00 |
| | 2 | 9 | 8.67 | 78.00 |
| | Total | 17 | | |
| ALUMINUM | 1 | 8 | 8.88 | 71.00 |
| | 2 | 9 | 9.11 | 82.00 |
| | Total | 17 | | |
| EC | 1 | 8 | 9.00 | 72.00 |
| | 2 | 9 | 9.00 | 81.00 |
| | Total | 17 | | |
| IRON | 1 | 8 | 10.44 | 83.50 |
| | 2 | 9 | 7.72 | 69.50 |
| | Total | 17 | | |
| MANGANESE | 1 | 8 | 7.19 | 57.50 |
| | 2 | 9 | 10.61 | 95.50 |
| | Total | 17 | | |
| SULFATE | 1 | 8 | 8.75 | 70.00 |
| | 2 | 9 | 9.22 | 83.00 |
| | Total | 17 | | |
| ZINC | 1 | 8 | 7.94 | 63.50 |
| | 2 | 9 | 9.94 | 89.50 |
| | Total | 17 | | |

**Test Statistics[a,b]**

| | ACIDITY | ALUMINUM | EC | IRON | MANGANESE | SULFATE | ZINC |
|---|---|---|---|---|---|---|---|
| Chi-Square | .083 | .009 | .000 | 1.226 | 1.952 | .037 | .678 |
| df | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Asymp. Sig. | .773 | .923 | 1.000 | .268 | .162 | .847 | .410 |

a. Kruskal Wallis Test

b. Grouping Variable: TYPE

## *Mann Whitney Tests*

**Ranks**

| | TYPE | N | Mean Rank |
|---|---|---|---|
| ACIDITY | 1 | 8 | 9.38 |
| | 2 | 9 | 8.67 |
| | Total | 17 | |
| ALUMINUM | 1 | 8 | 8.88 |
| | 2 | 9 | 9.11 |
| | Total | 17 | |
| EC | 1 | 8 | 9.00 |
| | 2 | 9 | 9.00 |
| | Total | 17 | |
| IRON | 1 | 8 | 10.44 |
| | 2 | 9 | 7.72 |
| | Total | 17 | |
| MANGANESE | 1 | 8 | 7.19 |
| | 2 | 9 | 10.61 |
| | Total | 17 | |
| SULFATE | 1 | 8 | 8.75 |
| | 2 | 9 | 9.22 |
| | Total | 17 | |
| ZINC | 1 | 8 | 7.94 |
| | 2 | 9 | 9.94 |
| | Total | 17 | |

**Table 5. Calculated flow rate and chemistry of inflow to the Red River for the reach adjacent to the Molycorp mine.**

| Date | Flow[1] | pH | Alkalinity |
|---|---|---|---|
| | Cfs | SU | (mg/L) |
| *Nov, 1965* | 9.3 | 7.88 | 45.7 |
| *Nov, 1965* | 4.3 | 7.67 | 18.4 |
| *Nov, 1970* | -1.5 | 7.00 | 96.3 |
| *Oct, 1988* | 4.0 | 6.55 | -81.5 |
| *Oct, 1992* | 3.2 | 6.59 | 88.1 |
| *Nov, 1995* | 3.1 | 6.94 | -58.2 |
| *Average[2]* | 3.7 | 6.94 | -8.3 |

*Notes to Table*

*1 - The average inflow chemistry was computed for 1965 assuming no flow in Columbine Creek and 5 cfs of flow. The calculated chemistry in 1970 represents the average water flowing out of the Red River, since in this year it was a losing reach.*

*2 - The average composition is based on 1965, 1988, 1992, and 1995 data. The data from 1970 were not used because the Red River was a losing reach in that year.*

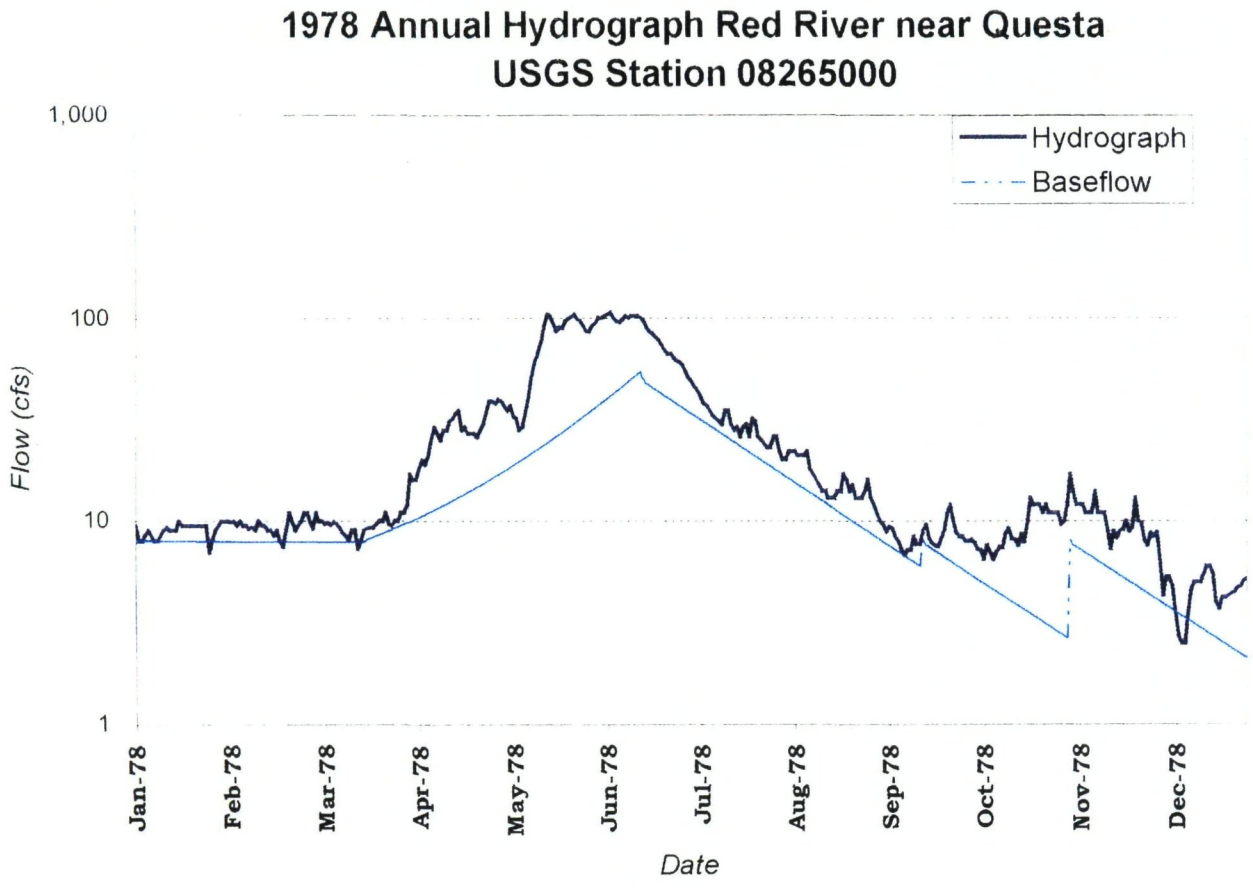


**Figure 1. Hydrograph and estimated baseflow for the Red River near Questa in 1978.**

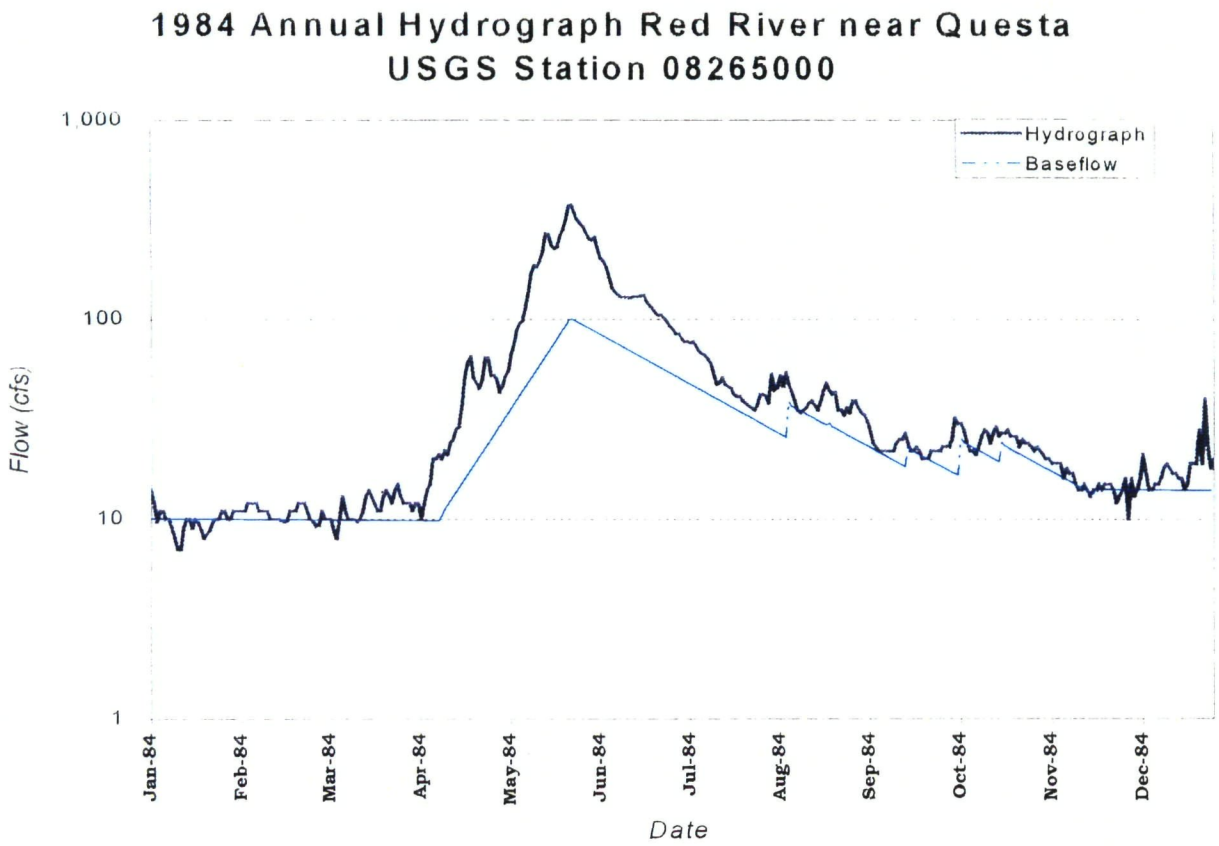


Figure 2. Hydrograph and estimated baseflow for the Red River near Questa in 1984.

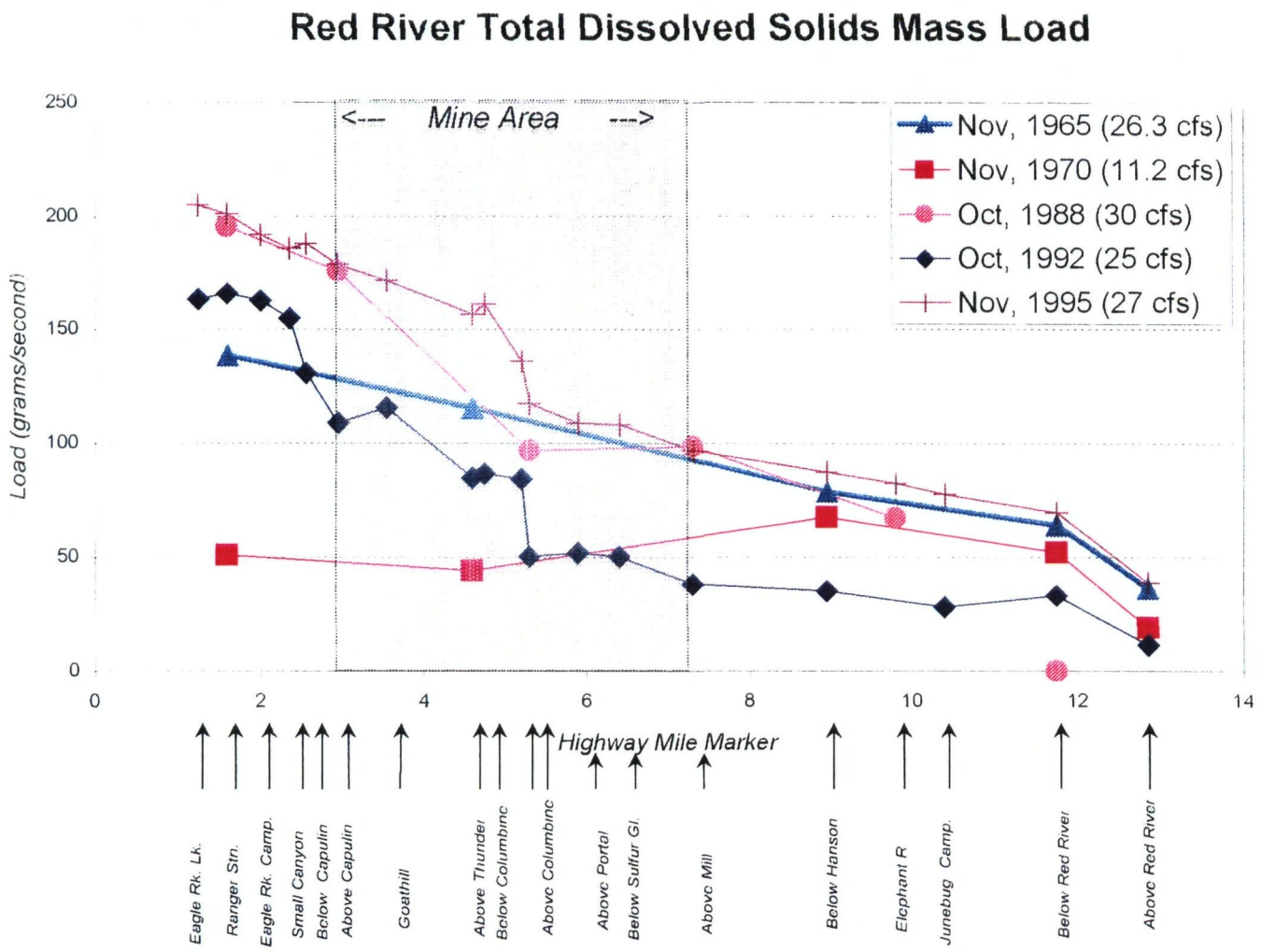


**Figure 3a. Total Dissolved Solid (TDS) mass load in the Red River for several dates of measurement (1965 to 1995).**

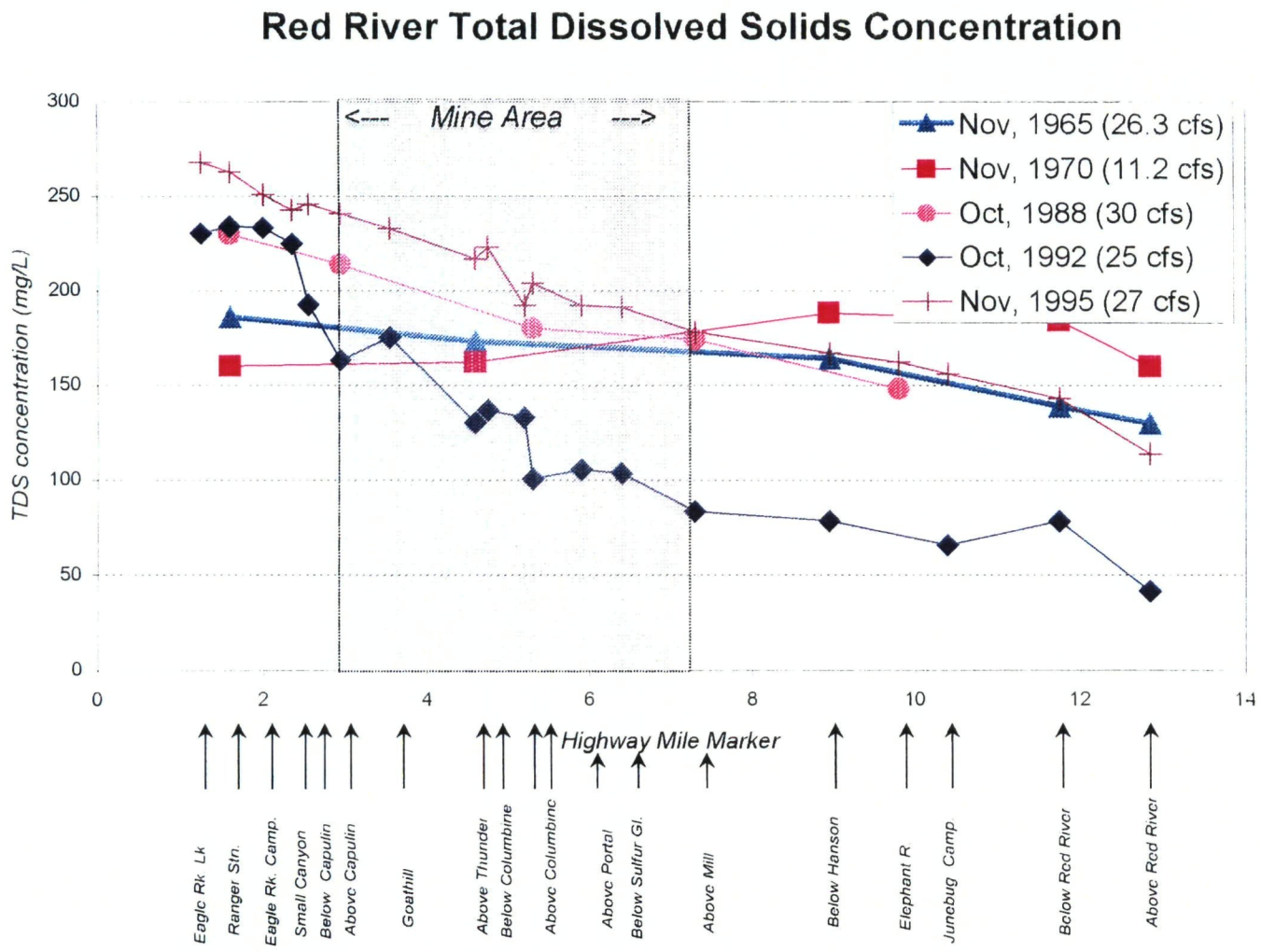


**Figure 3b. Total Dissolved Solid (TDS) concentration in the Red River for several dates of measurement (1965 to 1995).**

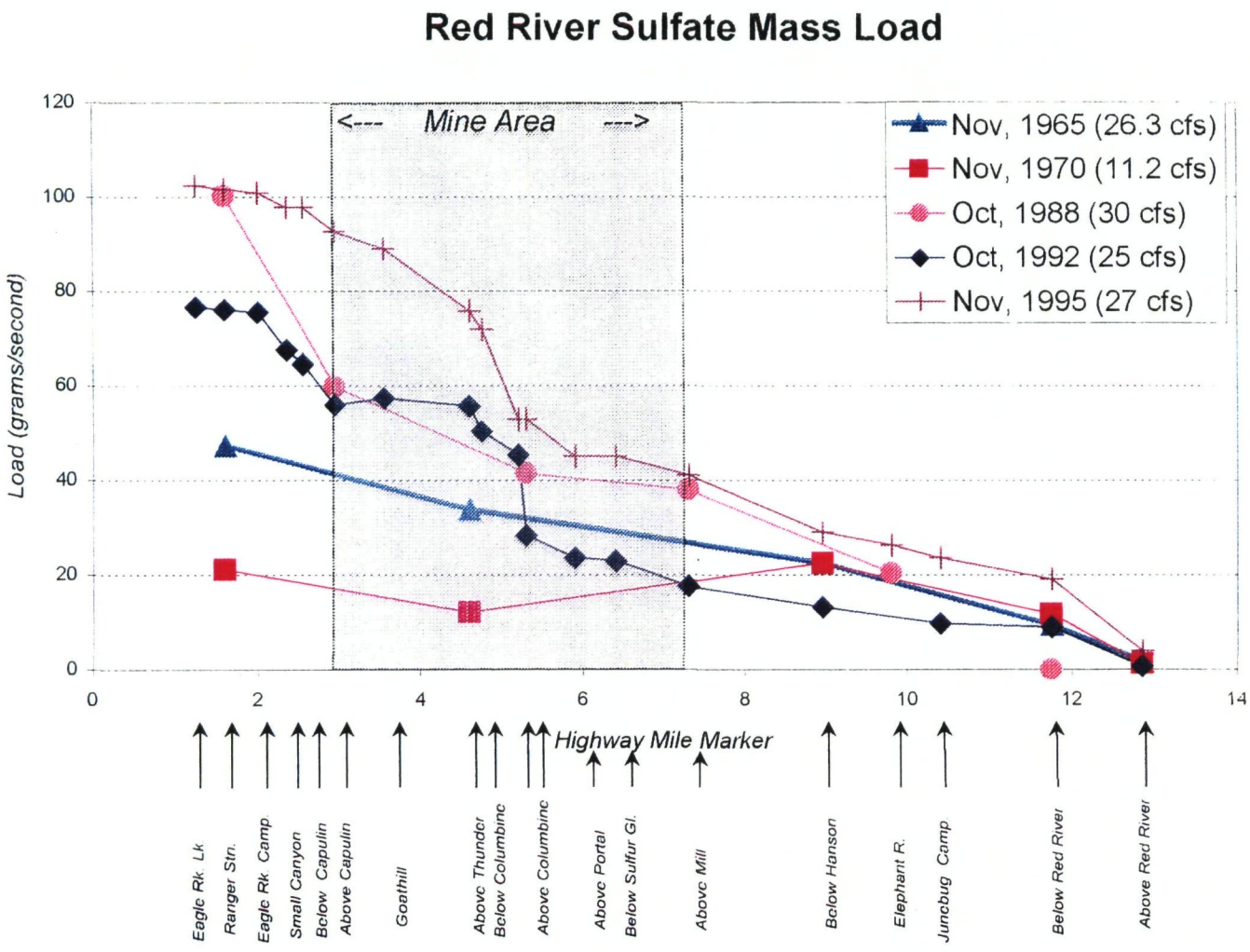


**Figure 4. Sulfate mass load in the Red River for several dates of measurement (1965 to 1995).**

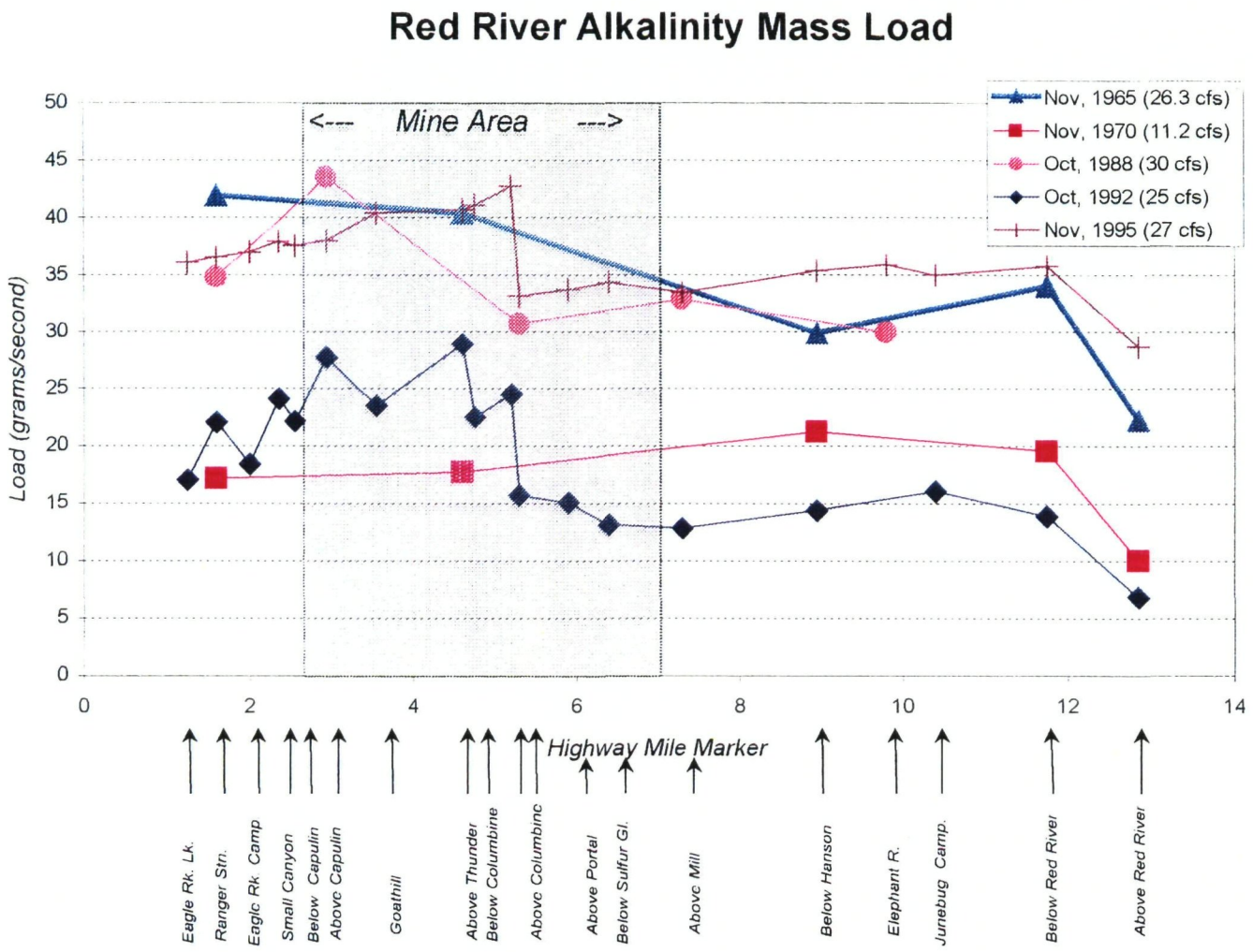


**Figure 5. Alkalinity mass load in the Red River for several dates of measurement (1965 to 1995).**

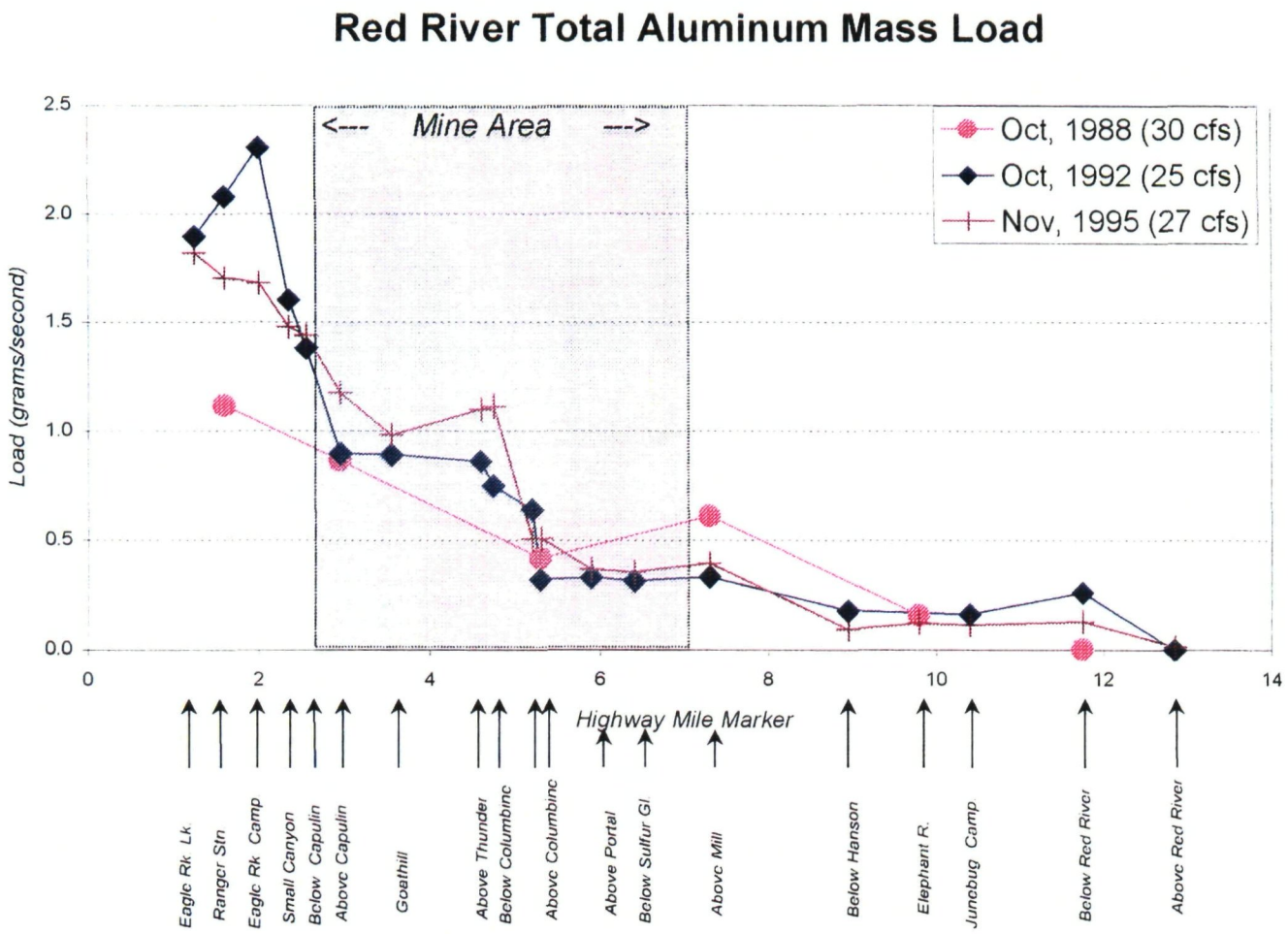


**Figure 6. Aluminum mass load in the Red River for several dates of measurement (1965 to 1995).**

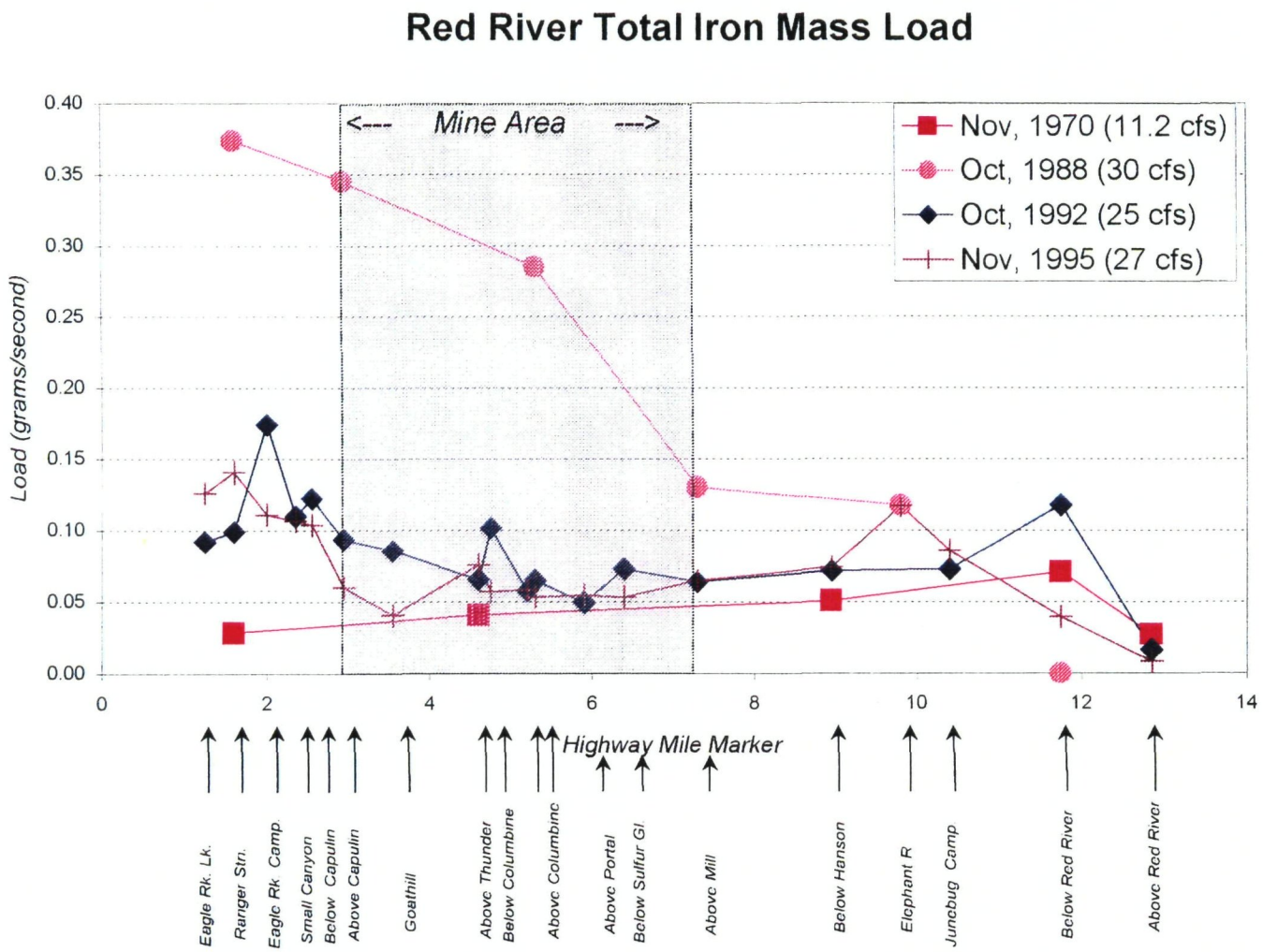


**Figure 7. Iron mass load in the Red River for several dates of measurement (1965 to 1995).**

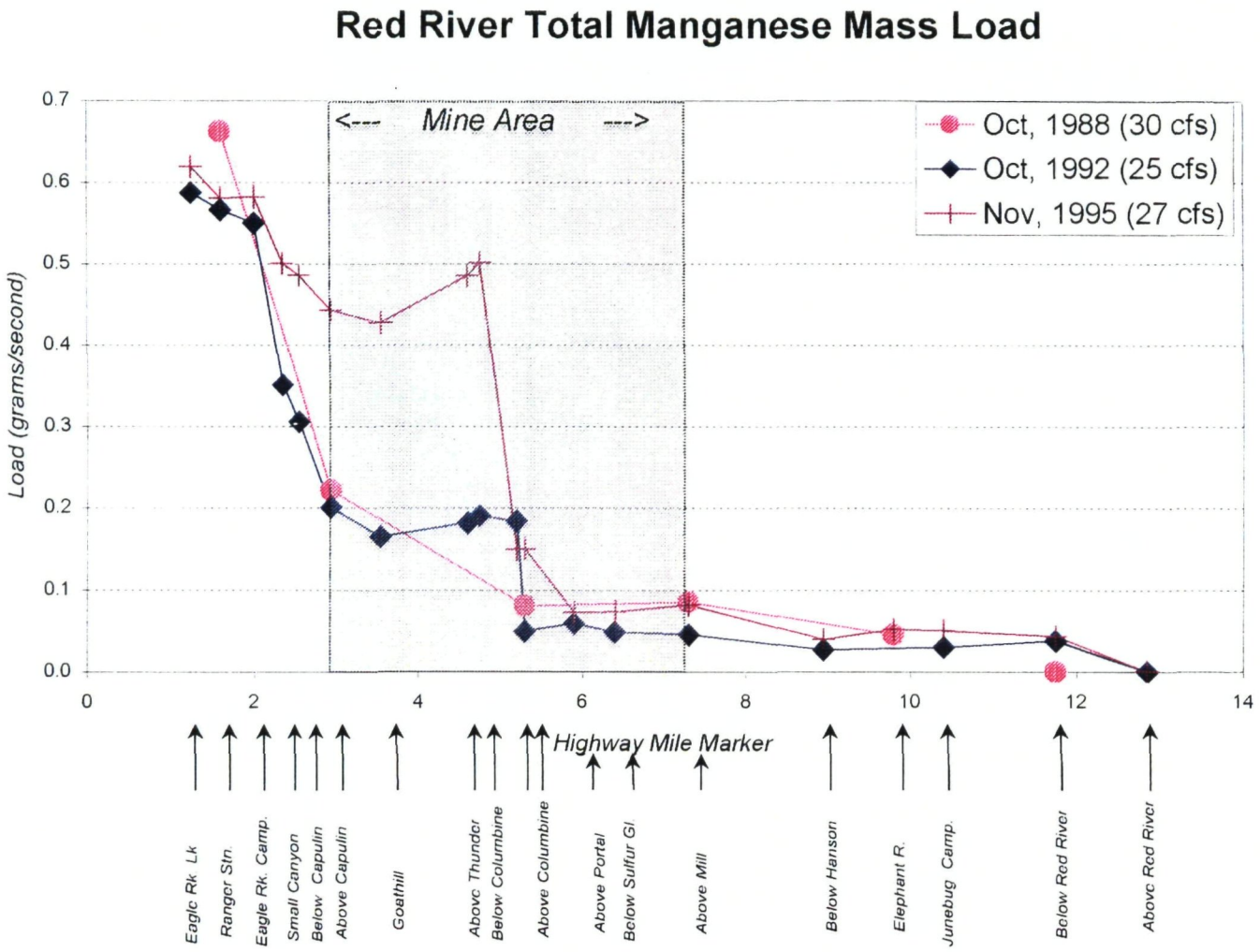


**Figure 8. Manganese mass load in the Red River for several dates of measurement (1965 to 1995).**

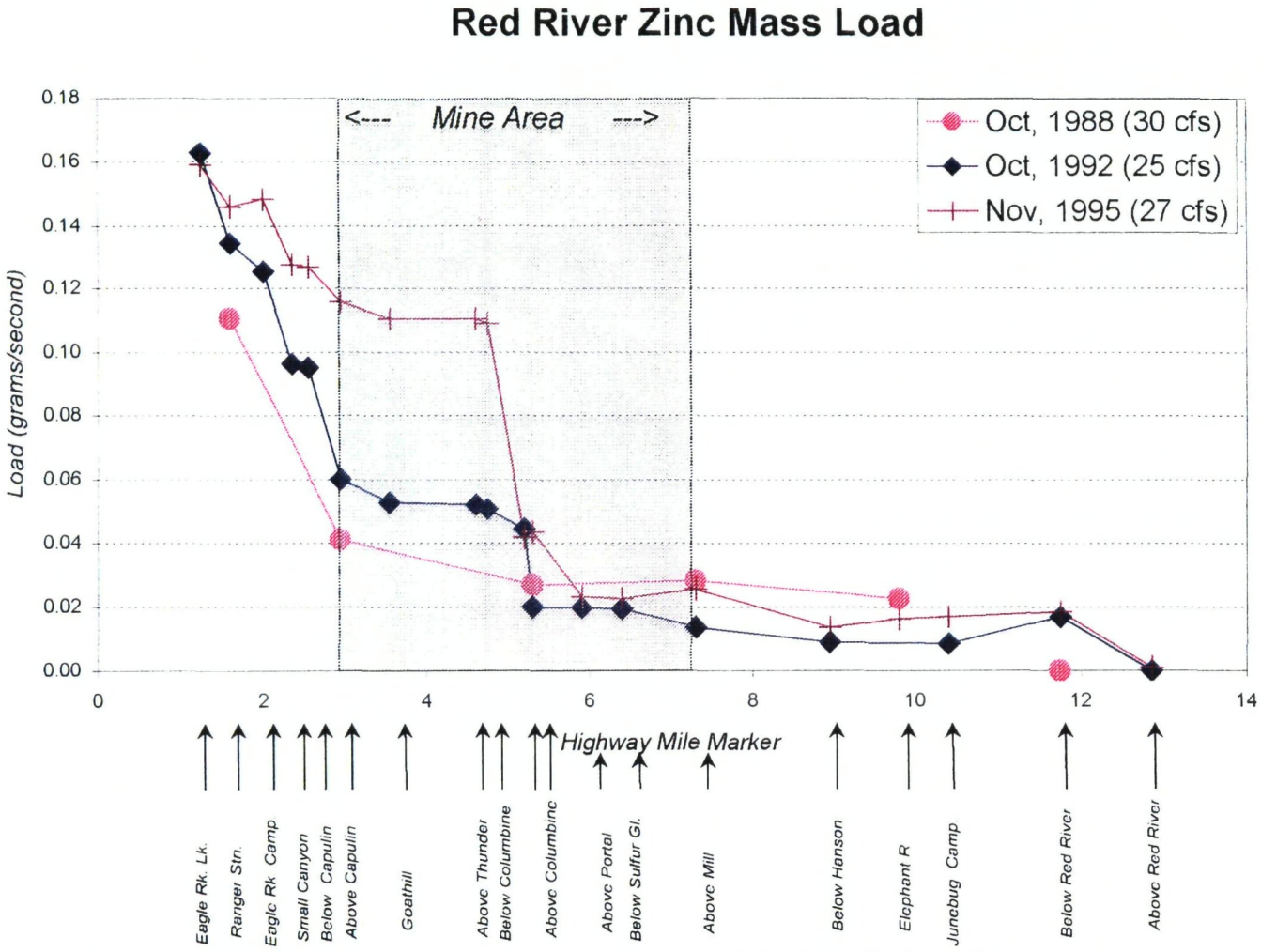


**Figure 9. Zinc mass load in the Red River for several dates of measurement (1965 to 1995).**

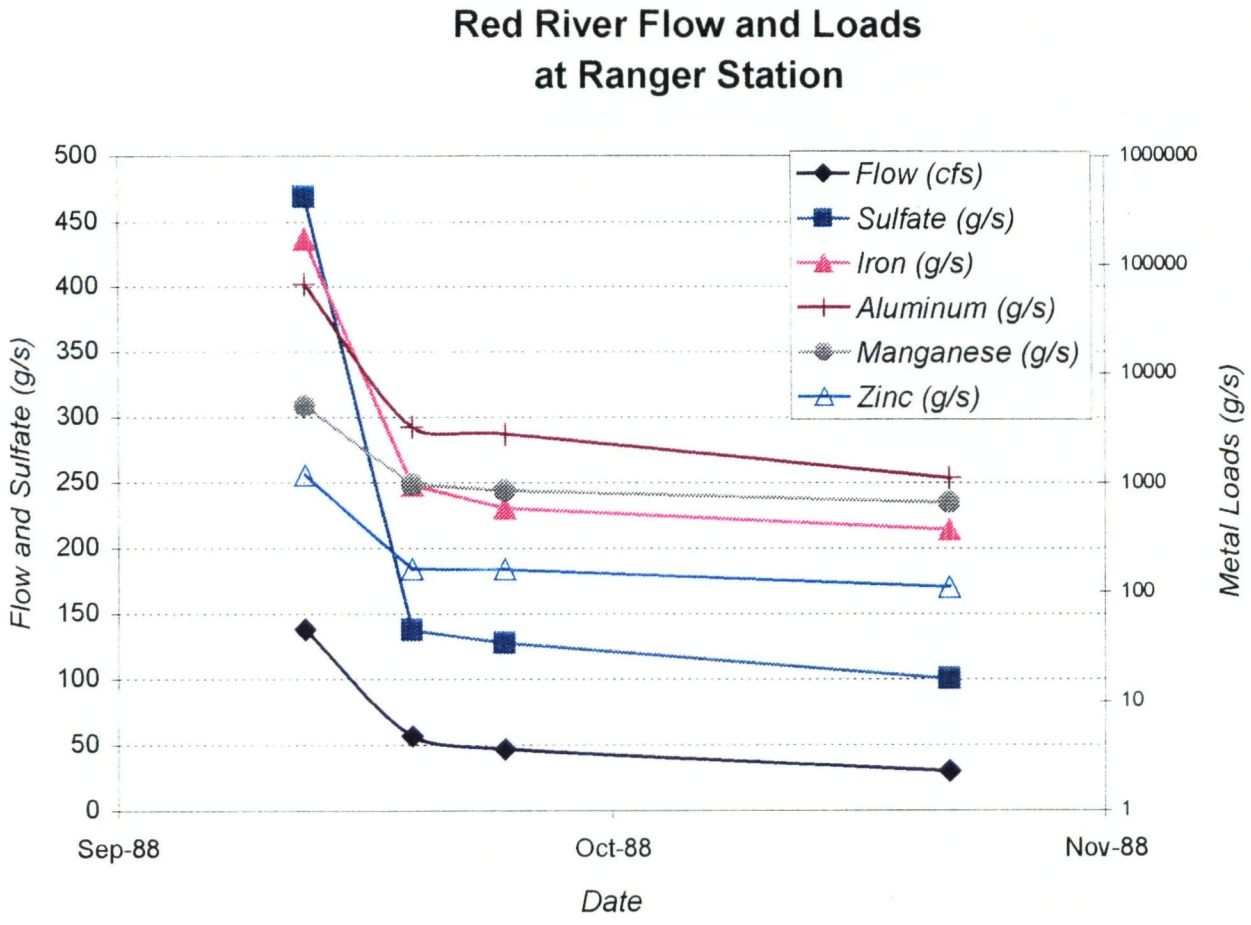


**Figure 10. Mass loads in the Red River at the USGS station near Questa for several September and October, 1988.**

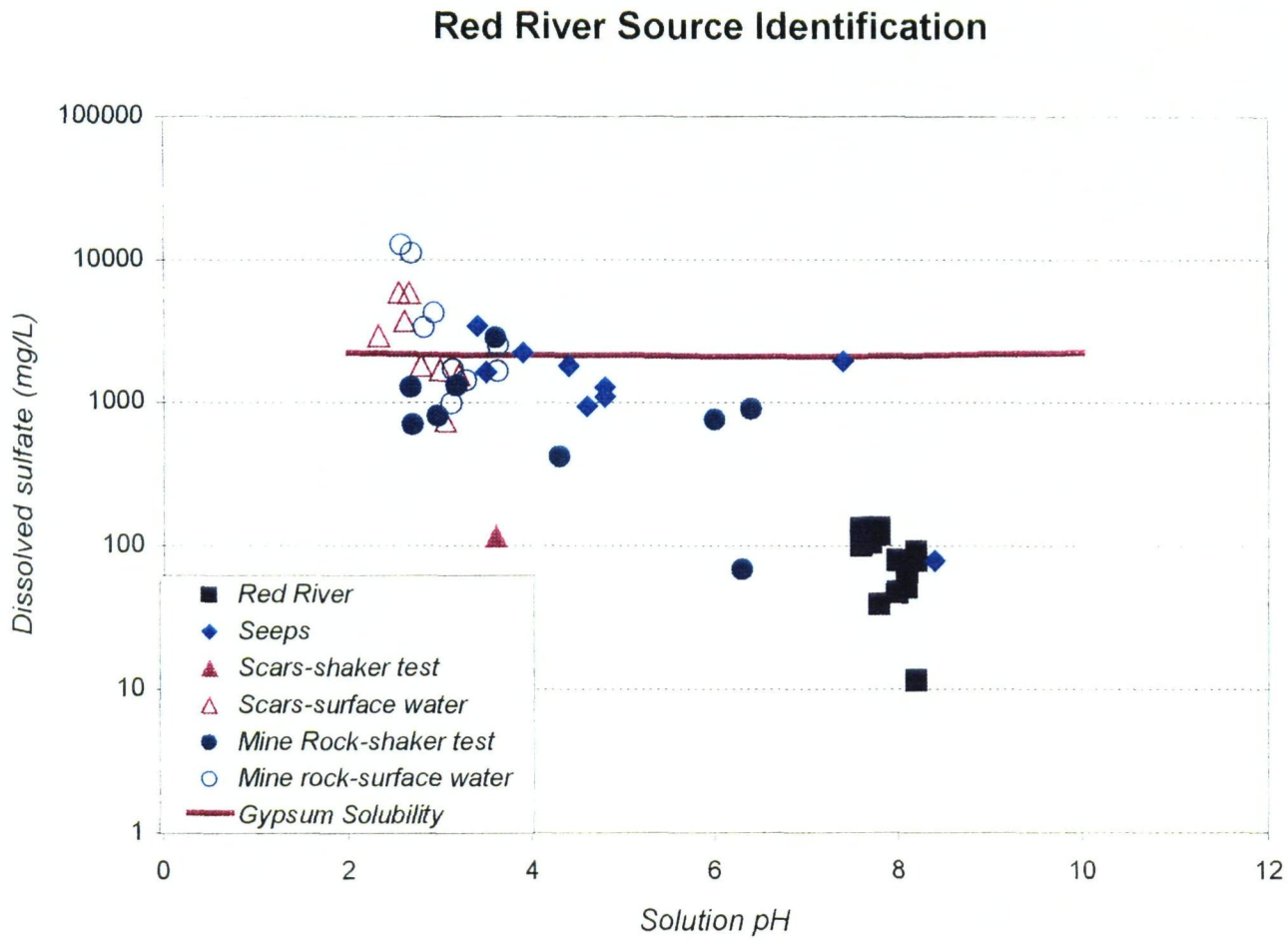


**Figure 11. Concentration of sulfate in the Red River, seeps, and in potential sources.**

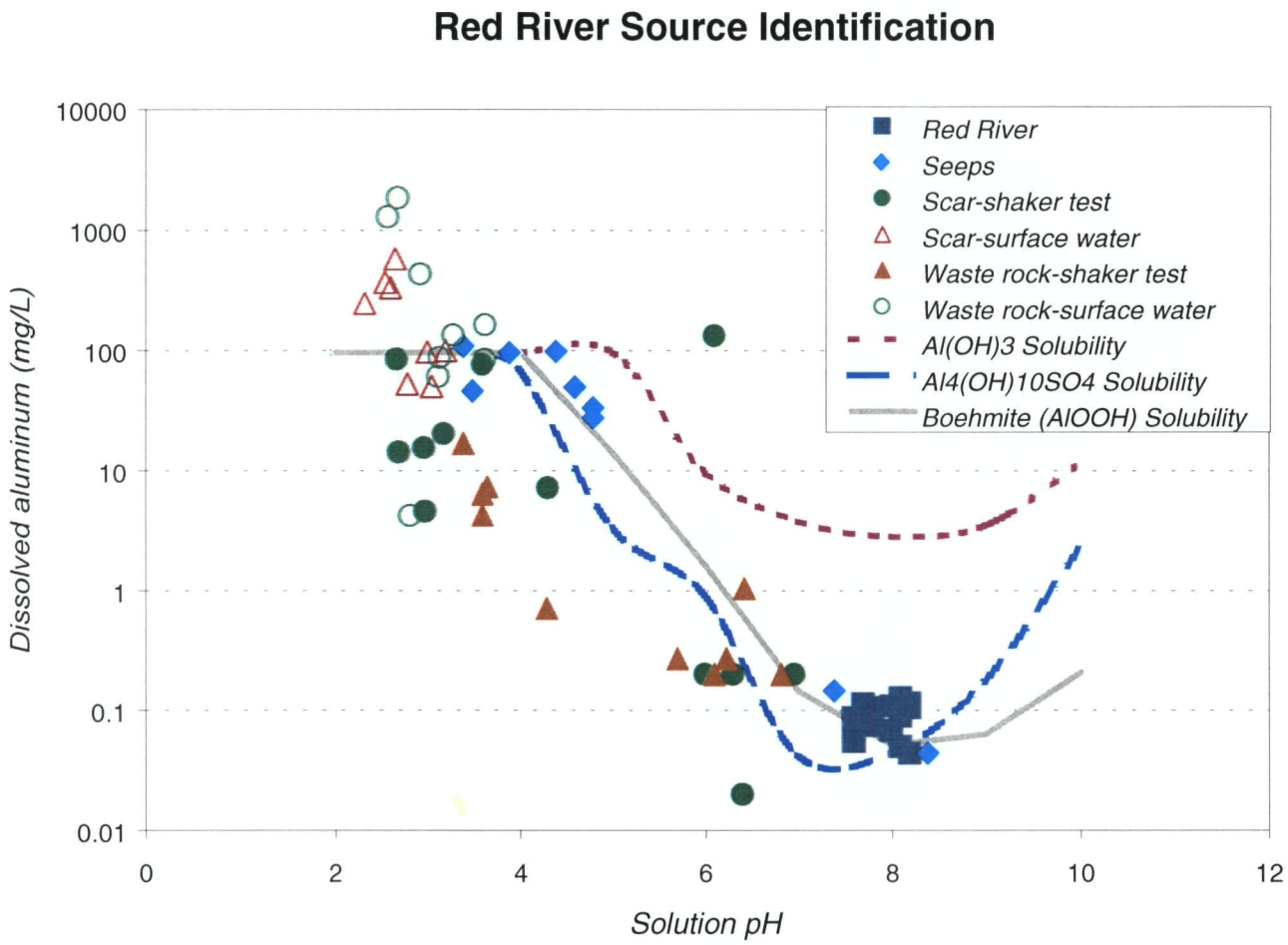


**Figure 12. Concentration of aluminum in the Red River, seeps, and in potential sources.**

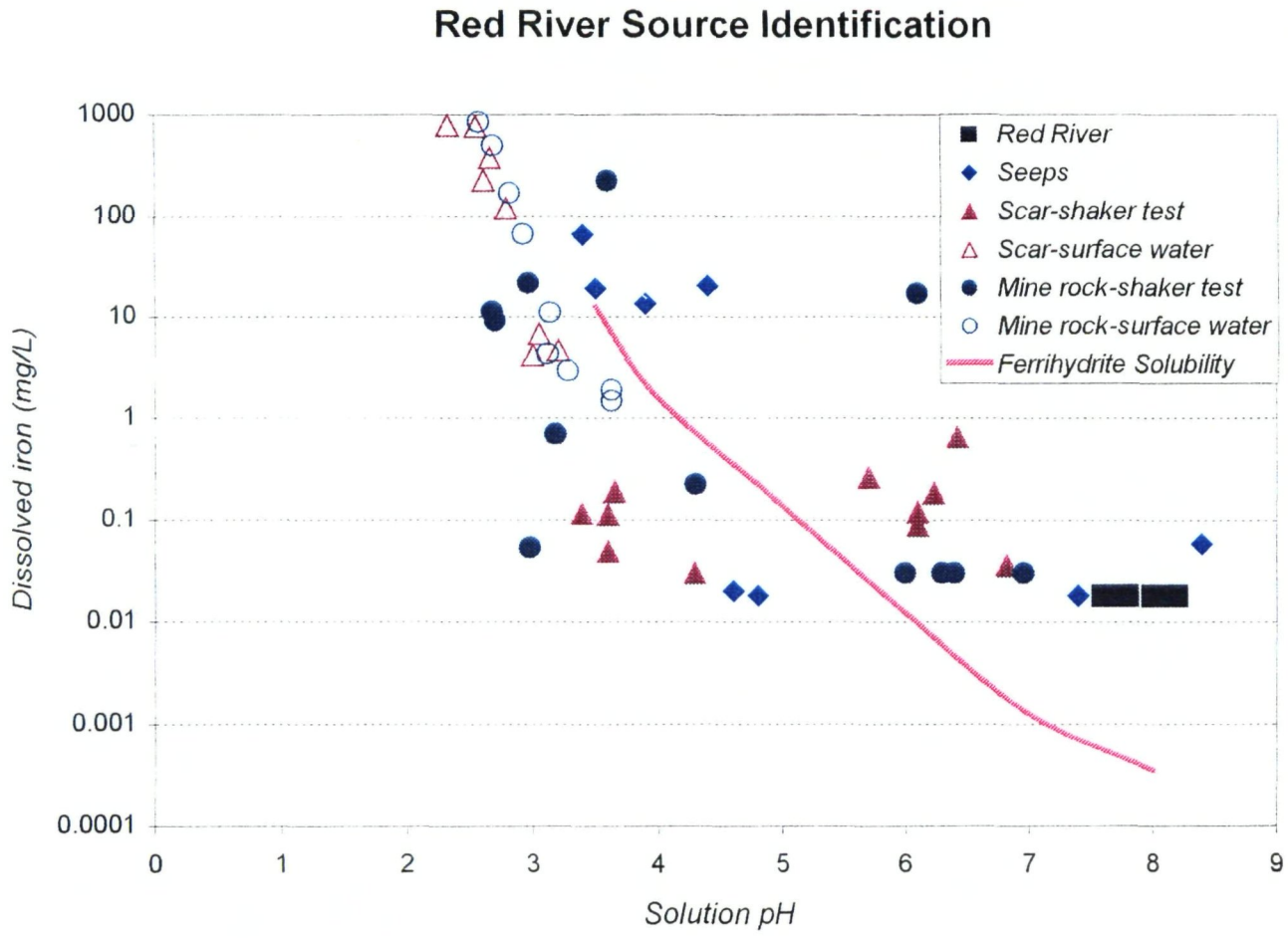


**Figure 13. Concentration of iron in the Red River, seeps, and in potential sources.**

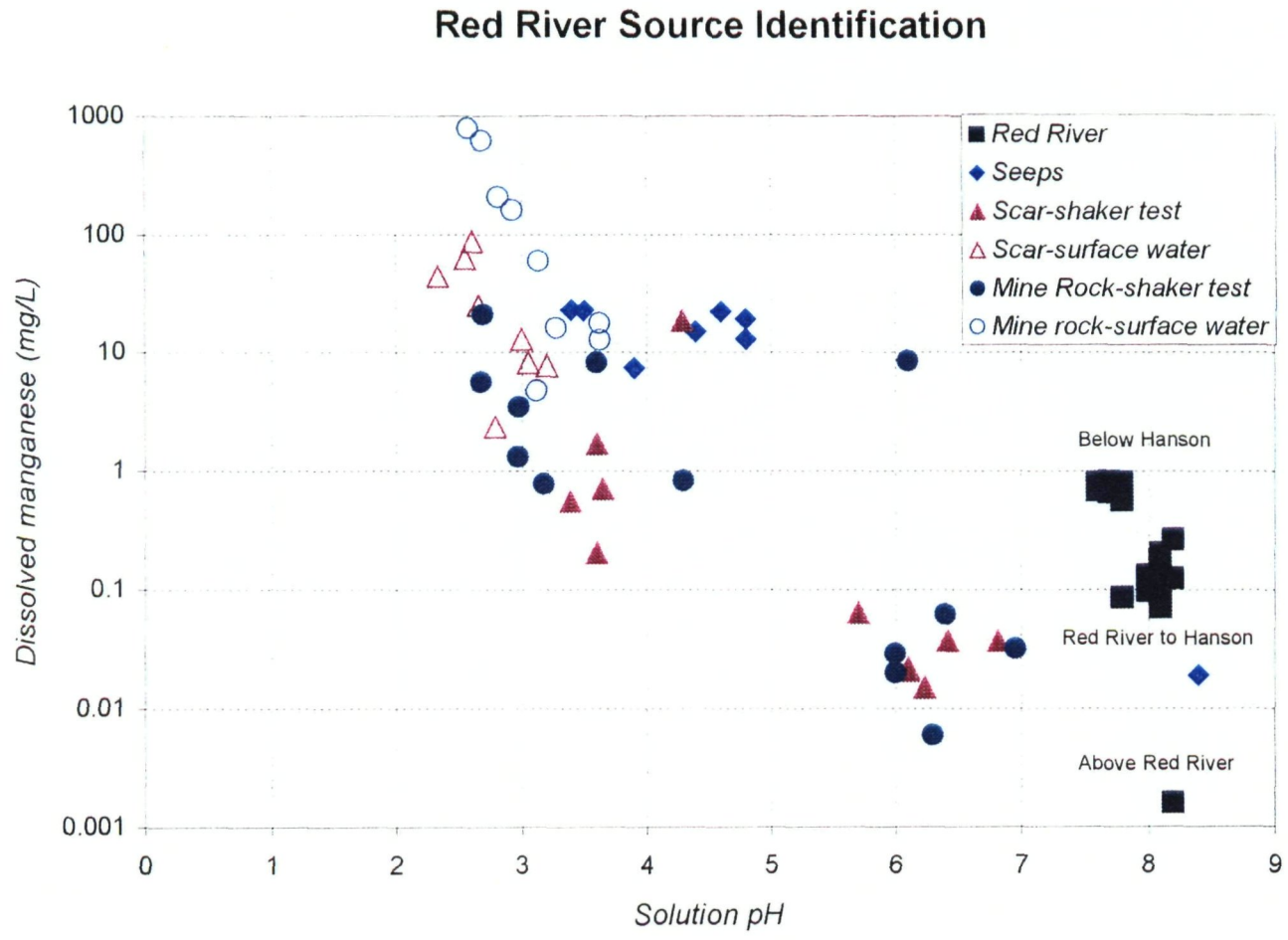


**Figure 14. Concentration of manganese in the Red River, seeps, and in potential sources.**

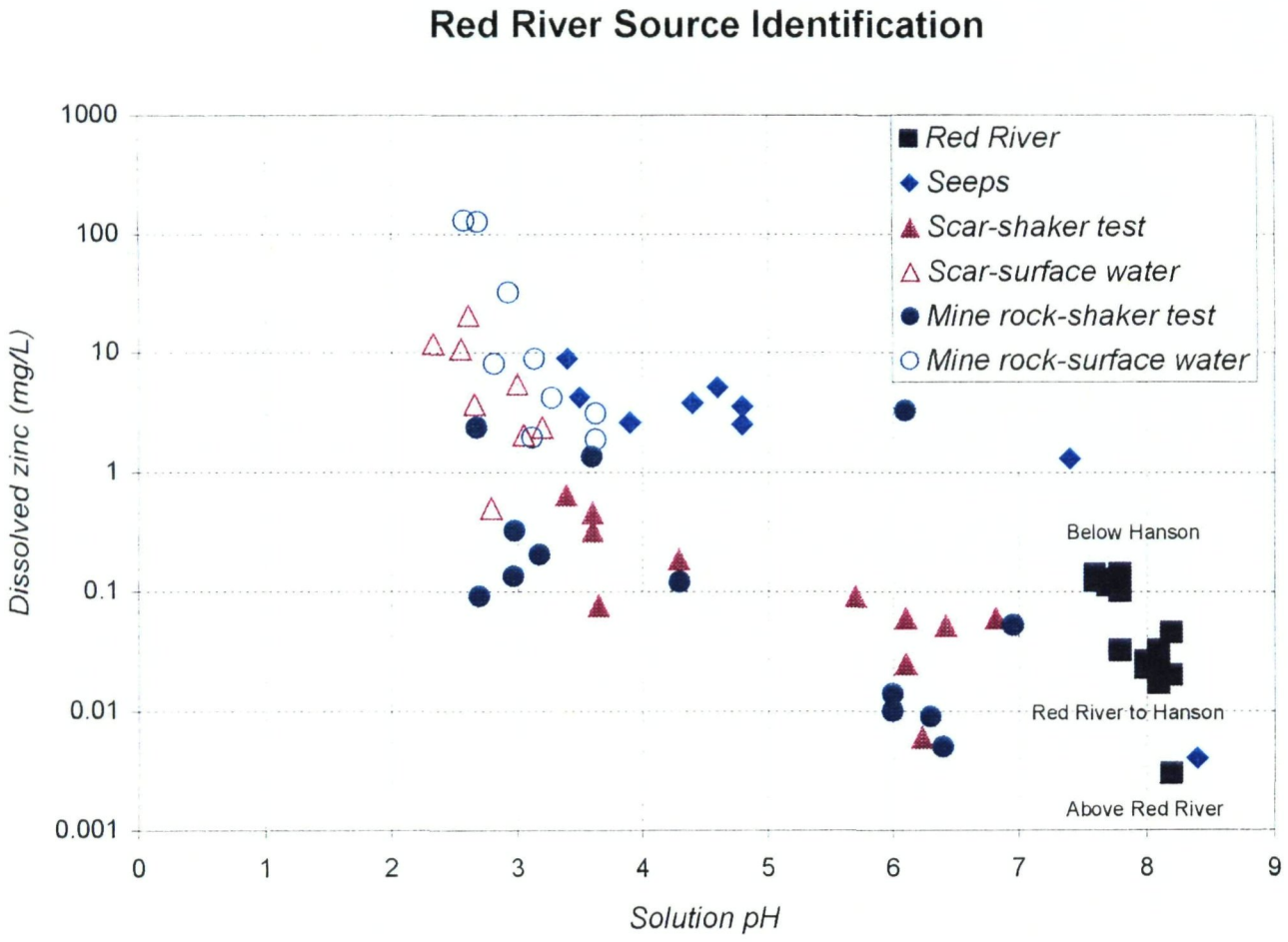


**Figure 15. Concentration of zinc in the Red River, seeps, and in potential sources.**

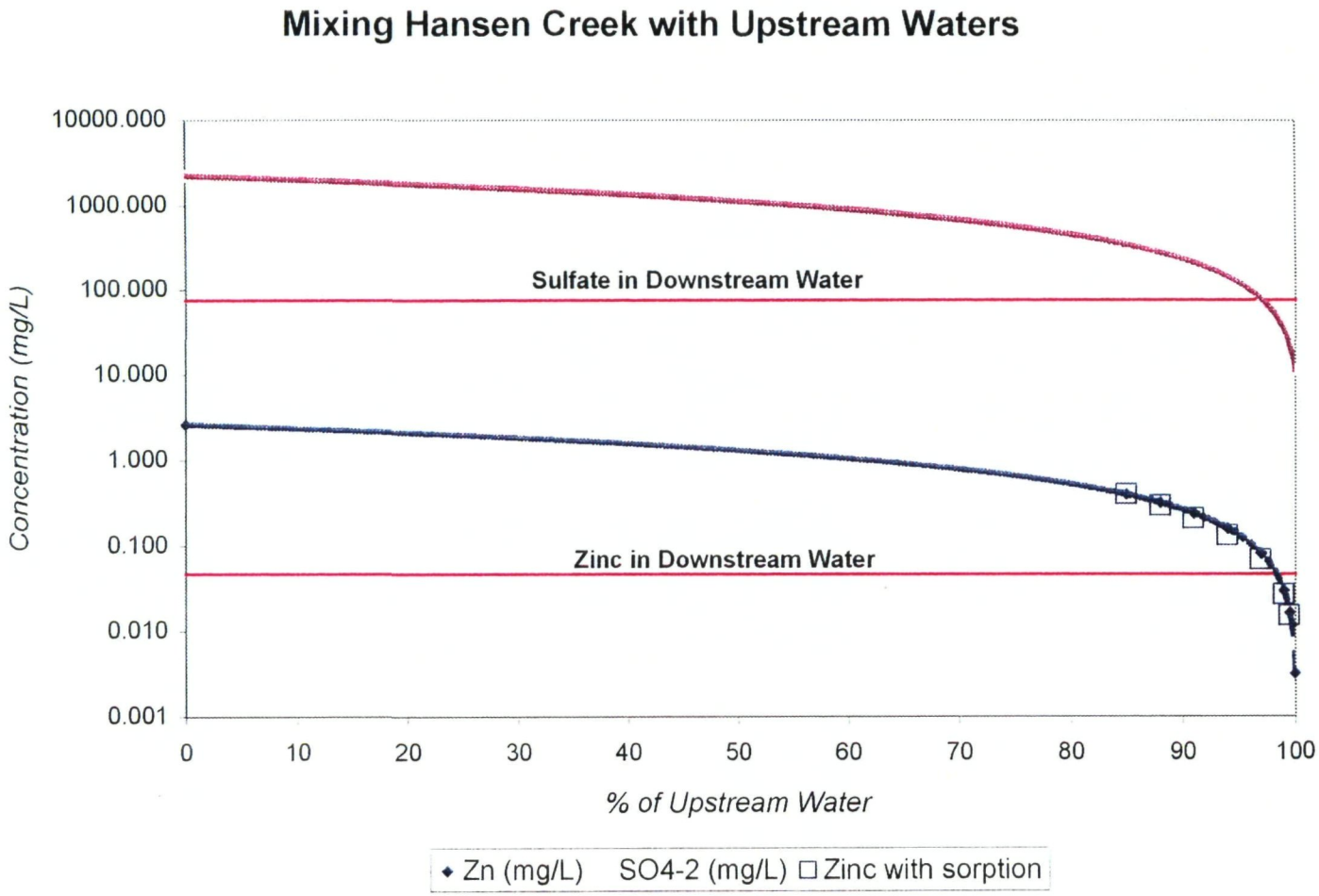


**Figure 16. Model of various mixtures of Red River water above Hanson Creek with acidic Hanson Creek water as compared with downstream water.**

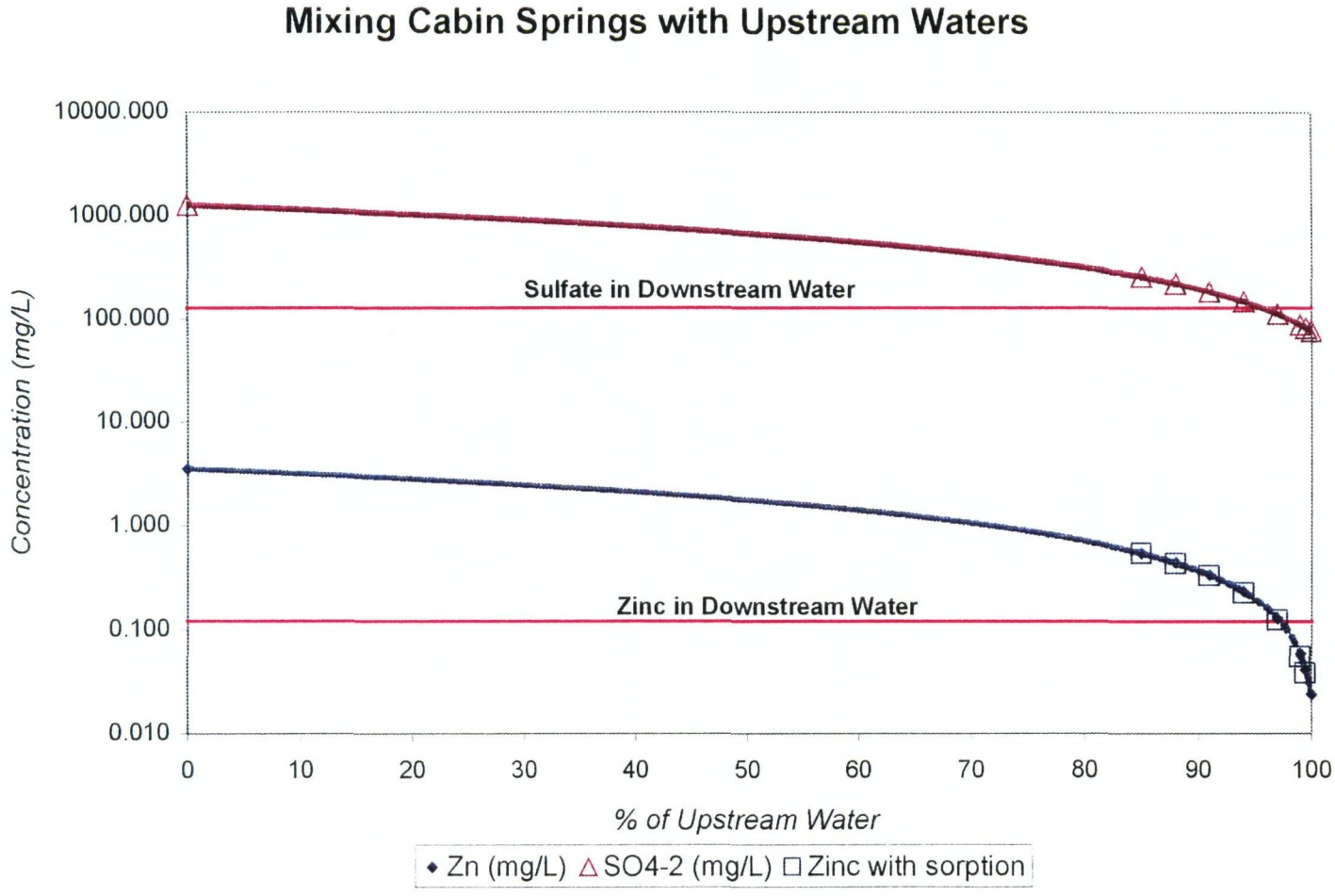


**Figure 17. Model of various mixtures of Red River water above Hanson Creek with Cabin Springs water as compared with downstream water.**

# Resume

## William M. Schafer

# *Resume*

# *Dr. William M. Schafer*

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## POSITION DESCRIPTION

POSITION: PRINCIPAL - SCHAFER AND ASSOCIATES

Dr. Schafer oversees a multi-disciplinary staff of scientists, engineers, and support staff. He is responsible for technical direction of projects, project team staffing, and office management. Dr. Schafer specializes in soil geochemistry, vadose zone and groundwater hydrology, and mine reclamation.

## PROFESSIONAL EXPERIENCE

SCHAFER & ASSOCIATES: 1985 TO PRESENT

**Mining Services:** Served as project manager or technical director for over 200 projects involving the environmental aspects of mining. Projects have included prediction, prevention, and control of acid rock drainage (ARD); mine closure including reclamation of waste rock, tailings, and spent ore piles; decommissioning of spent ore material; baseline studies in support of permit applications; groundwater and vadose zone monitoring programs. Extensive regulatory experience in the western US including Nevada, Montana, South Dakota, Colorado, New Mexico, Idaho, Utah, Washington and Arizona.

**Solid and Hazardous Waste:** Managed or directed numerous CERCLA investigations including RI/FS activities at several mining sites. Developed and implemented numerous work plans and planning documents to support site characterization, treatability studies, and risk assessments. Responsible for development and evaluation of the performance of in-situ remediation techniques for inorganic mine waste at CERCLA sites. Experienced in conducting fate and transport analysis of migration from a variety of contaminant sources. Conducted numerous field investigations using a variety of field screening techniques including soil gas surveys and X-ray fluorescence determination of soil lead, arsenic, copper, zinc, and chromium levels. Worked on a number of regional landfill sites involving siting, permitting, and groundwater monitoring.

**Project Management:** Successfully managed over 300 projects in the environmental sciences concerning hazardous waste (under CERCLA, SARA, and RCRA); solid waste landfills; disturbed land reclamation; baseline studies for mine and facility permitting; reclamation of abandoned mines; surface water, groundwater and vadose zone monitoring; soil investigations; contract R&D; delivery of educational short-courses; and services in support of litigation.

**Soil Investigations:** Conducted a number of soil survey investigations in support of mine permitting and planning, major facility siting, irrigation development, basin-wide erosion prediction and control, and salinity control. Numerous small-scale soil investigations have been performed for on-site waste treatment system siting and design; for land application/ treatment of liquid and solid wastes; litigation support for industrial damage claims; and in support of archaeological investigations.

**Expert Testimony:** Served as an expert witness for several cases involving the environmental effects of mining; acid-rock drainage; alleged contamination of surface water or groundwater with metals salinity and organic compounds; and Clean Water Act violations. Provided expert reports, sworn testimony, and depositions in lawsuits, and administrative hearings.

## EDUCATION

**Montana State University** *1979 to 1984*
Bozeman, Montana
ASSOCIATE PROFESSOR

Served as an Assistant Professor of Soil Science at Montana State University until 1984. Responsibilities included teaching, extension, and research in reclamation of disturbed areas, land resource management, and dryland and irrigated agriculture. Developed and delivered a number of professional short courses on vadose zone monitoring, cyanide heap leaching, underground storage system installer certification, groundwater impacts of petroleum exploration, control of dryland salinity, fertilization of small grains and forages, and salinity and sodium control under irrigation.

**Montana State University** *1976 to 1979*
Bozeman, Montana
PH.D. IN SOIL SCIENCE

Dissertation Topic: Completed an evaluation of the land capability of soils on reclaimed surface coal-mined areas throughout the Northern Great Plains.

**University of California at Davis** *1974 to 1975*
David, California
M.S. IN SOIL SCIENCE

Thesis Topic: Developed a technique to measure the shrink-swell potential of soils in the Central Valley of California, and to predict the hazard for construction.

**Colorado State University** *1971 to 1974*
Fort Collins, Colorado
B.S. IN WATERSHED SCIENCE

## PROFESSIONAL DEVELOPMENT

| | |
|---|---|
| 1984 | ON-SITE WASTE SYSTEM DESIGN (UNIV OF WASHINGTON) |
| 1986 | UNDERGROUND STORAGE SYSTEMS (NWWA COURSE) |
| 1987 | OSHA HEALTH AND SAFETY FOR SUPERFUND WORKERS (40 HOUR) |
| 1988 | OSHA HEALTH AND SAFETY FOR SUPERFUND SITE MANAGERS (WEX, 8 HR. COURSE) |
| 1990 | OSHA HEALTH AND SAFETY REFRESHER (8-HOUR) |
| 1991 | IBM PC APPLICATIONS IN GROUNDWATER POLLUTION AND HYDROLOGY (6-DAY NWWA COURSE) |
| 1991 | FIELD X-RAY FLUORESCENCE TRAINING (SPECTRACE INSTRUMENTS, FORT COLLINS, COLORADO) |

## ORGANIZATIONS

Professional improvement maintained through active involvement in professional societies (ASTM, National Water Well Association, Society of Mining Engineers, Soil Science Society of America). More than 50 articles, papers, and book chapters have been authored in professional publications. and in Symposia Proceedings

## PUBLICATIONS

### *SYMPOSIA PUBLICATIONS*

Schafer, W.M., Tom Grady, and Chris Luckay. 1997. Control of Tailings Oxidation Rate Using Tailings Placement Methods. Fourth International Conf. on Acid Mine Drainage

Spotts, E., W. M. Schafer, T.S. Mitchell and C.F. Luckay. 1997. Decreasing Surface Runoff Metal Loads from Historic Tailings Using In-Situ Liming and Reclamation Techniques. Fourth International Conf. on Acid Mine Drainage

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Spotts, E., W. M. Schafer, C. F. Luckay, and T. S. Mitchell, W. M. Schafer, C. F. Luckay, and T. S. Mitchell. 1996. Determination of runoff metal loading from reclaimed and unreclaimed tailings. Billings Conference

Schafer, W.M., Chris Luckay, Lisa Kirk, Troy Smith, Steve Smith and Fess Foster. 1996. Hydrologic Evaluation of Acid Rock Drainage Controls in a Sulfide-Enriched Waste Rock Pile. Fourth International Symposium on Environmental issues and Waste Management in Energy and Mineral Production

Schafer, W.M., Thomas Grady, Donald D. Runnells, Chris Luckay, and Ric Jones. 1996. Control of Tailings Oxidation Rate Using Spigotting Techniques. Fourth International Symposium on Environmental issues and Waste Management in Energy and Mineral Production. Cagliari, Italy

Spotts, E., W.M. Schafer, T.S. Mitchell and C.F. Luckay. 1996. Effect of IN-SITU Liming and Reclamation at Decreasing Surface Runoff Metal Loads from Clark Fork River Tailings. Colorado State University Tailings and Mine Waste Conference, Febraury, 1997. Fort Collins, CO

David A. King, Christopher F. Luckay, and William M. Schafer. 1996. Monitoring Instrumentation for Assessing ARD Development at Mine Sites SME Annual Meeting and Exhibit

Kirk, L.B., William M. Schafer, James Volberding and Scott Kranz. 1996. Mine Lake Geochemical Predication for the SPJV McDonald Project Billings Symposium pg 393-403

Spotts, E., and William Schafer. 1996. The Use of Kinetic Test Data to Develop Site-Specific Criteria for Acid Generation Potential - An Overview of Results from Several Mines. Whitefish Conference

Schafer, W.M., and Edward Spotts. 1996. Fate and Transport of Metals from Clark Fork River Streamside Tailings. Billings Conference

Schafer, W.M., Todd Duex , Chris Luckay2, and David King2. 1995. Characterization of the Contaminant Potential and Remediation Measures in Waste Rock Piles in the US. Wismut Waste Rock Remediation Workshop, Chemnitz-Siegmar, Germany, November 6-8, 1995.

Schafer, W.M., John G. Goering , Tom R. Grady, Edward Spotts, and Dennis R. Neuman. 1994. Modeling Recharge And Runoff To Predict Copper And Zinc Transport From Lime-Amended Tailings At The Silver Bow Creek Cerlca Site. Billings Conference

Schafer, W.M., Steven Smith, Chris Luckay and Troy Smith. 1994. Monitoring Gaseous And Liquid Flux In Sulfide Waste Rock. Proc. Of the Third Intl Conf of the Abatement of Acidic Drainage., Pittsburgh – April, 1994

Edward Spotts and William M. Schafer. 1994. Determination Of Metal Adsorption Capacity Of Soils For Disposal Of Mining Process Solutions By Land Application, Proc. Of the Third Intl Conf of the Abatement of Acidic Drainage., Pittsburgh – April, 1994

Schafer, W.M. 1993. Lime Neutralization of Acid Mining Waste in the Clark Fork Basin Presented at the Lime Products Tech. & Reclamation Conference, Anaconda, MT

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Steven C . Smith, Thomas J. Hudson and William M. Schafer. 1993. Field Evaluation of Land Application Performance: Metals Removal from Barren Leach Solution. Billings Symposium

Schafer, W.M. 1993. Mitigation of Acid Mining Waste Using Lime Application in the Upper Clark Fork Basin. Presented at the Lime Products Tech. & Reclamation Conference

Schafer, W.M. 1992. Environmental Management for Acid-Forming Mining Waste. Successful Mine Reclamation-What Works. Nevada Mining Association, Reno Nevada

Schafer, W.M. 1992. Acid Rock Drainage: Processes and Prediction Using, Static and Kinetic Testing. 1992 SME Annual Meeting

Schafer, W.M. 1992. Heap Leach Rinsing Principles and Examples. 1992 SME Annual Meeting

Schafer, W.M. 1992. Acid-Forming Mining Waste: Prediction, Control and Treatment. RANDOL Gold Forum Vancouver 1992. Pg 345-353

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Schafer, W.M., and Dirk Van Zyl. 1991. Cyanide Degradation Field Study of Spent Heap-Leach Ore at the Landusky Mine. Heap & Dump Leaching an International Newsletter

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Schafer, W.M. 1991. Sediment Control and Reclamation of Waste Rock and Heap Leach Spent Ore, presented at the Engineering and Environmental Aspects of Mine Waste Disposal Short Course, Society of Mining Engineers, February, 1991, Denver, Colorado.

Schafer, W.M. 1991. *In-Situ* Treatment of Acid Generating Tailings, presented at the Engineering and Environmental Aspects of Mine Waste Disposal Short Course, Society of Mining Engineers, February, 1991, Denver, Colorado.

Schafer, W.M. 1991. Heap Leach Rinsing and Spent Ore Disposal, presented at the Engineering and Environmental Aspects of Mine Waste Disposal Short Course, Society of Mining Engineers, February, 1991, Denver, Colorado.

Van Zyl, Dirk, W.M. Schafer, and Mike Henderson. 1988-1991. Cyanide Heap Leaching Technology Short Course, presented in Butte, Montana; Bend, Oregon; Denver, Colorado; and Reno, Nevada.

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Schafer, W.M., E. Spotts and T.J. Hudson. 1990. Soil Geochemistry of Lime-Amended Sulfide Mining Waste. p. II-13-34. In: Fifth Billings Symposium on Disturbed Land Rehabilitation. March, 1990. Billings, Montana.

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Schafer, W.M. 1990. Geochemistry of Amended Sulfide Mine Wastes in the Upper Clark Fork Basin (abstract), presented at the Clark Fork River Symposium, April, 1990, University of Montana, Missoula, Montana.

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Schafer, W.M., R.L. Garrison, and D.J. Dollhopf. 1989. Determination of Overburden Suitability by Statistical Analysis of Drillhole Lithologic Data at the WIDCO Centralia Mine, Washington. In: Reclamation: A Global Perspective, Canadian Land Reclamation Association. August, 1989. Calgary, Alberta.

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Schafer, W.M. and G.A. Nielsen. 1980. Soil development and plant succession on 1- to 50-year-old stripmine spoils in southeastern Montana. p. 541-549. In: M.K. Wali (ed.) Ecology and Coal Resource Development VI. Pergamon Press, NY.

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Schafer, W.M. 1979. Spatial variability of minesoils and natural soils in southeastern Montana (abstract) ASA annual meetings, August 6-9, 1979, Fort Collins, Colorado.

Schafer, W.M. and G.A. Nielsen. 1977. Pedologic characteristics of 2- to 50-year old stripmine spoils in southeastern Montana (abstract) ASA annual meetings, November 13-18, 1977, Los Angeles, California.

### *JOURNAL ARTICLES*

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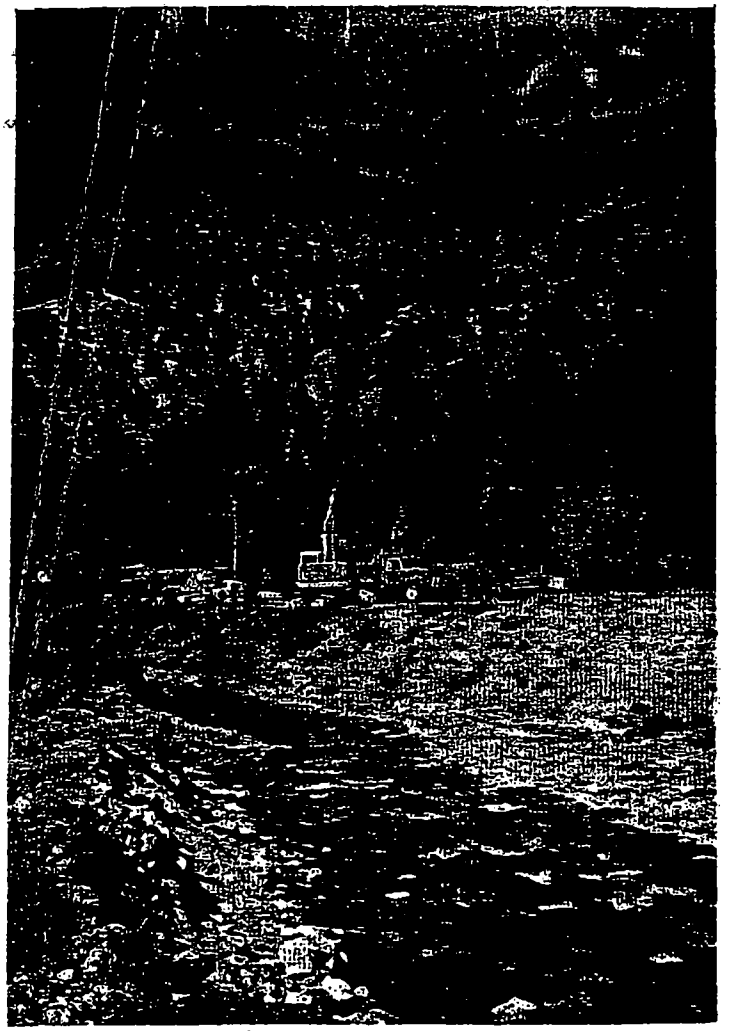

# RED RIVER GROUNDWATER INVESTIGATION

**Final Report**
**Submitted to USEPA, Region VI**
**March, 1996**

NM
22306

New Mexico Environment Department
Surface Water Quality Bureau

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# RED RIVER GROUNDWATER INVESTIGATION

FINAL REPORT

FUNDED IN PART BY A 319(h) GRANT FROM USEPA

PROJECT 92-A

DENNIS SLIFER
NEW MEXICO ENVIRONMENT DEPARTMENT
SURFACE WATER QUALITY BUREAU

March, 1996

030003

**Cover Illustrations:**

Top Photo: The Red River at confluence with Capulin Canyon. The machinery is installing a system of anoxic alkaline drains to treat acidic seepage that impacts the river here. Photo by Dennis Slifer, October 31, 1995.

Bottom Photo: The Red River, in its middle reach, flows past the Molycorp Questa Mine. Here the river can be seen in proximity to the large waste-rock dumps west of the Molycorp mill. Photo by Dennis Slifer, August, 1995.

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# I. INTRODUCTION

This report presents the findings of a project funded in part by U.S. Environmental Protection Agency, Region VI, under Section 319(h) of the Federal Clean Water Act. The project was conducted between June 1993 and December 1995 by the New Mexico Environment Department (NMED), Surface Water Quality Bureau (SWQB), Nonpoint Source Pollution Section. The organizational structure for this project is shown in Table 3. The technical staff member directly responsible for carrying out this project and preparing this report was Dennis Slifer. Michael Coleman assisted with completion of this project during 1995 with field work and preparation of data and figures, and was in charge of the anoxic drain BMP installation. Other staff members and programs at NMED have also been involved in environmental investigation activities within the Red River watershed during the period of this project. Field work, data, reports, and regulatory actions have been coordinated and shared between the Ground Water Quality Bureau (Karen McCormack), the Superfund Oversight Section (Stuart Kent), the Underground Storage Tank Bureau (Tony Moreland and Chris Holmes), the Point Source Regulation Section of SWQB (Richard Powell), New Mexico Office of Natural Resource Trustee (Steve Cary, Randy Merker, and John Pfeil), and a related 319(h) grant (Mineral Extraction Impacts, FY-91) within the Nonpoint Source Pollution Section of SWQB (Bob Salter). The author acknowledges the assistance of these colleagues, with special thanks to Bob Salter, Michael Coleman, Karen McCormack, and Stuart Kent for help in the field and sharing ideas. Portions of Sections I, II, and IV of this report are adapted from reports by Salter and Kent. The manuscript was reviewed by Michael Coleman, Steve Cary, Brian Wirtz, Jeff Lewellin, Jim Piatt, Stuart kent, Karen McCormack and Kim Edlund.

## 1.1 OBJECTIVE

The objective of this project is to determine groundwater quality and aquifer characteristics along the impaired reaches of the Red River in order to identify, and ultimately eliminate, impairment of both the aquifer and the designated uses of the river. Additionally, demonstration projects to treat contaminated groundwater seepage are intended to show feasibility of remedial technologies, and other best management practices are recommended for consideration in future restoration efforts in the Red River watershed.

## 1.2 PROJECT LOCATION AND DESCRIPTION

The Red River watershed, covering an area of 226 square miles, is a major tributary to the Rio Grande and begins as headwaters originating from the highest terrain in New Mexico. The east or main fork of the Red River begins at nearly 13,000 feet as springs just east of Wheeler Peak. The Red River has 21 perennial tributaries which originate as very high quality mountain streams.



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The location of the Red River watershed and the major areas of activity for this project are shown in Figures 1 and 2. The Red River watershed lies entirely within Taos County in northern New Mexico. Approximately 90% of the watershed is under management of the US Forest Service (USFS), Carson National Forest, and includes two wilderness areas (Wheeler Peak and Latir Peaks) and a wilderness study area (Columbine-Hondo). Elevations range from 13,161 feet at Wheeler Peak (highest point in New Mexico) to 6,500 feet at the confluence of the Red River and the Rio Grande. The USFS high country consists of the Taos Range of the Sangre de Christo Mountains, while the lower elevations of the watershed occur on the Taos Plain and are a combination of private lands and federal Bureau of Land Management (BLM) lands. The lowest four miles of the Red River flow through a spectacular canyon that is part of the BLM-managed Wild and Scenic River Area, which includes the Rio Grande Gorge. The only towns within the watershed are Questa (population 800) and Red River (population 400). At 8750 feet elevation, Red River is the highest incorporated town in New Mexico.

The region is semi-arid, but the elevational range accounts for large variations in temperature and precipitation. Annual precipitation varies from 8 to more than 20 inches, and winter temperatures range from -25 to 50 degrees F, with summer ranging from 30 to 90 degrees F. From May to October the moisture occurs as rain or hail, except in higher elevations where snow may occur throughout the year.

The Red River occupies one of the most popular multiple use watersheds in the state. The upper portion of the watershed is a mountainous area devoted to recreational activities, chiefly skiing, hunting, and fishing, along with livestock grazing by U.S. Forest Service permittees. Prior to the early 1970s, the Red River watershed had no major industrial facilities or urban development. Since 1966 both industrial and urban developments have increased significantly. Accordingly, there has been a decrease in the quality of water resources, primarily in the middle reach of Red River, from Bitter Creek to Lama Canyon. Concerns pertaining to heavy metals, low pH levels, biological toxins, septic tank effluent, municipal sludge, and petroleum product discharges have been documented in this once pristine watercourse.

In "Water Quality and Water Pollution Control in New Mexico, 1992", it was reported that the State Water Quality Control Commission (WQCC) had listed the Red River as a stream in which designated uses were not being attained due to various types of impairment. Section 2-119 of the Red River (from mouth of Red River upstream to the mouth of Placer Creek) fails to support the designated uses of cold water fishery, irrigation, and livestock and wildlife watering. The portion of the Red River in segment 2-120 (Red River upstream of Placer Creek, and all tributaries of Red River) does

not support its designated uses of high quality cold water fishery and domestic water supply. This impairment is derived primarily from nonpoint sources of pollution. For a summarized history of documented impairment of the Red River see Tables 5 through 8.

There are currently three NPDES-permitted point sources with a total of six outfalls (Figure 3) discharging into the Red River: the Town of Red River waste water treatment plant (WWTP), the State trout hatchery below Questa, and four NPDES-permitted outfalls for Molycorp Mine (two at the tailings impoundments and two at the mine site). Only the WWTP discharges upstream of the most impaired segment of the Red River, and its effluent is described as excellent quality. The hatchery discharge is return-water from the raceways and actually serves to improve water quality in the Red River due to its dilution effect. The Molycorp discharges are regulated under NPDES Permit Number 0022306, which was approved by EPA in September 1993 (on file at NMED SWQB). These discharge points are described briefly as follows:

Discharge Point 001: from Pope Lake in the tailings dam area. There has been no discharge reported here since the mining operation ceased in 1992.

Discharge Point 002: from the seepage collection system at the toe of tailings dams. This discharge is monitored and sampled as required in the permit. There have been no exceedances of specified concentration limits.

Discharge Point 004: Stormwater runoff from the mine area at the Goathill Gulch drainage (effectively, the area below the caved area). No discharges have been reported by Molycorp since the permit was approved in 1993.

Discharge Point 005: Stormwater runoff from the mine area in the vicinity of the mill, including drainage from Spring Gulch. No discharges have been reported since 1993.

Nonpoint sources (Figure 3) that are thought to be impacting the Red River include mining sites (primarily Molycorp, and to a lesser extent old gold mines and milling sites located in the Red River tributaries of Bitter Creek, Placer Creek, and Pioneer Creek); naturally occurring, highly erosive and acidic soils in mineralized areas known as hydrothermal alteration scars; septic tank leach fields in the alluvial valley bottoms above the Town of Red River; unlined sewage lagoons for the Village of Questa; three known leaking underground petroleum storage tanks in the Town of Red River; and sediment from steep, bare slopes at the Red River Ski Area and from many dirt roads, grazing allotments, and scar areas on the Carson National Forest.

Private lands adjacent to the Red River above the Town of Red River are intensely developed with hundreds of summer homes having

individual septic tanks. Within the Town of Red River, three leaking underground storage tanks have been documented, and at least one has released gasoline to the river. Red River Ski Area, located immediately adjacent to the town and the Red River, is affecting surface water in the Red River and Pioneer Creek. Steep, bare slopes with no erosion controls are a continuous source of sediment to the river during non-winter months. Below the Town of Red River, the Molycorp (Questa) Mine has a long history of more than sixty tailings spills (most of which entered the Red River) during the operational life of the mill. Although originating as point sources (slurry spilled from broken pipelines), the tailings were spread over significant areas of the Red River floodplain, and continue to act as ongoing nonpoint sources of pollution when dispersed and transported by runoff and floods. There is documented groundwater pollution from seepage from the Molycorp tailings ponds at Questa. Acid rock drainage from sulfide-rich scar areas and a number of large Molycorp mine waste piles in the canyon above Questa contaminates both groundwater and the Red River where many perennial acidic seeps emerge. Of all the above listed nonpoint sources of pollution potentially impacting the Red River, Molycorp Mine is by far the most significant, and as such has received proportionally greater scrutiny in this investigation.

As a gaining stream, the Red River is recharged throughout the length of its main stem by groundwater, as documented by the US Geological Survey and the NM State Engineers Office. As point sources of contamination come under better control, it becomes more apparent that nonpoint source contaminants contained in groundwater recharge are contributing to the continuing impairment of this river.

Human health implications and ecological damages from these sources of pollution are currently being evaluated. The NM Office of Natural Resource Trustee (ONRT) has recently contracted for a natural resource evaluation for the Molycorp-Red River area. Contamination of private wells by tailings seepage was documented by NMED, and in 1976 Molycorp provided alternative drinking water to those residents by connecting them to the Questa Community Supply system. The town of Questa has two community supply wells, both screened in the Santa Fe Formation aquifer, located approximately .5 miles northeast of Questa and serving approximately 800 people. No current drinking water intakes from the Red River have been identified; however, fisheries and sensitive environments are both present. The Red River Fish Hatchery produces approximately 11,000 lbs. of fish per year which are used to stock the Red River above and below the Molycorp mine site and the Rio Grande. One sensitive environment affected by impaired water quality in Red River is the federally designated Wild and Scenic River area which begins near the confluence of Red River and Rio Grande. Habitat for the Southwest Willow Flycatcher, which is under review for its federally endangered or threatened status, has been tentatively identified along the Red River (USFWS,

1992).

## 1.3 PREVIOUS INVESTIGATIONS

In 1966, in response to the Molycorp Mine open pit development and an enlarged milling and tailings transport system, the U.S. Department of Health, Education and Welfare (HEW), Federal Water Pollution Control Administration (predecessor to the EPA) conducted a baseline water quality survey of the Red River. While effects from numerous small mining sites adjacent to the Red River and tributaries included periodic elevation of metal concentrations leached from sulphide-rich waste rock or tailings during storm events, the overall quality of the river, including the segment adjacent to the Molycorp mine site, was determined to be of high quality (USDHEW, 1966). Although the report based on this survey indicated some minor impairment of biotic support capacity by 1966, overall it still rated the Red River as an "exceptional" high quality surface water resource. In its report "Water Quality Survey: Red River of the Rio Grande, New Mexico", HEW concluded in part II-1 that:

1. The chemical quality of the Red River is exceptional....
2. Biological conditions in the river are good....
3. Groundwater resources of the area are of high quality....

In November 1971 the United States Environmental Protection Agency concluded in the report, "A Water Quality Survey: Red River and Rio Grande: New Mexico," Page 3-4:

1. The chemical quality of the Red River water remains very good....
2. Biological conditions in the river are good....
3. ...occasional breaks in the [tailings] line are causing some degradation in stream quality and biota.

During this same period of the late 1960's and early 1970's, however, the New Mexico Department of Game and Fish discovered in the course of routine population studies that fish were conspicuously absent in the middle reach of Red River where thriving populations had once existed. Fish census data of 1960 indicate that approximately 572 fish per mile were estimated in the river. The 1988 fish census found no fish in this same reach (NMDGF, November 29, 1988).

In 1982 the U.S.EPA conducted a "Site Specific Water Quality Assessment" of Red River and found the stream to be substantially impaired from metal loading. This report concludes, on page 35:

1. Concentrations of ambient total arsenic, cadmium, and silver exceeded EPA-recommended acute criteria....
2. 'Control' stations...contained higher concentrations of all metals except zinc.... It is not known whether these

elevated concentrations are a result of background geologic conditions...or upstream nonpoint, mining-related, discharges to the river....

5. Bioassay results from tests with Red River water suggested some biological toxic response may be occurring in Red River.

In 1984 the BLM published results of its study of water quality in the Red River and Rio Grande between 1978 and 1983 in response to the creation of a component of the National Wild and Scenic River System (Garn, 1984). This study documented pollution sources and found a downstream increase in concentrations of various constituents, at times exceeding water quality standards, and found that the major impacts were due to mining and related activities. Nonpoint sources were found to be a major cause of elevated trace element concentrations.

Water quality concerns relating to the Molycorp site have been studied by several programs within NMED, predominantly by the Surface Water Quality Bureau, Ground Water Quality Bureau, and the Superfund Oversight Section. Point source discharges from the Molycorp tailings ponds at Questa have been monitored through a National Pollution Discharge Elimination System (NPDES) permit issued by U.S. Environmental Protection Agency. Renewal of the permit in 1993 included two additional discharge points for stormwater runoff from the mining site.

Two studies conducted by the NMED-SWQB in 1986 and 1988 confirmed high metal loading of the Red River by periodic storm events but that metal concentrations in the river and sediment were not elevated to the point of causing aquatic toxicity (Smolka and Tague, 1987 and 1989). The major elements which became elevated between the Red River Waste Water Treatment Plant and the Questa (USFS) Ranger Station were Fe, Al, Mn, and Zn. A portion of this segment abuts Molycorp property where mining operations have occurred. One conclusion drawn from these surface water surveys was that episodic run-off events erode oxidized, sulfide-rich soils from barren slopes and mining scars. This process generates acidic run-off which mobilizes and transports trace elements, including heavy metals, to the Red River. The acidic run-off temporarily reduces the pH of the river but the metals precipitate downstream as the pH becomes more neutral. Another result from these surveys was that biomonitoring in the Red River generally showed no chronic or acute toxicity but that biological indices were severely reduced below the Molycorp Mine.

During the period 1992 to 1994 a project dealing with mineral extraction impacts to water quality in the Red River (and other) watersheds was partially funded by EPA Region VI under CWA 319(h) and was carried out by SWQB (R. Salter, project manager). Some of the activities of that project, by necessity, overlapped with similar activities of this current project, and field work and data

were shared. The current project is distinguished by an emphasis on groundwater NPS sources as they impact the Red River. The sampling and monitoring efforts undertaken by SWQB since 1992 under the Mineral Extraction Impacts (MEI) project are not intended to establish a statistically valid trend documenting degraded conditions. The progressive degradation of the Red River has been established for many years and has been reported by the Water Quality Control Commission (WQCC) and the SWQB in the 1986, 1988, 1990, 1992 and 1994 305(b) reports to Congress (see Tables 5 to 8). The 1992 305(b) report listed an increased concentration in Red River in the vicinity of Molycorp Mine of several metals including Cd, Cu, Pb, Ag, and Zn. The 1992-94 MEI project was intended to provide a snapshot of the chemical makeup of the entire watershed under a variety of conditions in order to provide a general water quality profile of the tributaries and mainstem. SWQB continues to actively document the effectiveness of land management adjustments to restore chemical and biological integrity to this watershed.

A number of other previous investigations of water quality (primarily groundwater) in the watershed that focused on the Molycorp facilities have been generated by the regulatory involvement of NMED Ground Water Quality Bureau (GWQB). During 1987-90 Molycorp was proposing to build a new tailings impoundment area in the Guadalupe Mountain saddle area, located on BLM lands several miles north of the existing tailings ponds. The GWQB required Molycorp to conduct a number of hydrogeologic studies of the area as part of the requirements for a Ground Water Discharge Plan. These studies, by a number of consultants, characterize the geology, groundwater hydrology, geochemistry, and other factors for the region lying between the Red River, Rio Grande Gorge, and the mountain front at Questa (Dames and Moore, 1987 and 1988; Molycorp, April 1987; Vail Engineering, December 29, 1988; GWQB files). Molycorp never built the proposed new tailings facility because the mine operations ceased in 1992. In 1993 the GWQB required Molycorp to submit applications for Ground Water Discharge Plans for two areas believed to be contaminating ground water - the tailings impoundments and the mine waste-rock dumps. Again, a number of water quality investigations were generated at Molycorp as a result of this regulatory activity. A decision was made by GWQB in 1994 to require Discharge Plans for the tailings area (DP-933) and the mine waste rock piles (DP-1055). Much historical and current baseline data and information for both sites have been collected by Molycorp consultants and by the GWQB as part of these processes (South Pass Resources, July 14, 1993, Jan. 28, 1994, March 4, 1994, April 21, 1995; Vail Engineering, July 9 and September 24, 1993; Steffen, Robertson and Kirsten, April 13, 1995; NMED, GWQB and SWQB files). The site investigation and monitoring process is ongoing, particularly at the mine area, as dictated by Discharge Plan requirements.

During 1995 negotiations began with a series of meetings between Molycorp and the NMED programs that have statutory authority there to discuss entering into an administrative order on consent (AOC) that would guide future remedial work at Molycorp. Following several meetings this process stalled and is currently being reviewed by legal staff.

The U.S. EPA Superfund program (Region VI, Dallas, TX) conducted a Preliminary Assessment of the Molycorp site in May, 1980 and a Site Inspection in June, 1981. The conclusions of these reports, respectively, were for no further remedial action and placing the site at a lower priority. However, EPA funded field investigation teams (FIT) to investigate Molycorp in 1983 and 1985 (EPA Site Inspection Report, NM 00558, August 19, 1983; Ecology and Environment, June 4, 1986). Part of these investigations was an assessment of the Molycorp waste disposal area ("landfill") located near the head of Spring Gulch (above the mill area). This landfill was described as actually a mine rubble pile more than 100 feet thick that was used as a boneyard for discarded equipment and parts. Some unrinsed reagent drums from the mill were the only "hazardous" wastes observed. Soil samples were collected and analyzed for metals and organics in both investigations of the area, but were inconclusive, in part because appropriate background soil samples were not collected for comparison (for more detail see discussion of results in Section 2.3.1.1). The 1983 investigation concluded that the "opportunity for surface or ground water contamination was very low". The 1985 inspection observed a small oil spill (not sampled) and commented that the area was still active as a dump for empty drums and old equipment. Conclusions from the second investigation included the recommendation for further study of this landfill under RCRA authority. Molycorp has had two landfills (in Spring and Goathill Gulches) which are exempted from NM Solid Waste Management Regulations since they received only demolition and construction debris. The Spring Gulch site is inactive, having been covered with several hundred feet of overburden during subsequent mining operations that filled Spring Gulch (personal communication with D. Shoemaker, mine manager, 1993).

A Screening Site Inspection (SSI) was conducted by the NMED Superfund Oversight Section (under contract to U.S. EPA Region VI) for the Red River Mining District in 1989 (NMEID, August 31, 1989). This investigation evaluated the old mines (gold, silver, molybdenum, lead, and copper) located along the Red River and tributary headwaters, along with several small milling and smelter sites which operated between 1867 and 1900. The report concluded that, although some environmental impacts were present (acid rock drainage, elevated metals concentrations in wastes or soils, etc.), the old mining district site does not qualify for the National Priorities List (NPL, or Superfund).

The NMED Superfund Oversight Section initiated further CERCLA regulatory activities for the Molycorp Site in 1993 with the preparation of a Hazard Ranking System (HRS) Screen (NMED, August 13, 1993). That report evaluates Molycorp using the revised HRS (12/14/90), to determine if the site could potentially be listed on the National Priorities List. Subsequently, NMED Superfund initiated an Expanded Site Inspection (ESI) for the Molycorp site (includes the mine, waste rock dumps, and tailings impoundments). An ESI Workplan (NMED, Feb. 28, 1994) was approved by EPA in March 1994, and field work/sampling for the ESI was conducted on two occasions during 1994 (in coordination with similar activities by this project). The Superfund/CERCLA process is ongoing at the Molycorp site for the foreseeable future. The ESI Report was submitted to USEPA October 23, 1995.

Among the more significant preliminary results from the recent investigations by NMED Superfund and SWQB are observations and sampling of the acidic seeps along Red River below Molycorp. During shared field reconnaissance by this project and Superfund, water from groundwater seeps was observed emerging and entering Red River approximately one and a half miles below (southwest) Molycorp mine. Along this same stretch of the Red River, manganese concentrations were greater than three times the concentrations detected upstream (NMED, Feb. 28, 1994, Table 6; Smolka and Tague, 1989). The concentrations of zinc and total aluminum were two to three times greater than background. Other reports have determined that there is a general increase in the loading of sulfate, manganese, zinc and aluminum in the downstream direction, with those seeps located below Capulin Canyon being the major contributors (Vail Engineering, July 9, 1993).

During 1994 another, newly created, state agency became involved in regulatory investigations at the Molycorp site. The NM Office of Natural Resource Trustee (ONRT) is investigating natural resource damages from Molycorp in the Red River area, and has participated in sampling activities and review of Molycorp reports and workplans. A natural resource evaluation is being conducted.

During 1995 staff from the SWQB, Nonpoint Source Pollution Section were instrumental in initiating the formation of a Red River Watershed Association. Meetings have been held in the Town of Red River and the Village of Questa, with attendance and participation by interested citizens, state and federal agencies staff, environmental groups, and municipal representatives. It is hoped that this group will continue to play a role in management of the watershed for water quality protection.

Also during 1995 the Molycorp Mine became involved in the permitting process that is required by the recent New Mexico Mining Act (administered by the NM Mining and Minerals Division). NMED staff reviewed and commented on Molycorp's Site Assessment and Permit Application, made site inspections, and attended a public



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hearing in Questa in September, 1995. A site closure plan is required by the Act, and will be submitted in early 1996.

# II. RED RIVER WATERSHED

## 2.1 DESCRIPTION OF WATERSHED AND WATER QUALITY ISSUES

### 2.1.1 SURFACE WATER HYDROLOGY

The Red River watershed, covering an area of 226 square miles, is a major tributary to the Rio Grande and begins as headwaters originating from the highest country in New Mexico. The Red River has 21 perennial tributaries which originate as very high quality mountain streams. Those tributaries that do not have major concentrations of mining remain high quality streams up to their confluence with Red River.

Cabresto Creek is the largest tributary to Red River, having a drainage area of 36.5 square miles and an average discharge of 14 cfs, or 10,135 acre-feet/year (af/y). The average annual discharge of Red River, excluding Cabresto Creek, is 55.9 cfs, or 40,500 af/y. The upper Red River (above Zwergle Dam) has a drainage area of 29.42 square miles and discharges 17.7 cfs, or 12,820 af/y as an average (Dames and Moore, April 19, 1988). A number of seepage studies have demonstrated that the Red River is a gaining stream in the vicinity of both the Molycorp tailings area and mine area. The lower reach of the Red River (from Cabresto Creek to mouth of Red River) has been measured having an average accretion rate (seepage of groundwater) of 31 to 33 cfs out of a total flow of 84 cfs at the mouth of Red River (Winograd, 1959, p.40). In the middle reach of the Red River (the reach from Red River to Questa, which includes the Molycorp mine area) seepage studies have documented accretion from groundwater into Red River at average rates of 4 cfs (USGS, Oct. 1988).

The US Geological Survey has been measuring discharge and collecting water quality samples at various points on the Red River for over twenty years. Published data is available from their Water Resources Data Book for New Mexico for discharge, field parameters, anions/cations, and trace elements the following years: 1964-65 and 1969-1967 at the Fish Hatchery; 1978-1982 at Zwergle Dam, Molycorp Mine, Questa, Fish Hatchery, and mouth of Red River; 1983-87, at Questa, Fish Hatchery, and mouth of Red River. There is no data available for the period following 1987.

The drainage system of the Red River is controlled by the former radial dispersion of mountain glaciation from the Wheeler Peak and Gold Hill areas, as well as by fault patterns created during Miocene deformation. These effects are vividly displayed by the counter-clockwise course of the Red River (Clark and Read, 1972). The profiles of side streams tend to be short and have steep

gradients. The structural Red River graben element (described further in Section 2.2) is drained by the lower part of the Red River and Cabresto Creek, both of which are structurally controlled. Drainage patterns are similar to those in the Taos uplift, and locally a trellis pattern predominates. The hydrothermally altered scar areas that occur along the north side of the main stem of Red River are so easily eroded that mudflows are produced by heavy precipitation, creating debris aprons where tributaries enter Red River. Past major mudflows have at times dammed Red River, creating temporary lakes and meadowlands that have led to pronounced gradient changes in the stream profile (former dammed-up areas are now flatter spots, such as the location of the town of Red River, Forest Service Campgrounds west of Red River, the Molycorp mill site, etc.). Gradients in debris apron regions are in excess of 0.028, whereas gradients in regions between debris aprons are generally lower (Meyer and Leonardson, 1990).

Background or source water pH values within the Red River watershed range from 6.94 to 8.04, and conductivity values range from 114 to 177 umhos/cm. With exceptions, metal concentration values at these source waters are below detection limits and well below State standards. At the headwaters stations all metals except magnesium are below detection limits. Magnesium at these stations is generally well below 2.0 mg/1 (NMED-SWQB, Jan. 1995). Source water samples collected from Columbine Creek contained both chromium and lead at levels just above detection limits but within State standards. Bitter Creek's source waters contain chromium at similar levels. In both cases however, analytical results of subsequent same-day samples of the middle reach of these tributaries found all metals tested for were below detection limits. In the two roadless tributaries (East Fork of Red River and Columbine Creek) there are no significant changes in water chemistry up to their confluence with Red River. In fact within these tributary reaches there is a subtle increase in alkalinity and pH and a reduction in total dissolved solids (TDS) and conductivity.

Most of the mining in this watershed is concentrated in seven tributaries and in the middle reach of the mainstem of the Red River. Cabresto Creek drainage, with the exception of a few minor old prospects and mines, is free of mining impacts and associated water quality problems. Acid rock drainage (ARD) from a number of small mines on other tributaries to Red River (Bitter, Placer, Pioneer, Black Copper, Goose, and Bear Creeks) and from the Molycorp complex of waste dumps, underground mines, and open pit constitute the worst sources of metal loading in the Red River watershed. This ARD commonly exhibits pH values at or below 3.0 and conductivity over 3500 umhos/cm. This drainage is also characterized by very high values for total dissolved solids (TDS) and sulfates. Acidic metal-loaded seep waters collected from a variety of sources throughout the watershed show a range of pH

values from 2.44 to 3.22 and a range of conductivity values from 1769 to 3668 umhos/cm. Those metals found in typical acidic seeps along Red River that exceed state standards include Al, Fe, Mn, Co, Cu, Ni, Zn, and Cd (Table 1). In the three tributaries where most of the historic mining has occurred (Bitter, Pioneer, and Placer Creeks), there is a slight, but detectable increase in metal loading at base flows. The metals that show detectable increases are primarily aluminum, zinc, manganese, and magnesium. Obviously associated with this increase in metals is a slight increase in TDS and conductivity, however, the volume of ARD from these locations is quickly diluted by alkaline receiving waters. Metal loading in base flow conditions is not a serious problem until the mainstem of Red River encounters the five square miles (3,200 acres) of mining-related disturbance at the Molycorp mine operation twelve miles above the confluence of the Red River and the Rio Grande. The reach of Red River from just below the Molycorp mill to the Red River Fish Hatchery (a distance of approximately eight miles), has been adversely affected by pollutants, resulting in biological impoverishment. The primary reason for this current condition is an infusion of acidic, metal-loaded seep waters in such volume that it overwhelms the river's natural buffering capacity. As a result, the river in this reach is a pale-blue or milky-white color due to metal ions and minerals (primarily silica-aluminum hydroxide) precipitating out of solution. Mineral deposits precipitated in this reach have cemented the stream substrate thus limiting potential for benthic community colonization and development.

### 2.1.2 CONTAMINANT TRANSPORT

There are two general modes of contaminant transport at work in the hard rock mining districts of the Red River watershed; steady-state, or perennial form of ARD, and the pulse loading mode in which sometimes very large volumes of weathered sulfide waste rock and sediment are transported to stream channels by storm events and rapid snowmelt. These two principal mechanisms are addressed as separate but related issues.

The steady-state form of contaminant transport has received the most attention from researchers since its full pollution potential was first recognized. The earliest work in the U.S. in regard to this problem was carried out in the Appalachian coal fields. Further research into this form of water pollution has been carried out in the last twenty years in the Rocky Mountain region, much of it in response to widespread degradation of the Arkansas River in Colorado and a 120 mile reach of the Clark Fork River in Montana. In both cases the stream degradation originates in hard rock mineral extraction and processing areas. The mechanisms of ARD formation and its effects on aquatic ecosystems are well known. ARD is characterized by low pH and elevated concentrations of metals and TDS. The most common mechanism for its formation involves the oxidation and hydration of sulfide minerals (typically pyrite, or iron sulfide), resulting in the generation of sulfuric

acid and elevated concentrations of iron. A number of promising passive treatment technologies have emerged from the study of this phenomenon in recent years (see Sections 4.2 and 4.3).

The pulse loading mode of pollution from hardrock minesites is less well understood and can be more difficult to control. Field investigations and laboratory experiments have proven that pulse events not only transport large volumes of mine waste through direct erosive processes but also through solution facilitated by reduction in pH. The suspended metal load from a pulse event may fall out within a relatively short distance, but the dissolved metal load may be transported for many miles before pH conditions allow precipitates to form. In either case, the pulse loading mode of mine waste transport is the primary mechanism by which these contaminants are moved far from their origins.

Pulse loading of sediments and dissolved constituents is a significant problem in the Red River and several of its tributaries. The SWQB Standards and Surveillance Section has documented a rapid decrease in pH and increase in turbidity in the mainstem of the Red River just below a tributary above Fawn Lakes Campground (Hansen Creek) in response to a summer rain event. Analysis of water samples collected during this pulse event proved that metal loading also increased dramatically (Smolka and Tague, 1988). This tributary contains a large hydrothermal alteration scar that may have been exacerbated by erosion triggered by mineral exploration roads and at least one mine. The weathered sulfide materials exposed in large erosional scars in a number of locations within the Red River watershed do react rapidly with distilled water. Preliminary data from simple laboratory reactivity tests conducted by NMED staff using wastes from mines and soils from erosional scars have reproduced field pulse conditions and verified the rapid reduction in pH and increased turbidity. Subsequent X-ray Fluorescence (XRF) analysis of the soils and mine wastes used in these reactivity tests found higher levels of metals in mine wastes than in soils collected from erosional scars (SWQB files, personal communication B.Salter, 1993). Of the 21 perennial tributaries to the Red River only two, Columbine Creek, and the Upper East Fork do not contribute significant amounts of sediment in response to pulse events. Both of these sub-watersheds are roadless, have no mining activity, and do not contain alteration scars.

In response to pulse events such as snow melt or intense summer rainstorms, the Red River becomes seriously degraded from sedimentation. Much of this sediment load originates in large, barren erosional scars caused by slope failures in at least fifteen locations within the middle reach (Figures 3 and 4). Some of these slope failures may be related to human influences such as small mine and mineral exploration roads (for more information on scars see Section 2.3.2). Also, an extensive system of forest roads, mineral exploration roads, tracks, and off-road vehicle trails

erode and convey significant amounts of sediment to the Red River. The negative influence of these sedimentation episodes is mainly temporal. However, the effect on water quality and the dependent biotic community during these events is dramatic. The sediment loading problem in the Bitter Creek tributary is especially severe, and is being addressed by a separate 319(h) grant (Lower Bitter Creek Restoration, FY-94-B) which the SWQB has recently implemented

Of the two dominant mechanisms of contaminant transport at work within the watershed, the steady-state mode is of primary interest in this investigation because it involves the perennial, base-flow seepage of acid drainage that affects groundwater, and it is the impact of contaminated groundwater on the Red River that is of interest here.

### 2.1.3 CATEGORIES OF NPS POLLUTION IN THE WATERSHED

Metals

Metal loading of the Red River is the most widespread and significant form of NPS pollution in the watershed. The primary metals involved in contaminant transport, discussed previously, include; aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, and zinc.

The primary cause of metal loading in the Red River is by steady-state input of acidic, metal-enriched seep water. This first appears at the mouth of Bitter Creek and again in small volumes from several small drainages between The Town of Red River and just below Hansen Creek. From below Molycorp Mill to the Questa Ranger Station, a series of acidic, metal-loaded seeps appears to overcome the river's natural buffering capacity. From that area downstream to the Questa Fish Hatchery, the Red River appears to be largely devoid of many biotic communities.

Secondly, pulse event loading of acidic, metal-laden water is of concern. During and after pulse events, metals are transported from various source areas at high concentrations in both the suspended load and in the dissolved fraction of the water column. (Smolka and Tague, 1986, 1988). Metal loading problems associated with pulse events are largely temporal. In most cases, a degree of equilibrium is restored to affected stream reaches within a day or so after a major pulse event. Short-term biological impacts may however be significant due to exceedances of acute criteria. If high enough concentrations are reached, lethality is possible. Therfore even short term effects can cause long term biological impacts.

Sediment

Sediment transport in the middle reach of the Red River during pulse events is extreme - turbidity values in excess of 1000 NTU

are typical. Distinctive plumes of yellow-orange turbidity transform the Red River to its confluence with the Rio Grande, and similarly affect the Rio Grande for at least fifty miles downstream (NMED-SWQB field notes, August 1994). The primary source areas for sediment loading are the alteration scars plus unpaved roads in the watershed. As well, Pioneer Creek has been documented as exceeding turbidity standards on several occasions due to ski area runoff. (Those problems have been addressed in part by a separate 319(h) grant [Ski Area Impacts, FY-91] through the SWQB). Sediment transport from the sub-alpine components of the watershed is also a significant problem. Within these areas, the excessive road network and riparian loss due to historic grazing practices are primary causes of sediment loading.

Nutrients

Nutrient loading has not been documented as a water quality problem. There is however, evidence that nutrients may be increasing in summer sub-alpine grazing areas, and adjacent to housing developments above the Town of Red River. Dense algal mats have been observed in stream reaches adjacent to these developments, possibly in response to elevated nutrients concentrations (see Section 2.3.4).

## 2.2 GEOLOGIC AND HYDROGEOLOGIC SETTING

A geologic map of the Red River watershed is shown on Figure 5. The majority of the Red River watershed, including Molycorp mine, is located in the Taos Range, which is made up of intrusive igneous (granite) rock and metamorphic (amphibolites, quartzites and schists) rocks of Precambrian age which are overlain by Tertiary volcanics (Roberts et. al., 1990; Gustafson, 1966). The latter consists of flows, breccias and tuffs of andesite, latite and rhyolite. A series of thrust faults (trending N) and high angle faults (trending N to NW and E to NE) lead to the downfaulted area of the Molycorp mine site. Subsequent intrusion of granite stocks (Late Tertiary) caused fracturing and brecciation primarily along zones of contact with older rocks. Propylitization of volcanics surrounding the granite stock and hydrothermal alteration along brecciated zones caused the emplacement of molybdenite and other minerals in the granite near the contact with the propylitized rock (USDHEW, 1966). The down-faulted area referred to above is part of the Red River graben, a negative structural feature that consists of jumbled and tilted fault blocks aligned in an east-northeast direction, and stretching from near the western margin of the Sangre de Christo Range near Questa to the Midnight-Anchor Mines area at the head of Bitter Creek (fourteen miles in length and two to four miles wide). The major fault line along the graben follows the line of the Red River and Bitter Creek, although it is almost completely concealed by alluvium and mudflow. North of the Red River fault a line of hydrothermal alteration scars marks a parallel fault (see Section 2.3.2). The graben is segmented by a



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series of northerly striking faults, making a very complex structure (Clark and Read, 1972).

A useful conceptual model of the groundwater aquifers believed to be present in the middle reach of the Red River and at the Molycorp mine area consists of three distinct units for characterizing groundwater there: 1. groundwater which flows through fractures in the hard rock formations; 2. groundwater within the alluvial sediment of the Red River channel or; 3. groundwater within the alluvium of the side channels (tributary drainages). Separation of the groundwater flow into three systems is useful in understanding general hydrogeology near the mine site and assists in defining sources for the seeps near the Red River. It does not, however, necessarily preclude communication among systems. The placement and screening of twelve new monitoring wells drilled in the Molycorp mine area in 1994 was determined based on the model given above (Appendix C). Based on initial observations of these wells in 1994, groundwater flow velocities in the mine area (in all the units) are thought to be on the order of 50 to 500 ft/yr; gradients are up to .026 ft/ft (the steepest observed); and flow direction is to the southwest (toward the river) (J. Kepper, personal communication, Nov. 1994).

Five miles to the west of the Molycorp mine, the Village of Questa is situated on the Taos Plain, in the Rio Grande Basin, which resulted from Miocene uplifting of the Taos Range (Gustafson, 1966; Winograd, 1959). This downfaulted area has received alluvial sediment from the Taos Range. Intermittent extrusion of lava during late Pliocene and early Pleistocene resulted in interbedding of the lava with alluvium. These lithologies together with occasional lake deposits comprise the Santa Fe group.

The Santa Fe Group is the major water-bearing unit in the Rio Grande Basin of Taos County (Winograd, 1959, p. 15). Depth to water in the Questa area is generally in the range of 60 to 160 feet. Gradients range from only a few feet to 100 feet per mile. Groundwater flow near Questa and the tailings ponds is generally southwest, away from the mountains, and recharges the Red River and Rio Grande by numerous springs which generally emerge from the basalt layer. Those springs which recharge the Red River are located southwest of the tailings ponds toward the confluence of the Red River and Rio Grande. Some of these springs are hydrologically connected to the waste water leaching through the tailings ponds (Vail Engineering, Sep. 24, 1993).

A number of seepage studies have demonstrated that the Red River is a gaining stream in the vicinity of both the tailings area and the mine area. The lower reach of the Red River (from Cabresto Creek to mouth of Red River) has been measured having an average accretion rate (seepage of groundwater) of 31 to 33 cfs (Winograd, 1959, p.40). In the middle reach of the Red River (the reach from the Town of Red River to Questa, which includes the Molycorp Mine

area) seepage studies have documented accretion from groundwater into Red River at an average rate of 4 cfs (USGS, Oct. 1988).

## 2.3 GROUNDWATER NONPOINT SOURCES OF POLLUTION FOR RED RIVER

The list of potential nonpoint sources of groundwater pollution that are thought to be impacting the Red River include mining sites (primarily Molycorp Mine and tailings impoundments, and to a lesser extent old gold mines and milling sites located in the Red River tributaries of Bitter Creek, Placer Creek, and Pioneer Creek); naturally occurring, highly erosive and acidic soils in mineralized (scar) areas; septic tank leach fields, leaking underground storage tanks, and Questa's sewage lagoons. Several other nonpoint sources of pollution previously mentioned (tailings spills at Molycorp and sediment eroded from various sources) primarily affect Red River water quality via direct surface runoff rather than through seepage of contaminated groundwater. Therefore these nonpoint sources receive minimal discussion in this section.

While the cumulative impacts to Red River water quality from all of these NPS sources cannot be ignored, the single greatest impact is due to metal loading and associated pH changes related to acid rock drainage from mining activities and scar areas. The discussion of groundwater NPS sources that follows is prioritized accordingly.

The Red River watershed is one of the most severely impacted perennial stream system in regard to metal loading in New Mexico. The mainstem of the Red River is also among the most intensively studied stream reaches in New Mexico (see Section 1.3). In April of 1992, NMED began comprehensive documentation of the sources of metal loading in the upper watershed of Red River. Many of the smaller mine sites in this watershed are located on public lands within the Carson National Forest. However, the largest sources of metal loading within this watershed (Molycorp and other mine sites) are located on private patented inholdings removed from the public trust under provisions of the General Mining Law of 1872.

Upstream of the Molycorp Mine site the contribution of metal-loaded drainage is handled without apparent serious impact by the natural buffering and dilution capacity of the Red River. However, beginning at the vicinity of Molycorp Mine and Mill, the volume of metal-loaded drainage seeping out of the waste rock piles, scar areas, open pit, and the underground workings overwhelms the river and has significantly degraded water quality and biological integrity for at least eight miles to a point just below the Red River Fish Hatchery.

### 2.3.1 MINING-RELATED SOURCES

Those tributaries that do not have major concentrations of mining sites remain high quality streams up to their confluence with the



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Red River. Most of the mining in this watershed is concentrated in seven tributaries and in the middle reach of the mainstem of the Red River. Effects from numerous small mining sites adjacent to the Red River and these tributaries include periodic elevation of metal concentrations leached from sulfide-rich ores during pulse events. Metal loading from ARD in base flow conditions is not a serious problem until the mainstem of the Red River encounters the Molycorp mine operation. At least eight miles of Red River from Molycorp to the Red River Fish Hatchery is essentially a biologically dead reach. This zone of the Red River is due primarily to continual metal loading from seeps issuing from a number of locations along a six mile section of the middle reach, beginning below the Molycorp Mill and persisting until about the Questa Ranger Station.

### 2.3.1.1 MOLYCORP MINE AND TAILING AREAS

The Molycorp operation is a molybdenum mine, mill, and tailings disposal site, and has been inactive (on standby status) since 1992. It is currently under review by several regulatory programs within the New Mexico Environment Department (NMED), including the Superfund Oversight Section, which is determining whether the site is a potential candidate for inclusion on the National Priorities List (NPL). See pages 8 and 9 for a more complete description of Superfund activities at Molycorp Mine.

The mine, surrounded by Carson National Forest, occupies approximately three square miles on patented land owned by Molycorp, Inc. The mine consists of both underground and open pit operations. The tailings ponds occupy approximately 1 square mile and are located 1 mile west of Questa on land owned by Molycorp Inc., and consist of two large ponds and one smaller pond. A series of pipelines transport the tailings in a slurry from the mill site to the ponds.

Mining History of Molycorp

Molybdenum Corporation of America (MCA) acquired mining rights to Sulphur Gulch in 1920 and conducted small-scale mining operations until 1923 when the mill was constructed (Figure 7). The old underground workings consisted of adits, winzes and raises which followed the irregular vein system. In 1941, a haulage adit approximately one mile long was constructed to facilitate ventilation and drainage (USDHEW, 1966, p. 6). By 1954 this underground complex contained over thirty five miles of workings at fourteen production levels ranging in elevation from 7764 to 8864 feet. By 1954 all but the lowest three working levels were designed to drain by gravity out a mile-long service portal (known as the Moly Tunnel) located above the elevation of Red River. The lower three working levels gathered drainage in a sump and this water was pumped to the service portal where it was allowed to drain by gravity to Red River. This original underground Molycorp

mine continued to grow until the open pit mine was developed. In 1965, MCA switched to an open pit operation which required the transport of tailings via a pipeline approximately eight miles downstream to tailings ponds located 1 mile west of the Village of Questa (Figure 9). Tailing Dam #1 is located in Section 36 of T29N, R12E. Decant water from the associated pond was discharged to Red River via culvert tunnels through the dam. In 1969, a smaller dam was constructed north of Dam #1 with overflow weir structures to keep waste water from the dam face. Waste water was conveyed to a small holding pond (called Pope Lake) for further settling before discharge to the Red River. Molycorp referred to this discharge point as outfall #001 (now an NPDES outfall). In 1971, the second large dam (Dam #4) was constructed southwest of Dam #1 (in Section 35 of T29N, R12E) with an impermeable membrane on the dam face. Surface water diversion ditches were installed in 1974 on the north, east and west sides of the ponds to divert surface water run-on around the ponds. The following year, interceptor trenches (called seepage barriers) were constructed below Dam #1 and east of Dam #4 to collect leachate from the tailings ponds. This waste water is diverted around dwellings below the dams and discharged to Red River through NPDES outfall # 002. Several private wells located below the tailings ponds were used for drinking water purposes until Molycorp offered to switch them to the Questa community supply system after contamination from tailings seepage was discovered. This switch occurred approximately in 1976 (NMED, Feb. 28, 1994). While wells below the tailings pond are not used for drinking water purposes they still may be in use for agricultural purposes. The total population served by groundwater within four miles of the tailings ponds is approximately 2,400 (NMED, Feb. 28, 1994). In 1978, Unocal 76 Corporation purchased Molybdenum Corporation of America and shortened the name to Molycorp, Inc. Molycorp constructed an ion exchange plant near Pope Lake in 1983 to treat the waste water prior to discharge.

After extensive mineral exploration in Goathill Gulch during the 1970's and early 1980's, Molycorp ceased open pit operations in 1985 and reverted back to underground mining techniques. The recent mining activity is referred to as the new underground workings (Figure 7). Production declined significantly in 1989 due to decreased value of molybdenum and the number of employees shrank from a maximum of more than a thousand to approximately two hundred. Low production continued until 1992 when operations stopped. During the period of this project only eleven employees maintained the facility in a standby status. In 1995 Molycorp hired additional staff and resumed pumping the water that had been re-flooding the mine, and discharges this mine water via the tailings pipelines to the tailings ponds at Questa.

Waste Sources at Molycorp

A total of 328 million tons of mine waste rock has been deposited in four main drainages: Capulin Canyon, Goathill Gulch, Spring Gulch, and Sulphur Gulch (Figure 7). While the waste rock occupies a surface area of approximately 40 million square feet (NMED, Feb. 28, 1994), the bulk of it is in Sulphur Gulch where the open pit is located. No underlying liner or other containment structure for the waste rock is present. The mine waste rock consists primarily of two rock types: hydrothermally altered volcanics (andesite and rhyolite) which is yellow in color and the aplitic granite (also called soda granite) which is gray. XRF screening of two samples of mine waste rock indicated levels of copper, zinc, lead and cadmium above background concentrations (NMED, Feb. 28, 1994). Concentrations ranged from 40 ppm for cadmium to 240 ppm for zinc. Analytical data of samples from waste rock dumps and hydrothermal scars, collected by NMED Superfund Program in 1994, are used to compare concentration ratios of metals concentrations (Table 4 of Appendix A). The waste rock exhibited two to five times greater average concentrations of Mo, Zn, Cu, and Mn than scar material.

The tailings ponds, comprised of fine-grained tailings and waste water, occupy about 26 million square feet and are located behind three dams. The amount of tailings in these ponds is estimated to be 95 million tons. Only one of these dams has an impermeable liner on its face. No other liner is present but transmission of waste water from the tailings slurry to groundwater is slowed by fine-grained sediment of the waste (slimes). This waste material was characterized from split sample analysis conducted by Molycorp and the Questa Board of Education. Analytical results showed lead, copper and zinc at concentrations ranging from 90 ppm (lead) to 240 ppm (zinc). A subsequent analysis of the tailings by NMED reported lead and zinc but no copper.

The two primary waste sources of the Molycorp site (tailings dams below Questa and mine waste dumps above Questa) are located in different physiographic areas which are separated by regional block-faulting. The Molycorp mine, and associated mining waste rock, is located in the igneous and metamorphic rock of the Taos Range, whereas the tailings impoundments are located on alluvial sediments and basalt flows of the Rio Grande Basin.

A third source of waste from Molycorp exists in the remnant deposits of tailings that resulted from approximately one hundred spills from broken tailings pipelines. The tailings slurry pipeline was nine miles long; six miles of which was located only a few feet from the river. Sixty to eighty spills occurred between 1966 and 1976 (EPA Site Inspection Report, August 19, 1983). Each pipeline spill represented thousands of gallons of mill tailings slurry. Although many of these spills were cleaned up by Molycorp, some spilled into the river and have formed scattered residual deposits within the alluvium along the floodplain, where they are

subject to dispersal by flooding and erosion. The distribution of these tailings deposits has not been determined (although they have been observed in the field at various locations) and concentration of metals is unquantified.

A fourth possible source of NPS contamination from the Molycorp site may be represented by the old waste disposal ("landfill") area near the head of Spring Gulch (Figure 7). This landfill was described by EPA inspectors as actually a mine rubble pile more than one hundred feet thick that was used as a boneyard for discarded equipment and parts. Some unrinsed reagent drums from the mill were the only "hazardous" wastes observed (pine oil, methyl isobutyl carbinol, etc.). Chloroethane and oils used in the flotation process were reclaimed by a registered recycler. Soil samples were collected and analyzed for metals and organics in both investigations of the area, but were inconclusive, in part because appropriate background soil samples were not collected for comparison. A distinction was not made between soil areas developed in mineralized areas and those in non-mineralized areas. Some organic compounds were detected in very low concentrations, at estimated values below the instrument detection limits, in soil sampled above the site but not below it. The 1983 EPA investigation concluded that the "opportunity for surface or ground water contamination was very low". The 1985 EPA inspection observed a small oil spill (not sampled) and commented that the area was still active as a dump for empty drums and old equipment. The Spring Gulch landfill site is inactive, having been covered with several hundred feet of overburden during subsequent mining operations that filled Spring Gulch (personal communication with D. Shoemaker, mine manager, 1993).

Although not a mining waste, the hydrothermal alteration scars present at the Molycorp mine site need to be considered when dealing with the issues of background concentrations for both solids and groundwater at this site. Major scars occur in the heads of Goathill Gulch and Sulphur Gulch, where they affect the quality of surface runoff water and the acidic springs issuing from the base of the mine waste dumps.

Hydrology of the Molycorp Mine Area

With the shift to open pit mining, the original extensive underground complex ceased to be pumped dry, and the drainage portal (Moly Tunnel) was sealed with a concrete bulkhead in 1992. The open pit was developed on top of the older underground workings. The location of the open pit naturally led to interception of various levels of the old workings as the pit developed. The accumulation of surface waters and intercepted groundwater flows in this pit did not interfere with operations because water drained out of the bench cuts and was held at least for a while in the underground reservoir of the abandoned workings. Within a year or two of the development of the open pit (1965),



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longtime area residents began to notice a change in the color of the Red River below Molycorp (NMED-SWQB, Jan.,1995).

In the middle reach of the Red River (from the Town of Red River to Questa, which includes the Molycorp mine area) seepage studies have documented accretion from groundwater into the Red River between Columbine Creek and Questa Ranger Station at average rates of 4 cfs (USGS, Oct. 1988). While most of the leachate from the mine waste dumps and natural acidic run-on from scar areas is collected and purposely directed by Molycorp to groundwater within the new underground mine, the numerous fracture systems in the vicinity of the mine (which are well documented in the geological literature) may provide an avenue for the collected waste water to reach the Red River. Several statements from a recent hydrogeological report suggest this possibility. The past rate of dewatering the mine, 0.55 cubic feet per second (cfs), is less than 40% of the estimated amount of water available to recharge (1.45 cfs) (South Pass Resources, July 7, 1993, p. 8). Therefore, approximately 0.9 cfs is not collected by the mine. The report continues to state that fractures in the volcanics may provide an avenue for recharge to reach the Red River. Numerous geological reports mention that dominant structural features (fractures) in the mine area trend NNE to NE. In the most recent report by Molycorp (SPRI, April 21, 1995) on the hydrogeology of the mine area is the statement: "A common thread to all these geologic studies is that the mineralization at Questa was related to Tertiary magnetism and hydrothermal solutions focused along an east- to northeast-trending structural zone." Outcrops exposed along Highway 38 just east of the Questa Ranger Station display prominent, vertically-dipping fractures that strike N55E (toward the waste dumps in upper Capulin Canyon). Acidic seeps emerge into the Red River where this fracture zone intersects the river (Figures 3 and 4). Another geological report (Schilling, 1956) states that there is only one fracture system common throughout the Taos Range; it trends east to northeast and dips vertically to steeply north. In Sulphur Gulch (area containing the open pit) fracturing is especially well defined and strikes east-west. These fractures would therefore direct groundwater and seepage from the pit area west and southwest toward the concentration of acidic seeps along Red River near the mouth of Capulin Canyon.

Conversations with the Molycorp mine manager regarding mine schematics revealed that new underground workings progress below the elevation of the Red River. Most of the drainage in Sulphur Gulch (on-site precipitation and surface run-on) drains through the floor of the open pit, and makes its way into the old underground mine workings, and thence to a 700-foot vertical bore hole that conveys the water into the new underground mine workings. This water (along with inflow of surrounding groundwater as the former cone of depression in the water table rises) was filling the new mine workings during the period of this investigation (1992-1994). Pumping to dewater the mine began in 1995. Another source of water

that is being introduced into the underground mine (and hence to groundwater) is derived from the ARD (in this case, the worst-quality water so far observed in the watershed) flowing from the base of the large waste dumps in upper Capulin Canyon and Goathill Gulch. Some of this ARD has been collected with seepage barriers by Molycorp since 1991, and is conveyed through a 1700' horizontal borehole beneath the ridge dividing Capulin and Goathill, and is then allowed to flow down Goathill Gulch and into the new underground mine workings via a large collapse depression known as the caved area (Figure 7). The collected ARD is discharged into the caved area at flow rates of approximately 70 gpm. Average total base flow of waters introduced into the new underground mine workings is estimated to be 100 gpm (70 gpm from the horizontal borehole and 30 gpm from the base flow drainage into the open pit in Sulphur Gulch) (Vail Engineering, July 9, 1993). Stormwater runoff is also purposely diverted into the caved area (via the Sulphur Gulch open pit as well as runoff from Goathill Gulch). Since run-off and collected leachate from mine waste dumps is purposely directed to groundwater in the mine, a release to groundwater exists due to the presence of contaminants in the leachate from the mine waste dumps (South Pass Resources, July 14, 1993, p. 11). The elevation of the water level in the mine workings is being maintained by pumping at approximately 7600 feet (150 feet below the elevation of Red River at Goathill Gulch) (NMED field notes, personal communication with D. Shoemaker (mine manager), Nov. 1994). However, the Red River is a gaining stream at this location. One survey (USGS, Oct.25, 1988) measured an increase in flow of 4 cubic feet per second between Columbine Creek (upstream from Goathill Gulch) and Bear Canyon (approx. 1 mile downstream from Goathill Gulch). This stretch of the Red River measures 2.8 miles and includes groundwater seeps along the northern streambed. Because these seeps have perennial flow, the water table is inferred to be the approximate elevation of the Red River which is 7,750 feet at Goathill Gulch.

The mine site has some overland flow that is not intercepted or diverted to the underground workings. New NPDES discharge locations have been included into the current NPDES permit and the construction of a rock drain at the toe of the mining waste piles adjacent to Hwy 38 purposely conveys run-off to the Red River (NMED, February 28, 1994).

The Fagerquist's Cottonwood Park is a small, 12 unit resort approximately 1/3 mile south of the Molycorp mine and 100 feet below the confluence of Columbine Creek and the Red River. The resort's well represents the nearest well supplying drinking water. With the facility on the south side of the Red River, the source for their groundwater supply is likely recharge from the Columbine Creek area. Although less likely, a portion of their water supply may come from groundwater which has drained from the north side of the Red River. Field reconnaissance has determined that no other private wells exist between the mine and Questa Ranger Station on

the north side of the Red River (same side as the mine site).

The most recent and comprehensive discussions of the hydrology of the Molycorp mine site are found in consultant reports prepared for Molycorp (South Pass Resources, July 14, 1993, Jan.28, 1994, and April 13 and 21, 1995; Vail Engineering, July 9, 1993).

Hydrology of the Molycorp Tailings Impoundments

Numerous groundwater seeps and springs (approximately 25) have been identified along the Red River below the tailings ponds. An accretion rate of approximately 18 cfs to Red River has been described from the springs draining the area in Section 35 (Vail Engineering, September 24, 1993). Some of these have been used as an assessment of ambient groundwater quality whereas others have been hydrologically influenced by the tailings ponds. A recent hydrogeological report identified five seeps with elevated sulfate concentrations which included seepage attributable to the tailings (Vail Engineering, Sept.24, 1993). Two of these seeps/springs provide a portion of the water supply for the Red River Fish Hatchery (60% spring water, 40% Red River water). The lower reach of the Red River (from Cabresto Creek to mouth of Red River) has been measured having an average accretion rate (seepage of groundwater) of 31 to 33 cfs out of a total flow of 84 cfs at the mouth of Red River (Winograd, 1959, p.40).

Groundwater and surface water monitoring data presented to NMED by Molycorp in April, 1987 revealed contamination in wells downgradient from the tailings ponds. Analyses of monitoring wells, surface water discharge points and one private well was used to characterize leachate from the tailings ponds. One problem from the 1987 data is that there is no clear background well. The report, acquiring data from 1985 and 1986, used analytical results from numerous springs and two wells in the area as background conditions. These two wells, BLM Chiflo Campground Well and BLM Headquarters Well, are located three to four miles northwest of the tailings ponds and are screened in the deep basalt aquifer at depths of 415 feet and 546 feet, respectively. All springs used to characterize background conditions are located along the Red River where only basalt exists; the Santa Fe Group alluvium is not present (South Pass Resources, Sept.23, 1993). Subsurface hydrology is complex; characteristics of water from seeps located closely together can differ considerably. Use of analytical results from numerous springs, wells and seeps may not have accurately reflected background conditions, especially for the portion of the tailings ponds which overly the Santa Fe Group alluvium. Groundwater analyses submitted by Molycorp in September, 1993 used an off-gradient well to reflect background conditions. This well, labelled MW-CB, is screened in the middle to lower units of the Santa Fe Aquifer. Results from these analyses show elevated levels above background of iron, manganese and zinc in several monitoring wells and detected levels of chromium and lead in one

monitoring well (South Pass Resources, Sept.23, 1993, Table C-1). Elevated concentrations of TDS and sulfate have always been present in samples from many of the Molycorp tailings area monitoring wells, with occasional elevated concentrations of Mo and Mn in some of the wells. Typical values (in mg/l) for contaminated groundwater at the tailings area are: TDS=1700, SO4=840, Mo=2.0, Mn=1.4 (Vail Engineering, September 24, 1993). The most recent data and discussion of the hydrogeology of the Molycorp tailings area are found in a report by South Pass Resources, April 13, 1995 (summarized in Appendix E).

### 2.3.1.2 MINING AREAS ON TRIBUTARIES

Most of the mining activity in the Red River watershed is concentrated in seven tributaries and in the middle reach of the mainstem. The tributaries with concentrations of mining activity are Bitter, Pioneer, Placer, Goose, Bear, Black Copper, and Cabresto Creeks. The most significant clusters of small mines and mineral impacts are in Bitter, Pioneer, and Placer Creeks (Figure 8). Most of the historic mining activity in the Red River watershed has been either underground or placer mining, with associated milling operations. Bitter Creek has at least sixteen abandoned mine sites that contribute NPS pollution by either runoff or seepage to the Red River. Only two mines, the Oro Fino, and the Memphis contribute ARD to Bitter Creek in regularly detectable amounts (NMED-SWQB, Jan., 1995). This volume of steady-state drainage is not significant in the overall picture of metal loading in the Red River. All of the mines along Bitter Creek contribute significant levels of NPS pollution in pulse events. Metals commonly found at elevated concentrations in both pulse and steady state drainage in these streams includes iron, aluminum, lead, copper, cadmium, and molybdenum. Pioneer Creek has at least 14 small mines that contribute significantly to metal loading in pulse events, but none of these produce significant volumes of steady-state drainage. At least 12 mines along Placer Creek contribute noticeably to pulse contaminant loading, but again the steady-state contribution is quite low.

Some of the mine sites along the tributaries of Bitter, Pioneer, and Placer Creeks had associated mill facilities during their operational periods. These mostly small mills crushed and processed ores and disposed of mill tailings along with the coarser run-of-mine wastes. Certain mill beneficiation processes used cyanide and mercury, but water samples have yet to detect these substances at significant concentrations in the vicinity of the old mills.

Bitter Creek is a major source of NPS concerns in this watershed and is effectively split into two distinct hydrologic units by three reservoirs located just above a large slump area (hydrothermal alteration scar) three miles above town (Figure 6C). SWQB staff observed Bitter Creek immediately after a summer rain



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event in August 1994. Turbidity values below the slump were in excess of 1000 NTU, in contrast to samples taken upstream of the reservoirs where turbidity was measured at less than 25 NTU. During this particular storm event, based on visual observations and turbidity measurements, the lower portion of Bitter Creek apparently is the greatest single source of sediment loading in the Red River watershed. In addition, Bitter Creek delivers the first regularly detectable infusion of acidic, metal-loaded water to the Red River through groundwater flowing within alluvium of the channel. Groundwater sampled from two private wells on lower Bitter Creek (Figure 6C) in 1993 showed indications of ARD influence; the pH was 4.6 and 4.9, and iron, aluminum, and other metals were elevated. This subchannel groundwater flow may originate as surface water above the unstable slump area and infiltrate into the aggregation of unstable material that forms the slump to emerge intermittently in Bitter Creek under normal flow conditions. Where Bitter Creek discharges into the Red River can be seen the first occurrence of white mineral deposition on the substrate of the river. These deposits, mainly aluminum hydroxide, indicate ARD and the associated acidic pH changes, but the effects here are minimal in extent and duration compared to the major seep areas below Molycorp mine at Capulin Canyon.

### 2.3.2 HYDROTHERMAL ALTERATION SCARS

Within the Red River watershed there are approximately twenty prominent erosional scars that affect the river negatively during pulse events (Figure 4). The most comprehensive discussion of geological controls on alteration scar formation in the watershed is found in a paper by Meyers and Leonardson (1990), from which the following excerpts are taken:

> "Alteration scars are landforms characterized by steep slopes, a lack of soil, iron oxide staining and clay formation, rapid erosion and common slumping and landsliding. Scars are the most visible geologic features of the Questa-Red River region and are significant in that they represent source areas for mudflows that pose a substantial geologic hazard and have significantly altered the topographic form of the Red River drainage...During times of high precipitation, waters from these scars turn the Red River orange, giving the river its name...Recent geologic mapping by the authors has led to the re-interpretation of these scars as resulting from landsliding, and other erosional processes that are enhanced in regions where the rock has been weakened by faulting and supergene (secondary) weathering of pyrite...Low-angle fault zones are pervasive throughout the Questa-Red River region and served as conduits for intrusions, molybdenum mineralization, pyritization, and as zones of weakness for later landsliding and scar formation...High pyrite zones (>3% pyrite) were favored sites for later landslide activity and scar development...a dominance of mass transport processes inhibit

soil development...Secondary earth materials in the alteration scars include colluvium and ferricrete...Ferricrete is an iron oxide and silica-cemented rock that forms in regions of seepage from shallow-source waters that recharge from higher portions of the scar...Highly permeable colluvial deposits are commonly cemented during this process and form striking ferricrete breccias...A number of geologic factors control development of alteration scars...In order of decreasing significance, the major controls are slope angle, tectonic fracturing, pyrite content, and vegetative cover. A slope angle in excess of 25 degrees is a primary requirement for generation of all alteration scars in the region. Slope angles less than 20 degrees do not contain the driving force required for the initiation of mass-wasting processes...Pyrite contents of 3-5% are common in scar areas, whereas pyrite contents near 1% are typical throughout most of the region. Pyrite weathers in the near-surface environment to form iron oxides and sulfates. Acidic water generated from oxidation of pyrite reacts with feldspar minerals in the rock to form clay minerals, which have very low shear strength when saturated with water...Scars are believed to be initially exposed by landsliding in regions that are oversteepened by headward erosion of drainages...Erosion of scar interiors occurs at a very rapid rate, as drill roads in scars that are 20-25 years old are locally dissected by as much as 10-15 m...The scars pose a hazard to the region as a significant number of roads, buildings, and campsites are located on debris aprons deposited by mudflows that originated from the scars...In 1982, mudflows from the Hansen scar area resulted in a fatality to a motorist...The debris aprons cause stagnation of flow in the Red River drainage and the formation of upstream meadows."

Some of the scars show signs of mineral exploration roads and mines that obviously predated the present accelerated erosional episodes. Most of the erosional scars are located on south-facing slopes where vegetative colonization is tenuous. Any sort of disturbance that provides a nick point for erosional headcuts to begin can result in the loss of entire mountainsides. Where this process is advanced, the exposed fractured sulfide rock comes in contact with precipitation and oxygen, and acid drainage is the result.

The increase in metal loading of the Red River in a downstream direction is at least partially attributable to the acid drainage from scar areas (Smolka and Tague, 1987 and 1989; Vail Engineering, July 9, 1993), although, as mentioned above, many of these areas have been modified by a number of anthropogenic activities. While some of this drainage reaches the Red River by overland flow (e.g. Hansen Creek and Haut-n-Taut Creek), much infiltrates the colluvium and river channel alluvium and discharges to the Red River through seeps/springs. Many of these seeps have perennial flow, even during dry seasons. Therefore, an undetermined portion of the seep

is likely attributable to groundwater which recharges the river. Similar problems exist elsewhere in other mining districts that also contain scar areas. Since the advent of the Summitville Mine disaster in Colorado in 1993, much research has been conducted in that area. Sources of acidity and heavy metals in the Alamosa River Basin (from both mining and seeps related to natural scar areas) have been extensively studied (Kirkham, et. al., 1995). In some watersheds it was found that most degraded water resulted from natural processes, and in others the relative contribution of mining was calculated from estimated flow rates and loading of dissolved metals.

### 2.3.3 LEAKING UNDERGROUND STORAGE TANKS

In the Red River watershed there are three known sites where underground storage tanks have leaked petroleum products, all within the Town of Red River. None are yet known from the Village of Questa. The three sites in Red River are in various stages of investigation and remediation under the oversight and regulatory authority of the NMED Underground Storage Tank Bureau (USTB). A release from at least one of the sites was documented as directly contaminating the Red River with hydrocarbons. There is also the ever-present threat to water resources from petroleum products spilled in accidents, dumped illegally, or disposed carelessly (i.e., individuals changing motor oil near streams or storm-drains). The known leaking USTs are described below:

Chevron Red River: Southeast corner of Main Street and Jacks & Sixes Street in Red River. This facility is closed and is now occupied by High Country Jeep Rental. Contamination was discovered during removal of three USTs in August 1991. The site became a State Lead Site in the USTB in May 1992 after contaminated groundwater was discovered entering a storm sewer drain that emptied to the Red River 350 feet south of the site. Groundwater at the site is very shallow, fluctuating seasonally to within two feet of the surface. A hydrogeological investigation was completed in August 1992 with the installation of twelve monitoring wells. An air sparging remediation system was installed by July 1993, with an estimate that cleanup would take two years. Quarterly sampling is done to monitor the systems effectiveness and rate of contaminant reduction, which has been satisfactory.

Old Diamond Shamrock Station: This was formerly a Chevron Station and is located on the south side of Highway 38 in the center of Red River. In September 1991 four tanks (3,000 gallons each) were permanently closed. The tanks were almost completely under water (shallow groundwater), and contamination of both soil and groundwater was documented by inspectors. The water table at the site is as shallow as three feet, and the Red River is located 150 feet to the south. The responsible party (Colomex Oil and Gas Co.) was

very delinquent in responding to repeated requests and warnings from the USTB to begin the required site investigation and remediation process. In January, 1995 a consultant had been retained to initiate a hydrogeologic investigation (personal communication, Chris Holmes, USTB, January, 1995).

Red River Ski Area: Located at the Red River Ski area between the maintenance shop and Pioneer Creek. The site is still active but two USTs were removed in May 1993. The tanks were within 50 feet of Pioneer Creek. Contaminated soil was detected by the USTB inspector at the site (to 1300 ppm at a depth of 16 feet). A site summary by the USTB in August 1993 includes these remarks: "considerable soil contamination, Pioneer Creek is threatened, contaminated soil placed onsite, this site has languished...". Several joint site inspections were made during 1994 by staff of SWQB and USTB to check for signs of hydrocarbon pollution in Pioneer Creek and to motivate the operator to comply with the required site investigation and remediation process. On January 6, 1995 the operator submitted the required On-site Investigation Report. The report described the six soil borings and five monitoring wells installed and sampled. The contamination is diesel fuel and is present only in the immediate vicinity of the former USTs. Plans for remediation are underway.

### 2.3.4 SEPTIC TANKS AND SEWAGE LAGOONS

The upper Red River valley (above the Town of Red River) has become densely developed with subdivisions having hundreds of homes on small lots (Figure 2). A total of at least 410 houses are reported to exist in the upper valley as of 1995 (personal communication, Bob Perry, Director of Public Works, Town of Red River, 1995). Many of the lots are as small as 1/4 acre, and all have individual liquid waste systems (septic tank leach fields or holding tanks). There is no community waste treatment system or water supply system in the upper valley. Because these leach fields are in close proximity to the river (some homes are within twenty five feet of the river) in an area of very shallow groundwater and permeable alluvial soils, there is a concern that effluent from the leach fields is contaminating the shallow groundwater and seeping into the river.

The Village of Questa discharges up to 60,000 gallons per day of domestic sewage to a series of four lagoons (a fifth is currently under construction) located 1.5 miles southwest of Questa and approximately 300 feet from the Red River. This discharge is permitted and monitored under a NMED Ground Water Discharge Plan (DP-191), which was originally approved in 1983. The location of the lagoons is shown in Figures 2 and 3. These lagoons are unlined and are designed to function as rapid infiltration basins. (Questa is in the process of installing two lined lagoons for primary

aeration and settling, which will precede discharge to the infiltration lagoons). The Red River is a gaining stream in this area (see Section 2.1.1) and groundwater flow is from the lagoons toward the river. Some groundwater contamination is expected to occur in a limited area, and is monitored by a set of four monitoring wells located between the lagoons and the river. Property owners in the area have agreed not to drill any wells nearby. The ultimate discharge of the sewage effluent is to the Red River, where due to dilution by river water and by groundwater flowing through the highly transmissive alluvial aquifer, contaminant levels are expected to be well below surface water standards. Concentrations of the expected contaminants (nitrate, TKN) have in fact been below state standards in the monitoring wells and in the river (DP-191 file, NMED Ground Water Section).

# III. INVESTIGATION

## 3.1 METHODS AND DATA COLLECTION

### 3.1.1 General Approach - Research Design

Water quality data from samples collected by NMED are summarized in Tables 1 and 2, with locations of samples shown in Figure 6. All field procedures and analytical work were performed in accordance with the SOPs for the NMED Groundwater Quality Bureau and Surface Water Quality Bureau. Field screening was used to select sample points (measurement of field parameters such as pH, conductivity, temperature, DO, turbidity). All analytical work was done by the NM Scientific Laboratory Division (SLD) in Albuquerque in accordance with the QAPP for this project, with the exception of data generated by the NMED Superfund Oversight Section, which used EPA Contract Laboratories (that data is tabulated in Appendix A). Sampling was designed for the following locations and purposes:

1. Twelve monitoring wells were drilled by Molycorp along the Red River between the Molycorp mill and the Questa Ranger Station to determine groundwater quality, evaluate aquifer characteristics, and to aid in attribution of the sources of numerous acidic seeps that are impacting the river. Appendix C contains the rationale for well locations, screen placements, and completion data for these wells. All drilling and sampling activity was closely coordinated between NMED programs, Molycorp, and South Pass Resources Inc. (SPRI - consultants to Molycorp). Wells were sampled in November, 1994 for metals (total and dissolved) and anions/cations in accordance with the QAPP and with protocol established by the NMED Ground Water Section. Sampling frequency will be semi-annually for the first year (in order to evaluate seasonal hydrologic fluctuations), and annually after the first year. Data generated by this project will be evaluated by comparing the analytical results to the numerical water quality

standards for groundwater promulgated by the NM Water Quality Control Commission (WQCC).

2. Groundwater was sampled by Molycorp within the underground mine workings (see Appendix D, Table D4), to characterize the water that is currently flooding the mine, as well as to characterize background groundwater where it enters the upgradient side of the mined area as seeps. Samples were analyzed for metals (total and dissolved) and anions/cations, on a one-time basis. Molycorp has been recording water levels and sampling water in the mine on a monthly basis.

3. Potential impacts of the old Molycorp "landfill" in Spring Gulch were evaluated. Two monitoring wells (MMW-14 and 16) were installed by Molycorp in the vicinity of the confluence of Spring Gulch and Sulfur Gulch in 1994. Reports from EPA inspections were evaluated, and the site was inspected again in 1994 by SWQB staff.

4. Existing wells located upgradient of Molycorp (Red River Wastewater Treatment Plant, Molycorp mill production wells) were sampled to better determine "background". Samples were analyzed for metals (dissolved) and anions/cations, according to the protocol established by the NMED Groundwater Section.

5. Approximately ten selected acid seeps along the Red River were monitored for changes through time. Seeps were observed, measured for field parameters, and sampled for metals (total and dissolved) and anions/cations. The most significant source area for acid seeps (Capulin Canyon) was sampled on five different occasions to check for seasonal variations and to provide sufficient data for statistical analysis.

6. Samples were collected from the Molycorp mine dump leachate from seepage collection systems in head of Capulin Canyon and Goathill Gulch. Water chemistry was compared to that of the acid seeps along the Red River. Samples were analyzed for metals (total and dissolved) and anions/cations.

7. River water was sampled to evaluate possible contamination from septic tanks in developed areas along headwaters of the Red River upstream of the Town of Red River. Samples were collected one time only, during the summer season (most of these houses are summer homes), and analyzed for NO3, TKN, and anions/cations.

8. The existing monitoring wells (14) and springs in the Molycorp tailings area were sampled in order to update the existing data base of water chemistry for characterizing groundwater contamination from tailings and the possible impact to the Red River. Included are the two springs used for water supply by the Red River Fish Hatchery. Monitor wells were sampled in August, 1993 and November, 1994.

Along with the sampling program listed above, the following pertinent and accessory tasks were undertaken as part of this project:

1. Acquire and study well/borehole logs and well construction details for wells sampled in order to meaningfully compare analytical results.

2. Conduct further sampling and observations on the scar areas in the Red River watershed in order to better understand the relative contribution of acidic, metal-laden waters from the scar areas and from recent mining activity.

3. Evaluate aerial photography for structural clues in aiding placement of monitoring wells, and possible clues concerning fracture systems that could influence groundwater movement in the mine area.

4. Evaluate the possibility of conducting dye tracing experiments to confirm hydrologic connections between the seeps along Red River and certain areas on the Molycorp property.

5. Investigate three sites in the Town of Red River where underground storage tanks (USTs) are reported to have leaked. Coordinate activities with NMED UST Bureau (the lead agency for enforcement/remediation of USTs). This project will evaluate the status and effectiveness of efforts by the UST Bureau and will assess any groundwater contamination impacting the Red River from USTs.

6. Continue to monitor performance of the Oro Fino Mine demonstration project (anoxic alkaline drain) on Bitter Creek, a tributary of the Red River, that was installed in September, 1993. Performance is evaluated by measuring field parameters and sampling discharge for metals (total and dissolved) and anions/cations, on a semi-annual basis.

7. Conduct X-ray Fluorescence (XRF) surveys of mine wastes at Molycorp (tailings and mine dumps) and possibly other mining sites in the watershed to better quantify metals concentrations available for release to surface water and groundwater. The XRF work at Molycorp will be done in cooperation with a NMED Superfund investigation.

8. Conduct an inventory of septic tanks and other onsite waste disposal systems in the heavily developed areas upstream of the Town of Red River. This information can be used to evaluate the likelihood of groundwater contamination from septic tanks in the headwaters of the Red River. It can be used to plan sampling methods and locations.



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9. Complete an inventory of all abandoned mine sites in the tributaries of the Red River (Placer Creek, Pioneer Creek, Bitter Creek, Cabresto Creek, Goose Creek, and Black Copper Canyon). Prioritize sites according to their threat to groundwater and the Red River.

### 3.1.2 Molycorp Mine Site

A release of contaminants to the Red River from the mining site results primarily from ARD-impacted groundwater seeps which are derived in-part from infiltration through the waste rock piles, open pit, and underground workings. While much of the run-off from the waste rock piles is directed to groundwater via the mine workings, a portion of the runoff may drain to the Red River. Some of this runoff is collected and discharged (during extreme runoff events only) to the Red River via Molycorp's recently renewed NPDES permit. Other nonpoint source discharge occurs where rock drains have been constructed at the toe of waste rock piles in Sulphur Gulch to convey water to the Red River (NMED, Feb.28, 1994, p. 29). Most of the overland flow not discharged under the NPDES permit is likely to infiltrate the alluvium of tributaries and the river channels prior to reaching the Red River. Therefore, seeps/springs located downstream from the mining site were sampled and evaluated.

Evaluation of the impact of the Molycorp mining operation on the Red River must distinguish effects which occur naturally. Background and downgradient groundwater samples were used to determine any observed release of contaminants. With variations in lithologies (including the presence of alteration scars that surround and underlay much of the Molycorp site), geologic structures, and mining operations over the entire mine site, background conditions are not considered to be homogeneous. Therefore, several sampling locations were used to evaluate background groundwater chemistry. These locations (listed below) have been selected to represent groundwater which flows through either the fractured bedrock aquifer, the alluvium of the Red River channel, or alluvium in the side channels (tributary drainages) which is impacted by natural scar drainage. Separation of groundwater flow into these three systems is useful in understanding general hydrogeology near the mine site and assists in defining sources for the seeps near the Red River. It does not, however, necessarily preclude communication among systems.

Potential background groundwater samples were collected from seven separate sources to evaluate groundwater contamination from the mine: the water which is currently filling the new underground workings; water accumulating in higher-level mine workings; a groundwater sample from one of the two production wells at the mill site; a groundwater sample from the Red River Waste Water Treatment Plant; samples from wells at Elephant Rock and Fawn Lake Campgrounds; and a seep near the mouth of Hansen Creek (fig. 6C). The water which is currently filling the mine (new workings) is



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groundwater which receives surface run-off and collected leachate (ARD) from the mine waste dumps. While this groundwater is presumably impacted (i.e. geochemically altered) by surface drainage, it is of better quality than seepage at the river and may be useful as an approximation of background conditions for comparison to the seeps along the Red River. With few alternative sampling locations, use of the groundwater from the deep mine workings to represent background conditions was deemed appropriate.

Downgradient groundwater samples were collected from twelve of the seventeen seeps (Figure 6, Table 1) which have been identified along the Red River from Molycorp to Questa Ranger Station (Vail Engineering, July 9, 1993). Selection of specific seeps to be sampled was based upon field readings of electrical conductivity and pH during preliminary field reconnaissance. One of these seep areas is located at the mouth of Capulin Canyon and extends approximately a quarter-mile below Capulin Canyon (Figures 3 and 7). An opportunity for collecting a sample of ARD-influenced groundwater near the Capulin seeps was serendipitously provided by highway construction during September, 1993. An excavation on the north side of Rt. 38, approximately 700 feet south of Capulin Canyon, revealed groundwater at a depth of only six feet with a pH of 3.9. Other, equally poor quality seep water was also found filling a segment of old (abandoned) river channel approximately 500 feet downstream of the mouth of Capulin Canyon. All of the above sample locations are part of a single source consisting of a linear seep front along the north bank of the Red River extending from the mouth of Capulin Canyon downstream for hundreds of yards. Samples of groundwater considered to be down-gradient of Molycorp mine wastes were also collected at other seeps, notably the Portal Spring and Cabin Springs areas (Figure 7).

Sampling included water samples from both the seeps and Red River. Surface water samples were collected above the Molycorp property boundary, below Sulphur Gulch, above, within and below Columbine Creek (a major tributary) and above and below each of the two reaches where seeps are numerous. Samples of surface water and seepage were analyzed for both metals and general chemistry.

To evaluate possible impacts from the former Molycorp waste disposal (landfill) site in Spring Gulch, reports from EPA Site Inspections (1983 and 1985) were evaluated, and the site location was inspected. Two groundwater monitoring wells were installed in Sulphur Gulch below the mouth of Spring Gulch in the 1994 drilling season, but these wells have so far been dry.

Determining attribution of contaminants to the Molycorp Mine requires the characterization of leachate emanating from the waste-rock and comparison to water chemistry of the acid seeps. Water chemistry was evaluated at water sampling locations to determine whether a chemical similarity exists between the leachate from the mine waste piles and the downgradient seeps. Leachate samples

were collected from the toe of the waste-rock piles at the head of Capulin Canyon and Goathill Gulch (Figure 7). Leachate samples were also collected from hydrothermal scar areas (Figures 3 and 4). Molycorp consultants who are expert in ARD, along with Unocal research staff, are continuing to research methods of fingerprinting waters from various sources at the mine site, including environmental isotopes (Steffen, Robertson and Kirsten, April 21, 1995).

Dilution of groundwater from seeps by river water flowing through the alluvium was expected. Sampling sometimes involved the collection of groundwater from small pits dug into the river alluvium immediately below a seep. Sampling was located closer to the mouths of the side canyons so as to minimize the dilution by river water within the channel alluvium. To minimize the number of sampling pits, selection of pit locations was directed toward those seeps containing higher concentrations as determined during reconnaissance sampling. Samples were analyzed for general chemistry and metals.

During the period July-September, 1994, Molycorp drilled twelve new monitoring wells in the mine area, at various locations along the Red River canyon. Locations of these wells are shown on Figures 6B and 7, and the rationale for their siting, along with completion information is given in Appendix C. These are the first monitoring wells to be drilled in the vicinity of the mine and the waste dumps. They were sampled initially in early November, 1994. A discussion of the results of sampling and well pumping tests is given in Appendices B and D. In addition to these twelve new wells in the mine area, two new groundwater extraction wells (for use in remediation) were also drilled in the tailings area during the 1994 drilling season. Consultants responsible for planning and monitoring the drilling program were with South Pass Resources. Major reports from South Pass Resources evaluating the results were submitted to NMED in April, 1995, along with recommendations for the next phase of investigations. In addition, other Molycorp consultants (Vail Engineering) have been conducting semi-annual river surveys of the middle reach of Red River to sample and measure pH and conductivity at dozens of stations (river water and seeps). The consulting firm of Steffen, Robertson, and Kirsten has conducted an initial geochemical assessment of the mine site to evaluate ARD conditions there (Stephen, Robertson and Kirsten, April 13, 1995). A summary of their findings is given in Appendix F.

### 3.1.3 Molycorp Tailings Site

Because the Molycorp mine site apparently has a greater relative impact on Red River water quality than does the tailing impoundment area (where most of the seepage is intercepted and directed through an NPDES-permitted outfall), less emphasis was placed on investigation of the tailings area in this project. This rationale

is further justified by the fact that a great deal of work had already been done in the tailings area in past years by NMED Groundwater Section and by Molycorp consultants. For instance, although the mine area had no monitoring wells prior to 1994, the tailings area contained fourteen existing monitoring wells when this project was initiated. Much analytical data from the existing monitoring wells and from private wells and springs was already available. However, some existing wells were sampled in conjunction with ongoing investigations of the tailing area by both the NMED Groundwater and Superfund Oversight Sections during this project, and several newly installed monitoring and extraction wells were also sampled. The most comprehensive discussions of seepage from the tailings dams are contained in reports by Molycorp consultants (Vail Engineering, September 24, 1993 and August 24, 1989; South Pass Resources, Sept.23, 1993 and April 13, 1995).

The purpose of groundwater sampling in this area was to document or confirm a release to the aquifer underlying the tailings ponds and determine the level of contamination and the relative contribution to the Red River. Sampling locations consist of those monitoring wells recently sampled by both Molycorp and NMED-Groundwater Section which demonstrated elevated levels of TDS and sulfate. Prior analyses of monitoring wells 1-4 showed detectable levels of lead, zinc and copper in well #3 and zinc in the other wells (NMED, Feb.28, 1994). All four of these monitoring wells were sampled. One background sample was collected from a monitoring well, labelled MW-CH, located east of Dam 1 tailings pond, and from major springs located in the Rio Grande Gorge (Figure 6A).

### 3.1.4 Other Nonpoint Sources

#### Septic Tanks

As mentioned earlier, the upper Red River valley (above the town of Red River) has become densely developed with subdivisions having hundreds of homes on small lots. Many of the lots are as small as 1/4 acre, and all have individual liquid waste systems (septic tank leach fields or holding tanks). During site inspections in 1994 an attempt was made to count the number of houses in this area. In the area between Fourth of July Canyon and Foster Park Canyon (an area of 1.5 miles by .25 miles) approximately 125 houses were counted. This area includes the Valley of the Pines Subdivision (the lowest subdivision in the upper valley), and many of the houses are located very near the banks of the river. Others are built on very steep slopes that appear to have thin soils overlying bedrock. The subdivisions in the upper valley area above Fourth of July Canyon contain approximately 200 houses (difficult to count because many are in forest). An initial effort to quantify the septic tank situation was made by contacting the NMED Field Office staff in Taos, NM for information about liquid waste permits, which are required for construction of any household waste disposal

system. The Environmentalist in charge of the Red River area (Bill King) indicated that such information would be meaningless because some builders in that area apparently do not apply for the permit and install their septic tanks illegally. He had only received two requests for liquid waste permits in the last six months, and believed that many more houses than that had been built in that period. Enforcement is a problem. Other NMED staff from SWQB were told of concerns by a local resident about illegal installations by a local plumbing contractor in the area who was installing holding tanks (that should be pumped out when full) with holes punched in the bottoms. Strategies for documenting pollution in groundwater and the river include sampling the river near observed algal blooms, and sampling private wells for analyses of nitrate and TKN. As a field screening technique to identify possibly contaminated wells, approximate nitrate concentrations can be determined in the field by using one of the Department's Hach Kits, which use a colorimetric technique to quantify nitrate (10 mg/l is the NM groundwater standard). Confirmatory samples would then be submitted for laboratory analysis.

During 1995 others expressed additional concern over potential problems in the upper valley, and began coordinating activities in this regard. Bill King (NMED, Taos Field Office) reported receiving increasing numbers of complaints from upper valley residents about failing septic systems. (Efforts to address septic systems are handled through NMED's Liquid Waste Program). Bob Perry (Director of Public Works for Town of Red River) assumed a leadership role in the recently created Red River Watershed Association, and began to focus on the water quality impacts in the upper valley. From a coordination meeting between these parties in April, 1995, it was determined that there are approximately 450 houses in the upper valley now, with a capacity for about 1000 more in the future. Only 203 houses have been issued Liquid Waste Disposal Permits from NMED since 1973, implying that over 200 have illegal systems. It is assumed that there are at least 400 private water supply wells in the area. In order to curtail the installation of more illegal systems and to alleviate existing (probable) water quality impacts to the Red River from the upper valley, the Town of Red River would like to extend its sewer and water service to the upper valley. The existing WWTP can handle the increased flow, and costs are estimated at approximately ten million dollars. The town is applying for assistance in funding this project, and hopes for completion in about five years. In order to further document the need for this project, several activities will be conducted in the upper valley during the summer months of 1996 in joint efforts between the Town of Red River, the NMED Taos Field Office, and NMED-SWQB. A Water Fair will be held, during which residents can bring samples of their well water for testing and analyses (nitrate screening being used to indicate possible contamination with septic system wastes). To follow up on wells that may be contaminated, inspections and possibly dye traces will be conducted. Both banks of the river will be walked

through developed portions of the upper valley to look for evidence of illegal direct discharges to the river and for signs of failing septic systems in proximity to the river.

Leaking Underground Storage Tanks

Since the NMED Underground Storage Tank Bureau (USTB) has regulatory authority over investigation and remediation of sites contaminated by leaking USTs, the role of this project in regard to UST sites has been to consult with and maintain close communication with the appropriate technical staff in the USTB about progress at the three known sites in the Red River watershed. Their files were copied and incorporated into the records for this project, and site visits were coordinated with USTB staff for all three sites in Red River. Quarterly monitoring reports, data, and consultants reports are provided to this project as they are received by USTB staff. Frequent inspections have been made for evidence of hydrocarbon release at the Chevron Red River site, where past discharges to the river through a storm sewer have been observed.

Questa Sewage Lagoons

The Questa sewage lagoons fall under the regulatory authority of the NMED Ground Water Section, which reviews the required groundwater monitoring at the facility through a Ground Water Discharge Plan (DP-191). These analytical results, which have not revealed contamination above State standards, are on file with NMED-GWS. This project reviewed the DP-191 file and consulted with Ground Water Section staff, but did not see a need to conduct any further sampling or field work at this site.

Scar Areas

The approximately twenty alteration scars in the watershed are a significant source of NPS pollution due to their extreme sediment yields in pulse events and, more importantly to this project, their steady-state ARD. It is therefore important to understand their geochemical nature in order to distinguish their naturally occurring "background" effects on Red River from the impacts of Molycorp and other mining sites. Much of the Molycorp mine site is surrounded by large scar areas in the upper parts of Goathill Gulch and Sulphur Gulch. The waste rock dumps in these drainages overlay scar material in places. Some scars that are distant from Molycorp (Bitter Creek, Hansen Creek, Haut-N-Taut Creek) have discharges of natural ARD, although some evidence of exploration roads and mining within these areas raises the question of how natural the erosion rates and consequent ARD generation are (Morain, 1996). In order to facilitate a better understanding of the role of alteration scars in Red River water quality, numerous scars were observed (primarily upstream from Molycorp) under conditions of base flow and pulse events. Seeps issuing from scars

were documented and sampled, as well as surface runoff in tributary channels and Red River above and below their confluences. Preliminary laboratory leaching tests were conducted, as were a few XRF evaluations, of scar materials. Aerial photos were obtained and studied for clues in scar development and growth, and evidence of roads and mining activity within scars was documented. In a few locations on Bitter Creek it was possible to sample groundwater from private wells that are believed to be impacted by scar-derived ARD. Analytical results of groundwater were evaluated by various graphical and comparative methods along with sample results from Red River seeps and mine waste leachate. Further research into scar areas and BMP treatments will be forthcoming under a SWQB project directed at the slump (debris flow) problem in Bitter Creek in an EPA Section 319(h) FY95 Grant (94-B).

Old Mining Areas on Tributaries to the Red River

In order to evaluate the potential for nonpoint source impacts to the Red River from seepage of contaminated groundwater from mining sites in the old mining districts encompassing tributaries, extensive field reconnaissance was conducted in Placer, Pioneer, Goose, Cabresto, and Bitter Creeks, and Fourth of July and Black Copper Canyons (Figures 2 and 8). In addition, information was obtained from the following sources:

> Screening Site Inspection for the Red River Mining District, August 31, 1989, by Dale Doremus, NMEID Superfund Section.
>
> Geology and Ore Deposits of Eagle Nest Area, NM, 1972, by K.F. Clark and C.B. Read, NMBMMR Bulletin 94.
>
> USFS, Carson National Forest, n.d., brochure on the Mining history of Pioneer Canyon.
>
> USFS, Carson National Forest, Questa Ranger District, report and files from mine surveys conducted in 1990 and 1991 on Pioneer Canyon, Placer Creek, and Bitter Creek.

Results and further discussion of scar areas are given in Section 3.2.3.

## 3.2 RESULTS AND DISCUSSION

A summary of the analytical data for water samples collected by NMED-SWQB during this project is contained in Tables 1 and 2, with sample locations shown in Figures 6A,B,C. Data from samples collected by NMED Superfund Section in the 1994 investigation of Molycorp Mine are given in Appendix A. Other environmental data collected by Molycorp and their consultants are included in Appendices B through F. The analytical data reports from the various laboratories used by NMED-SWQB, NMED Superfund, Molycorp,



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and others are not included in this report; summations of the data are given in the appropriate tables. The data report sheets are on file with the respective sources.

### 3.2.1 Molycorp Tailings Area

As discussed in Section 3.1.3, the tailings area hydrogeology has been studied and characterized in numerous investigations by NMED and Molycorp consultants since the mid-1980's. The most current understanding of the hydrogeology and water quality of the area is presented in reports submitted to NMED by Molycorp (SPRI, April 21, 1995 [summarized in Appendix E of this report] and September 23, 1993). Portions of the discussion that follows are based on information contained in these reports. The most current analytical data for groundwater samples collected by NMED from wells in the tailings area are found in Tables 1 and 2, and in Appendix A.

Seepage from the tailings has contaminated the underlying shallow alluvial aquifer with elevated concentrations of sulfate and TDS, and in several monitoring wells with elevated concentrations of Mn and Mo. As an initial groundwater remediation (containment) effort, Molycorp has constructed seepage collection barriers between the toe of the dams and Red River. Collected seepage water is discharged to Red River via NPDES-permitted outfall #002.

In 1994 five new monitoring/extraction wells were installed in the tailings area by Molycorp, bringing the total number of monitoring wells in that area to fifteen. Water from wells located east of Dam #4 and south and east of Dam #1 are characterized by a high-TDS, calcium sulfate water that derives from tailings seepage.

The major hydrogeologic units in the tailings area are the Santa Fe Group (an alluvial sequence of aquifers and aquitards) and the underlying volcanic sequence consisting of a basalt unit that extends beneath both tailings ponds and a sequence of tuffs and lava flows in fault contact with the basalt and the Santa Fe Group along the west side of Dam #4 (SPRI, April 31, 1995). Groundwater flow paths are influenced by northeast-trending high-angle fault lines. There are multiple perched groundwater zones in the Santa Fe Group. The main perched zone is south of Dam #4 and may extend to the Red River.

Piezometric surfaces are complex composites involving unconfined and semi-confined conditions in the various units. The shallow private wells that are contaminated by leachate are probably screened in the main perched zone, whereas deeper wells screened in the basalt unit or lower aquifer unit of the Santa Fe Group contain water that meets drinking water standards (except for wells MW-1 and EW-1). Groundwater flow directions in the basalt aquifer range from S20W to S75W; hydraulic gradients range from 0.1 ft/ft to as low as 0.003 ft/ft. Flow rate estimates were calculated by



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SPRI from a mixing equation for the volcanic aquifer at Dam #4 at 5.9 cfs. This suggests a high degree of dilution for any leachate from the tailings that reaches the water table (and the river), and appears to be supported by sulfate and TDS values of samples from MW-11, Red River, and springs down-gradient of Dam #4. Mixing equations and sample data both indicate that there is sufficient dilution from both the high groundwater flow rates in the basalt aquifer and from the Red River to dilute inflow from the perched zones to below State standards for both groundwater and surface water. The section of river that may be receiving tailings seepage is 1.8 miles in length (between the #002 outfall and the Fish Hatchery). This portion of the Red River is well-documented to be a gaining stream. The various studies that have been done in the area generally conclude that the net gain between Questa and the confluence with the Rio Grande is approximately 30 cfs. Vail (1993) provides the most recent estimates for groundwater accretion and the contribution of sulfate concentrations from each tributary source. Accretion estimates for the alluvial section of river between the highway bridge at Questa and the Questa Springs complex indicates sulfate concentrations can be expected to increase from an average value of 119 mg/l at the bridge to 131 mg/l below the springs complex. This calculation considers dilution of seepage waters having elevated sulfate concentrations in the range of 800 to 1000 mg/l. Samples of river water below the spring had a sulfate concentration of 138 mg/l. Similar results derived for the portion of the river in the upper gorge (above the Fish Hatchery). For more detail on these calculations and sampling data see Appendix E. Analytical data from samples collected by NMED-SWQB from springs flowing from the basalt aquifer at locations in the lower Red River Gorge and the Rio Grande Gorge (Figure 6C, Table 1) further support the general conclusion that seepage from the tailings area currently is not significantly impacting the Red River, and the seepage is not hydraulically connected to the Rio Grande. Similarly, the two spring complexes being used as a water supply by the Fish Hatchery, although seemingly in a vulnerable location near the tailings dams, are to date not contaminated above standards by leachate (Table 1, Figure 6C). In a seepage analysis of the tailings ponds Vail estimated that the Hatchery's warm water supply may be composed of approximately 43% seepage water from the tailings area (Vail Engineering, September 24, 1993). Sulfate concentrations in tailings seepage was given as 120 mg/l, and that from the spring discharge (a mixture of tailings seepage and clean groundwater) as 63 mg/l. Thus there is some contamination by tailings seepage in the Hatchery warm water spring, but due to dilution it does not result in an exceedance of groundwater standards.

### 3.2.2 Molycorp Mine and the Hydrothermal Alteration Scar Areas

The hydrogeology of the Molycorp Mine area has been previously discussed in Section 2.3.1.1 and is further discussed in reports by Molycorp consultants (South Pass Resources, Inc., Vail

Engineering, and Steffen, Robertsen, and Kirsten, Inc.), portions of which are included as excerpts in Appendices B through F. Figures 4 and 7 show maps of the area, and analytical data relevant to this discussion are in Tables 1 and 2, and in Appendix A.

The middle reach of the Red River from Questa to the Town of Red River, and containing Molycorp Mine and most of the major scar areas, became the primary focus of this project because it is here that the most significant water quality degradation to Red River occurs. A number of river surveys by NMED and Molycorp have documented significant declines in Red River water quality progressing downstream from the town of Red River to Questa (Smolka and Tague, 1987 and 1989; Vail, July 9, 1993; and unpublished data). The negative but temporal impacts of stormwater runoff are likewise well-documented, and have been previously discussed. Management of stormwater runoff by Molycorp has apparently been effective in eliminating surface discharges from the mine site to Red River (based on NPDES reporting and on field observations during storm events). Of primary interest in this project is the role of steady-state contribution of ARD to Red River in the form of acid seeps and perennial drainage that originates from Molycorp sources as well as from naturally occurring hydrothermal alteration scars in the watershed. Distinguishing the relative contribution of these two sources is thus a critical aspect of this and other regulatory efforts focused on Molycorp. The commonly accepted approach of sampling groundwater at locations upgradient of the source(s) of contamination is not so easily applied at Molycorp Mine because of the presence of potential natural sources of ARD (scar areas) located upgradient of, and beneath, the mine area. The structural and mineralogical complexity of this area makes hydrogeological interpretation difficult.

Groundwater flow in the mine area is controlled by fractures and faults, preferred channels within debris flow material, and differences in hydraulic conductivity between bedrock, mine waste rock piles, and valley fill/alluvium. Hydrogeologic units are a Pre-Cambrian aquitard, volcanic and sedimentary rock aquifers, and valley fill alluvial or debris flow aquifers. The waste dumps contain perched aquifers. Groundwater gradients are toward the Red River, except for the cone of depression created by mine dewatering. Fan delta deposits at the mouths of tributary canyons are the principal hydraulic connection between the river and up-gradient sources. During 1994 twelve monitoring wells were installed by Molycorp consultants (SPRI) at sites near the mouths of tributary canyons draining the mine area, and were screened in bedrock and fan delta aquifers. Sampling and water level measurements have been conducted jointly by NMED and SPRI.

Water sampled from wells, seeps, and the underground mine workings is derived from both natural and mine-related sources. The river is the primary discharge point for groundwater systems in the area, but the deep underground mine intercepts some of it, which is

dewatered by pumping via the slurry line to the tailings impoundments at Questa. Thus water impacted by acidic drainage, from mine sources as well as natural scar areas, is discharged by natural drainage to the Red River and by pumping and pipeline flow to the tailings area.

3.2.2.1 Water Quality of Seeps and Red River

Although more than twenty individual seeps have been identified along the north side of the Red River between Questa and Molycorp, there are three principal areas of concern where seepage is concentrated and appears to have the most significant impact on water quality - Capulin Canyon, Portal Spring, and Cabin Spring (Figure 7). Although water chemistry varies between seepage areas and is somewhat site-specific, all are acidic (pH ranges from 2 to 5) and contain elevated concentrations (exceed NM groundwater standards) of sulfate, TDS, Al, Fe, Mn, Co, Cu, Ni, Zn, Cd, and Fl (Table 1). Of the three seepage areas mentioned above, the one at Portal Springs (#40 and 41 in Table 1, POS-1 in Table D2 of Appendix D) is located nearest to Molycorp sources, being situated within a hundred yards of the toe of the Sugar Shack waste-rock dump complex. It is likewise located in proximity to the mouth of the Moly Tunnel (hence the name Portal Spring). Portal Spring was discovered by the author on January 19, 1994. In previous inspections of the area no seepage was observed in this location. Following consultation with Molycorp it was realized that this represented a newly emerged seep; it has been flowing perennially since January 1994. The Molycorp workplan for placement of monitoring wells was consequently modified to include characterization of this area.

The Cabin Springs seepage area is located 0.5 mile south/southwest of the Sugar Shack dumps, and the Capulin Canyon seepage area is located approximately 1.5 miles southwest of the dumps in upper Capulin Canyon and Goathill Gulch. As discussed previously in Section 2.3.1.1, the orientation of these seep areas in relation to Molycorp waste dumps (ie, located southwest of the dumps) is important information, given the well-documented occurrence of dominant geological structures/fractures trending northeast/southwest throughout the mine area. Although groundwater flow in valley fill and fan delta deposits may contribute ARD to the seeps along Red River, the role of bedrock fracture flow as a pathway between mine waste sources and the river seeps cannot be overlooked (Cabin Springs is solely fracture flow). In addition to the waste rock dumps, the open pit and underground mine workings at Molycorp should be considered as ARD sources that may impact water quality of Red River seeps.

Stiff Diagrams of major ions and metals were plotted by SPRI for water samples, including the seeps at Capulin Canyon, Portal Spring, and Cabin Springs (Appendix D). All three seep areas are characterized as calcium sulfate waters. Seasonal changes in seep



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water (or in the monitoring wells) is not yet well known (the Capulin seep has been sampled by this project a total of five times; see Table 1, map location #'s 37,46,50,63,66). The Capulin seeps exhibit the worst water quality, followed by Cabin Springs and Portal Spring. The dominant metals in all seeps are, in order of concentration, Al, Mn, and Fe. An unusual feature of the seep area that extends for hundreds of yards along the river at the mouth of Capulin Canyon is the segment of old (abandoned) river channel that now collects highly acidic seepage (see illustrations). The Capulin channel seep exhibited the highest concentrations of the four metals (Al, Mn, Cu, Be) that were documented at concentrations at least three times background (well at Red River WWTP) in data from NMED Superfund Oversight Section (NMED, October 23, 1995, p.16). During field work in the area on September 21, 1993, highway construction activity had caused an excavation on the north shoulder of the road opposite the mouth of Capulin Canyon. Water was present at a depth of six feet, representing the water table. The water was sampled (#35 in Table 1) and measured with a pH of 3.9 and a conductivity of 2450 umhos/cm. This water is presumably indicative of water quality of seepage before it emerges and is diluted with river water in the alluvium adjacent to the river. As a demonstration BMP a group of three anoxic limestone drains was installed by this project during October 1995 in this area to neutralize and treat acid drainage in the seeps at Capulin Canyon. Details of this BMP are given in the discussion in Section 4.2, and in Appendix H.

New seeps continue to come to our attention. At the end of this project in December, 1995, a previously undocumented seep was reported to the SWQB by a group of concerned Questa citizens. Located approximately one mile upriver of the Molycorp mill on the north bank of the Red River, this seep exhibits a pH of 4.5 and a conductivity of 700 umhos/cm. It emerges from a pool in the river alluvium and flows approximately seventy five feet to the river, leaving a prominent trail of thick, white precipitate. Water quality samples were collected and submitted for analysis on December 15, 1995 (results will be forwarded to EPA when they are received from the lab).

The effects of the seeps on Red River water quality are known from observations and various river surveys and sampling by NMED and Molycorp. NMED data are derived from river surveys by the SWQB Surveillance and Standards Section (Smolka and Tague, 1987 and 1989), sampling by the Superfund Section for investigations at Molycorp between 1993 and 1995 (Appendix A), and sampling by this project (Table 1). Water quality data and impairment status for the Red River derived from the biennial CWA 305(b) Report to Congress has been compiled and summarized in a November, 1995 report by NMED/SWQB for submittal to the NM State Engineers Office (see Tables 5 through 8). Molycorp has employed Vail Engineering to conduct annual river surveys and sampling since 1992 (see Vail, 1993, as well as data in Appendix D - Table D3, and Appendix F -

Table 1.5). The US Geological Survey has also been measuring discharge and collecting water quality samples at various points on Red River for over twenty years. Published data is available from their Water Resources Data Book for New Mexico for the following years: 1964-65 at the Fish Hatchery (discharge, field parameters, anions/cations, trace elements); 1969-77, same as above; 1978-1982, at Zwergle Dam, Molycorp Mine, Questa, Fish Hatchery, and mouth of Red River (discharge, field parameters, anions/cations, trace elements); 1983-87, at Questa, Fish Hatchery, and mouth of Red River (for above parameters). There is no USGS data available for the period following 1987.

Molycorp mine and the majority of scar areas are located on the north side of the river. No known acid seeps occur on the south side. The watershed on the south side of the middle reach of Red River is relatively undisturbed. As Red River in this area is a gaining stream, some seepage probably enters the bed of the river unseen, in addition to the visible seepage along the river banks. Acid seep areas are visible due to precipitation of white and red-colored mineral deposits and occasional growth of green algae in the seeps. All the acid seeps produce a prominent plume of white precipitate that coats river substrate, in some cases for scores of yards in a downstream direction (see illustrations P-11,12,19). At the Capulin seeps iron compounds precipitate out of solution first, and deposit a rust-colored precipitate for several feet around the emergence point, followed by much larger areas of the white precipitate. X-ray diffraction analyses have shown the white precipitate to be a combination of aluminum hydroxide and amorphous aluminum silicate compounds (personal communication, R. Vail). It is these aluminum compounds that, in suspension and solution in river water, are largely responsible for producing the milky-blue color that is commonly observed in the river between Molycorp and the Fish Hatchery (more pronounced during winter and spring months - see illustration P-6,11,19). Anecdotal evidence in the form of testimony by long-time residents claims that the river did not turn blue prior to the 1970's. Molycorp commenced large-scale, open pit mining in 1965. USGS seepage studies in 1965 and 1988 indicate that groundwater seepage to Red River below the Molycorp mine increased substantially between the two dates, which span the period before and after open pit development (unpublished draft Open File Report 95-1, NMONRT).

The mechanism for precipitation of minerals/metals by the seeps is controlled by changes in solubility brought about by pH buffering as a result of dilution by the river. The highly acidic groundwater can dissolve and transport elevated concentrations of contaminants, but when the seeps emerge and mix with river water the pH is raised and dissolved constituents begin to deposit. Aluminum has a double solubility curve (ie, it is soluble at both low and elevated pH values), and is therefore present as precipitated deposits on substrate and as dissolved and suspended aluminum compounds carried in river water. The combination of

cemented river substrate (resulting in impacted benthic habitat), increased acidity, and elevated concentrations of dissolved and suspended phase contaminant loads has cumulatively impacted the aquatic habitat of the middle reach of Red River. If the river is sampled at mid-stream at some distance below a seep the dilution effect is such that water quality impacts appear minimal, but sampling closer to the river bank below a seep produces evidence of greater chemical changes. The cumulative impact becomes obvious and significant when one considers the steady degradation in water quality progressing downstream from the Town of Red River, past the scars and Molycorp, to the Fish Hatchery below Questa. In this stretch of river there is a progressive decline in pH and a corresponding increase in conductivity; TDS ranges in value from <100 mg/l upstream of the Town of Red River to >250 mg/l in the vicinity of Molycorp at Sulfur Gulch. During runoff events many dissolved (and total) constituents in the Red River exceed New Mexico numeric stream standards. In the 1994 New Mexico WQCC Water Quality [305(b)] Report to Congress, the Red River is listed as exceeding chronic criteria for Al, Zn, and Cd (Table 18, B-5). According to data from river samples (dissolved constituents) collected during base flow conditions by NMED Superfund Oversight Section and by Molycorp consultants on various dates, chronic criteria have been exceeded for Al, Zn, Cu, and Cd (Appendix D, Table D2 and D3; Appendix F, Table 1.5; and Appendix A, Tables 15,16,17). Although no numeric stream standard exists for Mn (despite an erroneous statement to the contrary by Molycorp in Appendix D, page D-13), there is a significant increase in mean concentration of dissolved Mn from above Molycorp property (0.1 mg/l) to below Molycorp at the USFS Ranger Station (.64 mg/l). For the above reach of river mean concentrations of dissolved Zn increase from .05 mg/l to .11 mg/l. The subject of contaminant loading rates to the river is further discussed in Appendix F (Table 1.6). Garrabrant (1993) lists the following constituents that have been documented in excess of State standards in the Red River by the USGS and NMED: pH, TDS, turbidity, sulfate, total phosphorus, Al, As, Ba, Cd, Cu, Cn, Fe, Pb, Mn, Mo, Ag, and Zn. Appendix G shows figures from Garrabrant illustrating ranges of concentrations of certain analytes.

Samples of streambed sediments collected by NMED Superfund Oversight Section in 1994 further document a release of contaminants to the Red River in the reach encompassing Molycorp Mine (NMED, October 23, 1995, p.23) (Table 18 of Appendix A). This contamination could be due to suspended sediment or precipitation of metal oxides from seeps. The metals Be, Cu, Pb, Mn, and Zn were elevated above three times background concentrations in at least four of the eight downstream sample locations. The elevated concentrations generally increased in a downstream direction. These same metals were most elevated in soil samples from Molycorp waste rock dumps relative to scar material (Table 4 of Appendix A).

In their geochemical assessment of ARD potential, Molycorp consultants conclude that acid generation is occurring in the waste dumps and is a relatively young process in some of the dumps. Over time those dumps (especially the ones closest to the river) have the potential to produce more ARD or worse-quality ARD, resulting in increased sulfate and metal loads in local springs and seeps (Steffen, Robertson, and Kirsten, April 19, 1995, p.35). That report further states that the seeps at Capulin Canyon are impacted by mine waste drainage that occurred prior to construction of the seepage collection system in upper Capulin Canyon in 1992.

3.2.2.2 Mine Water Quality

Discussions of water quality from mine waste-rock dumps seepage and groundwater in the underground workings are presented in excerpts contained in Appendices D and F, and NMED data for waste dump seepage is shown in Table 13 of Appendix A. Water samples have been collected from the collected seepage (leachate) at the waste dumps in upper Capulin canyon and Goathill Gulch, from several bedrock seeps occurring in Capulin Canyon, from seepage that infiltrates into the open pit, and from several locations within the underground workings (Shaft No.1 and the Decline). The worst water quality by far (in fact, the worst water observed at any location within the watershed) is the leachate that flows from the bases of the waste-rock dumps in Capulin Canyon and Goathill Gulch. Molycorp collects and diverts approximately 70 gpm of this collected leachate into the underground mine via the caved area in Goathill Gulch. This seepage is acidic (pH values of 2 to 3), has TDS values of approximately 25,000 mg/l, sulfate concentrations are in the 13,000 mg/l range, has very high levels of Fe, Mn, Zn, and Al (ie, dissolved aluminum is present at concentrations ranging from 1,1000 to 1,300 mg/l). On Stiff Diagrams (Appendix D) these seep waters are calcium and magnesium sulfate water, with occasional high Al or Fe exceeding the Ca/Mg. Tritium analyses of selected water samples on Molycorp property indicate that seepage from waste rock dumps is post-1952 in age (Appendix D). Preliminary data (from a very limited data set) from experiments with Pb and Sr isotopes indicates that dump seepage may have a different signature than natural acid seeps (SPRI, April 21, 1995, p.D-12). In evaluating the chemistry of seepage from the waste rock dumps it is important to consider that some of the dumps either overlay existing scars or contain scar material (altered volcanics) that was former overburden in the open pit area. Therefore the chemistry of seep waters from scar material needs to be understood and accounted for in any analysis of the water quality at mine waste sources. Water quality of scar areas (located both within and without the Molycorp mine area) is discussed in Section 3.2.2.3, and comparisons are made in Section 3.2.2.5.

Water representative of drainage from disturbed, acid-generating material in the open pit was acidic (pH <3) and contained high



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concentrations of sulfate, Al, Fe, Mn, and Zn. Samples of groundwater collected at various locations in the underground mine workings represent a mixture of ambient groundwater, oxygenated vadose water, and ARD introduced from the open pit drainage plus the waste-rock dumps seepage collection system. Groundwater samples from the Decline and Shaft No.1 thus represent diluted ARD discharges. Samples from these locations are near neutral pH, have TDS concentrations between 2,000 and 3,000 mg/l, and equal or exceed State Groundwater standards for sulfate, Al, Fe, Mn, and Cd. Fluoride concentrations exceed EPA MCLs. The current dewatering of the mine (pumped to the tailings impoundments) creates a cone of depression in the water table that may prevent some water containing the above listed contaminants from discharging to the Red River. Increased seepage inflow to the Red River in this reach, however, suggests that cone of depression is not capturing all water (NMONRT, 1995). Discharged at the tailings impoundments, a portion of these contaminants likely, over time, end up in the Red River downgradient of that location via seepage losses.

In the most recent and comprehensive geochemical assessment of the mine area, Molycorp consultants conclude that the main sources of ARD from Molycorp getting into the river are the waste-rock dumps in upper Capulin Canyon and those dumps adjacent to the Red River (Sugar Shack South, Middle and Spring and Sulfur Gulch), through alluvium and geologic structures of high hydraulic conductivity (SRK, April 13, 1995, p.11).

3.2.2.3 Scar Water Quality

Analytical data for water samples collected from scar areas exists for stormwater runoff and, more germane to this project, for seepage of ARD-influenced groundwater from the scars. The nature and distribution of scars in the watershed is discussed in Section 2.3.2. The most recent comprehensive investigation of the geochemical properties (ARD potential) of scars is found in the report for Molycorp by Steffen, Robertson, and Kirsten (SRK, April 19, 1995), which is excerpted in Appendix F. Other data from Molycorp for seepage samples from scar areas in Hansen Creek, Haut-N-Taut Creek, Goathill Gulch, and Capulin Canyon are presented in Appendix D (see samples CCS-2, CCS-4, GHS-3, HCS-1 and 2, HTS-1). NMED data for scar area water samples from this project are in Table 1 (#28,29,30,45,57,64,65). Other NMED data, from the Superfund Section's investigation of Molycorp, are in Appendix A (Tables 3,4,6,7, and 13).

Due to oxidation of sulfide minerals (mainly pyrite) in the scar areas, ARD is generated and has been documented in samples of both runoff and seepage waters. All such samples exhibit acidic pH (in the 2 to 4 range), high concentrations of TDS, sulfate, Al, Fe, Mn, Cu, Zn, and Fl, with other trace elements present, including Cd, Co, Cr, and Ni. Average concentrations of metals (in mg/l) in samples of seepage from the scar areas in Hansen Creek and Goathill

Gulch include the following: Al=163, Fe=484, Mn=42, Zn=9, Cu=3 (Appendix A, Table 13). In groundwater sampled from two private wells located on Bitter Creek, which are probably completed in debris flow material associated with scars, standards were exceeded for Al, Cd, Co, Fe, and Mn (Table 1, #28 and 29). The drainage from the Hansen Creek scar area contained concentrations of Al, Co, Fe, Mn, and Ni in excess of standards (Table 1, #45 and 64). The production well at the Red River waste water treatment plant is completed in scar area debris flow material, and consequently has poor water quality (Appendix A, Table 6).

### 3.2.2.4 Mine Monitoring Well Water Quality

In 1994 twelve new monitoring wells were installed by Molycorp in the vicinity of the mine to evaluate the impacts of mining operations on surface water (Red River) and groundwater, and to evaluate the relative contributions of natural versus mining-related sources on water quality impacts. A summary of the installation and testing of these wells is contained in Appendix C. Aquifer tests and water quality sampling have been conducted by SPRI for Molycorp (summarized in Appendix D) and water quality sampling has been conducted by NMED (see Appendix A and Tables 1 and 2). Locations of these wells are shown in Appendices C and D, and in Figure 6. Wells were sited in order to define linkages between sources and river seeps, and results are best described in that sense.

Wells MMW-10A,-10B,-10C, and -11 are between the Sugar Shack South waste-rock dump and Portal Springs. These wells contain calcium sulfate water that is acidic (pH 4.7 to 5.8) and concentrations of TDS ranging from 1400 to 2000 mg/l and sulfate in excess of 1000 mg/l. Water chemistry of these wells is similar to the Portal Springs seepage, and Tritium analysis indicates a post-1952 source. State groundwater standards are exceeded in these wells for TDS, sulfate, Al, Cd, Co, Cu, Mn, and Ni.

Wells MMW-7,-8A, and -8B are meant to evaluate the possible flow path along the unnamed tributary canyon east of Shaft No. 1 that could convey water between the Sugar Shack West waste-rock dump, the east end of the Goathill Gulch waste-rock dump, and the river. MMW-7 contains magnesium aluminum sulfate water that is acidic (pH 4.4), has very high conductivity (16,000 mg/l) and sulfate (9366 mg/l), and exceeds groundwater standards for the following metals: Al, Cd, Co, Cu, Fe, Pb, Mn, and Ni. It is similar to the waste-rock seepage at Capulin Canyon and Goathill Gulch. NMED Superfund data show that MMW-7 water samples exceeded three times background concentrations (in water from the underground workings) for the CERCLA metals As, Cd, and Cu (NMED, October 23, 1995, p. 16). Water from wells MMW-8A and -8B, which are located closer to the river, is not as acidic (pH 6.4 and 8.2) and contains moderate TDS concentrations (2200 and 1100 mg/l respectively). Metal concentrations are low. A possible relationship between water from



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the perched zone in MMW-7 and that seeping from a similar perched zone at Cabin Springs is suggested. Tritium analysis indicates Cabin Springs seepage is post-1952.

Wells MMW-2 and MMW-3 are in lower Capulin Canyon along a likely flow path between the waste-rock dumps in upper Capulin Canyon and the acid seeps at the confluence of Capulin Canyon and Red River. Water from these wells is classified as calcium sulfate water. Well MMW-2 is in valley-fill and contains acidic water (pH 4.9) with a TDS of 3400 mg/l and sulfate concentrations of 2177 mg/l. MMW-2 contains the following metals in excess of standards: Al, Cd, Co, Fe, Mn, Ni, and Zn. Well MMW-3 is completed in bedrock and contains water that is not acidic (pH 7.5) but has elevated concentrations of TDS (2900 mg/l) and sulfate (1759 mg/l). Metals exceeding groundwater standards are Co, Mn, and Ni. Water in MMW-2 resembles somewhat the surface flow in Capulin Canyon that infiltrates the alluvium about 1000 feet up-gradient (sample CCS-4 in Appendix D, Table D2). In the Stiff diagram in Appendix D (D7A) there is a correspondence in the ratio of metals concentrations between water from the Capulin waste-rock dump seepage (CCS-1), well MMW-2, and the seepage at the mouth of Capulin Canyon (CCS-6). Relative concentrations decrease in the order given, as would be expected, with increasing distance from source to seep.

3.2.2.5 Comparison of Water Quality Results

In comparing water quality results from sampling in the Molycorp mine area and the hydrothermal alteration scar areas, the principal concern is distinguishing between water contaminants derived from mine wastes and from natural (mineralized) scar areas. To date, the best information of this type is found in the geochemical assessment by SRK dated April 13, 1995 (Appendix F), and in the data tables prepared by Stuart Kent of the NMED Superfund Oversight Section in the Expanded Site Inspection Report (Draft Document) on the Molycorp Site dated October 23, 1995 (data tables are in Appendix A). These reports and data show that water from mine-related sources, especially the waste-rock dumps, contains significantly greater concentrations of sulfate and metals (Al, Fe, Mn, Zn, Cu, Cd) than water from the scar areas. Water from both types of sources is similarly acidic; pH ranges from 2.3 to 3.6. The most significant ions at increased concentrations in mine waste drainage are sulfate, Al, Mn, and Zn.

In Kent's discussion of the groundwater pathway and methods of attributing a release to the two aquifers from Molycorp sources (NMED, October 23, 1995, p.18), he first compares data between background samples at the Red River WWTP well (which is screened in scar-derived mudflow material, and is thus a conservative estimate for background) and samples from down-gradient seeps. This approach demonstrates a release (concentrations three times background) of the metals Be and Cu to the alluvial aquifer (Table

6 of Appendix A). A second method compared down-gradient seeps (below Molycorp) to an up-gradient seep originating from a scar area at Hansen Creek. The data show over a three-fold increase in Be, Al, Cu, and Mn in the down-gradient seeps (Table 7 of Appendix A). To further support this attribution, leachate from mine wastes showed greater concentrations of Be, Al, Cu, and Mn than from scar material (Table 13 of Appendix A), and Cu and Mn were detected at twice the concentration in soil samples from waste dumps than in scar areas (Table 4 of Appendix A). Data from other studies by Molycorp consultants support these findings (Vail, July 9, 1993, Appendix 1). Kent also presents data showing a release of As, Cd, and Cu to the fractured bedrock aquifer that is at least partially attributable to Molycorp (see data for well MMW-7 and Cabin Spring in Table 8 of Appendix A). Attribution is reasonable to assume because Cd and Cu are present at greater concentrations in both soil and leachate from waste dumps as compared to scar areas (Tables 4, 13, 14 of Appendix A).

In Capulin Canyon there are elevated concentrations of Zn in shallow alluvial water (9.48 mg/l) as well as in the waste-rock seepage (130 mg/l), while seepage from the "scar area" (as identified by Molycorp) in Capulin Canyon has low concentrations of Zn (2.08 mg/l). These data suggest that the shallow alluvial water in Capulin Canyon (and by extension, the seeps at Red River) are impacted by waste-rock ARD (Steffen, Robertson and Kirsten, April 13, 1995, p.14).

In comparison to concentrations of Al and Mn in drainage from scar areas, the drainage from waste rock in Capulin Canyon and Goathill Gulch contains up to an order of magnitude increase in concentration of Al and Mn (SRK, April 13, 1995, p.28). From the same report (p.29), it is stated seepage from acid-generating waste-rock can be anticipated to have higher concentrations of sulfate, Al, Zn, and Ni, with respect to seepage from undisturbed scar material. Only Fe is present at greater (average) concentrations in seepage from scars than waste-rock. Fluoride is present at elevated, but roughly similar, concentrations in mine waste and scar drainage.

#### 3.2.2.6 Acid Rock Drainage Assessment

Acid rock drainage (ARD) from Molycorp mine waste and the hydrothermal alteration scars in the watershed has been well documented in many previous investigations in the area. The temporal effects of runoff and the persistent adverse effects of base-flow seepage to groundwater and the Red River have been described here in Sections 2.3 and 3.2. Analytical data for water samples presented in Tables 1 and 2, and Appendices A, D, and F all confirm that the Red River and groundwater that recharges the river are being impacted by elevated concentrations of TDS, sulfate, Fl, and dissolved metals (Al, Fe, Mn, Cu, Zn, Cd, Co, Cr, Ni, and Pb). The latest and most comprehensive investigation of ARD from



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Molycorp Mine and surrounding area is a geochemical assessment performed by the consulting firm of Steffen, Robertson, and Kirsten in 1994-1995 (SRK, April 13, 1995). Their data and conclusions are summarized in Appendix F, and below.

Samples of scar material collected in and adjacent to the mine area possess significant acid generating potential. The scars produce runoff and drainage water with elevated concentrations of sulfate, Fl, Al, Cu, Fe, Mn, Cd, Co, Cr, and Ni, plus a high soluble salt load.

At the mine, samples of mixed volcanic waste rock also show significant acid generation potential and current acid generation from material excavated from Sulphur Gulch during open pit construction. This material is now in the dumps located north, south, and west of the open pit, and also remains exposed in the west pit wall. The suite of contaminants is similar to those given above for scar water, but are present at significantly greater concentrations in drainage from mine waste, probably due to a greater degree of disturbance (from blasting, excavation, and disposal) and hence greater surface area within waste-rock dumps for oxidation and ARD generation. Particularly, ARD from waste rock contains higher concentrations of sulfate, Al, Zn, and Ni (SRK, April 13, 1995, P.29). A portion of the open pit waste rock consists of andesite/aplite/granite, which is shown to have limited potential for leaching of sulfate and metals. Similarly, development rock from the old and new underground workings indicate low potential for acid generation, but some exposed cut slopes within the new mine currently exhibit acid generation. The relict tailings from the old mine that are located near the mill indicate current acid generation and the potential for leaching of metals and sulfate.

The hydrothermal scars represent a mature source of ARD (the oxidation process has been taking place over geologic time), and therefore the potential for acid generation is relatively constant as erosion exposes fresh, un-oxidized material. Mine wastes however, due to the recent disturbances and resultant increased surface areas available for the oxidation process, represent new and enhanced sources of ARD. Thus many of the waste rock piles can be expected to generate ARD of worsening water quality in the future and for an indefinite period of time. The potential for increasing concentrations of sulfate and metals to the Red River exists for the mine waste seepage in Capulin Canyon, subsurface seepage from the new underground mine and the old tailings at the mill site, and seepage from the waste rock dumps at Sugar Shack South, Middle and Spring and Sulphur Gulch (SRK, April 19, 1995, p. 38). Although numerous acidic seeps are known to occur along the Red River near the mine, the exact location of seepage plumes in relation to waste sources is currently unknown, as is the relative contribution of the sources. There is little doubt, however, that seepage of ARD-influenced groundwater through the

waste-rock piles can reach the Red River through the shallow alluvial aquifer and upper fractured bedrock perched aquifers, and therefore has an adverse impact on the quality of the springs and seeps adjacent to Red River. The following quotation is taken from the geochemical assessment by SRK (April 19, 1995, p. 35): "Over time, ongoing acid generation in the waste rock disposal areas adjacent to Red River, and the consumption of the neutralizing potential of the waste rock, and consumption of the remaining attenuation capacity in the alluvium in seepage flow paths has the potential to increase sulfate and metal loads in local springs and seeps".

3.2.2.7 Contaminant Loading Rates and Groundwater Recharge Rates

The subject of contaminant loads affecting Red River has been initially addressed in Section 3.2.2.1 and recharge rates to Red River have been touched on in the discussion of the hydrology of the Molycorp Mine area in Section 2.3.1.1. Estimates of contaminant loading and recharge rates to the Red River have been made in previous reports (Vail, 1993; SPRI, 1993 and 1995; SRK, 1995; NMED, October 23, 1995); all use sulfate concentrations as a proxy for metals, along with USGS flow measurements on which to base their analyses.

The average annual discharge of the Red River at Questa Ranger Station is approximately 41 cfs (Vail, 1993). Discharge ranges from 7.74 cfs to 262.5 cfs have been measured by USGS over a twelve year period. In the middle reach of the Red River, seepage studies by USGS have documented accretion from groundwater into Red River at approximately 4 cfs. Therefore a portion of the 2 cfs that comes from the north side of the river originates from the drainage area of Molycorp Mine. Other studies by SPRI (April 21, 1995) estimate groundwater recharge to the Red River from the Molycorp Mine area to be between 1.45 and 2.56 cfs. The most conservative estimate is based on the Molycorp Mine area being 6% of the total area of the Red River watershed. Assuming uniform distribution of recharge (this is questionable) and an average baseflow of the Red River at 11.04 cfs, the mine area would contribute 0.66 cfs of groundwater accretion to Red River. To further complicate an already confusing array of estimates, arguments are made by Molycorp consultants that cyclic patterns of precipitation and discharge in the region have the potential to affect groundwater recharge rates to the Red River (SPRI, April 21, 1995, B-5; SRK, April 19, 1995, pp 19 and 39). While this is a reasonable hypothesis, local seepage increases and decreases at the sub-watershed scale suggests that other forces are at work as well (NMONRT, 1995).

An analysis of groundwater accretion to Red River based on data by USGS in their two seepage studies in 1965 and 1988 indicates there was approximately 31% more accretion in 1988 than in 1965 (NMONRT, November 29, 1995, Draft OFR 95-1). A notable difference occurs

in the reach between Columbine Creek and the Questa Ranger Station, where groundwater seepage inflow increased 149% between 1965 and 1988 (from 2.1 cfs to 5.2 cfs). Both seepage studies were conducted under similar flow conditions in the month of November, and at the same approximate stations. The major change in the watershed was that in 1965 there was no open pit at Molycorp, whereas in 1988 the pit and associated waste dumps had been in place for more than twenty years. This suggests the possibility that increased seepage to Red River below the mine area could be due to enhanced groundwater recharge resulting from interception of water by the pit and dumps. Additionally, in recent years Molycorp has been diverting nearly all stormwater runoff from the mine site to the pit, caved area, and a number of retention ponds, all of which may enhance groundwater recharge.

The ratio of seepage flow to stream flow for a given reach has important implications for water quality of the river. In the example given above, seepage flow was 7.9% of stream flow in 1965 but was 16.4% in 1988. In other words seep flow was diluted by 12 to 1 in 1965 but by only 5 to 1 in 1988 (ONRT, November 29, 1995).

An understanding of the relative contribution of scar area sub-watersheds to the contaminant loading of Red River is only beginning to take place. For example, the Hansen Creek sub-watershed (located east and up-river from Molycorp) covers 0.11 square miles, of which approximately 0.08 square miles is scar area. In base flow the average surface and sub-surface contribution to Red River is approximately 0.1 cfs. (SRK, April 13, 1995, p.20). More data of this kind, along with water quality, are needed in order to accurately model and predict the relative contribution of contaminants to the Red River from the mine and the scar areas.

Groundwater recharge rates to the Red River are determined by aquifer characteristics such as transmissivity and hydraulic conductivity. These hydrogeologic parameters have been measured in pumping tests at some of the twelve new monitoring wells installed in the mine area since 1994 (SPRI, April 21, 1995 and Appendix C). As stated earlier, there are two main aquifers in the mine area; a fractured igneous and volcanic bedrock aquifer, and an overlying alluvial/colluvial aquifer. Based on pumping tests, these aquifers are considered interconnected. The hydraulic conductivity of the fractured bedrock aquifer is reported between 5.1 gallon/day/square foot and 629 gallons/day/square foot, and the alluvial aquifer was 1,141 gallon/day/square foot (SPRI, April 21, 1995, B-9). That hydraulic conductivity ranges over two orders of magnitude for the bedrock aquifer is a function of the degree of fracturing present.

Estimates of groundwater travel time (seepage velocity) between the caved area in Goathill Gulch and Red River have been calculated to be approximately 0.48 foot/day, or 19.97 years from the caved area

to the Red River (SPRI, April 21, 1995, B-11). This travel time is a rough guess, and could be considerably shortened by preferential pathways such as faults and fracture zones that cut across the structure of the mineralized zone.

Estimated loading rates for sulfate and selected metals are shown in Table 1.6 of Appendix F. At low-flow conditions in the Red River, the loading rate for sulfate increases from 2768 kg/day above Molycorp mill to 8741 kg/day below Capulin Canyon. Correspondingly, similar increases occur in this reach for TDS, Fl, Al, Mn, Fe, Cu, and Zn. Mass loading of sulfate, Al, and probably most other analytes present in the sources is more significant during low-flow conditions in Red River. This is logical since significant dilution of seep and spring discharges occurs during higher river flows.

In their evaluation of sulfate gains and contaminant loading to Red River, the various Molycorp consultants have concluded that the increased loading rates between the mill and the Questa Ranger Station either: (1) cannot be ascribed with certainty to mine wastes or scars, (2) are due primarily to scars, or (3) are a result of climatic variability. NMED believes the documented increases in contaminant loading in the middle reach of Red River are due in large part to the increasing generation of ARD from Molycorp waste-rock piles, sulfide-rich material in the open pit and underground mine workings, and relict tailing deposits at the mill. In support of this view that contaminant loading in the middle reach of Red River is largely attributable to Molycorp sources are the data and preliminary evaluation of sulfate gain by Kent (NMED, October 23, 1995, Draft Document) (Appendix A). This approach used eight data sets covering a period of 29 years, and focused on the reach of river solely between Molycorp property and the Questa Ranger Station. Significant increases (up to 80% of total gain) in sulfate in the lower half of this reach seem to coincide with creation of the waste rock dumps from the open pit operation, and then abruptly decreased to 52 % of total gain in 1992 when the Capulin collection system was installed and cut off much of the surface flows in the two tributaries of Capulin Canyon and Goathill Gulch. A subsequent increase suggests a new source for sulfate has developed since 1992. The present project has observed that new sources of ARD-influenced groundwater recharge are in fact developing along the Red River; the author documented a significant newly-emerged acid seep opposite the Moly tunnel in January, 1994 (sample numbers 40 and 41 in Table 1, Portal Spring samples in various Molycorp reports and data tables). Since scar areas are not likely to have increased in size or acid generation since 1992, it is reasonable to assume the increase in sulfate is probably due to groundwater recharge impacted by mine waste sources. This postulate is further illustrated by the plotting of sulfate versus stream discharge shown in Appendix A (from NM Office of Natural Resource Trustee, Draft Document). It clearly shows increased sulfate input at lower flows, and that groundwater input

has increased since 1965. The emergence of some of the acid seeps along the river is currently controlled, in part, by the cone of depression in the regional (bedrock) water table caused by pumping/dewatering of the mine. A post-mine rewatering configuration of the water table has been estimated. If pumping/dewatering ceased, points of discharge from the underground workings would be the Moly tunnel (also known as the 7960 adit) and through the alluvium south of the caved zone in Goathill Gulch (SRK, April 13, 1995, p.18). In order to avoid increased acid seepage to the river, or direct discharge of mine water to the river, this scenario should probably be avoided, which implies perpetual pumping of the mine or perpetual treatment of seepage points before the water enters the river.

### 3.2.3 Other Mining Sites in the Red River Watershed

Based on field reconnaissance and a review of the sources listed in Section 3.1.4, it was determined that Bitter Creek, Pioneer Creek, and Placer Creek contain the greatest concentrations of old mining sites among the seven tributaries where mining activity has occurred within the Red River watershed. The distribution of these sites (mines, mills, prospects) is as follows:

| Tributary | Total Sites | Sites with seepage | Sites with mills |
|---|---|---|---|
| Bitter Creek | 17 | 4 | 5 |
| Pioneer Creek | 16 | 3 | 1 |
| Placer Creek | 14 | 3 | 4 |
| Cabresto Creek | 6 | 0 | 0 |
| Goose Creek | 5 | 0 | 0 |
| Black Copper Cyn | 1 | 1 | 1 |
| | 59 | 11 | 11 |

In addition to these sites located on tributaries there were formerly several mill sites and smelters located adjacent to the Red River in the area of the present town (Copper King Mine and smelter, June Bug Mill, and Sampson Mine), but nothing remains of these operations today. All of the sites listed in the table above were fairly small operations, therefore associated waste piles are relatively minor. No mine in the Red River district produced more than a few hundred tons of ore, except the Memphis Mine on Bitter Creek, which produced 3500 tons of ore (Roberts, et. al, 1990). Most of the work in the district was development and exploration.

In Bitter Creek the significant sites are the Memphis, Anchor, Midnight, and Oro Fino. All waste dumps are small scale, although some are in the flood plain of Bitter Creek (e.g., the dump at Midnight Mine is 7400 square yards, and at Anchor Mine is 2800 square yards). The Oro Fino Mine is the site with the most significant discharge of ARD. An anoxic alkaline drain was installed here in 1994 as an experimental BMP, and has resulted in a dramatic improvement in water quality (Table 1). The majority of mine waste accumulations on Bitter Creek represent a source of

nonpoint source contamination to the stream (sediment, TDS, sulfate, metals, and in some cases acidity) during runoff-producing events, but have little or no impact on the creek during normal weather (base flow conditions). Even the ARD from the Oro Fino (before BMP) had a negligible effect on the water quality in Bitter Creek due to low seepage rates and dilution effects.

The same observations hold true for sites in the other tributaries. Seeps were evaluated by measuring field parameters (pH, electrical conductivity, DO, temperature); none were found to exhibit significant flows of degraded water quality (pH values ranged from 5.5 to 7.0 and conductivity from 115 to 2400). The largest site on Pioneer Creek was the Caribel Mine and mill, which was dismantled in 1980.

In summary, although many of the sites contribute some nonpoint source contamination to nearby surface waters during runoff events, none of them appear to represent a significant source of ARD discharge to either groundwater or to streams. Taken as a whole, the cumulative impacts to water quality in the upper reaches of the Red River and its tributaries from these old mining sites is relatively insignificant in comparison to the much greater sources of the scar areas and Molycorp Mine in the middle reach of the Red River.

### 3.2.4 Leaking Underground Storage Tank Sites

In Section 2.3.3 is given a description of the three known sites where underground storage tanks have leaked petroleum products, all within the town of Red River. Since the NMED Underground Storage Tank Bureau (USTB) has regulatory authority over investigation and remediation of sites contaminated by leaking USTs, the role of this project in regard to UST sites has been to consult with and maintain close communication with the appropriate technical staff in the USTB about progress at the three known sites in the Red River watershed. Their files were copied and incorporated into the records for this project, and site visits were coordinated with USTB staff for all three sites in Red River. Quarterly monitoring reports, data, and consultants reports are provided to this project as they are received by USTB staff. Frequent inspections have been made for evidence of hydrocarbon release at the Chevron Red River site, where past discharges to the river through a storm sewer have been observed. Subsequent and ongoing remediation at this site has been effective in containing and treating contamination. No evidence of hydrocarbon contamination reaching Red River has been found, either in sample data or observation, since 1992.

In anticipation of road work and infrastructure changes along State Highway 38 through the Town of Red River, the NMHTD commissioned an environmental investigation along the right-of-way by Camp, Dresser, and McGee, Inc.(CDM) in 1994. CDM has completed several phases of investigation focusing on potential environmental hazards

in the project area (basically the entire Main Street area of Red River), which included soil borings and monitoring wells at potential risk areas (CDM, Jan. 1994). Seven sites of potential concern were identified in Phase 1A: Diamond Shamrock station, Edelweiss Inn (former Texaco/Gulf station), Pioneer Lodge (former Phillips 66 station), Bittercreek Rentals (former Shamrock/Chevron station), Angelinas Restaurant (former Texaco station), High Country Rentals (former Chevron/Gulf station), Resort Realty (former Conoco station). Two of these seven sites (High Country Rentals and Bittercreek Rentals) have confirmed releases and are under investigation or remediation. At the other sites no hydrocarbon contamination has been detected in any of the soil samples collected from borings, and no groundwater samples have shown hydrocarbon contamination above regulatory action levels. Groundwater flow gradient was measured at 0.0073 ft/ft, in a direction of west to northwest.

### 3.2.5 Septic Tanks and Sewage Lagoons

As mentioned earlier in Section 2.3.4, the upper Red River valley (above the town of Red River) has become densely developed with subdivisions having hundreds of homes on small lots. During site inspections in 1994 an attempt was made to count the number of houses in this area. In the area between Fourth of July Canyon and Foster Park Canyon (an area of 1.5 miles x .25 miles) approximately 125 houses were counted. This area includes the Valley of the Pines Subdivision, which is the lowest one on the upper valley, and many of the houses are located very near the banks of the river. Others are built on very steep slopes that appear to have thin soils overlying bedrock. The subdivisions in the upper valley area above Fourth of July Canyon contain approximately 200 houses (difficult to count because many are in forest). An initial effort to quantify the septic tank situation was made by contacting the NMED Field Office staff in Taos, NM for information about liquid waste permits, which are required for construction of any household waste disposal system. The Environmentalist in charge of the Red River area (Bill King) indicated that such information would be meaningless because most builders in that area do not apply for the permit and install their septic tanks illegally. He had only received two requests for liquid waste permits in the last six months, and believed that many more houses than that had been built in that period. Enforcement is a problem. Other NMED staff from SWQB were told of concerns by a local resident about illegal installations by a local plumbing contractor in the area who was installing holding tanks (that should be pumped out when full) with holes punched in the bottoms. Strategies for documenting pollution in groundwater and the river include sampling the river near observed algal blooms, and sampling private wells for analyses of nitrate and TKN. Nitrate concentrations can be determined in the field by using one of the Department's Hach Kits, which use a colorimetric technique to quantify nitrate (10 mg/l is the NM



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groundwater standard). Efforts under the State's Liquid Waste Program are continuing.

During 1995 others expressed additional concern over potential problems in the upper valley, and began coordinating activities in this regard. Bill King (NMED, Taos Field Office) reported receiving increasing numbers of complaints from upper valley residents about failing septic systems. Bob Perry (Director of Public Works for Town of Red River) assumed a leadership role in the recently created Red River Watershed Association, and began to focus on the water quality impacts in the Upper Valley. From a coordination meeting between these parties in April, 1995, it was determined that there are approximately 450 houses in the upper valley now, with a capacity for about 1000 more in the future. Only 203 houses have been issued Liquid Waste Disposal Permits from NMED since 1973, implying that over 200 have illegal systems. It is assumed that there are at least 400 private water supply wells in the area. In order to curtail the installation of more illegal systems and to alleviate existing (probable) water quality impacts to the Red River from the upper valley, the Town of Red River would like to extend it's sewer and water service to the Upper Valley. The existing WWTP can handle the increased flow, and costs are estimated at approximately ten million dollars. The town is applying for assistance in funding this project, and hope for completion in about five years. In order to further document the need for this project, several activities will be conducted in the upper valley during the summer months of 1996 in joint efforts between the Town of Red River, the NMED Taos Field Office, and NMED-SWQB. A Water Fair will be held, during which residents can bring samples of their well water for testing and analyses (nitrate screening being used to indicate possible contamination with septic system wastes). To follow up on wells that may be contaminated, inspections and possibly dye traces will be conducted. Both banks of the river will be walked through developed portions of the upper valley to look for evidence of illegal direct discharges to the river and for signs of failing septic systems in proximity to the river.

The Questa sewage lagoons, described earlier in Section 2.3.4, fall under the regulatory authority of the NMED Ground Water Section, which reviews the required groundwater monitoring at the facility through a Ground Water Discharge Plan (DP-191). These analytical results, which have not revealed contamination above State standards, are on file with NMED-GWS. This project reviewed the DP-191 file and consulted with Ground Water Section staff, but did not see a need to conduct any further sampling or field work at this site. An additional lagoon cell was being planned for construction by Questa in late 1995 (personal communication, George Long, USFS, Questa RD).

## IV. BEST MANAGEMENT PRACTICES AND REMEDIATION

### 4.1 REMEDIAL STRATEGY

In discussing solutions to groundwater nonpoint source pollution problems within a large watershed involving major mining sites with complex background issues, a distinction should perhaps be made between best management practices (BMPs) and remediation activities. Within the context of 319(h) projects, implementation of BMPs for improving water quality during the two-year period of the grant has traditionally been emphasized. Addressing multiple NPS sources, some of which are huge, complex mining sites, within a watershed of 226 square miles during a two-year period is unrealistic. Furthermore, it must be recognized that groundwater contamination problems typically require decades and often millions of dollars to correct or contain. Cleanup of some contaminated aquifers may in fact prove to be technically infeasible at the present time. Therefore, a remedial strategy must distinguish between short-term treatment or containment of symptoms versus long-term remediation activities aimed at complete site restoration that effectively and permanently deals with pollution sources. A remedial strategy that addresses mining sites must also employ different tactics in addressing abandoned sites and active ones. If Molycorp mine again becomes active (which now appears likely, see news articles in Appendix I), formulating and implementing remedial projects and a comprehensive site closure plan becomes a complex task involving many technical issues and several regulatory agencies (NMED Groundwater Quality Bureau, Surface Water Quality Bureau, Air Quality Bureau, and Superfund Section; NM Office of Natural Resource Trustee; and NM Mining and Minerals Division).

Treatment strategies need also to consider the separate but related mechanisms of contaminant transport (ARD vs. pulse event runoff) by which mining sites and scar areas are contaminating Red River. At the smaller abandoned mine sites in the tributaries, BMPs could probably be implemented that would effectively address both types of problems. Access may be a problem at some of these sites which are patented (privately owned under the 1872 General Mining Act). Effectively treating ARD-contaminated groundwater problems at a huge site such as Molycorp, or at most scar areas, will not be permanently solved by implementing simple BMPs. Interim treating of the symptoms with passive systems such as anoxic alkaline drains may be the only viable alternative while more expensive and long-term solutions for remediating the source of the problems are designed and implemented. The feasibility of trying to address scar area problems in general is being investigated by the Bitter Creek 319(h) Project. These are large, unstable, dynamic areas subject to rapid geologic processes that tend to dwarf human efforts at intervention. It may be determined that resources would be better utilized in solving other NPS problems in this watershed



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(e.g., cleaning up abandoned minesites, site reclamation at Molycorp, passive treatment of seeps, better enforcement of septic tank installations or connecting subdivisions to WWTPs, etc.).

Most water quality data for the Red River watershed was collected during base flow conditions. As efforts to provide improvements within the watershed increase, emphasis must be placed on monitoring discrete runoff events for given areas in order to more accurately characterize the effects of resource extraction activities on water quality. A long-term program of systematic BMP implementation to reduce or eliminate pulse event contamination from small minesites (and perhaps some priority scar areas) would be facilitated by more intensive monitoring and sampling at these sites for pulse events .

## 4.2 DEMONSTRATION PROJECTS for BMPs

During 1993 an appropriate site was sought to install a small-scale anoxic alkaline drain treatment system to treat ARD on a pilot project basis at a small minesite in the watershed. The Oro Fino Mine site on Bitter Creek (Figures 2 and 6) was selected for this demonstration project, which was installed in September, 1993. Funding and in-kind services for this project came from the Carson National Forest, NMED-SWQB, and Amigos Bravos, a conservation group in Taos. Based on two samples collected six months apart, this system has significantly raised pH and reduced concentrations of metals in solution from this water source (Table 1).

A larger version, up to 300 feet long, of an anoxic alkaline drain is planned for a portion of the large seep area near the mouth of Capulin Canyon. This system would be used as a pilot project for large scale remediation of ARD. A portion of this system was successfully installed during the period October 30 to November 1, 1995 (Appendix H). A total of 170 feet of trenches, in four segments, was completed during this time in a cooperative effort involving NMED-SWQB technical staff, Molycorp Mine, the NM Highway and Transportation Department (NMHTD), and the US Forest Service - Questa Ranger District. NMED staff (Dennis Slifer, Mike Coleman, Peter Monahan) provided planning, coordination, and oversight, photo-documentation, and sampling of water and soil samples. Molycorp Mine provided heavy equipment (track-hoe) and operator, and purchased the limestone and clay for the project (approximately $12,000). Because the project took place within the right-of-way of State Highway 38, the NMHTD provided clearance work, heavy equipment (backhoe, loader, dump trucks), and a crew of up to ten operators and traffic control personnel. The USFS expedited all necessary NEPA clearance (the project is located within the Carson National Forest). The trenches were excavated 13 to 15 feet deep and 5 to 8 feet wide. Acidic groundwater was encountered, along with areas of oxidized iron-stained soil, in all trenches at depths of approximately 10 to 12 feet. Samples were collected and submitted for analysis (results are pending). The trenches were



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filled with approximately 4 to 5 feet of limestone cobbles, followed by a 16-mil plastic liner and several feet of bentonitic clay, with the remainder backfilled with overburden to grade. The disturbed areas were seeded and mulched the following week. A more comprehensive report accompanied by design specifications is in Appendix H. The seeps are being monitored frequently for signs of improvement. Subsequent data and an evaluation of the project's effectiveness will be submitted to EPA as an addendum when the data become available. A professionally produced video program about this project is hoped to be produced in 1996, to be used for outreach purposes, and will also be submitted to EPA upon completion.

If successful, this technology could be employed wherever acidic seep fronts can be accessed by surface trenching. All the major seep areas along the Red River between the Molycorp mill and the Questa Ranger Station potentially could be treated using this interim treatment method. In addition, isolated sources of acidic drainage such as tributary drainages from scar areas between town and the Molycorp Mill, as well as subchannel contributions from Bitter Creek, could also be treated in this fashion. Although desirable, anoxic alkaline drain treatment addresses symptoms rather than the causes of acid rock drainage. Given the magnitude and complexity of the causes of ARD discharge to the Red River, this may be the best short-term treatment while long-term remedial actions are considered.

Molycorp, in conjunction with their research staff at Unocal, has expressed interest in designing passive treatment systems for ARD from the waste rock piles in Capulin Canyon and Goathill Gulch. These systems will probably consist of anoxic alkaline drains and constructed composting wetlands, and would be constructed just below the present seepage collection systems so that inflow rates can be controlled.

## 4.3 RECOMMENDATIONS FOR BEST MANAGEMENT PRACTICES

The following BMPs have proven to be effective in reducing pollution from mineral extraction and processing sites.

### 4.3.1 STEADY-STATE ACID ROCK DRAINAGE

1. Sulfide reduction chambers - This technology involves collecting ARD and directing it into a sealed chamber filled with composted manure. The drainage works its way through the organic material from an inlet at the base of the chamber and issues from an outlet at the top. Sulfide reduction occurs through bacterial action within the chamber and effluent generally has reduced metals concentrations. Problems with this technology include a finite collection and treatment

capacity, freezing of inlet or outlet lines and a tendency to add sulphur to effluent at levels that can prove toxic to fish.

2. Anoxic Alkaline Drains - This passive treatment technology involves the interception of ARD in a sealed limestone-filled trench. The limestone (with high CaCo3 content) buffers the low pH, which facilitates the precipitation of metals. These systems often discharge into smaller retention basins where most metals precipitate out of solution, before the drainage flows into a constructed compost wetland for secondary treatment. Problems with these systems include an acute sensitivity to increased levels of dissolved oxygen that can lead to coating of the limestone with iron hydroxides, rendering it ineffective.

3. Wetlands - Over the past decade the use of wetlands to treat acid mine drainage (as well as municipal sewerage) has increased dramatically. This passive technology has proven to be a very cost effective alternative to standard chemical treatment. Bacterial activity in the wetland substrate and roots of emergent vegetation accomplishes most of the metal reduction in wetland treatment systems. Problems with this technology include damage to the system and release of metal-loaded drainage during peak runoff events. Also, many researchers in this area warn that a wetland treatment system can become overloaded with metal precipitates held in the organic substrate, and these are then subject to pulse releases in flood times and can become toxic to the emergent vegetation that hold the system together. Periodic clean-out of wetland treatment systems and subsequent reconstruction will almost certainly become a component of this passive treatment technology anywhere it is employed.

4. Source Control - Ultimately the most effective and permanent method of addressing ARD is to control its generation by remediating the source. By capping and sealing waste-rock piles and tailings piles, the supply of water and oxygen (both necessary to sustain the ARD process) can be eliminated or reduced. Similarly, by consolidating various sources into a single unit, total surface area available for oxidation and infiltration is reduced.

5. Other BMPs - Sodium hydroxide feeders and other expensive chemical treatment systems that require constant maintenance in perpetuity are not considered appropriate technologies for the treatment of acid rock drainage.

4.3.2 PULSE LOADING - SURFACE RUNOFF

1. Material Binders - In recent years products have been placed on the market that bind surface materials together in ore

stockpiles, waste dumps, or tailing facilities. Most of these products are sprayed as either a liquid emulsion or a fine grained solid on the surface of material piles. The effect of these products is to bind surface particulates together to form a shield against wind and water transport. Problems with this approach include the short duration of their effectiveness and uncertainty about potential toxic side effects.

2. Filter Strips - In many cases the installation of vegetative and or fabric filter strips can greatly reduce the pulse loading impact from minesites, at least for a while. Mines and mills have often been developed in narrow canyons or montaine environments, where they commonly disposed of their wastes in piles adjacent to or in stream channels. This configuration set up two basic stream degrading situations that persist and often worsen over the years. First, the linear placement of wastes along stream channels truncates drainage patterns upslope of the piles, setting up the classic condition that results in ARD. Secondly, the outslope of waste piles being at or near the angle of repose maximizes the volume of waste that is transported to the stream channel in pulse events. The re-establishment of a stable riparian community in a strip along the outslope of waste piles in conjunction with a fabric filter fence during the first season or two of growth could greatly reduce the general sediment load from such piles. It is likely, however, that the benefits from actions of this sort would be short term unless the offending piles were subsequently stabilized. Problems with BMPs involving filter strips include the likelihood of phyto-toxic response to sediments and leachate in areas in need of vegetative treatment, and the short duration of effectiveness when used as the sole BMP at a given site.

3. Complete site reclamation - The only known effective long-term means to eliminate contaminant transport from mining sites is to carry out complete site reclamation. Complete reclamation is a series of connected processes designed to restore damaged natural system components. These processes include returning a site to a stable drainage configuration by reconstructing truncated drainage channels and establishing reasonable slopes between drains before developing a suitable growth medium on the slopes to facilitate the return of stable native vegetative communities. The use of temporary diversions and slope terracing is often necessary to achieve the desired end. The result is a stable and self-sustaining natural ecosystem. Most of the problems associated with complete reclamation are tied to the high cost of implementing such BMPs. The will and the necessary budget required to maintain and repair failed reclamation components can also become problematic.

## 4.4 COSTS OF BMP IMPLEMENTATION

Any accurate estimate of costs associated with BMP implementation for a specific site is difficult without a detailed analysis of the area in question. With that in mind the following range of estimated costs are provided for general planning purposes.

Steady-state acid rock drainage:

1. Sulfide reduction chambers - The size of the chamber depends on the volume of drainage and other site specific conditions. The estimated range of costs for construction and maintenance is $6,000 - $30,000 per system.

2. Constructed Wetlands - Site conditions and the availability of onsite construction materials will affect costs. The estimated range of costs for construction and maintenance is $2,000 - $15,000 per acre of constructed wetland.

3. Anoxic Alkaline Drains - Again site conditions and size of the installation will greatly affect the estimated range of costs: $5,000 - $250,000 per system.

Pulse Loading - Stormwater Runoff:

1. Material Binders - The difficulty of mobilizing to a site and applying material binders will affect the estimated range of costs: $600 - $2,000 per acre of area treated.

2. Filter strips - $5 - $20 per linear foot of installed filter strip.

3. Complete Site Reclamation - Obviously site accessibility and conditions will have a significant effect on costs. The estimated range of costs for complete site reclamation is $10,000 - $65,000 per acre. If remediation of contaminated aquifers is involved as part of the complete site reclamation the costs can increase exponentially.

If the anoxic drain demonstrations prove the feasibility for application of this passive treatment technology at sites in the Red River watershed it is conceivable that a series of large systems could be employed to treat acid rock drainage that has impacted the middle reach of the Red River.

The prospects for success in controlling pulse loading from the small sites above Molycorp are good if adequate funding and support for this effort can be generated. The Molycorp site with its massive waste piles, open pit, miles of roads, and tailings ponds will remain a challenge for the foreseeable future.

## V. SUMMARY

The Red River Groundwater Investigation was a two-year project funded by USEPA under a CWA Section 319(h) grant to NMED. The objective of this project was to determine groundwater quality and aquifer characteristics along the impaired reaches of the Red River in order to identify, and ultimately eliminate, impairment of both the aquifer and the designated uses of the river. Following an initial literature review and evaluation of existing data, a period of extensive field work ensued to document, monitor, and sample at areas of concern. After reviewing point source discharges and sources of contamination for stormwater runoff that could impact the Red River, the investigation focused on nonpoint sources of contamination that impact the river through seepage inflow of contaminated groundwater.

For most of its length, the Red River has been shown to be a gaining stream; groundwater recharge contributes to the flow of the main stem throughout most of the reach from the upper valley above the Town of Red River to the confluence with the Rio Grande. A progressive downstream deterioration of water quality has been documented, from pristine headwaters originating in alpine wilderness, past the Town of Red River, to the biologically impoverished reach of approximately eight miles between the Molycorp mine and the Village of Questa. Water quality degradation in this reach is illustrated by increasing downstream concentrations of total dissolved solids, sulfate, and metals.

A number of groundwater-related nonpoint sources of pollution to Red River were identified and investigated, and are listed here in order of their significance:

1. Mining-related sources of acid rock drainage, or ARD (Molycorp mine and mill, and the old abandoned hard rock mining sites located on several tributaries to Red River)

2. Scar areas and debris flows that generate ARD (naturally occurring hydrothermal alteration erosional scars).

3. Septic tank leachfields and liquid waste holding tanks in subdivisions of the upper Red River valley.

4. Unlined sewage lagoons for the Village of Questa.

5. Sites of former leaking underground storage tanks (USTs) in the Town of Red River.

Of the sources listed above, by far the greatest impact is the steady-state seepage of ARD in the form of dozens of acidic metal-loaded seeps or springs. The ARD is from two principal sources: mining wastes or disturbed areas, and the hydrothermal alteration scars. A few of the old mine sites located on Red River

tributaries exhibit ARD but these sources are insignificant compared to the massive disturbances of Molycorp mine and the approximately twenty scar areas in the watershed. The scar areas are known to generate ARD and therefore have an impact on local groundwater and surface water resources. Because some scars are located upgradient of Molycorp mine, and underlay some of the mine features, the problem of attributing relative contributions of ARD from Molycorp wastes and the scar areas becomes complex. Sources of ARD from the mine include high-sulfide material in the waste-rock dumps, open pit, underground workings, and relic tailings deposits near the mill. The principal areas of seepage to the river occur at Cabin Springs, Portal Spring, and the mouth of Capulin Canyon. Geochemical studies indicate that the acid generation process within mine waste sources is relatively immature and is likely to worsen in the future and continue for an indefinite period. Water quality of seeps and springs impacted by ARD may further deteriorate.

In 1994 a series of twelve new groundwater monitoring wells were installed by Molycorp along the middle reach of the Red River. These were the first monitoring wells to be installed in the area of the mine and various waste sources (fourteen other wells have been previously installed by Molycorp in the tailings area below Questa). There are two principal, and interconnected, groundwater systems in the mine area - a fractured bedrock aquifer and an overlying aquifer within the alluvium and valley-fill of the Red River and tributary drainages. The new monitoring wells have provided hydrogeologic information and water quality data for both systems. The various seeps have also been sampled; most are located in alluvium but some discharge from bedrock. Water from all the new mine monitoring wells, as well as the seeps in the middle reach of the Red River, exceed NM Groundwater Standards for certain constituents (TDS, sulfate, Fl, Al, Fe, Mn, Co, Cu, Ni, Zn, Cd). For both aquifers there is evidence for a release of these contaminants from Molycorp sources. Data show that water from mine wastes contains significantly greater concentrations of sulfate and metals (Al, Be, Mn, Zn, Cu, Cd) than water from scar areas. In comparing water quality of seeps located downgradient of Molycorp to seeps located at scars upgradient of the mine, a more than three-fold increase is shown for concentrations of Be, Al, Cu, and Mn. Data for the fractured bedrock aquifer indicates a release of As, Cd, and Cu that is partially attributable to Molycorp mine.

Analysis of data from USGS groundwater seepage investigations in 1965 and 1988 indicates that there was a significant (149%) increase in seepage rates (groundwater accretion) to the middle reach of the Red River near Molycorp in 1988 as compared to 1965. The Molycorp open pit was begun in 1965; by the time of the 1988 seepage investigation the pit had been in place for more than twenty years. The pit and associated waste-rock dumps enhance groundwater recharge and may be responsible for the documented increase in seepage rates, and changes in water quality.

Another approach to assessing the relative impacts to the Red River from scars versus Molycorp Mine is to consider biological indices in the river. Although baseline water chemistry data are lacking for the river prior to Molycorp's large scale mining that commenced in the 1960's, there is evidence from NMDGF reports that a significant and healthy population of native trout flourished in the middle reach at that time. In the 1970's surveys documented declining fish populations, and today there is a complete absence of a reproducing population of trout and a lack of suitable benthic habitat. Only frequently-stocked hatchery trout are present now, which survive in the Red River long enough to get caught. With the advent of modern large-scale mining in the watershed and the subsequent increase in ARD from mining wastes, the rivers's natural buffering capacity was overwhelmed, resulting in the biologically impoverished condition that exists now.

The water quality impacts from Molycorp tailings impoundments below Questa are relatively better known than at the mine. Seepage from the tailings has contaminated the shallow alluvial aquifer with elevated concentrations of TDS, sulfate, and metals (Al, Fe, Mg, Ca, Mo, Mn). These constituents are found in the tailings monitoring wells as well as seeps emerging from the base of the tailings dams. Private water supply wells were found contaminated in the 1970's, after which Molycorp provided connection to the Questa community water supply system. Tailings seepage is intercepted by Molycorp and discharged via an approved NPDES permit to the river. There are no known acid seeps such as at the mine area that discharge to the river below the tailings. The absence of acid conditions in the tailings, and a less toxic suite of metals, combined with a significant dilution by a high rate of groundwater underflow at the tailings area results in a much lessened impact to the river as compared to the mine area. In the vicinity of the mine, contaminant loading rates have been estimated for sulfate and selected metals. At low flow, sulfate increases from 2768 kg/day above the Molycorp mill to 8741 kg/day below Capulin Canyon. Correspondingly, similar increases occur in this reach for TDS, Fl, Al, Mn, Fe, Cu, Zn, and probably other metals.

It was determined that Bitter Creek, Pioneer Creek, and Placer Creek contain the greatest concentrations of old mining sites among the seven tributaries where mining activity has occurred within the Red River watershed. A total of 59 sites are known to exist within the tributaries of upper Red River, of which 47 are located on Bitter, Pioneer, and Placer Creeks. All of the sites were fairly small operations, therefore associated waste piles are relatively minor. No mine in the Red River district produced more than a few hundred tons of ore, except for the Memphis Mine on Bitter Creek which produced 3500 tons of ore. Most of the work in the district was development and exploration. Although many of the sites contribute some nonpoint source contamination to nearby surface waters during runoff events, none of them appear to represent a

significant source of ARD discharge to either groundwater or to streams.

The upper Red River valley (above the Town of Red River) has become densely developed with subdivisions having hundreds of homes on small lots. Many of the lots are as small as 1/4 acre, and all have individual liquid waste systems (septic tank leach fields or holding tanks). Many of the houses are located very near the banks of the river. Others are built on steep slopes that have thin soils overlying bedrock. It was determined that there are approximately 450 houses in the upper valley now, with a capacity for about 1000 more in the future. Only 203 houses have been issued Liquid Waste Disposal Permits from NMED since 1973, implying that over 200 have illegal systems. It is believed that a number of leaking or failing systems are probably contaminating the shallow alluvial groundwater in the upper valley and hence may also be impacting the nearby river. In order to curtail the installation of more illegal systems and to alleviate existing (probable) water quality impacts to the Red River from the upper valley, the Town of Red River would like to extend its' sewer and water service to the upper valley.

The Village of Questa discharges up to 60,000 gallons per day of domestic sewage to a series of four lagoons (a fifth has been recently constructed) located 1.5 miles southwest of Questa and approximately 300 feet from Red River. This discharge is permitted and monitored under a NMED Ground Water Discharge Plan which was originally approved in 1983. These lagoons are unlined and are designed to function as rapid infiltration basins. Some groundwater contamination is expected to occur in a limited area, and is monitored by a set of four monitoring wells located between the lagoons and the river. The ultimate discharge of the sewage effluent is to the Red River, where due to dilution by river water and by groundwater flowing through the highly transmissive alluvial aquifer, contaminant levels are expected to be well below surface water standards.

In the Red River watershed there are three known sites where underground storage tanks have leaked petroleum products, all within the town of Red River. None are yet known from the Village of Questa. The three sites in Red River are in various stages of investigation and remediation. A release from at least one of the sites was documented as directly contaminating the Red River with hydrocarbons for a short period of time in 1992. The three sites are Chevron Red River, Diamond Shamrock, and Red River Ski Area. In anticipation of road work and infrastructure changes along State Highway 38 through the Town of Red River, the NMHTD commissioned an environmental investigation along the right-of-way in 1994. Seven sites of potential concern were identified: Diamond Shamrock station, Edelweiss Inn (former Texaco/Gulf station), Pioneer Lodge (former Phillips 66 station), Bittercreek Rentals (former Shamrock/Chevron station), Angelinas Restaurant (former Texaco

station), High Country Rentals (former Chevron Red River station), Resort Realty (former Conoco station). Two of these seven sites (Chevron and Diamond Shamrock, as mentioned above) have confirmed releases and are under investigation or remediation. At the other sites no hydrocarbon contamination has been detected in any of the soil samples collected from borings, and no groundwater samples have shown hydrocarbon contamination above regulatory action levels. At present there is no known impact to the Red River from these sites.

The greatest need for action at any of the nonpoint pollution sources that have been described above is in dealing with the seepage of acid rock drainage from Molycorp mine sources and scar areas, and in controlling releases from liquid waste systems in the developments of the upper Red River valley. Efforts to address some of these problems have begun. A 319(h) workplan has been written to address stabilization and sediment control of scar areas in the Bitter Creek watershed (94-B), and the Liquid Waste Program continues to grapple with the septic tank problems. Although agencies and municipalities continue to be involved in this process, the best hope for effective long term solutions to water quality problems in the Red River watershed lies with a concerned citizenry and an active Red River-Questa Watershed Association.



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030081

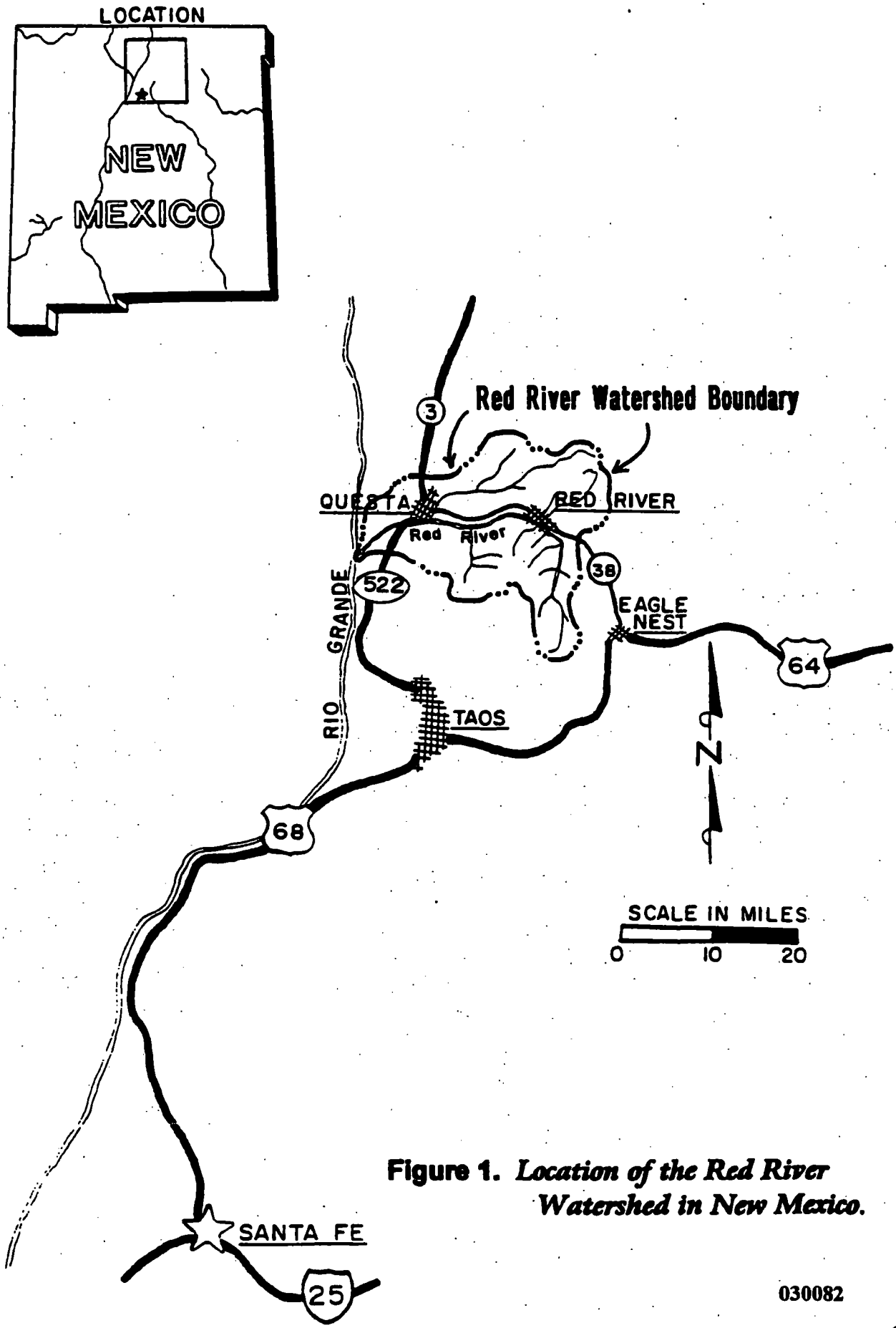



**Figure 1.** ***Location of the Red River Watershed in New Mexico.***

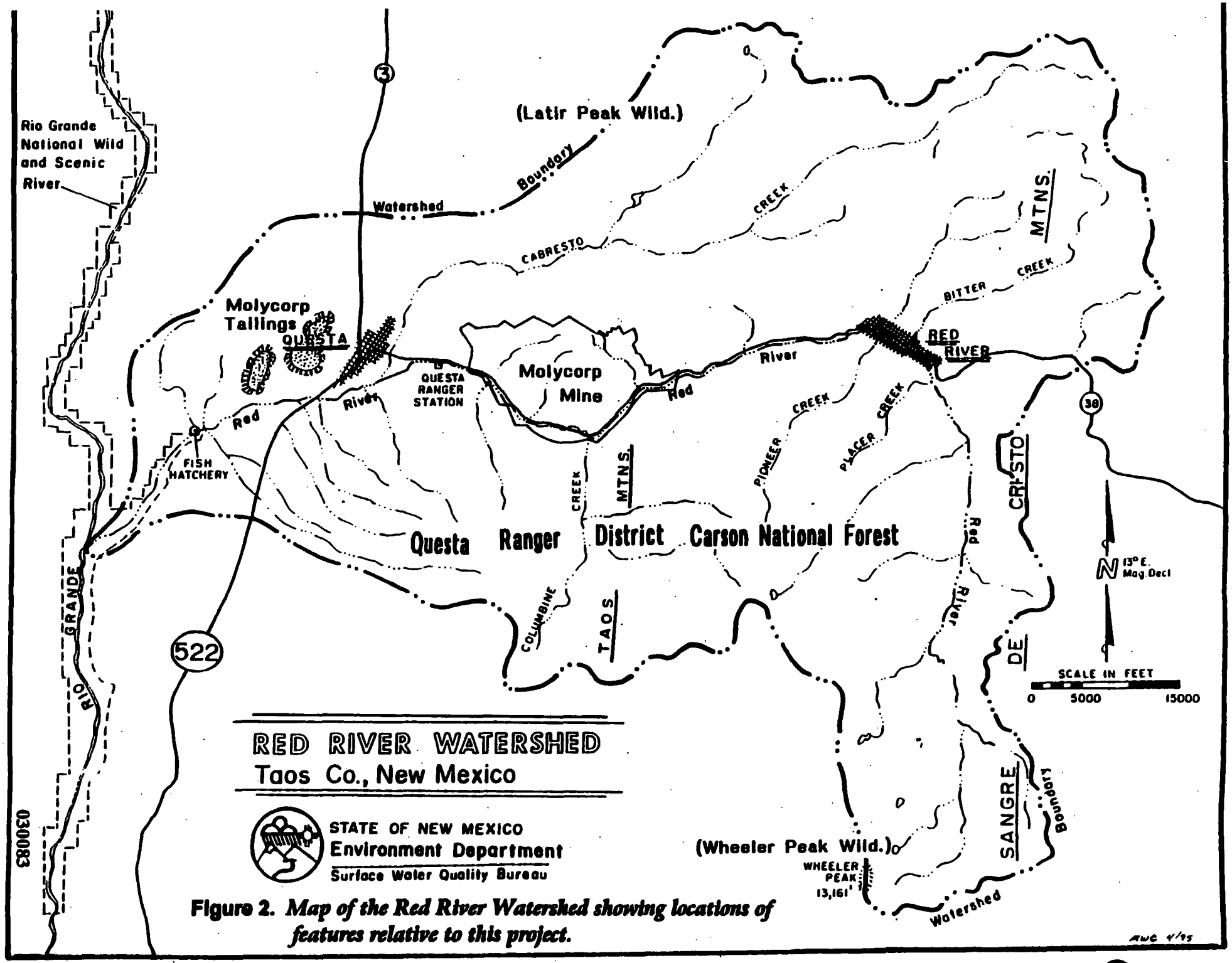



**Figure 2.** ***Map of the Red River Watershed showing locations of features relative to this project.***

FIGURE 2.

Figure 3.

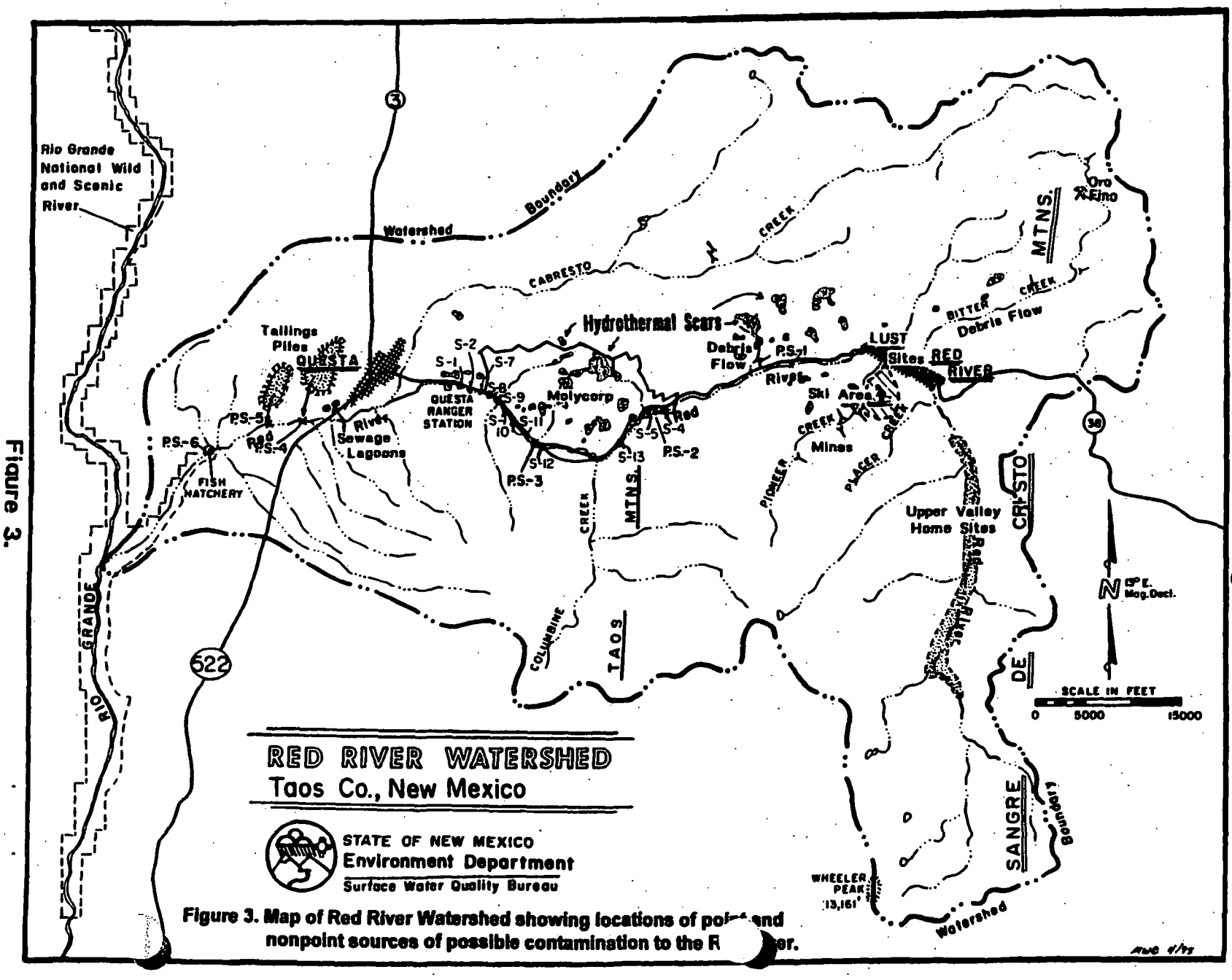



**Figure 3. Map of Red River Watershed showing locations of poi[illegible] and nonpoint sources of possible contamination to the R[illegible]er.**

## EXPLANATION

### POINT SOURCE POLLUTION:

PS-1: Town of Red River Wastewater Treatment Plant

PS-2: Molycorp Mill Site Outfall #005

PS-3: Molycorp Mine, Goathill Gulch Outfall #004

PS-4: Molycorp East Tailings Pile Outfall #002

PS-5: Molycorp Pope Lake/W.Tailings Outfall #001

PS-6: Red River Fish Hatchery (NMDG&F)

### NONPOINT SOURCE POLLUTION:

S-1 to S-13: Red River Groundwater Seeps (ARD)

Hydrothermally Altered Volcanic Rock Scars

Molycorp Mine

Scattered Abandoned Mine and Mill Sites (Esp. Pioneer and Bitter Creeks)

Upper RR Valley Home Sites: septic tanks, leach fields

Town of Red River: Leaking Underground Storage Tanks (LUST)

Red River Ski Area

Town of Questa Sewage Lagoons

Landslide/ Debris Flow Gravels and Sedim[illegible] (Bitter, Hansen and Hotentot Creeks)

Figure 3.

Figure 4

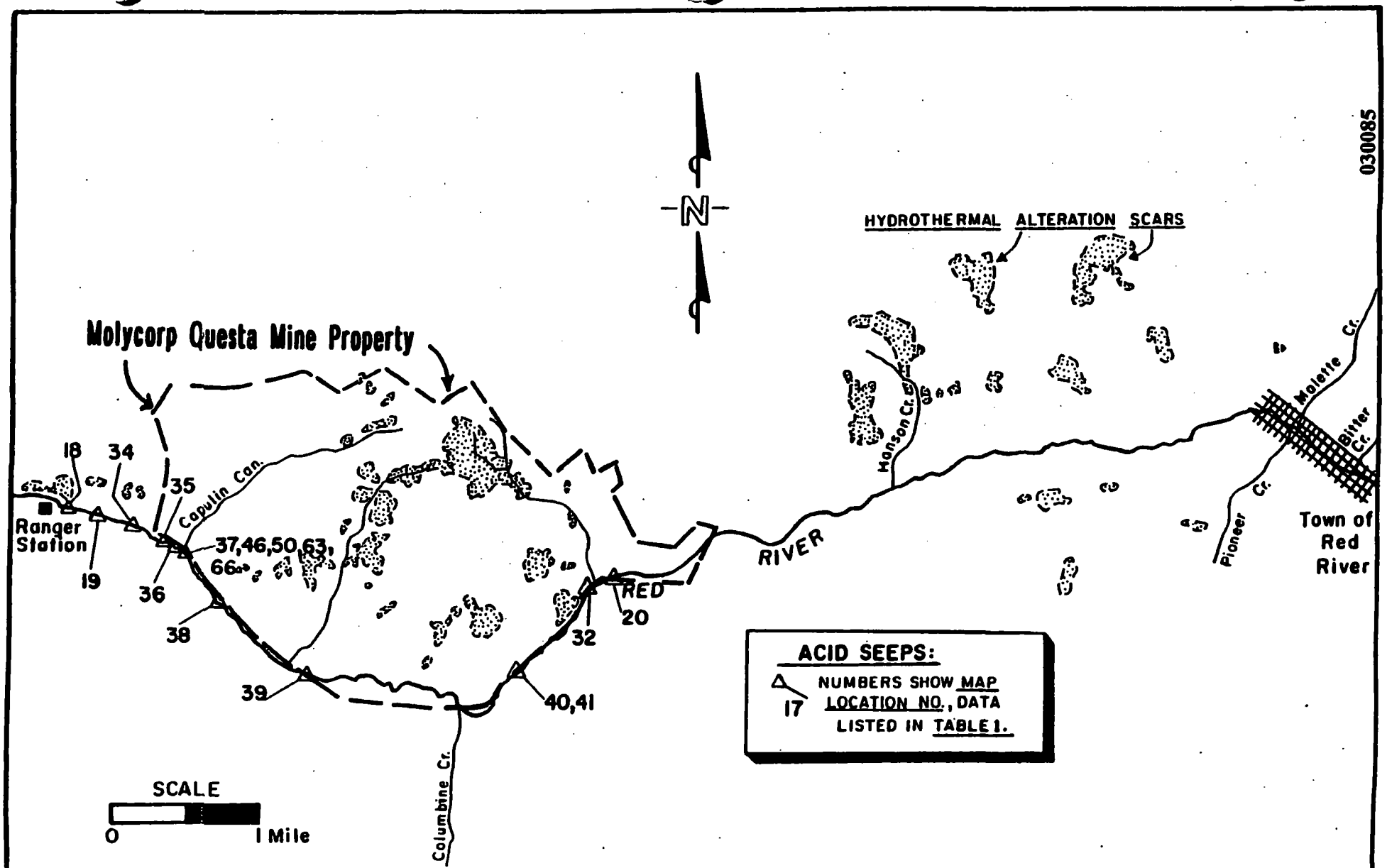
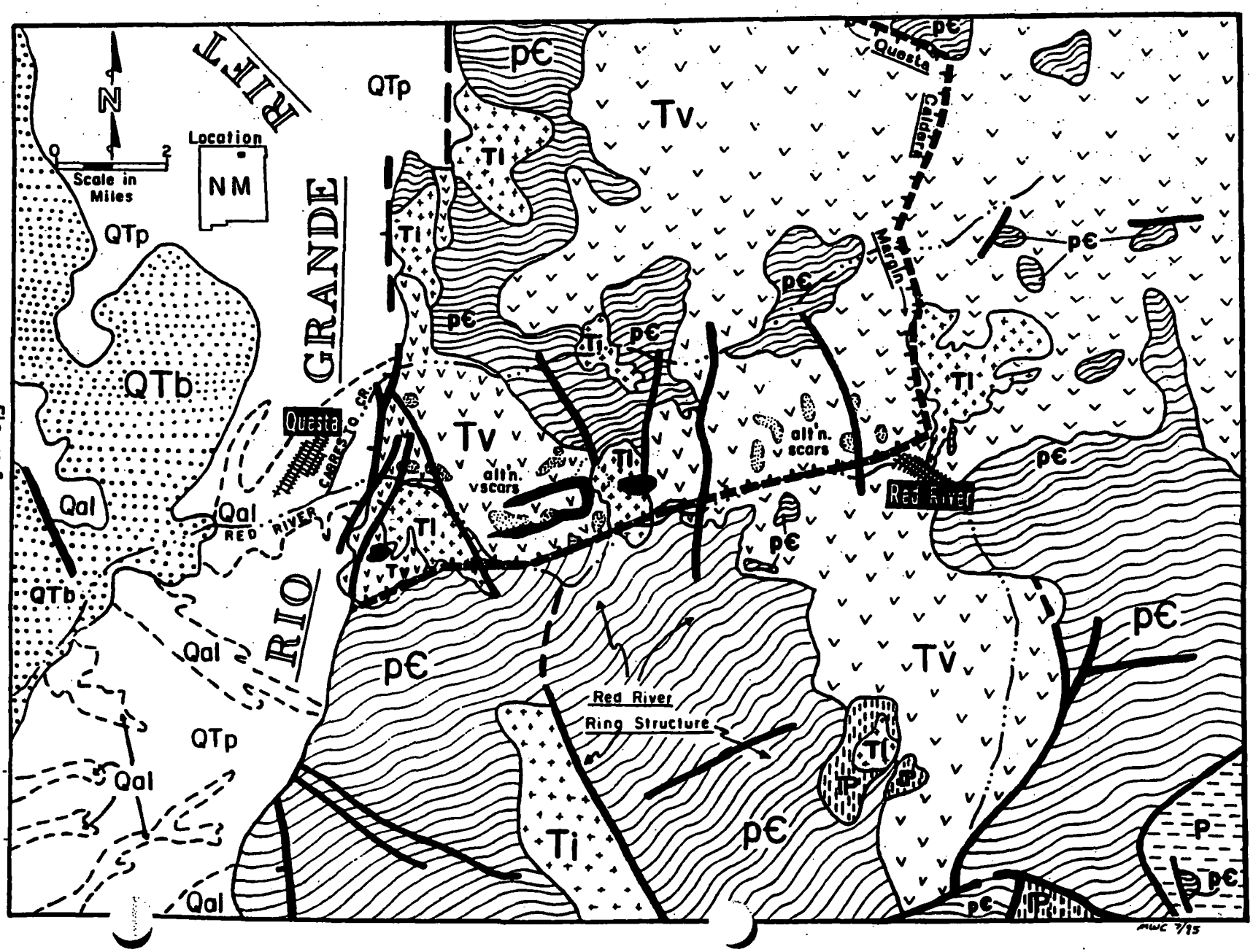



**Figure 4.** *Map of the middle reach of the Red River showing the Molycorp Questa Mine, acid seeps and natural hydrothermal scar areas.*

030086




**EPA / NMED RED RIVER WATERSHED PROJECT**
**319(h) Grant (92-A)**

Figure 5. Composite Geologic Map of Red River-Questa Area.

Figure 5.

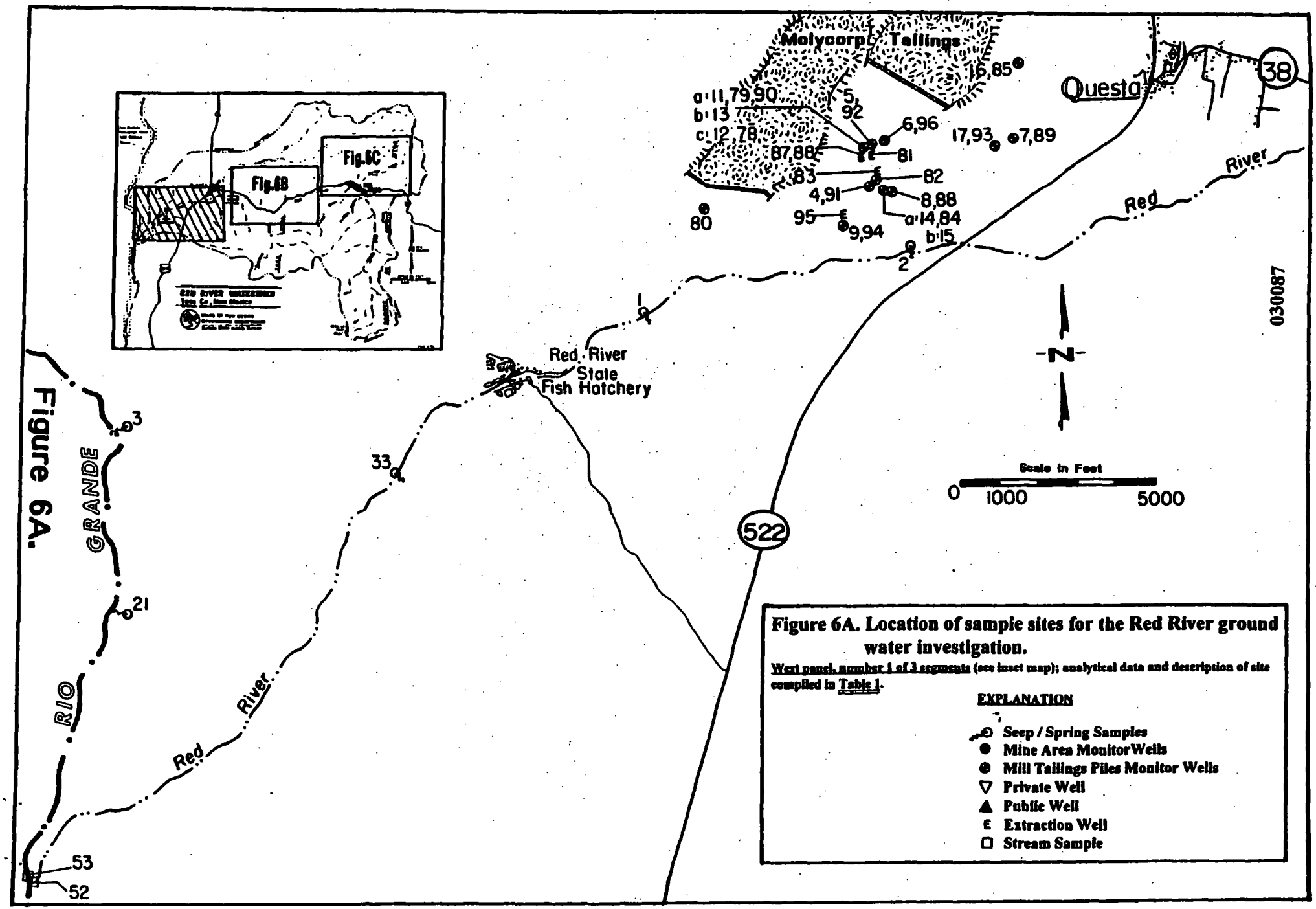



Figure 6A.

**Figure 6A. Location of sample sites for the Red River ground water investigation.**

West panel, number 1 of 3 segments (see inset map); analytical data and description of site compiled in Table 1.

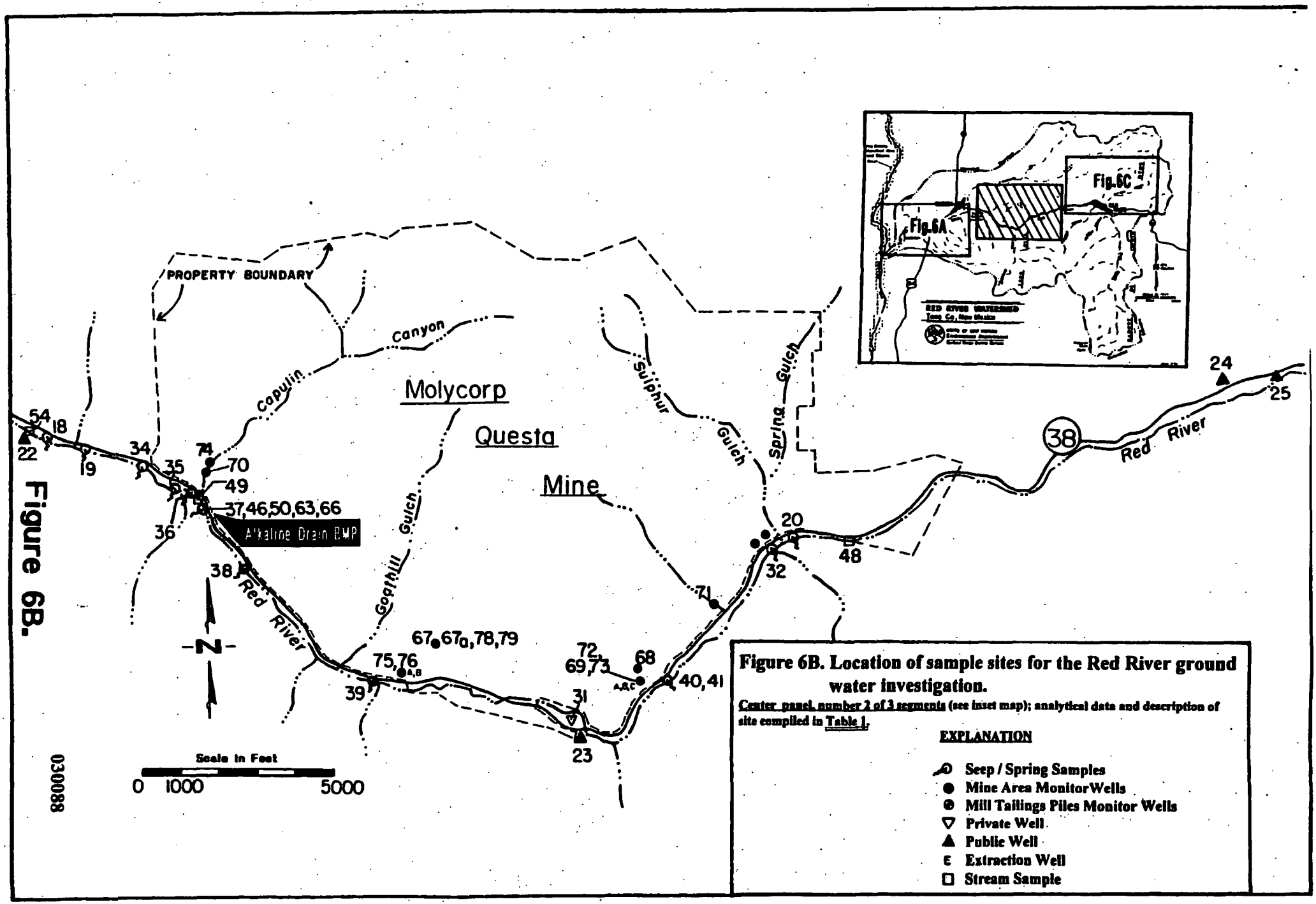



Figure 6B.

030088

**Figure 6B. Location of sample sites for the Red River ground water investigation.**

Center panel, number 2 of 3 segments (see inset map); analytical data and description of site compiled in Table 1.

**EXPLANATION**

- Seep / Spring Samples
- Mine Area Monitor Wells
- Mill Tailings Piles Monitor Wells
- Private Well
- Public Well
- Extraction Well
- Stream Sample

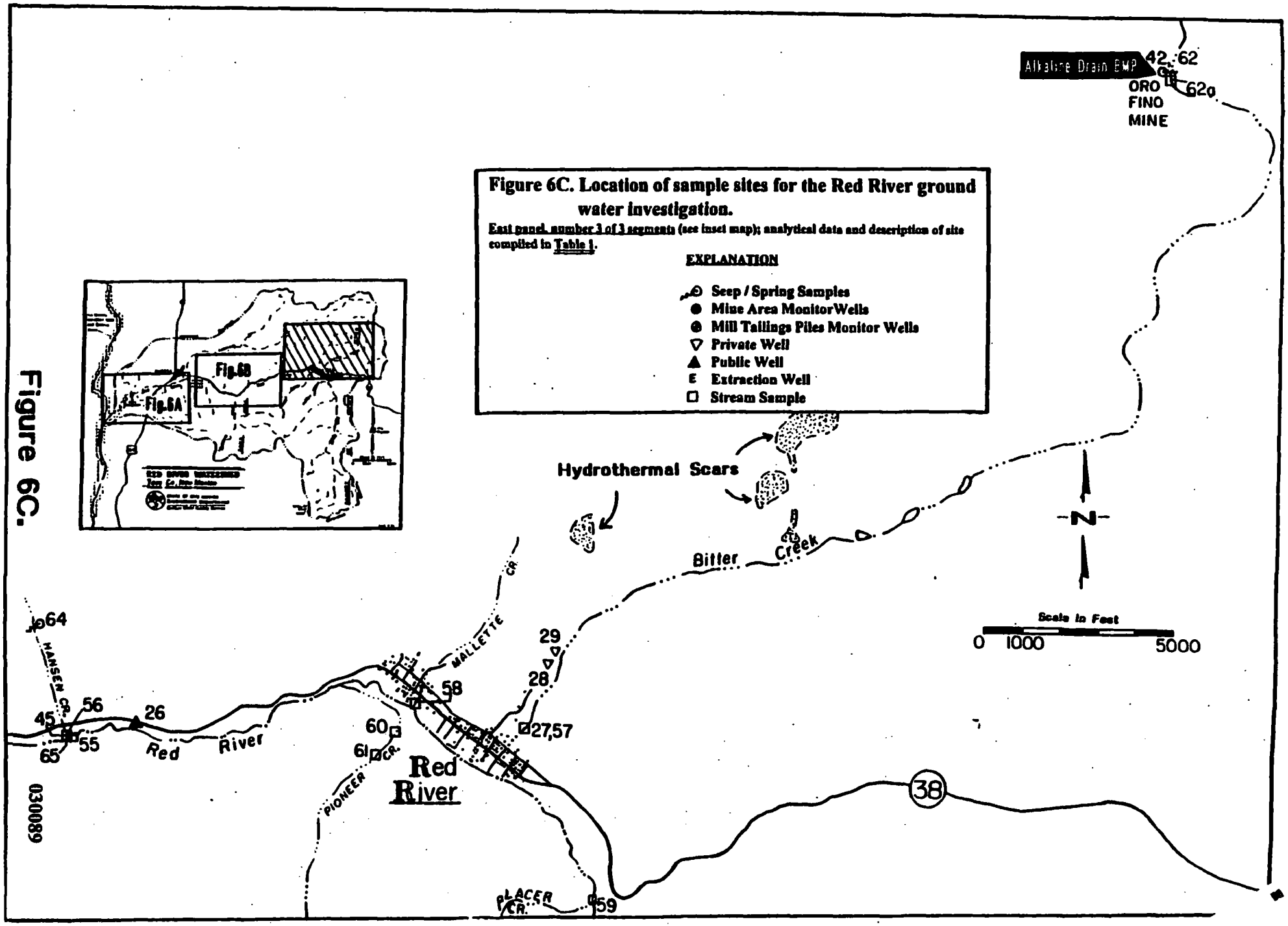



**Figure 6C. Location of sample sites for the Red River ground water investigation.**

East panel, number 3 of 3 segments (see inset map); analytical data and description of site compiled in Table 1.

**EXPLANATION**

- Seep / Spring Samples
- Mine Area Monitor Wells
- Mill Tailings Piles Monitor Wells
- Private Well
- Public Well
- Extraction Well
- Stream Sample

Figure 6C.

030089

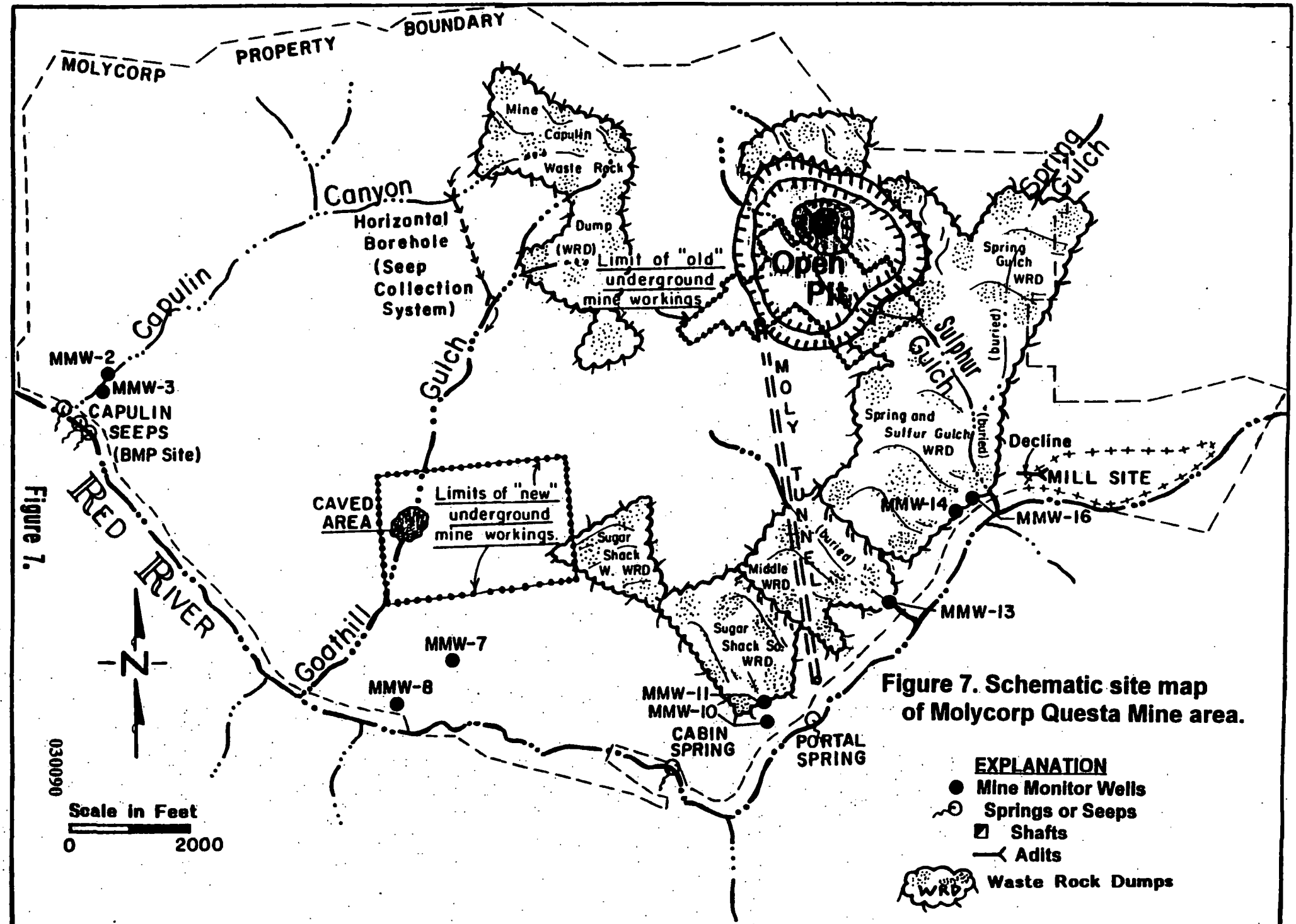



Figure 7.

**Figure 7. Schematic site map of Molycorp Questa Mine area.**

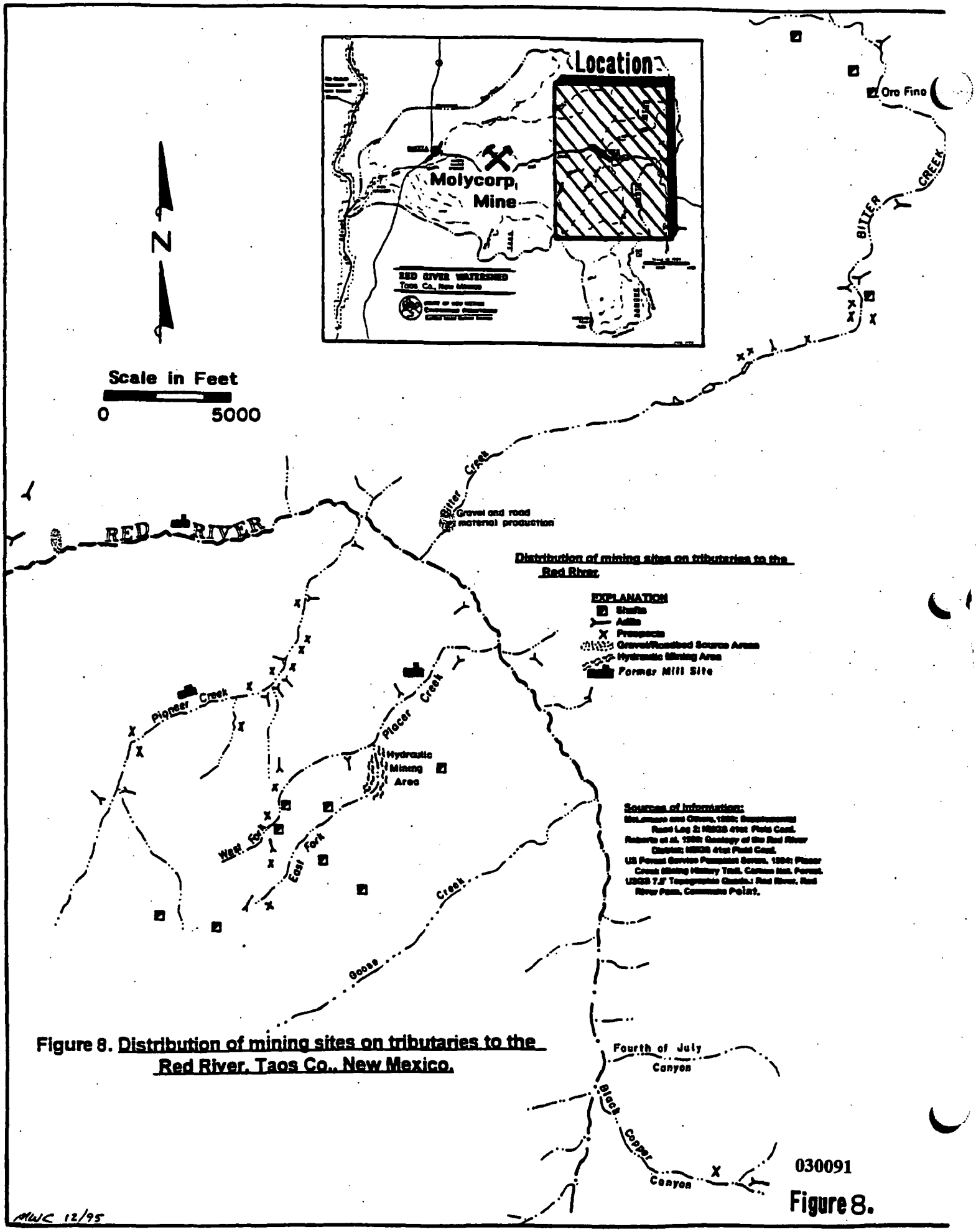



**Figure 8. Distribution of mining sites on tributaries to the Red River, Taos Co., New Mexico.**

MWC 12/95

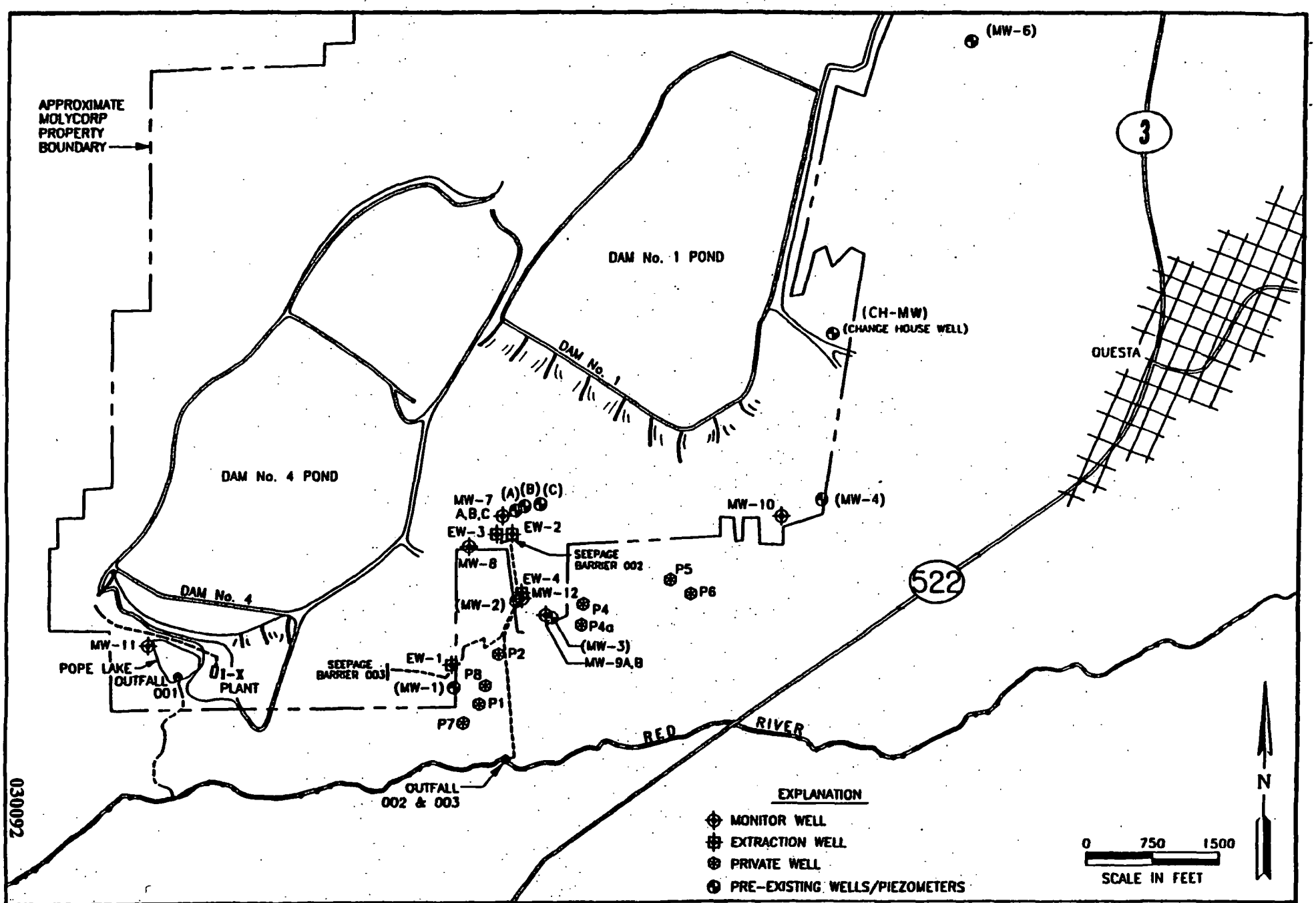



Figure 9.

030092

**EPA / NMED Red River Watershed Project (92-A)**

**Figure 9. Molycorp Questa Mine – Tailings Area Site Map**

**(Modified after South Pass Resources report to Molycorp, Fig. 3, dated 2/10/95)**

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030093

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp Area.



(Updated 3/18/96, mwc)

Orig.File: RdRiv1.XLA

| Map Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Hatchery (Cold) | Hatchery (Warm) | B. Arsenic Spring | MW-2 | MW-A | MW-C | MW-4 | MW-3 | MW-1 | MW-11 |
| | | | | (Samples from wells monitoring MolyCorp tailings) | | | | | | |
| North Latitude | | | | | | | | | | |
| West Longitude | | | | | | | | | | |
| Date Sampled | 8/12/93 | 8/12/93 | 8/12/93 | 8/17/93 | 8/17/93 | 8/17/93 | 8/17/93 | 8/17/93 | 8/17/93 | 8/17/93 |
| Sample Type | Spring-gw | Spring-gw | Spring-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw |
| | * Filtered or **Unfiltered Sample (Dissolved or Total Metals) | | | | | | | | | |
| Analyte (mg/L) | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF |
| | ** | ** | ** | * | * | * | * | * | * | * |
| Al | < 0.1 | < 0.1 | < 0.1 | | < 0.01 | | < 0.02 | < 0.01 | < 0.02 | < 0.02 |
| Cd | 0.002 | < 0.001 | < 0.001 | < 0.001 | 0.003 | 0.007 | < 0.001 | < 0.01 | < 0.001 | < 0.001 |
| Co | < 0.05 | < 0.05 | < 0.05 | | | | | | | |
| Cu | < 0.05 | < 0.05 | < 0.05 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| Fe | < 0.1 | 0.1 | < 0.1 | 0.09 | 0.07 | 0.16 | < 0.05 | < 0.05 | < 0.05 | < 0.05 |
| Pb | < 0.005 | < 0.005 | < 0.005 | < 0.001 | < 0.001 | 0.005 | < 0.001 | < 0.001 | < 0.001 | < 0.005 |
| Mn | < 0.05 | < 0.05 | < 0.05 | **0.49** | 0.03 | **3.6** | < 0.01 | < 0.01 | 0.04 | < 0.01 |
| Mo | 0.01 | < 0.05 | < 0.01 | **1.83** | | **2.3** | 0.25 | | 0.052 | 0.11 |
| Ni | < 0.1 | < .1 | < .1 | | | | | | | |
| Zn | < 0.05 | < 0.05 | < 0.05 | < 0.05 | | 0.02 | < 0.01 | | 0.01 | 0.02 |
| SO4 | | | | **870** | 570 | **1080** | 515 | **735** | 510 | 89 |
| Hardness | | | | | | | | | | |
| FieldConduct. | 355 | 290 | 210 | 1250 | 990 | 1510 | 920 | 1200 | 900 | 325 |
| TDS | 300 | 382 | 160 | | | **1880** | **1003** | **1343** | **982** | 268 |
| Field pH | 6.5 | 6.5 | | 7.7 | 7.4 | 7.2 | 7.3 | 7.4 | 7.2 | 8.1 |
| Turbidity/r=rain | | | | | | | | | | |

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm;Turbidity in NTU; pH in units;other analytes in mg/l.

030094

Table 1. Water Analysis of Selected Analyses From Red River / MolyCorp Area.



Orig.File: RdRiv2.XLA

| Map Location | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | MW-7a | MW-7c | MW-7b | MW-9a | MW-9b | Change House | MW-10 | S-1 | S-2 | S-4 |
| | (Wells monitoring tailings areas) | | | | | | | | | |
| North Latitude | | | | | | | | 36*42.15' | 36*42.082' | |
| West Longitude | | | | | | | | 105*33.804 | 105*33.64' | |
| Date Sampled | 8/18/93 | 8/18/93 | 8/18/93 | 8/18/93 | 8/18/93 | 8/18/93 | 8/18/93 | 8/24/93 | 8/24/93 | 8/24/93 |
| Sample Type | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | Seep-gw | Seep-gw | Seep-gw |
| | *Filtered or **Unfiltered Sample | | | | (Dissolved or Total Metals) | | | | | |
| Analyte (mg/l) | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * |
| Al | < 0.02 | 0.01 | < 0.02 | < 0.02 | 0.02 | < 0.02 | **1.9** | **100.0** | **100.0** | 0.6 |
| Cd | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | **0.04** | **0.045** | 0.002 |
| Co | | | | | | | | **0.27** | **0.3** | < 0.05 |
| Cu | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.05 | < 0.01 | 0.01 | 0.5 | **0.86** | < 0.05 |
| Fe | < 0.05 | < 0.01 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | **0.69** | **0.6** | **0.8** | 0.01 |
| Pb | < 0.005 | 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.005 | 0.006 | **< 0.10** | < 0.005 |
| Mn | 0.01 | < 0.01 | < 0.01 | **1.3** | 0.12 | < 0.01 | **0.09** | **44** | **44.0** | **0.28** |
| Mo | 0.015 | | 0.008 | 0.012 | | 0.004 | 0.025 | < 0.1 | < 0.1 | < 0.1 |
| Ni | | | | | | | | **0.08** | **0.7** | < 0.1 |
| Zn | 0.03 | | 0.018 | 0.032 | | 0.35 | 0.02 | **9.3** | **8.8** | 0.15 |
| SO4 | **625** | | **710** | 348 | 50 | 58 | 54 | **1510** | **1090** | 176 |
| Hardness | | | | | | | | 693 | 471 | 291 |
| Field Conduct. | 690 | 1980 | 1150 | 740 | 230 | 382 | 240 | 1250 | 1190 | 355 |
| TDS | **1146** | | **1176** | 752 | 183 | 286 | 192 | | | 374 |
| Field pH | 7.1 | **10.6** | 8.9 | 7.6 | 7 | 7.5 | 8.1 | **3.9** | **4.1** | 6.8 |
| Turbidity/r=rain | | | | | | | | | | |

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

030095

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp. Area



| Map Location | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | L. Arsenic Spring | Ranger Station | Columbine C.G. | Fawn Lakes C.G | Elephant Rock C.G. | Junebug C.G. | Bitter Creek | HarrisonWell (Bitter Ck.) | Davis Well (Bitter Ck.) | Mallette Rd. Seep (S-6) |
| North Latitude | | 36*42.19' | 36*40.855' | 36*42.342' | 36*42.484' | 36*42.54' | 36*42.548' | | | |
| West Longitude | | 105*33.97' | 105*30.901 | 105*27.33' | 105*26.864 | 105*26.146' | 105*23.955' | | | |
| Date Sampled | 8/24/93 | 8/24/93 | 8/24/93 | 8/24/93 | 8/24/93 | 8/24/93 | 8/24/93 | 8/24/93 | 8/24/93 | 9/8/93 |
| Sample Type | Spring-gw | P Well-gw | P Well-gw | P Well-gw | P Well-gw | P Well-gw | Spring-sw | P Well-gw | P Well-gw | Seep-gw |
| | | *Filtered or **Unfiltered Sample (Dissolved or Total Metals) | | | | | | | | |
| Analyte (mg/l) | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF * | F / UnF ** | F / UnF ** | F / UnF * |
| Al | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | 0.2 | **9.9** | 2.9 | 0.4 |
| Cd | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | **0.011** | 0.003 | 0.004 |
| Co | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | **0.06** | < 0.05 | < 0.05 |
| Cu | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | 0.79 | 0.32 | < 0.05 |
| Fe | < 0.1 | < 0.1 | < 0.1 | 0.1 | 0.1 | **0.7** | 0.6 | **1.6** | **1.7** | **5.1** |
| Pb | < 0.005 | 0.018 | 0.01 | < 0.005 | < 0.005 | 0.009 | < 0.005 | < 0.005 | < 0.005 | < 0.005 |
| Mn | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | **2.61** | **0.8** | **1.9** |
| Mo | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 1.0 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 |
| Ni | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 |
| Zn | < 0.05 | 0.09 | 1.5 | < 0.1 | 0.15 | **8.6** | 0.08 | 2.0 | 0.22 | 0.39 |
| SO4 | 17 | 96 | 10 | 105 | 60 | 44 | 46.0 | 308 | 114 | 156 |
| Hardness | 82 | 152 | 80 | 152 | 135 | 121 | 82 | 259 | 86 | 148 |
| FieldConduct. | 193 | 215 | 120 | 230 | 160 | 175 | 155 | 420 | 195 | 220 |
| TDS | | | | | | 150 | | | | 298 |
| Field pH | 7.8 | 7.3 | 6.6 | 6.9 | 7.1 | 6.8 | 7.2 | **4.9** | **4.6** | **5.3** |
| Turbidity/r=rain | | | | | | | | | | |

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

030096

Table 1. Water Analysis of Selected Analytes From Red RIver / MolyCorp. Area



| Map Location | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Fagerquist Motel | Sulfur Gulch(S-5) | .Red Riv Spring | Red Riv. Seep (S-7) | S-8 Seep Rd.Excav'n | S-9 Seep Rv.Channel | Red Riv. Seep (S-10) | Red Riv. Seep(S-11) | Red Riv. Seep(S-12) | Red Riv. Seep(S-13a) |
| North Latitude | | | | 36*42.145' | 36*41.879' | 36*41.862' | 36*41.82' | 36*41.627' | 36*41.097' | 36*41.092' |
| West Longitude | | | | 105*33.485 | 105*33.039 | 105*32.948' | 105*32.943' | 105*32.762 | 105*32.008' | 105*30.512' |
| Date Sampled | 9/9/93 | 9/9/93 | 9/10/93 | 9/21/93 | 9/21/93 | 9/21/93 | 9/21/93 | 9/21/93 | 9/21/93 | 2/3/94 |
| Sample Type | Pr. Well-gw | Seep-gw | Spring-gw | Seep-gw | Seep-gw | Seep-gw | Seep-gw | Seep-gw | Seep-gw | Seep-gw |
| | *Filtered or **Unfiltered Sample (Dissolved or Total Metals) | | | | | | | | | |
| Analyte (mg/l) | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF | F / UnF |
| | ** | * | ** | * | * | * | * | * | * | * / ** |
| Al | < 0.1 | 1.2 | 0.1 | **96.0** | **180.0** | **140.0** | **130.0** | **65.0** | **36.0** | **24 / 23** |
| Cd | 0.001 | 0.004 | < 0.001 | 0.039 | **0.087** | **0.018** | **0.019** | **0.012** | **0.011** | **0.019 / 0.02** |
| Co | < 0.05 | < 0.05 | < 0.05 | **0.27** | **0.72** | **0.25** | **0.22** | **0.11** | **0.12** | **0.07 / 0.07** |
| Cu | < 0.05 | < 0.05 | < 0.05 | 0.9 | 2.0 | 0.77 | **1.3** | **1.1** | 0.15 | 0.17 / 0.3 |
| Fe | < 0.1 | < 0.1 | < 0.1 | < 0.1 | **2.1** | **7.3** | **29.0** | 0.4 | < 0.1 | < 0.1 / 0.3 |
| Pb | < 0.005 | < 0.005 | < 0.005 | < 0.005 | 0.004 | < 0.005 | < 0.005 | < 0.005 | < 0.005 | < .001 / .001 |
| Mn | < 0.05 | 0.06 | < 0.05 | **42.0** | **110.0** | **21.0** | **20.0** | **10.0** | **4.4** | **13.0 / 12.0** |
| Mo | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 / < 0.1 |
| Ni | < 0.1 | < 0.1 | < 0.1 | **0.7** | **1.6** | **0.5** | **0.5** | **0.3** | **0.4** | **0.3 / 0.2** |
| Zn | < 0.05 | 0.41 | < 0.05 | 8.7 | **23.0** | 4.7 | 4.1 | 2.7 | 1.5 | 1.38 / 1.5 |
| SO4 | 9.0 | 344 | 19 | **1200** | **2600** | **1800** | **1700** | **828** | **1400** | **914** |
| Hardness | 68 | 351 | 68 | 533 | 1420 | 834 | 824 | 427 | 1160 | 768 |
| Field Conduct. | 104 | 500 | 195 | 1140 | 2450 | 1800 | 1670 | 850 | 1200 | 800 |
| TDS | 90 | 562 | 164 | **2047** | **4580** | **3008** | **2797** | **1476** | **2400** | **1362** |
| Field pH | 6.8 | 6.1 | 6.9 | **4.2** | **3.9** | **3.3** | **3.6** | **4.5** | **4.9** | **4.9** |
| Turbidity/r=rain | | | | | | | | | | |

030097

Bold numeric values exceed NM WQCC standards for gw (seep,spring,well) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp. Area



Orig.File: RdRiv5.XLA

| Map Location | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Seep (S13b) | Orofino Mn. treat.drain | U.Red Rive algal pool | Upper Red Riv. | Hansen Cr. at confluence | Seep (S10) abv. Capulin | UpperR.R. V.of Pines | R.R.upstr. of Moly. mill | R.R. blw. Capulin Cn. | Capulin at R.R. (S10) |
| North Latitude | 36*41.092' | | | | 36*42.153' | 36*41.82' | | | | 36*41.82' |
| West Longitude | 105*30.512' | | | | 105*27.757' | 105*32.943' | | | | 105*32.943' |
| Date Sampled | 2/3/94 | 6/22/94 | 7/21/94 | 7/21/94 | 5/4/94 | 5/4/94 | 8/2/94 | 8/2/94 | 8/2/94 | 8/2/94 |
| Sample Type | Seep-gw | Seep-gw | Stream-sw | Stream-sw | Seep-gw | Seep-gw | Stream-sw | Stream-sw | Stream-sw | Seep-gw |
| | | *Filtered or **Unfiltered Sample | | | (Dissolved or Total Metals) | | | | | |
| Analyte (mg/l) | F / UnF * | F / UnF * ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF * ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** |
| Al | **13.0** | 0.7 / 1.7 | | | **86** | **120 / 130** | | 1.8 | 4.4 | **120** |
| Cd | **0.014** | <.001/<.001 | | | 0.007 | <0.1 / <0.1 | | < 0.001 | < 0.001 | **0.032** |
| Co | < 0.05 | 0.08 / 0.08 | | | **0.15** | **.22 / .21** | | < 0.05 | < 0.05 | **0.2** |
| Cu | 0.09 | 0.01 / 0.01 | | | 0.12 | **1.2 / 1.2** | | 0.01 | 0.03 | **1.2** |
| Fe | < 0.01 | **7.0 / 10.0** | | | **19.0** | **31.0 / 32.0** | | **4.1** | **4.4** | **12.0** |
| Pb | 0.002 | <0.1 / <0.1 | | | < 0.005 | <0.1 / <0.1 | | 0.016 | 0.011 | 0.007 |
| Mn | **6.2** | **1.8 / 1.9** | | | **7.2** | **19.0 / 19.0** | | 0.19 | **0.76** | **19.0** |
| Mo | < 0.1 | <0.1 / <0.1 | | | < 0.1 | <0.1 / <0.1 | | < 0.1 | < 0.1 | < 0.1 |
| Ni | **0.2** | 0.1 / 0.2 | | | **0.4** | **0.5 / 0.4** | | < 0.1 | < 0.1 | **0.5** |
| Zn | 1.1 | 0.08 / 0.06 | | | 2.3 | **5.0 / 4.6** | | 0.03 | 0.14 | 4.3 |
| SO4 | **743** | 647 | | | | | | 68 | 123 | **1532** |
| Hardness | 705 | 766 | | | | | | 123 | 163 | 799 |
| FieldConduct. | 750 | 1100 | 335 | 150 | 1700 | 1600 | 105 | 220 | 290 | 1500 |
| TDS | **1134** | **1028** | 106 | 234 | | | | 196 | 238 | **2302** |
| Field pH | **5.3** | 6.6 | 7.0 | 7.0 | **3.1** | **3.5** | 7.0 | 6.9 | **5.9** | **4.0** |
| Turbidity/r=rain | | | | | | | | | | |

030098

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp. Area



Orig.File: RdRiv6.XLA

| Map Location | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Rio Grande at Pilar | RR at RGnd confluence | RG at RR confluence | RR at Questa RS | RR at Hansen Cr. | Hansen Cr. at RR confl. | Bitter Cr. above RR | Mouth of MalletteCr. | R.R. at Placer Ck. | Pioneer Cr. blw.Ski area |
| North Latitude | | | | 36*42.188' | 36*42.153' | 36*42.154' | 36*42.548' | 36*42.575' | 36*41.709' | 36*42.58' |
| West Longitude | | | | 105*34.108' | 105*27.757 | 105*27.756' | 105*23.955 | 105*24.603 | 105*23.56' | 105*24.706' |
| Date Sampled | 8/3/94 | 8/31/94 | 8/31/94 | 8/31/94 | 8/31/94 | 8/31/94 | 8/31/94 | 8/31/94 | 8/31/94 | 8/31/94 |
| Sample Type | Stream-sw | Stream-sw | Stream-sw | Stream-sw | Stream-sw | Stream-sw | Stream-sw | Stream-sw | Stream-sw | Stream-sw |
| | *Filtered or **Unfiltered Sample | | | (Dissolved or Total Metals) | | | | | | |
| Analyte (mg/l) | F / UnF * ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** | F / UnF ** |
| Al | 0.2 / 11.0 | | 0.2 | 16 | 1.3 | 340.0 | 360.0 | 38.0 | 0.8 | 4.8 |
| Cd | <.001/ <.001 | | < 0.001 | 0.003 | < 0.001 | 0.013 | 0.026 | 0.001 | < 0.001 | < 0.001 |
| Co | <.05 / <.05 | | < 0.05 | <0.05 | < 0.05 | 0.4 | 0.21 | <0.05 | < 0.05 | < 0.05 |
| Cu | <.01 / 0.04 | | < 0.01 | 0.22 | 0.03 | 0.66 | 9.4 | 0.3 | < 0.01 | 0.04 |
| Fe | 0.4 / 38.0 | | 0.3 | 53.0 | 3.8 | 1300.0 | 1200.0 | 69.0 | 0.9 | 13.0 |
| Pb | .002 / 0.1 | | < 0.002 | 0.062 | 0.008 | 2.3 | 1.6 | 0.3 | 0.001 | 0.029 |
| Mn | <.05 / 0.39 | | < 0.05 | 1.5 | 0.16 | 32.0 | 13.0 | 1.1 | < 0.05 | 0.32 |
| Mo | <.10 / <.10 | | < 0.1 | <0.1 | < 0.1 | < 0.1 | 0.6 | <0.1 | < 0.1 | < 0.1 |
| Ni | <.10 / <.10 | | < 0.1 | < 0.1 | < 0.1 | 0.9 | 0.6 | <0.1 | < 0.1 | < 0.1 |
| Zn | 0.04 / 0.11 | | < 0.1 | 0.4 | 0.04 | 3 | 1.5 | 0.5 | < 0.1 | 0.04 |
| SO4 | 84 | 119 | 30 | 143 | | | | 43 | 13 | 29 |
| Hardness | 133 | 154 | 96 | 173 | | | | 41 | 94 | 84 |
| FieldConduct. | 320 | 270 | 195 | 260 | 178 | 1200 | 850 | 72 | 125 | 110 |
| TDS | 262 | 244 | 186 | 270 | | | | 172 | 112 | 136 |
| Field pH | 6.9 | 7.0 | 7 | 6.4 | 6.4 | 4.2 | 3.4 | 7.2 | 6.2 | 7.2 |
| Turbidity/r=rain | >1000(r) | 265 | 4.96 | >1000(r) | 35.7 | >1000(r) | >1000(r) | >1000 | 18.4 | 293(r) |

num ...xceed NM WQCC standards ...w (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp. Area



| Map Location | 61 | 62 | 62a | 63 | 64 | 65 | 66 | 67 | 67a | 68 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Pioneer Cr. abv.Ski area | Oro Fino ARD | B.Cr. at the OroFinoMn | Capulin Cn. Seep | Hansen Cr. scar drain. | Hansen Cr. at Hwy. | Capulin Cn. mouth | MMW-7 @ 61.1' | MMW-7 duplicate | MMW-11 @ 89.5' |
| North Latitude | 36*42.303' | | | | | | | | | |
| West Longitude | 105*24.92' | | | | | | | | | |
| Date Sampled | 8/31/94 | 7/24/92 | 7/24/92 | 7/8/92 | 7/8/92 | 7/7/92 | 2/21/95 | 11/7/94 | 11/7/94 | |
| Sample Type | Stream-sw | Seep-gw | Seep-gw | Seep-gw | Seep-gw | Stream-sw | Seep-gw | M Well-gw | M Well-gw | M Well-gw |
| | | | *Filtered or **Unfiltered Sample | | | (Dissolved or Total Metals) | | | | |
| Analyte (mg/l) | F / UnF ** | F / UnF * ** | F / UnF * | F / UnF * ** | F / UnF * ** | F / UnF * ** | F / UnF * ** | F / UnF * | F / UnF * | F / UnF * |
| Al | 1.5 | **89 / 95** | 0.27 | **130 / 140** | **88 / 89** | 110 / 120 | **150 / 120** | **950** | **890** | **54** |
| Cd | < 0.001 | .005 / .005 | <0.001 | **.028 / .029** | .004 / .003 | .008 / .006 | **.021 / .025** | **0.11** | **0.11** | **0.04** |
| Co | < 0.05 | **0.52 / 0.54** | <0.05 | **0.22 / 0.22** | **.11 / .11** | 0.2 / 0.21 | **.23 / .20** | **4.3** | **3.9** | **0.25** |
| Cu | < 0.01 | 0.29 / 0.32 | <0.05 | **1.3 / 1.3** | .05 / <.05 | .156 / .152 | **1.5 / 1.4** | **4.5** | **4.5** | **0.9** |
| Fe | 3.0 | **990 / 1050** | 0.3 | **20.0 / 21.0** | **36 / 45** | 7.3 / 7.5 | **20.0 / 24.0** | **420** | **380** | <0.1 |
| Pb | 0.007 | <.005/<.005 | <0.005 | <.005/<.005 | <.005/<.005 | <.005/<.005 | <.005 / .007 | **1.0** | **0.8** | <0.01 |
| Mn | 0.1 | **4.2 / 4.2** | <0.05 | **18.6 / 19.1** | **5.08 / 5.32** | 10.9 / 11.11 | **19.0 / 18.0** | **69** | **72** | **28** |
| Mo | < 0.01 | **2.4 / 2,8** | <0.1 | <0.1 / <0.1 | <0.1 / <0.1 | <0.1 / <0.1 | <0.1 / <0.1 | <0.1 | <0.1 | <0.1 |
| Ni | < 0.01 | **1.5 / 1.5** | <0.1 | 0.5 / 0.5 | **0.3 / 0.3** | 0.5 / 0.5 | **0.5 / 0.4** | **9.5** | **8.6** | **0.6** |
| Zn | 0.01 | 1.5 / 1.4 | <0.05 | 4.7 / 4.8 | 2.3 / 2.5 | 3.33 / 3.33 | 4.9 / 4.2 | 9.7 | 9.8 | 4.6 |
| SO4 | 25 | | <5.0 | | | | **1490** | **9366** | **9066** | **1287** |
| Hardness | 84 | | 50 | | | | 839 | 6097 | 6039 | 1004 |
| FieldConduct. | 109 | | | | | | 1400 | 7100 | 7100 | 1490 |
| TDS | 130 | | 78 | | | | **2,232** | **15,258** | **16,524** | **2,124** |
| Field pH | 7.2 | | | | | | **4.0** | **4.4** | **4.4** | **5.6** |
| Turbidity | **88.5** | | 1.33 | | | | | | | |

030100

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp. Area



Orig.File: RdRiv8.XLA

| Map Location | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | MMW-10B | MMW-3 | MMW-13 | MMW-10A | MMW-10C | MMW-2 | MMW-8B | MMW-8A | Dupl.MW-3 | MW-7C |
| (Depth to water) | @ 21.6' | @ 29.6' | @ 109.1' | @ 21.7' | @ 21.8 | @ 33.7' | @ 96.0' | @ 96.8' | @ 20.4' | @ 116.2' |
| North Latitude | | | | | | | | | | |
| West Longitude | | | | | | | | | | |
| Date Sampled | 11/7/94 | 11/7/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/9/94 |
| Sample Type | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw |
| | | | *Filtered or **Unfiltered Sample | | | (Dissolved or Total Metals) | | | | |
| Analyte (mg/l) | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * |
| Al | 7.6 | 1.0 | <0.1 | 33 | 31 | 68 | 0.2 | 0.4 | <0.1 | 0.4 |
| Cd | 0.02 | 0.003 | <0.001 | 0.03 | 0.025 | 0.02 | <0.002 | <0.005 | <0.002 | <0.002 |
| Co | 0.08 | 0.07 | 0.011 | 0.14 | 0.1 | 0.33 | 0.003 | 0.003 | <0.002 | <0.002 |
| Cu | 0.2 | <0.1 | <0.01 | 0.5 | 0.4 | <0.1 | <0.02 | <0.01 | <0.02 | <0.02 |
| Fe | 0.07 | 0.1 | 0.2 | <0.1 | <0.1 | 61 | 3 | <0.1 | 0.08 | 0.1 |
| Pb | 0.03 | <0.1 | <0.001 | <0.01 | <0.01 | <0.01 | <0.002 | <0.001 | <0.002 | <0.002 |
| Mn | 8.5 | 33 | 0.91 | 15 | 16 | 53 | 7.8 | 0.23 | 0.05 | <0.002 |
| Mo | <0.01 | <0.01 | 0.051 | <0.01 | <0.01 | <0.01 | 0.01 | <0.001 | 0.004 | 0.009 |
| Ni | 0.3 | 0.2 | <0.1 | 0.3 | 0.3 | 0.7 | <0.1 | <0.1 | <0.1 | <0.1 |
| Zn | 1.4 | 1.3 | 0.2 | 2.1 | 2.9 | 10 | <0.02 | 0.2 | <0.02 | <0.02 |
| SO4 | 1080 | 1759 | 717 | 1030 | 849 | 2177 | 1279 | 716 | 729 | 754 |
| Hardness | 1193 | 1708 | 847 | 952 | 795 | | 1440 | 686 | 738 | 858 |
| FieldConduct. | 2050 | 2050 | 1050 | 1210 | 1020 | 3139 | 2276 | 1326 | 1463 | 1538 |
| TDS | 1882 | 3070 | 1442 | 1882 | 1690 | 3524 | 2292 | 1282 | 1400 | 1360 |
| Field pH | 7.5 | 7.5 | 7.9 | 5.9 | 4.7 | 7.3 | 8.1 | 6.0 | 7.3 | 7.2 |
| Turbidity/r=rain | | | | | | | | | | |

030101

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp. Area



Orig.File: RdRivr9.XLA

| Map Location | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Duplicate o MW- 7A (at 61.6') | MW-11 @ 194.4' | EW-2 @ 150.6' | MW-12 @ 129.7 | EW-4 @ 21' | MW-9A @ 29.1' | ChangeHouse CH-MW | Outfall 002 | EW-3 @ 60.2' | MW-3 @ 20.4' |
| North Latitude | | | | | | | | | | |
| West Longitude | | | | | | | | | | |
| Date Sampled | 11/9/94 | 11/9/94 | 11/9/94 | 11/9/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/4/94 | 11/8/94 | 11/9/94 |
| Sample Type | M Well-gw | M Well-gw | E Well | M Well-gw | E Well-gw | M Well-gw | M Well-gw | NPDES-sw | E Well-gw | M Well-gw |
| | *Filtered or **Unfiltered Sample (Dissolved or Total Metals) | | | | | | | | | |
| Analyte (mg/l) | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * |
| Al | 0.3 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.06 | <0.01 | <0.02 |
| Cd | <0.002 | <0.001 | <0.002 | <0.001 | <0.001 | <0.01 | <0.001 | <0.001 | <0.001 | <0.001 |
| Co | <0.002 | <0.001 | <0.002 | <0.001 | <0.001 | <0.01 | <0.001 | 0.003 | 0.001 | 0.001 |
| Cu | <0.02 | | <0.02 | <0.01 | <0.01 | <0.1 | <0.01 | <0.01 | <0.01 | <0.01 |
| Fe | 0.1 | <0.05 | <0.05 | <0.05 | <0.05 | 0.2 | <0.1 | <0.1 | <0.1 | 0.1 |
| Pb | <0.002 | <0.001 | <0.002 | <0.001 | <0.001 | <0.01 | <0.001 | <0.001 | <0.001 | <0.001 |
| Mn | 0.002 | 0.003 | 0.15 | 0.002 | 0.005 | 0.17 | 0.006 | 1.9 | 0.07 | 0.06 |
| Mo | 0.009 | 0.067 | 0.007 | 0.012 | 0.003 | <0.01 | 0.003 | 2.3 | 0.001 | 0.004 |
| Ni | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Zn | <0.02 | <0.01 | <0.02 | <0.01 | <0.01 | <0.1 | 0.9 | <0.01 | <0.01 | <0.01 |
| SO4 | **755** | 52 | 85 | 61 | 139 | **703** | 65 | 896 | 418 | **728** |
| Hardness | 829 | 126 | 194 | 165 | 281 | 670 | 157 | 958 | 534 | 759 |
| FieldConduct. | 1422 | 315 | 431 | 282 | 560 | 1460 | 504 | | 1032 | 1544 |
| TDS | **1336** | 243 | 283 | 296 | 480 | **1318** | 382 | 2124 | 898 | **1432** |
| Field pH | 7.5 | 7.0 | 7.5 | **8.4** | 7.7 | 6.4 | **8.6** | | 7.5 | 7.3 |
| Turbidity/r=rain | | | | | | | | | | |

030102

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

Table 1. Water Analysis of Selected Analytes From Red River / MolyCorp. Area



Orig.File: RdRivr10.XLA

| Map Location | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 |
|---|---|---|---|---|---|---|---|---|
| Station | MW-4 | MW-7A | MW-2 | MW-A | MW-10 | MW-1 | EW-1 | MW-C |
| | @ 41.6' | @ 61.6' | @ 22.9' | @ 32.6' | @ 28.5' | @ 54.0' | @ 83.0' | @ 3.1' |
| North Latitude | | | | | | | | |
| West Longitude | | | | | | | | |
| Date Sampled | 11/18/94 | 11/18/94 | 11/17/94 | 11/17/94 | 11/8/94 | 11/7/94 | 11/7/94 | 11/7/94 |
| Sample Type | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | M Well-gw | E Well-gw | M Well-gw |
| | | *Filtered or **Unfiltered Sample | | | (Dissolved or Total Metals) | | | |
| Analyte (mg/l) | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * | F / UnF * |
| Al | <0.01 | <0.01 | <0.04 | <0.04 | <0.01 | <0.04 | <0.1 | <0.1 |
| Cd | <0.001 | <0.001 | <0.004 | <0.004 | <0.001 | <0.004 | <0.002 | <0.004 |
| Co | <0.001 | 0.001 | <0.004 | <0.004 | <0.001 | <0.004 | <0.002 | <0.004 |
| Cu | <0.01 | <0.01 | <0.04 | <0.04 | <0.01 | <0.04 | <0.02 | <0.04 |
| Fe | <0.1 | <0.1 | **5.4** | 0.4 | <0.1 | 0.2 | <0.1 | <0.1 |
| Pb | <0.001 | <0.001 | <0.004 | <0.004 | <0.001 | <0.004 | <0.002 | 0.004 |
| Mn | 0.004 | <0.001 | **0.38** | 0.037 | <0.001 | 0.02 | 0.02 | **0.88** |
| Mo | 0.21 | 0.002 | **1.7** | 0.6 | 0.004 | 0.047 | 0.02 | 1.2 |
| Ni | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Zn | <0.01 | <0.01 | <0.04 | <0.04 | <0.01 | <0.04 | <0.02 | <0.04 |
| SO4 | 413 | **720** | **819** | 528 | 32 | 565 | **603** | **896** |
| Hardness | 444 | 772 | 730 | 638 | 87 | 606 | 715 | 917 |
| FieldConduct. | 1090 | 1422 | 1525 | | 230 | 1238 | 1348 | 1786 |
| TDS | 878 | **1278** | **1374** | **1036** | 198 | **1066** | **1140** | **1608** |
| Field pH | 7.0 | 7.5 | 7.0 | 8.0 | 7.2 | 6.2 | 7.7 | 7.8 |
| Turbidity/r=rain | | | | | | | | |

030103

Bold numeric values exceed NM WQCC standards for gw (seep,spring,wells) or sw (stream) samples.

Wells: M=monitor, Pr=private, P=public, E=extraction.

Conductivity in umhos/cm; Turbidity in NTU; pH in units; other analytes in mg/l.

Table 2

Molycorp round-Water Sample Analyses (mg/L except as noted) Page 1

| Constituent | EW1 | EW2 | EW3 | EW4 | MW1 | MW2 | MW3 | MW4 | MW7A |
|---|---|---|---|---|---|---|---|---|---|
| Ca | 192 | 55.6 | 152 | 76.4 | 172.4 | 213.2 | 215.2 | 120.4 | 231.2 |
| Mg | 57.1 | 13.4 | 37.4 | 21.9 | 42.6 | 47.9 | 53.9 | 34.8 | 47.2 |
| K | 6 | 6 | 5 | 4 | 6 | 6 | 4 | 4 | 6 |
| Na | 39 | 21 | 29 | 16 | 53 | 93 | 69 | 64 | 39 |
| Hardness | 715 | 194 | 534 | 281 | 606 | 730 | 759.5 | 444 | 772 |
| Alkalinity | 144 | 118 | 108 | 148 | 133 | 80 | 146 | 138 | 116 |
| HCO3 | 176 | 144 | 132 | 180 | 162 | 98 | 178 | 168 | 142 |
| CO3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| Cl | 18 | <5 | 12 | 21 | 10 | 10 | 13 | <5 | 12 |
| Fl | 0.3 | 0.5 | 0.2 | 0.2 | 0.3 | 1 | 0.5 | 0.7 | 0.2 |
| SO4 | 603 | 85 | 418 | 139 | 565 | 814 | 728 | 413 | 720 |
| NO3 | 0.7 | 0.2 | 0.6 | 0.4 | 0.6 | <0.1 | 0.3 | 0.3 | 0.3 |
| Cond. (uS/cm) | 1348 | 431 | 1032 | 560 | 1238 | 1525 | 1544 | 1090 | 1422 |
| pH (pH units) | 7.7 | 7.54 | 7.54 | 7.72 | 6.23 | 6.99 | 7.34 | 7.01 | 7.51 |
| TSS | <3 | 3 | <3 | <3 | <3 | 8 | <3 | <3 | <3 |
| TDS | 1140 | 283 | 898 | 480 | 1066 | 1374 | 1432 | 878 | 1278 |
| ion sum | 1003 | 253 | 719 | 367 | 930 | 1233 | 1171 | 720 | 1126 |
| ion balance (%) | 0.41 | 8.80 | 3.45 | -0.41 | -0.61 | -0.15 | -0.51 | 1.66 | -1.17 |
| total depth (ft.) | 157 | 214 | 104 | 58 | 117 | 80 | 52 | 102 | 146 |
| screen intvl. (ft. | 83-157 | 104-185 | 62-77 | 42-58 | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Sample Date | 11/07/94 | 11/09/94 | 11/08/94 | 11/08/94 | 11/07/94 | 11/07/94 | 11/08/94 | 11/08/94 | 11/08/94 |
| SLD # (ions) | wc946413 | wc946437 | wc946422 | wc946430 | wc946412 | wc946416 | wc946420 | wc946418 | wc946417 |
| SLD # (NO3) | wc946381 | wc946406 | wc946391 | wc946399 | wc946380 | wc946384 | wc946389 | wc946387 | wc946386 |

030104

Table 2

Molycorp - Ground-Water Sample Analyses (mg/L except as noted) Page 2

| Constituent | MW7C | MW7D | MW9A | MW10 | MW11 | MW12 | MWA | MWC | CH |
|---|---|---|---|---|---|---|---|---|---|
| Ca | 249.2 | 238 | 195 | 24.4 | 26.8 | 42 | 166 | 277.6 | 42.8 |
| Mg | 57.1 | 56.9 | 44.3 | 6.3 | 14.3 | 14.6 | 54.2 | 54.2 | 12.2 |
| K | 6 | 6 | 5 | 3 | 5 | 5 | 6 | 6 | 4 |
| Na | 45 | 44 | 71 | 14 | 27 | 27 | 50 | 78 | 61 |
| Hardness | 858 | 829 | 670 | 87 | 126 | 165 | 638 | 917 | 157 |
| Alkalinity | 118 | 118 | 96 | 72 | 76 | 121.4 | 150 | 158 | 197 |
| HCO3 | 144 | 143 | 118 | 88 | 93 | 146.9 | 184 | 194 | 235 |
| CO3 | <3 | 0 | <3 | <3 | <3 | <3 | <3 | 3 | 4 |
| Cl | 11 | 12 | 13 | <5 | 7 | <5 | 11 | 14 | <5 |
| Fl | 0.2 | 0.2 | 0.5 | 0.5 | 1.3 | 0.4 | 0.4 | 1.2 | 0.8 |
| SO4 | 754 | 755 | 703 | 32 | 52 | 61 | 528 | 896 | 65 |
| NO3 | 0.3 | 0.3 | 0.6 | 0.3 | 0.4 | 0.3 | 0.4 | <0.1 | 0.5 |
| Cond. (uS/cm) | 1538 | 1544 | 1460 | 230 | 315 | 282 | na | 1786 | 504 |
| pH (pH units) | 7.23 | 6.92 | 6.38 | 7.18 | 7.02 | 8.4 | 8.07 | 7.79 | 8.58 |
| TSS | 3 | 10 | 3 | <3 | <3 | <3 | 8 | <3 | <3 |
| TDS | 1360 | 1336 | 1318 | 198 | 243 | 296 | 1036 | 1608 | 382 |
| ion sum | 1194 | 1183 | 1090 | 124 | 180 | 223 | 906 | 1425 | 306 |
| ion balance (%) | 2.27 | 0.54 | -1.16 | 6.40 | 14.78 | 10.85 | 2.46 | -0.84 | 5.88 |
| total depth (ft.) | 146 | | 147 | 136(?) | 249 | 234 | 38 | 15 | 250 |
| screen intvl. (ft. | | | | | | 203-234 | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Sample Date | 11/09/94 | 11/09/94 | 11/08/94 | 11/08/94 | 11/09/94 | 11/08/94 | 11/07/94 | 11/07/94 | 11/08/94 |
| SLD # (ions) | wc946435 | wc946436 | wc946429 | wc946421 | wc946434 | wc946432 | wc946415 | wc946414 | wc946423 |
| SLD # (NO3) | wc946404 | wc946405 | wc946398 | wc946390 | wc946403 | wc946401 | wc946383 | wc946382 | wc946397 |

030105

| Constituent | MW23 | 002 | MMW2 | MMW3 | MMW8A | MMW8B | MMW10A | MMW10B | MMW10C |
|---|---|---|---|---|---|---|---|---|---|
| Ca | 213.2 | 279.6 | na | 498 | 184.4 | 407 | 231.6 | 321 | 192.8 |
| Mg | 49.8 | 63 | na | 112 | 54.7 | 102.6 | 90.7 | 95.1 | 76.1 |
| K | 5 | 8 | 28 | 10 | 5 | 7 | 14 | 7 | 12 |
| Na | 73 | 97 | 81 | 103 | 33 | 41 | 32 | 26 | 25 |
| Hardness | 738 | 958 | na | 1708 | 686 | 1440 | 952 | 1193 | 795 |
| Alkalinity | 136 | 156 | <3 | 209 | 10 | 154 | <3 | 18 | <3 |
| HCO3 | 166 | 190 | <3 | 255 | 13 | 187 | <3 | 22 | <3 |
| CO3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| Cl | 13 | 11 | <5 | <5 | <5 | 5 | 21 | 22 | 15 |
| Fl | 0.5 | 2.1 | 28 | 2.8 | 1.9 | 2.6 | 8.3 | 13.2 | 17.8 |
| SO4 | 729 | 896 | 2177 | 1759 | 716 | 1279 | 1030 | 1080 | 849 |
| NO3 | 0.4 | 0.1 | <0.1 | <0.1 | 0.8 | <0.1 | 6.5 | 3 | 4.6 |
| Cond. (uS/cm) | 1463 | 1875 | 3139 | 2723 | 1326 | 2276 | 1823 | 3057 | 1563 |
| pH (pH units) | 7.27 | 6.86 | 3.86 | 7.63 | 5.99 | 8.07 | 4.41 | 6.19 | 4.53 |
| TSS | 5 | <3 | 28 | 5 | <3 | 7 | <3 | 33 | <3 |
| TDS | 1400 | 2124 | 3524 | 3070 | 1282 | 2292 | 1882 | 1882 | 1690 |
| ion sum | 1166 | 1450 | 2314 | 2610 | 1002 | 1936 | 1434 | 1578 | 1192 |
| ion balance (%) | -0.70 | 3.23 | -82.89 | -2.52 | 0.29 | 1.45 | -4.01 | 3.01 | -3.23 |
| total depth (ft.) | | | 68 | 145 | 161 | 129 | 144 | 189 | 50 |
| screen intvl. (ft. | | | 38-58 | 65-115 | 125-161 | 67-117 | 79-130 | 133-189 | 31.5-50 |
| | | | | | | | | | |
| | | | | | | | | | |
| Sample Date | 11/08/94 | 11/04/94 | 11/08/94 | 11/07/94 | 11/08/94 | 11/08/94 | 11/08/94 | 11/07/94 | 11/08/94 |
| SLD # (ions) | wc946433 | wc946439 | wc946438 | wc946427 | wc946419 | wc946431 | wc946425 | wc946428 | wc946424 |
| SLD # (NO3) | wc946402 | wc946385 | wc946407 | wc946395 | wc946388 | wc946400 | wc946393 | wc946396 | wc946392 |

030106

Table 2

Molycorp - Ground-Water Sample Analyses (mg/L except as noted) Page 4

| Constituent | MMW11 | MMW13 |
|---|---|---|
| Ca | 229 | 258 |
| Mg | 104.5 | 48.9 |
| K | - 20 | 7 |
| Na | 34 | 32 |
| Hardness | 1004 | 847 |
| Alkalinity | 156 | 146 |
| HCO3 | 190 | 178 |
| CO3 | <3 | <3 |
| Cl | 36 | 13 |
| Fl | 21 | 1.8 |
| SO4 | 1267 | 717 |
| NO3 | 6.2 | 2.6 |
| Cond. (uS/cm) | 1985 | 1478 |
| pH (pH units) | 4.43 | 6.59 |
| TSS | <3 | 3 |
| TDS | 2124 | 1442 |
| ion sum | 1811 | 1168 |
| ion balance (%) | -16.87 | 0.19 |
| total depth (ft.) | 185 | 148 |
| screen intvl. (ft. | 145-185 | 105-148 |
| | | |
| | | |
| Sample Date | 11/07/94 | 11/08/94 |
| SLD # (ions) | wc946440 | wc946426 |
| SLD # (NO3) | wc946408 | wc946394 |

030107

Table 2
page 5

MOLYCORP
Ground Water San... Analyses
NMED - Ground Water Section
November 4 - 9, 1994
(data reported in mg/L except as noted)

| | EW1 | EW2 | EW3 | EW3dup | EW4 | MW1 | MW2 | MW3 | MW4 | MW7A | MW7Adup | MW7C | MW9A | MW10 | MW11 | MW12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ca | 192 | 55.6 | 152 | 213.2 | 76.4 | 172.4 | 213 | 215.2 | 120.4 | 231.2 | 238 | 249.2 | 195 | 24.4 | 26.8 | 42 |
| Mg | 57.1 | 13.4 | 37.4 | 49.8 | 21.9 | 42.6 | 47.9 | 53.9 | 34.8 | 47.2 | 58.9 | 57.1 | 44.3 | 6.3 | 14.3 | 14.6 |
| Na | 39 | 21 | 29 | 73 | 16 | 53 | 93 | 69 | 64 | 39 | 44 | 45 | 71 | 14 | 27 | 27 |
| HCO3 | 176 | 144 | 132 | 166 | 180 | 162 | 98 | 178 | 168 | 142 | 143 | 144 | 118 | 88 | 93 | 146.9 |
| CO3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | 0 | <3 | <3 | <3 | <3 | <3 |
| Cl | 18 | <5 | 12 | 13 | 21 | 10 | 10 | 13 | <5 | 12 | 12 | 11 | 13 | <5 | 7 | <5 |
| SO4 | 603 | 85 | 418 | 728 | 139 | 565 | 814 | 728 | 413 | 720 | 755 | 754 | 703 | 32 | 52 | 61 |
| NO3 | 0.7 | 0.2 | 0.6 | 0.4 | 0.4 | 0.6 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.6 | 0.3 | 0.4 | 0.3 |
| Fl | 0.3 | 0.5 | 0.2 | 0.5 | 0.2 | 0.3 | 1 | 0.5 | 0.7 | 0.2 | 0.2 | 0.2 | 0.5 | 0.5 | 1.3 | 0.4 |
| K | 6 | 6 | 5 | 5 | 4 | 6 | 6 | 4 | 4 | 6 | 6 | 6 | 5 | 3 | 5 | 5 |
| Hardness | 715 | 194 | 534 | 738 | 281 | 606 | 730 | 759.5 | 444 | 772 | 829 | 858 | 670 | 87 | 126 | 165 |
| Alkalinity | 144 | 118 | 108 | 136 | 148 | 133 | 80 | 146 | 138 | 116 | 118 | 118 | 96 | 72 | 76 | 121.4 |
| Cond. (uS/cm) | 1348 | 431 | 1032 | 1463 | 560 | 1238 | 1525 | 1544 | 1090 | 1422 | 1544 | 1538 | 1460 | 230 | 315 | 282 |
| pH (pH units) | 7.7 | 7.54 | 7.54 | 7.27 | 7.72 | 6.23 | 6.99 | 7.34 | 7.01 | 7.51 | 6.92 | 7.23 | 6.38 | 7.18 | 7.02 | 8.4 |
| TSS | <3 | 3 | <3 | 5 | <3 | <3 | 8 | <3 | <3 | <3 | 10 | 3 | 3 | <3 | <3 | <3 |
| TDS | 1140 | 283 | 898 | 1400 | 480 | 1066 | 1374 | 1432 | 878 | 1278 | 1336 | 1360 | 1318 | 198 | 243 | 296 |
| Ion sum | 996 | 246 | 714 | 893194 | 363 | 923 | 1226 | 1167 | 715 | 1120 | 1177 | 1187 | 1085 | 120 | 173 | 217 |
| Ion balance (%) | 0.41 | 8.80 | 3.45 | 3.45 | -0.41 | -0.61 | -0.26 | -0.51 | 1.66 | -1.17 | 0.54 | 2.27 | -1.16 | 6.40 | 14.78 | 10.85 |
| Al | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | <0.1 | <0.1 | <0.1 | <0.10 |
| Sb | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | | | | | <0.01 | <0.001 | <0.001 | <0.001 |
| As | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | <0.001 | <0.001 | <0.002 | <0.002 | <0.01 | <0.001 | 0.003 | 0.002 |
| Ba | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Be | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | <0.001 | <0.001 | <0.002 | <0.002 | <0.01 | <0.001 | <0.001 | <0.001 |
| Bo | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cd | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | <0.001 | <0.001 | <0.002 | <0.002 | <0.01 | <0.001 | <0.001 | <0.001 |
| Ca | 240 | 61 | 170 | 310 | 100 | 200 | 260 | 300 | 160.00 | 310.00 | 320.00 | 280.00 | 300 | 28 | 30 | 51 |
| Cr | <0.002 | <0.002 | <0.001 | 0.003 | <0.001 | <0.004 | <0.004 | 0.008 | <0.001 | 0.001 | <0.002 | <0.002 | <0.01 | <0.001 | <0.001 | <0.001 |
| Co | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | <0.001 | 0.001 | <0.002 | <0.002 | <0.01 | <0.001 | <0.001 | <0.001 |
| Cu | <0.02 | <0.02 | <0.01 | <0.02 | <0.01 | <0.04 | <0.04 | <0.01 | <0.01 | <0.01 | <0.02 | <0.02 | <0.1 | <0.01 | <0.01 | <0.01 |
| Fe | <0.1 | <0.05 | <0.1 | <0.1 | <0.05 | 0.2 | 5.4 | 0.1 | <0.1 | <0.1 | 0.10 | 0.06 | 0.2 | <0.1 | <0.05 | <0.05 |
| Pb | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | <0.001 | <0.001 | <0.002 | <0.002 | <0.01 | <0.001 | <0.001 | <0.001 |
| Hg | <.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Mg | 49 | 9.3 | 30 | 58 | 18 | 40 | 56 | 53 | 33.00 | 49.00 | 60.00 | 49.00 | 48 | 4.3 | 8 | 8.3 |
| Mn | 0.02 | 0.15 | 0.07 | 0.05 | 0.005 | 0.02 | 0.38 | 0.06 | 0.004 | <0.001 | <0.002 | <0.002 | 0.17 | <0.001 | 0.003 | 0.002 |
| Mo | 0.02 | 0.007 | 0.001 | 0.004 | 0.003 | 0.047 | 1.7 | 0.004 | 0.21 | 0.002 | 0.009 | 0.009 | <0.01 | 0.004 | 0.067 | 0.012 |
| Ni | <0.02 | <0.02 | <0.01 | <0.02 | <0.01 | <0.04 | <0.04 | <0.01 | <0.01 | <0.01 | <0.02 | <0.02 | <0.1 | <0.01 | <0.01 | <0.01 |
| Se | <0.01 | <0.005 | <0.01 | <0.025 | <0.005 | <0.005 | <0.025 | <0.025 | <0.025 | <0.025 | <0.05 | <0.05 | <0.025 | <0.005 | <0.005 | <0.005 |
| Si | 14 | 15 | 12 | 11 | 13 | 9.1 | 2.1 | 11 | 10.00 | 12.00 | 14.00 | 13.00 | 10 | 11 | 16 | 14 |
| Ag | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | <0.001 | <0.001 | <0.002 | <0.002 | <0.01 | <0.001 | <0.001 | <0.001 |
| Sr | 0.9 | 0.3 | 1.2 | 1.5 | 0.8 | 0.7 | 1.8 | 1.4 | 0.80 | 1.70 | 2.00 | 1.70 | 1.3 | 0.2 | 0.2 | 0.4 |
| Tl | <0.002 | <0.002 | <0.001 | <0.002 | <0.001 | <0.004 | <0.004 | <0.001 | <0.001 | <0.001 | <0.002 | <0.002 | <0.01 | <0.001 | <0.001 | <0.001 |
| Sn | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| V | 0.004 | 0.011 | <0.001 | <0.002 | 0.001 | <0.004 | <0.004 | <0.002 | <0.001 | <0.001 | <0.002 | <0.002 | <0.01 | <0.001 | 0.011 | 0.005 |
| Zn | <.02 | <0.01 | <0.01 | <0.02 | <0.01 | <0.04 | <0.04 | <0.01 | <0.01 | <0.01 | <0.02 | <0.02 | <0.1 | ,0.01 | <0.01 | <0.01 |
| Sample Date | 11/07/94 | 11/09/94 | 11/08/94 | 11/08/94 | 11/08/94 | 11/07/94 | 11/07/94 | 11/08/94 | 34648 | 34648 | 11/09/94 | 11/09/94 | 11/08/94 | 11/08/94 | 11/09/94 | 11/08/94 |
| SLD # (ions) | wc946413 | wc946437 | wc946422 | wc946433 | wc946430 | wc946412 | wc946416 | wc946420 | | | | | wc946429 | wc946421 | wc946434 | wc946432 |
| SLD # (NO3) | wc946381 | wc946406 | wc946391 | wc946402 | wc946399 | wc946380 | wc946384 | wc946389 | | | | | wc946398 | wc946390 | wc946403 | wc946401 |
| SLD#(Metals) | lc940643 | lc940665 | lc940653 | lc940664 | lc940661 | lc940642 | lc940646 | lc940651 | lc940649 | lc940648 | lc940667 | lc940666 | lc940660 | lc940652 | lc940665 | lc940663 |

030108

MOLYCORP MOLYCORP
Ground Water S Ground Water Sample Analyses
NMED - Ground NMED - Ground Water Section
November 4 - 9, November 4 - 9, 1994
(data reported in (data reported in mg/L except as noted)

| | MWA | MWC | CH | 002 | MMW2 | MMW3 | MMW7 | MMW7dup | MMW8A | MMW8B | MMW10A | MMW10B | MMW10C | MMW11 | MMW13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ca | 166 | 277.6 | 42.8 | 279.6 | na | 498 | | | 184.4 | 407 | 231.6 | 321 | 192.8 | 229 | 258 |
| Mg | 54.2 | 54.2 | 12.2 | 63 | na | 112 | | | 54.7 | 102.6 | 90.7 | 95.1 | 76.1 | 104.5 | 48.9 |
| Na | 50 | 78 | 61 | 97 | 81 | 103 | | | 33 | 41 | 32 | 26 | 25 | 34 | 32 |
| HCO3 | 184 | 194 | 235 | 190 | <3 | 255 | | | 13 | 187 | <3 | 22 | <3 | 190 | 178 |
| CO3 | <3 | 3 | 4 | <3 | <3 | <3 | | | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| Cl | 11 | 14 | <5 | 11 | <5 | <5 | | | <5 | 5 | 21 | 22 | 15 | 36 | 13 |
| SO4 | 528 | 896 | 65 | 896 | 2177 | 1759 | | | 716 | 1279 | 1030 | 1080 | 849 | 1267 | 717 |
| NO3 | 0.4 | 0.1 | 0.5 | 0.1 | 0.1 | 0.1 | | | 0.8 | 0.1 | 6.5 | 3 | 4.6 | 6.2 | 2.6 |
| Fl | 0.4 | 1.2 | 0.8 | 2.1 | 28 | 2.8 | | | 1.9 | 2.6 | 8.3 | 13.2 | 17.8 | 21 | 1.8 |
| K | 6 | 6 | 4 | 8 | 28 | 10 | | | 5 | 7 | 14 | 7 | 12 | 20 | 7 |
| Hardness | 638 | 917 | 157 | 958 | na | 1708 | | | 686 | 1440 | 952 | 1193 | 795 | 1004 | 847 |
| Alkalinity | 150 | 158 | 197 | 156 | <3 | 209 | | | 10 | 154 | <3 | 18 | <3 | 156 | 146 |
| Cond. (uS/cm) | na | 1786 | 504 | 1875 | 3139 | 2723 | | | 1326 | 2276 | 1823 | 3057 | 1563 | 1985 | 1478 |
| pH (pH units) | 8.07 | 7.79 | 8.58 | 6.86 | 3.86 | 7.63 | | | 5.99 | 8.07 | 4.41 | 6.19 | 4.53 | 4.43 | 6.59 |
| TSS | 8 | <3 | <3 | <3 | 28 | 5 | | | <3 | 7 | <3 | 33 | <3 | <3 | 3 |
| TDS | 1036 | 1608 | 382 | 2124 | 3524 | 3070 | | | 1282 | 2292 | 1882 | 1882 | 1690 | 2124 | 1442 |
| ion sum | 900 | 1415 | 297 | 1440 | 2258 | 2597 | | | 995 | 1927 | 1412 | 1558 | 1163 | 1770 | 1159 |
| ion balance (%) | 2.46 | -0.86 | 5.88 | 3.23 | -82.90 | -2.52 | | | 0.29 | 1.44 | -4.01 | 3.01 | -3.23 | -16.87 | 0.19 |
| Al | <0.1 | <0.1 | <0.1 | <0.1 | 68 | 1 | 950 | 890 | 0.4 | 0.2 | 33 | 7.6 | 31 | 54 | <0.1 |
| Sb | <0.004 | <0.004 | <0.001 | <0.001 | <0.01 | <0.01 | <0.1 | <0.1 | <0.001 | <0.002 | <0.01 | <0.01 | <0.01 | <0.01 | 0.002 |
| As | <0.004 | <0.004 | <0.001 | <0.001 | 0.02 | <0.01 | <0.1 | <0.1 | <0.001 | 0.003. | <0.01 | <0.01 | <0.01 | <0.01 | <0.001 |
| Ba | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Be | <0.004 | <0.004 | <0.001 | ,0.05 | 0.03 | <0.01 | 0.1 | 0.1 | <0.001 | <0.002 | <0.01 | <0.01 | <0.01 | 0.01 | <0.001 |
| Bo | <0.1 | <0.1 | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cd | <0.004 | <0.004 | <0.001 | <0.001 | 0.02 | 0.003 | 0.11 | 0.11 | <0.005 | <0.002 | 0.03 | 0.02 | 0.025 | 0.04 | <0.001 |
| Ca | 210 | 390 | 50 | 360 | 600 | 640 | 550 | 540 | 230 | 580 | 290 | 410 | 230 | 260 | 310 |
| Cr | <0.004 | <0.004 | <0.001 | 0.002 | <0.01 | <0.01 | 0.2 | 0.2 | <0.005 | <0.002 | <0.01 | <0.05 | 0.035 | <0.01 | <0.001 |
| Co | <0.004 | <0.004 | <0.001 | 0.003 | 0.33 | 0.08 | 4.3 | 3.9 | 0.003 | 0.003 | 0.14 | 0.08 | 0.1 | 0.25 | 0.011 |
| Cu | <0.04 | <0.04 | <0.01 | <0.01 | <0.1 | <0.1 | 4.5 | 4.5 | <0.01 | <0.02 | 0.5 | 0.2 | 0.4 | 0.9 | <0.01 |
| Fe | 0.4 | <0.1 | <0.1 | <0.1 | 61 | 0.1 | 420 | 380 | <0.1 | 2.3 | <0.1 | 0.07 | <0.1 | <0.1 | 0.2 |
| Pb | <0.004 | 0.004 | <0.001 | <0.001 | <0.01 | <0.01 | 1 | 0.8 | <0.001 | <0.002 | <0.01 | 0.03 | <0.01 | <0.01 | <0.001 |
| Hg | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.005 | <0.0005 | <0.005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Mg | 35 | 69 | 9.7 | 42 | 150 | 110 | 1290 | 1150 | 64 | 110 | 83 | 88 | 82 | 110 | 38 |
| Mn | 0.037 | 0.88 | 0.006 | 1.9 | 53 | 37 | 69 | 72 | 0.23 | 7.8 | 15 | 8.5 | 16 | 28 | 0.91 |
| Mo | 0.6 | 1.2 | 0.003 | 2.3 | <0.01 | <0.01 | <0.1 | <0.1 | <0.001 | 0.01 | <0.01 | <0.01 | <0.01 | <0.1 | 0.051 |
| Ni | <0.04 | <0.04 | <0.01 | <0.02 | 0.7 | 0.2 | 9.5 | 8.6 | 0.06 | <0.02 | 0.3 | 0.3 | 0.31 | 0.6 | <0.01 |
| Se | <0.005 | <0.025 | <0.01 | <0.025 | <0.05 | <0.05 | <0.13 | <0.025 | 0.025 | <0.025 | <0.05 | <0.05 | <0.025 | <0.005 | <0.05 |
| Si | 11 | 12 | 10 | <1 | 23 | 7.1 | 19 | 15 | 19 | 13 | 14 | 13 | 9.4 | 12 | 8.5 |
| Ag | <0.004 | <0.004 | <0.001 | <0.001 | <0.01 | <0.01 | <0.1 | <0.1 | <0.001 | <0.002 | <0.01 | <0.01 | <0.01 | <0.01 | <0.001 |
| Sr | 1.1 | 2 | 0.5 | 2 | 4.1 | 4 | 4.1 | 3.9 | 1.3 | 6.5 | 1.6 | 2.1 | 1.1 | 1.6 | 11 |
| Tl | <0.004 | <0.004 | <0.001 | <0.001 | <0.01 | <0.01 | <0.1 | <0.1 | <0.001 | <0.002 | <0.01 | <0.01 | <0.01 | <0.01 | <0.001 |
| Sn | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <1.0 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| V | <0.004 | <0.004 | 0.002 | <0.001 | <0.01 | <0.01 | 0.1 | 0.1 | <0.005 | <0.002 | <0.01 | <0.01 | <0.05 | <0.5 | <0.001 |
| Zn | <0.04 | <0.04 | 0.9 | <0.01 | 10 | 1.3 | 9.7 | 9.8 | 0.2 | <0.02 | 2.1 | 1.4 | 2.9 | 4.6 | 0.2 |
| Sample Date | 11/07/94 | 11/07/94 | 11/08/94 | 11/04/94 | 11/08/94 | 11/07/94 | 11/07/94 | 11/07/94 | 11/08/94 | 11/08/94 | 11/08/94 | 11/07/94 | 11/08/94 | 11/07/94 | 11/08/94 |
| SLD # (Ions) | wc946415 | wc946414 | wc946423 | wc946439 | wc946438 | wc946427 | | | wc946419 | wc946431 | wc946425 | wc946428 | wc946424 | wc946440 | wc946426 |
| SLD # (NO3) | wc946383 | wc946382 | wc946397 | wc946385 | wc946407 | wc946395 | | | wc946388 | wc946400 | wc946393 | wc946396 | wc946392 | wc946408 | wc946394 |
| SLD#(Metals) | lc940645 | lc940644 | lc940654 | lc940647 | lc940669 | lc940658 | lc940641 | lc940640 | lc940650 | lc940662 | lc940656 | lc940659 | lc940655 | lc940639 | lc940657 |

Table 3:

Red River Groundwater Investigation (#92-A)
NPS Project
Organizational Chart

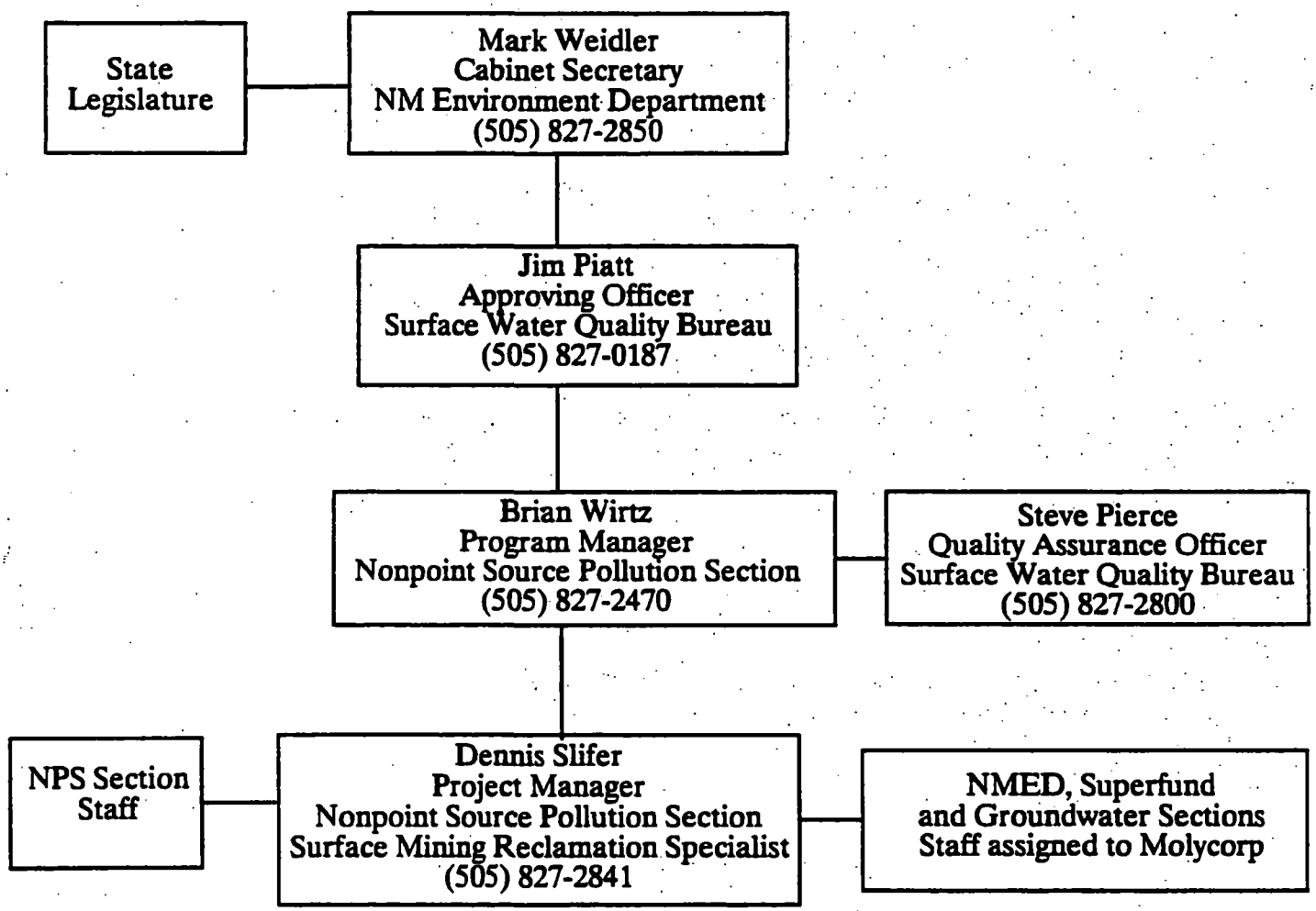

Table 4: List of persons and agencies involved in management of the Red River watershed.

New Mexico Environment Department (NMED)
- Surface Water Quality Bureau
  - Nonpoint Source Pollution Section
    - Project Managers: Dennis Slifer, 827-2841
      Michael Coleman, 827-0505
  - Point Source Regulation Section (NPDES Permits)
    - Program Manager: Glenn Saums, 827-2827
  - Surveillance and Standards Section (stream surveys)
    - Program Manager: Steve Pierce, 827-2800
- Ground Water Protection and Remediation Bureau
  - Ground Water Section (discharge plans)
    - Karen McCormack (Molycorp DPs), 827-2936
    - Doug Jones (Questa sewage lagoons DP), 827-2903
  - Superfund Section
    - Stewart Kent (Molycorp investigation), 827-0037
- Taos Field Office (1215-B, Gusdorf Street, Taos)
  - Ken McCallum or Bill King, 758-8808

New Mexico Office of the Natural Resource Trustee (ONRT)
- Steve Cary (Deputy Director), 827-0135

New Mexico Department of Game and Fish (NMDGF)
- Mike Hatch, 827-7905

USFS, Carson National Forest, Questa Ranger District
- Ron Thibideau (District Ranger), 586-0520

US Bureau of Land Management, Taos Resource Area
- Sam DesGeorges, 758-8851

US Bureau of Land Management, Albuquerque Office
- Joe Mirabal, 761-8731

Town of Red River
- Mayor, John Tillery, 754-2277
- Director of Public Works, Bob Perry, 754-2277

Village of Questa
- Mayor, Bobby Ortega, 586-0694

Molycorp, Questa Mine
- Mine Manager, Dave Shoemaker, 586-0212

Amigos Bravos, Taos, NM
- Brian Shields or Saunee Morris, 758-3874

Table 5 Assessed Stream Reaches Partially Supporting or Not Supporting Designated or Attainable Uses. Red River entries, 1980-1994.

| Water Body (Basin, segment) Evaluated or Monitored (E/M) | Year Listed | Uses Not Fully Supported | Probable Causes of Nonsupport | Probable Sources of Nonsupport | Total Size Affected (Miles) |
|---|---|---|---|---|---|
| Red River from mouth on Rio Grande to Placer Creek (Rio Grande, 2-119), M | 1994 | HQCWF | Metals, turbidity, siltation | Agriculture (1500), resource extraction, (5600, 5700, 5900), road construction/ maintenance (8300) | 20.2 |
| Red River from Zwergle Dam to confluence of East and West Forks (Rio Grande, 2-120) | 1992 | HQCWF | Siltation, reduction of riparian vegetation, | Construction (3200), recreation (8700, 8703) | 3.9 |
| Red River from Placer Creek to Zwergle Dam (Rio Grande, 2-120) | 1992 | HQCWF | Metals, total phosphorus, siltation | Construction (3200), resource extraction (5100) | 1.6 |
| Red River from mouth on Rio Grande to Placer Creek (Rio Grande, 2-119) | 1992 | CWF, IRR, L&WW | Metals, turbidity, pathogens, siltation, priority organics | Agriculture (1500), resource extraction (5600, 5700,5900), land disposal (6800) | 20.2 |
| Red River from head to Zwergle Dam (Rio Grande, 2-120) | 1990 | HQCWF | Siltation, nutrients, reduction of riparian vegetation, streambank destabilization | Construction (3200), recreation (8700, 8703) | 9.2 |
| Red River from Zwergle Dam to mouth of Placer Creek (Rio Grande, 2-120) | 1990 | HQCWF | Metals, total phosphorus | Construction (3200), resource extraction (5100) | 1.6 |
| Red River from mouth of Placer Creek to Elephant Rock Campground (Rio Grande, 2-120) | 1990 | HQCWF, DWS, IRR, L&WW | Metals, turbidity, siltation, pH, total phosphorus, pathogens | Construction (3100, 3200, 3201), urban runoff (4000), resource extraction (5900), recreation (8700, 8701) | 3.8 |
| Red River from Elephant Campground to Molycorp Mill (Rio Grande, 2-120) | 1990 | HQCWF, DWS, IRR, L&WW | Metals, turbidity, siltation, pH, total phosphorus, conductivity | Construction (3200), resource extraction (5700), recreation (8700) | 3.0 |
| Red River from Molycorp Mill to Red River Fish Hatchery (Rio Grande, 2-119) | 1990 | HQCWF, DWS, CWF, IRR, L&WW | Metals, turbidity, siltation, pH, total phosphorus, conductivity, reduction of riparian vegetation, streambank destabilization | Construction (3100, 3200), resource extraction (5100, 5600, 5700, 5800, 5900), recreation (8700) | 11.0 |
| Red River from Red River Fish Hatchery to mouth on Rio Grande (Rio Grande, 2-119) | 1990 | CWF, L&WW | Metals, turbidity, siltation | Agriculture (1500), resource extraction (5600) | 3.5 |

Table 5 Assessed Stream Reaches Partially Supporting or Not Supporting Designated or Attainable Uses, continued. Red River entries, 1980-1994.

| Water Body (Basin, segment) Evaluated or Monitored (E/M) | Year Listed | Uses Not Fully Supported | Probable Causes of Nonsupport | Probable Sources of Nonsupport | Total Size Affected (Miles) |
|---|---|---|---|---|---|
| Red River from Elephant Campground to Molycorp Mill (Rio Grande, 2-120) | 1988 | HQCWF, DWS, L&WW | | | 3.0 |
| Red River from Molycorp Mill to 1.5 miles above Red River Fish Hatchery (Rio Grande, 2-120) | 1988 | HQCWF, DWS, L&WW | | | 9.5 |
| Red River from 1.5 miles above Red River Fish Hatchery to mouth on Rio Grande (Rio Grande, 2-119) | 1988 | CWF | | | 5.0 |
| Red River from Molycorp mine to below Village of Questa (Rio Grande, 2-120) | 1986 | HQCWF | Metals, turbidity, streambottom deposits, reduction of riparian vegetation | Resource extraction (5100, 5501, 5900) | 9.5 |
| Red River from Questa upstream to Town of Red River (Rio Grande, 2-120) | 1984 | HQCWF | Total phosphorus, streambottom deposits | Municipal point sources (0200), resource extraction (5100, 5501, 5900) | 14 |
| Red River from 1.5 miles above bridge at Red River Fish Hatchery to headwaters (Rio Grande, 2-120) | 1982 | | Plant nutrients, streambottom deposits | Industrial wastewater (0100), municipal point sources (0200) | |
| Red River from the Rio Grande upstream to 1.5 miles above bridge at Red River Fish Hatchery (Rio Grande, 1-119) | 1982 | | Metals, pH, cyanide | Industrial wastewater (0100) | |
| Rio River from Rio Grande to Town of Red River (Rio Grande, 17 & 18) | 1980 | HQCWF | Turbidity, pH, cyanide, streambottom deposits, plant nutrients | Industrial point sources (0100), municipal point sources (0200), resource extraction (5000, 5501, 5900) | 27 |

Table 6 Assessed Stream Reaches with Threatened Designated or Attainable Uses. Red River entries, 1994.

| Water Body (Basin, segment) Evaluated or Monitored (E/M) | Uses Not Fully Supported | Probable Causes of Nonsupport | Probable Sources of Nonsupport | Total Size Affected (Miles) |
|---|---|---|---|---|
| Red River from Placer Creek to confluence of East and West Forks (Rio Grande, 2-120), M | HQCWF | Siltation, habitat alteration | Agriculture (1500), resource extraction (5100) | 13.0 |
| West Fork of Red River from confluence with East Fork to headwaters (Rio Grande, 2-120), E | HQCWF | Siltation, habitat alteration | Recreation (8701) | 2.6 |
| Middle Fork of Red River from mouth on West Fork to headwaters (Rio Grande, 2-120), E | HQCWF | Siltation, reduction of riparian vegetation | Recreation (8700, 8701) | 1.3 |

Table 7 Assessed Stream Reaches Partially Supporting or Not Supporting Designated or Attainable Uses. Tributaries of the Red River entries, 1980-1994.

| Water Body (Basin, segment) Evaluated or Monitored (E/M) | Year Listed | Uses Not Fully Supported | Probable Causes of Nonsupport | Probable Sources of Nonsupport | Total Size Affected (Miles) |
|---|---|---|---|---|---|
| Bitter Creek from mouth on Red River to headwaters (Rio Grande, 2-120), M | 1994 | HQCWF | Metals, siltation, reduction of riparian vegetation, streambank destabilization | Agriculture (1500), resource extraction, (5100..5800), road runoff (8300), recreation (8700) | 7.1 |
| Pioneer Creek from mouth on Red River to headwaters (Rio Grande, 2-120), M | 1994 | HQCWF | Turbidity, siltation, reduction of riparian vegetation, streambank destabilization | Resource extraction, (5200, 5900), recreation (8701, 8705) | 4.3 |
| Placer Creek from mouth on Red River to headwaters (Rio Grande, 2-120), E | 1994 | HQCWF | Siltation, reduction of riparian vegetation, streambank destabilization | Resource extraction (5300, 5900) | 1.3 |
| Cabresto Creek from mouth on Red River to headwaters (Rio Grande, 2-120), M | 1994 | HQCWF | Flow alteration, reduction of riparian vegetation, siltation, turbidity | Agriculture (1200, 1500), road construction/ maintenance (8300) | 14.6 |
| Bitter Creek from mouth on Red River to headwaters (Rio Grande, 2-120) | 1992 | HQCWF | Metals, turbidity, total phosphorus, pH, siltation, reduction of riparian vegetation, streambank destabilization | Resource extraction (5300, 5700), road runoff (8300), recreation (8700) | 7.6 |
| Cabresto Creek from mouth on Red River to headwaters (Rio Grande, 2-120), M | 1992 | HQCWF | Metals | Resource extraction (5100) | 14.6 |
| Bitter Creek from mouth on Red River to headwaters (Rio Grande, 2-120) | 1990 | HQCWF | Turbidity, total phosphorus, pH, siltation, metals | Resource extraction (5100), road runoff (8300), recreation (8700) | 7.6 |
| Cabresto Creek from USLM No. 5 Mine to mouth on Red River (Rio Grande, 2-120), M | 1990 | HQCWF | Metals | Resource extraction (5100) | 14.6 |

Table 8 Assessed Stream Reaches with Threatened Designated or Attainable Uses. Tributaries of the Red River entries, 1994.

| Water Body (Basin, segment) Evaluated or Monitored (E/M) | Uses Not Fully Supported | Probable Causes of Nonsupport | Probable Sources of Nonsupport | Total Size Affected (Miles) |
|---|---|---|---|---|
| Columbine Creek at its mouth on Red River (Rio Grande, 2-120), M | HQCWF | Siltation, habitat alteration | Recreation (8700) | 0.5 |
| Mallette Creek from mouth on Red River to headwaters (Rio Grande, 2-120), M | HQCWF | Turbidity, total phosphorus, metals | Recreation (8700, 8701) | 2.3 |

## APPENDICES

Appendix A: Tabulated analytical data for samples collected at Molycorp mine and tailings site by NMED Superfund Oversight Section in 1993/1994, and an evaluation of sulfate gain to Red River excerpted from draft document (NMED, October 23, 1995).

Appendix B: Discussion of Molycorp mine area hydrogeology, excerpted from SPRI Report, April 21, 1995.

Appendix C: Report on the installation and testing of 12 new monitoring wells at Molycorp mine in 1994, excerpted from SPRI Report, April 21, 1995.

Appendix D: Water quality results from 1994 sampling at Molycorp mine, excerpted from SPRI Report, April 21, 1995.

Appendix E: Summary report on latest hydrogeological studies and sampling at Molycorp tailings area, excerpted from SPRI Report, April 13, 1995.

Appendix F: Summary of geochemical assessment for acid rock drainage potential at Molycorp mine, excerpted from SRK Report, April 13, 1995.

Appendix G: Selected tables and figures pertaining to Red River water quality from Garrabrant, 1993, USGS Water Resources Investigation Report 93-4107.

Appendix H: Report on installation of anoxic limestone drains at Red River and Capulin Canyon in October, 1995.

Appendix I: News media articles about Red River and Molycorp from the time period of this project (1994-1995).



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# LANDSCAPE CHANGE SURVEY
# RED RIVER REGION, NEW MEXICO

(Questa and Red River Quadrangles)

1996
Aerial Photo Interpretation

by
Stan Morain
Certified Photogrammetrist

Purpose:

This survey represents a "quick look" interpretation of a series of federally acquired aerial photographs collected along the Red River Canyon between Questa and the town of Red River, New Mexico between 1935/36 and 1992. The requested goals of the interpretation were to:

1. trace growth and development of (hydrothermally altered?) scar areas associated with mining activities, and relate them to features such as roads, mine workings, etc.;

2. trace evolution of scar areas and sizes relative to mine dumping;

3. trace volume and area of waste rock piles at the mine site over time;

4. calculate areas and volumes of waste rock dumps and scars throughout the area;

5. trace the development of fan deposits in the drainages below scarred areas;

6. prepare a lineament map of the region.

Items three and four were not performed as part of this effort because the images under review were not orthorectified to correct roll, pitch, and yaw distortions, and because vertical relief in the area (given these distortions) precluded accurate calculation of volumes and areas on any of the images or stereograms. Comparison of volumes and areas from one date to another on different scales of images are not possible without orthorectifying the images to be compared.

Image Materials:

Table 1 lists the image sources, dates, scales, and visual qualities. The images for which there is a calculated scale are those actually reviewed for this report. Note that in some cases there is a significant difference between the nominal and calculated scales for these materials, most of which is attributable to local relief. The calculated scales were measured using the appropriate one, of three, baselines as shown in Figure 1. These three are located: between the confluence of Goathill Gulch and BM7581; between BM7870 and Hill 9538; and between elevation marker 8245 and Hill 10,556 near Elephant Rock. Relief in the area is sufficiently

rugged that scale changes between flight lines are common. If BM7870 and Hill 9538 were visible on adjacent flight lines, scale was calculated for each and averaged.

## Regional Notes

1935/35 USDA/SCS (**Photos 2893/2894**):

Red River valley between Sulphur Gulch and Elephant Rock Campground is filled along most of its length with erosional material derived from what appear under stereoscopy to be landslide areas north of the river. Stereoscopic examination of vegetation densities suggests several ages for these erosional (landsliding?) episodes.

The large, heavily eroded area at the headwaters of Sulphur Gulch appears not to have produced much detrital material at Red River, suggesting an origin not long before the photographs were taken (perhaps a matter of years). The eroded areas east of Sulphur Gulch appear to be much older judging from the amount of deposited material downslope and their more or less heavily vegetated appearance. The source areas, however, remain unvegetated, suggesting they are active sources of detritus.

With the notable exception of the Sulphur Gulch erosional feature, the other erosional/detrital systems in the reach between BM8164 on State Highway 38 and Fawn Lakes Campground (Sections 31 and 32, T29N R14E) appear to be more balanced volumetrically. One must, nevertheless, assume that a fair portion of the detrital material removed from these scars has been transported as natural sediment out of the region over many decades (centuries?).

1935/36 USDA/SCS (**Photos 2979/2980**):

The headwaters of Sulphur Gulch and Goathill Gulch are erosional features with little or no vegetation. Roads into the areas are evident, but there is no sign of mining equipment. There is a water impoundment evident near the river, but there is no clear evidence that it is related to mining. Aside from this impoundment east of Sulphur Gulch, there is no clear evidence of economic activity along Red River Canyon. There are three or four erosional (terrace) and depositional (fan) surfaces, probably related to long term hydrological cycles.

The general trace of Red River is evident but no water or water quality information is discernible.

There is evidence of a road and mining activity on the first drainage west of Sulphur Gulch. It is not shown on the USGS topographic quadrangle map, but has been photo-located by this interpreter as an asterisk in Figure 1.

1979 NASA (**Photos 1324/1325**):

The trace of Red River can be followed quite easily from near Fawn Lakes on the East to State Highway 522 on the west. However, there do not appear to be significant differences in water color between flow upstream from the Molycorp mine and flow downstream from it. There does appear to be a difference in color between ponded water upstream vs downstream, but the impoundments are small (at this scale) and few in number.

The entire area bounded by Capulin Canyon on the west to Sulphur Gulch on the east, and from Red River to the ridge crest on the north is densely traversed by switch-back roads

(see Capulin Canyon, Goathill Canyon, and Sulphur Gulch/Spring Gulch notes for more details on when the road net first appears.) The network becomes less dense north of the ridge crest.

The entire area from Goathill Gulch to Sulphur Gulch has been mined, though there appears to be little material escaping the area south of the highway into Red River. This suggests little direct impact on the river itself, but one must remember the small scale of these photographs and their date of acquisition.

**Comparison of 1935/36 (Photos 2979/2980) with 1992 NAPP and 1979 NASA:**

With regard to task #2, it appears that dump material is being used to fill the canyons of Sulphur Gulch, lower Spring Gulch, and all the minor drains immediately east and south of Hill 9538. Two of these canyons and the east slope of upper Goathill Gulch contained natural scar areas, although one of the canyon scars might also have been an early 20th Century mine. It appears that the switch-back road network is used to fill these canyons by starting at the bottom and gradually filling upslope.

## Sulphur Gulch/Spring Gulch

6/22/52 USFS (**Photos DRA-16-49/50**):

Roads leading from Red River Canyon into side canyons east of Sulphur Gulch to roughly elevation marker 8245 are evident, but there is no evidence of switch-back or ridgeline roads. These roads may all be exploratory (possibly even jeep trails) and they are manifested on the photos as highly reflective linear features that follow the canyon bottom. They cannot be traced exactly because they are partly obscured by their highly reflective surroundings. There is minor evidence of human disturbance in the scar areas north of Red River between elevation marker 8245 and Fawn Lakes Campground. There are also scars evident in this area south of Red River canyon. Most of the subject scars on Photo 49 are near the northern edge of the photo. Because of sharp contrast, there is little to no detail in the scar areas themselves.

10/9/58 USFS (**Photos EEB 4-72/73**):

Sulphur Gulch is highly eroded but there are still scattered shrubs and trees throughout the scar area. There is no direct evidence of mining at the scar, but the canyon leading into the primary scar shows pockets of mine waste. Some of the side canyons, including Spring Gulch, also show signs of activity.

There is an evident switch-back road system linking Goathill Gulch and Sulphur Gulch and on the ridgeline north of Sulphur Gulch.

There do not appear to be many mine buildings in Red River Canyon though there are initial signs of mine infrastructure (tailings ponds) along the river east of Sulphur Gulch. Details are obscured by high reflectance, as though there was a patina of dust over everything. Even the trees have a higher than usual reflectance in the vicinity of the tailings ponds. The small mine dump north and just east of BM7870 is evident.

6/10/59 USFS (**Photos 7-56/57**):

Mine dumps near BM7870 are evident. Depositional material can be seen at the confluence of Red River wiith Sulphur Gulch and with the canyon immediately to the west. The drainage line in Goathill Gulch is a major source of erosional material emptying into Red River.

Mine roads and buildings in the Goathill/Sulphur Gulch area are as described for EEB 4-72/73 (1958, above).

10/8/62 USGS (**Photos VANC 9-14/15**):

One can see the beginnings of mine dumps in the lower elevations along Sulphur Gulch, but they have not changed significantly from their first appearance in 1958. Spring Gulch retains its essentially natural appearance.

9/15/65 USFS (**Photos EPB 1-239/240**): (see also EPB 1-204 to 206)

There is evidence of significant mining activity in Sulphur Gulch and Spring Gulches. A very intricate network of roads is evident throughout the Goathill to Spring Gulch area. A

complete mine infrastructure of mine buildings, processing units, earth moving vehicles is evident around Hill 9538 as well as in Red River Canyon and in Spring Gulch. Massive mine dumping is visible on the eastern slopes of Hill 9538 and in Spring Gulch. Concomitant with this increased activity there is evidence of increased sediment flowing southward out of this operation into Red River.

9/26/75 USFS (**CA/SF 6973-68/69**):

Sulphur Gulch and Spring Gulch mine dumps are in advanced stages of development. Many mine buildings, vehicles, and full mine infrastructure are visible. Dump trucks use switch-back roads to haul material to dump sites up-slope. Dumped material is then contoured and leveled.

9/20/81 USFS (**Photos 881-235 to 237**):

At this scale (calculated 1:26,900), it appears that the patterns traced on the 1989 NHAP photos around the mine pit were already in existence by 1981 (possibly as early as 1975--see the ink tracing for 1989).

8/28/92 NAPP (**Photos 3507-82/83**):

Compared to 1935/36 photography, the number, size, and relative shapes of scarred areas north of the Red River and east of Sulphur Gulch are about the same. A few small new scars are visible. It does appear, however, that there is a general patina of highly reflective dust over the region. This "condition" is observable on NASA CIR 1979 photos, but not as prominently.

West of Sulphur Gulch, and both north and south of Red River, there are numerous roads and trails. There are also several small scars south of the river, all of which are linked by switch-back roads that were present before 1979. A map of these areas was drawn using photos 3507-14/15 (see the ink tracing for this date).

## BM 8164 to Fawn Lakes Campground (Sections 31, 32, 33 T29N R14E)

6/22/52 USFS (**Photos DRA 16-49/50**):

There is no evidence of alluvial material along Red River derived from scars. This is a notable absence compared to later images of the alluvial fan at elevation marker 8245.

8/31/59 USFS (**Photos EEB 9-9/10**):

The most notable feature on this photo pair is the more or less natural appearance of the alluvial fan at elevation marker 8245 in Sec 32 on the Red River road west of Fawn Lakes Campground. The fan is vegetated though it appears that sediment is being actively added from the scar up-canyon.

There are a few jeep trails in Sections 31 and 32; otherwise there is no well developed road network except those leading from Red River into the canyons to the north.

9/23/59 USFS (**Photos EEB 10-64/65**):

Erosion from natural scars in Section 32 and 33 appears to be active but stable with regard to ecosystem balance. Alluvial fans built up along Red River canyon are vegetated. One can imagine that during periods of high run-off, some erosional material reaches Red River. All-in-all, the area appears to be stable. There are very few mining roads visible, and most are confined to Red River Canyon.

10/8/62 USGS (**Photos VANC 9-14/15**):

There is increased sediment outflow up-canyon north of elevation marker 8245, and the fan at its foot shows evidence of a new cycle of deposition that extends to Red River. As opposed to its earlier appearance, the fan is now unvegetated. It appears also that there are at least three erosional breaches along State Highway 38 between elevation marker 8245 and Fawn Lakes Campground. The scars in the headwaters upstream from these depositional/erosional features, however, appear to be natural. It is possible that penetration of mining roads up the valleys and along the ridgelines have, themselves, contributed to a more active cycle of erosion.

10/8/62 USGS (**Photos VANC 9-37/38**):

Scars on the north slope of Red River Canyon between BM8164 and the village are mostly in a natural condition.

9/24/65 USFS (**Photos EPB 5-98 to 100**):

Mine roads are visible between the major scar areas in Section 31 and 32.

10/14/65 USFS (**Photos EPB 10-59/60**):

The alluvial fan at elevation marker 8245 is growing both up- and down-canyon. The entire canyon bottom in the reach between Fawn Lakes Campground and Sulphur Gulch is

highly altered through increased sediment load and erosion--probably from mine roads as well as from natural scars and mining activity. There is an appearance that the system has lost its natural stability.

9/25/75 USFS (**Photos CA/SF 6273 162/163**):

These photos reveal a more or less stable situation with regard to erosional activity and sediment transport between the village of Red River and Fawn Lakes Campground. Level areas and alluvial fans are vegetated. The river between Elephant Rock Campground and the village, however, appears to be sediment laden, as evidenced by its distinct brown color.

9/25/75 USFS (**Photos CA/SF 6373-155 to 157**):

There is evidence of increased erosion at the scar upstream from elevation marker 8245. Detail within the scarred areas is somewhat obscured by high reflectivity. In general, scarred areas on color photography are a mottled "cream"/ocher color. Where disturbed by roads or dumping, the mottling is interrupted by areas of higher reflectivity that are white to pale cream color.

The area roughly bounded by elevation marker 8245 and Fawn Lakes Campground, northward to Elephant Rock, appears to be experiencing a rejuvenated cycle of erosion with detrital material extending downslope to Red River. After visually scanning the stereo-triplet under magnification, there is an evident correspondence between the mine road network and each scar, as though the roads were designed to intersect with these scars. It appears also that minor mine dumping has occurred at some of these scarred areas to fill ravines by gravity flow. Increased alluvium at Red River would be a logical result of such dumping

A well developed network of switch-back roads and ridge roads is evident both north and south of Red River.

9/20/81 USFS (**Photos 881-235-237**):

There appears to be some growth in the alluvial sediment volume associated with the scar upstream from elevation marker 8245 on State Highway 38.

9/16/83 USFS (**Photos 1281-75 to 77**):

Detrital material from a scar upstream from elevation marker 8245 on State Highway 38 extends to the river and presumably adds sediment to it.

The scale is reasonably good for mapping scars and some mining activity, but not adequate for interpreting water quality along the river.

7/17/89 USGS (**Photos 524-81/82**):

Between Sulphur Gulch and Fawn Lakes north of Red River, the scar pattern at this scale (1:80,640) and contrast appear similar to the pattern in 1935/36, except for the alluvial fan at elevation marker 8245. It appears that increased disturbance has altered the interior character

of the scars--i.e., leveling, smoothing contours (perhaps some dumping)--because they have lost their natural erosional appearance. Heavier use of roads into each of the areas is evident.

## Capulin Canyon

9/18/52 USFS (**Photos DRA 18-8/9**):

Capulin Canyon and Goathill Gulch are visible throughout their entirety. There is evidence of a natural scar in the ravine below Hill 9668 and there are no roads in the area. There is a jeep trail along Capulin Creek. The ridgeline between Capulin Canyon and Sulphur Gulch has not been breached. There is undisturbed forest to the ridgeline on the Capulin Canyon side.

10/9/58 USFS (**Photos EEB 5-19 to 21**):

A road has been constructed in the headwaters of Capulin Canyon near the ridgeline with Sulphur Gulch. Spring Gulch is essentially natural, but there is growing evidence of mine activity along the Red River valley east of the confluence of Sulphur and Spring Gulches.

10/7/62 USGS (**Photos VANC 8-56/57**):

Capulin drainage is pristine throughout.

10/14/65 USFS (**Photos EPB 10-253/254**):

Mine roads are visible on the eastern slopes of Capulin Canyon extending throughout its reach from the ridgeline with Goathill Gulch to the canyon bottom. In some places, the roads extend across the canyon onto the western slopes. There is no evidence of mine dumping except possibly on the scarred slope below Hill 9668.

9/24/75 USFS (**Photos CA/SF 6273-42/43**): (note: compare to 6/21/81 781-9/10)
9/26/75 USFS (**Photos CA/SF 6973-154/155**):

Capulin Canyon appears to be in a more or less natural condition immediately upstream from its confluence with Red River. Near the eastern edge of the stereogram, a mine road network is evident, and some of them extend into Capulin Canyon. There does not appear to be any dumping in the canyon itself, but there is definite evidence of gravity dumping into tributaries near the headwaters of Capulin below Hill 9668.

6/21/81 USFS (**Photos 781-9/10**):

Mine dumping is evident at the headwaters of Capulin Canyon along the ridgeline adjacent to Sulphur Gulch. There is no change in the mine road network in the rest of the canyon compared to photos CA/SF 6273-42/43 9/24/75). There does not appear to be a significant increase in sediment transport down-canyon.

**Comparison** of 1935/36 (**Photos 2979/2980**) with **1992 NAPP** and **1979 NASA**

Some mine waste may be accumulating in the very upper reaches of Capulin Canyon as a result of downslope movement of detritus; OR, by 1992 there is evidence of a new mine dump developing through gravity flow after off-loading from trucks on the mining road.

In 1936, there were no mine scars or roads in Capulin Canyon. By 1979, the east slopes and headwaters region were penetrated by roads that came downslope from the ridge separating Goathill Gulch from Capulin Canyon. New scars are visible on drains to the west of Hill 9668.

## Goathill Gulch

9/18/52 USFS (**Photos DRA 18-8/9**):

Goathill Gulch has a mine road following the drainage line to the ridgeline with Sulphur Gulch and thence into the erosional pit in the headwaters of Sulphur Gulch. In the headwaters area, there are scars that appear to be natural. There do not appear to be ridgeline roads from which dumping might occur. There could, however, be small mine dumps being built from the bottom, up (compare with evidence in 1935/36).

10/9/58 USFS (**Photos EEB 5-19/21**):

Headwaters of Goathill Gulch show evidence of significant change since the 1952 coverage. It appears that mine dumping has been initiated, although the mine road network is not fully developed compared to later images.

6/10/59 USFS (**Photos 7-56/57**):

Mine dumps near BM7870 are evident. Depositional material is evident at confluence of Red River with Sulphur Gulch and with the canyon immediately to the west. The drainage line in Goathill Gulch is a major source of erosional material emptying into Red River.

Mine roads and buildings in the Goathill/Sulphur Gulch area are as described for EEB 4-72/73 (1958).

10/7/62 USGS (**Photos VANC 8-56/57**):

Goathill scars are advancing downslope; otherwise not much change in this area since 1958.

10/14/65 USFS (**Photos EPB 10-253/254**):

There is evidence of significant dumping in Goathill Gulch with attendant erosion and increased sedimentation in the canyon bottom, extending to Red River.

Red River Canyon in the reach between Goathill Gulch and BM7870 appears to have been developed as a mining community. Red River, itself, is not easily traceable in this reach as the canyon bottom has been enormously altered by the settlement pattern.

## Region South of Red River Canyon

1935/36 USDA/SCS (**Photos 2979/2980**):

South of Red River the area appears to be pristine.

10/8/62 USGS (**Photos VANC 9-14/15**):

There are very small erosional scars south of Red River and east of elevation marker 8245, but the vegetation appears to be essentially undisturbed. There is no evidence of a road network.

1979 NASA (**Photos 1324/1325**):

By 1979 the switch-back road network had expanded south of the Red River, but there were no other evidences of environmental disturbance.

9/16/83 USFS (**Photos 1281-75 to 77**):

Although there is an evident road network that passes nearby most of the natural scars south of the Red River, there is little evidence, if any, of mine dumping.

7/17/89 USGS (**Photos 524-81/82**):

South of the Red River, scars are evident with linking roads.

## Bitter Creek Area

1935/36 USDA (**Photos 3937/3938**):

Bitter Creek Canyon is pristine. There is a jeep trail traceable in a few short segment. The canyon bottom is dotted at the foot of larger side canyons with what appear to be landslide debris from past tectonic activity. These debris flows are all vegetated. The larger ones may from time to time impound surface runoff.

At the confluence of Bitter Creek and Red River there is a narrow outwash plain.

6/22/52 USFS (**Photos DRA 15-128/129**):

Canyon bottom road is evident throughout its length. There are a few man-made impoundments east of the main scar located in the headwaters of a side canyon about one mile east of the canyon mouth in section 25, T29N R14E.

10/23/58 USFS (**Photos EEB 5-120/121**):

Numerous buildings (cabins, dwellings?) are visible along the canyon bottom east of the main scar, especially around the small water impoundments.

10/8/62 USGS (**Photos VANC 9-37/38**):
10/8/62 USGS (**Photos VANC 9-65/66**):

In the village of Red River, there is evidence of erosion emanating from canyons in the northeast. The eastern-most of these canyons shows both erosional and depositional material extending southward across Red River. There are jeep trails leading up most of the canyons and a few small natural scars, mainly at the ridgelines, but no evidence of serious human activity. The source of the sediment is not visible on these photos, unless the primary source is the feature extending northeast from "High Road (name?)."

There are no remarkable changes in Bitter Creek Canyon since 1958.

10/11/65 USFS (**Photos EPB 9-9/10**):

No remarkable changes from 1958 except perhaps decreased vegetation in the canyon bottom. This may be a result of increased human traffic associated with habitation.

9/26/75 USFS (**Photos CA 35055 6973-114/115**):

Scars appear to be natural in their colorations. Number of cabin sites has increased in the vicinity of the impoundments along the canyon bottom.

9/20/81 USFS (**Photos 981-6/7**):

Road is evident along ridgeline between Bitter and Mallette Creeks. Bare area is evident on west end of first water impoundment east of "scar canyon." The bare area on top of the debris flow at the mouth of "scar canyon" has grown since 1975.

9/25/88 USGS (**Photos NHAP 518-48/49**):

The scar area on top of the debris flow at the mouth of "scar canyon" continues to grow. It has taken on the appearance of an alluvial fan superimposed onto the flow, but it is not possible to tell if it is an erosional or depositional feature.

9/24/91 USGS (**Photos NAPP 3505-026/027**):

Human activities along Bitter Creek are noticeably altering its erosional stability. The bare area mentioned on the NHAP photos above continues to grow in a down-canyon direction.

Table 1. Photographic Materials

| Source | Date | Type | Nominal Scale | Calculated Scale | Roll & Frame Numbers | Quality |
|---|---|---|---|---|---|---|
| USDA/SCS | 1935/36 | B&W | 1:31,680 | 1:34,000 | 2893 to 95; 2979/80, 2993/94, 3937/38 | good; 3937/8 underexposed |
| USFS | 6/22/52 | B&W | 1:40,000 | 1:37,348 | DRA 15-128/9; 16-49 to 51 | glossy, contrasty |
| USFS | 9/18/52 | B&W | 1:40,000 | 1:48,000 | DRA 18-8 to 10 | good |
| USFS | 10/9/58 | B&W | 1:15,840 | 1:19,573 | EEB 4-72 to 76 | good |
| USFS | 10/23/58 | B&W | 1:15,840 | | EEB 5-19 to 21 | good |
| USFS | 6/10/59 | B&W | 1:15,840 | 1:21,629 | EEB 7-54 to 59; 115-120 | good |
| USFS | 8/31/59 | B&W | 1:15,840 | 1:20,942 | EEB 9-8 to 9-12 | good |
| USFS | 9/23/59 | B&W | 1:15,840 | | EEB 10-64 to 66 | good |
| USGS | 10/7/62 | B&W | 1:31,680 | 1:32,256 | VANC 8-55 to 57 | good |
| USGS | 10/8/62 | B&W | 1:31,680 | 1:46,345 | VANC 9-14 to 16; 37-39; 65,66 | good |
| USFS | 9/15/65 | B&W | 1:15,840 | 1:18,000 | EPB 1-204 to 206; 237-242 | contrasty |
| USFS | 9/24/65 | B&W | 1:15,840 | | EPB 5-97 to 100 | good |
| USFS | 10/11/65 | B&W | 1:15,840 | | EPB 9-9/10 | good |
| USFS | 10/14/65 | B&W | 1:15,840 | 1:18,442 | EPB 10-59 to 62; 223-227; 251-257 | good |
| USFS | 9/24/75 | Color | 1:15,840 | not calculated | CA/SF 6273 40 to 43 | good |
| USFS | 9/25/75 | Color | 1:15,840 | | CA/SF 6273 161 to 163; 6373 154 to 157 | v. good |
| USFS | 9/26/75 | Color | 1:15,840 | 1:17,684 (67-71) | CA/SF 6973 67 to 71; 114/115; 152 to 158 | v. good |
| NASA | 1979 | Color IR | 1:58,800 | 1:58,800 | 1324/25 | excellent |
| USFS | 6/21/81 | Color | 1:24,000 | 1:25,000 | 781-8 to 11 | v. good |
| USFS | 9/20/81 | Color | 1:24,000 | 1:26,900 | 881-235 to 237; 981-6/7 | good |
| USFS | 9/16/83 | Color | 1:24,000 | 1:23,300 | 1281-75 to 77 | good |
| USGS | 9/25/88 | B&W | 1:80,000 | | NHAP-02 518-32/33; 48/49 | good |
| USGS | 7/17/89 | B&W from CIR | 1:80,000 | 1:80,640 | NHAP-02 524-81/82 | contrasty/grainy |
| USGS | 8/28/92 | B&W from CIR | 1:40,000 | 1:44,800 | NAPP 3507-14 to 16; 81-83; 103/104 | contrasty |
| USGS | 9/24/92 | B&W from CIR | 1:40,000 | | NAPP 3505-026/027 | contrasty |

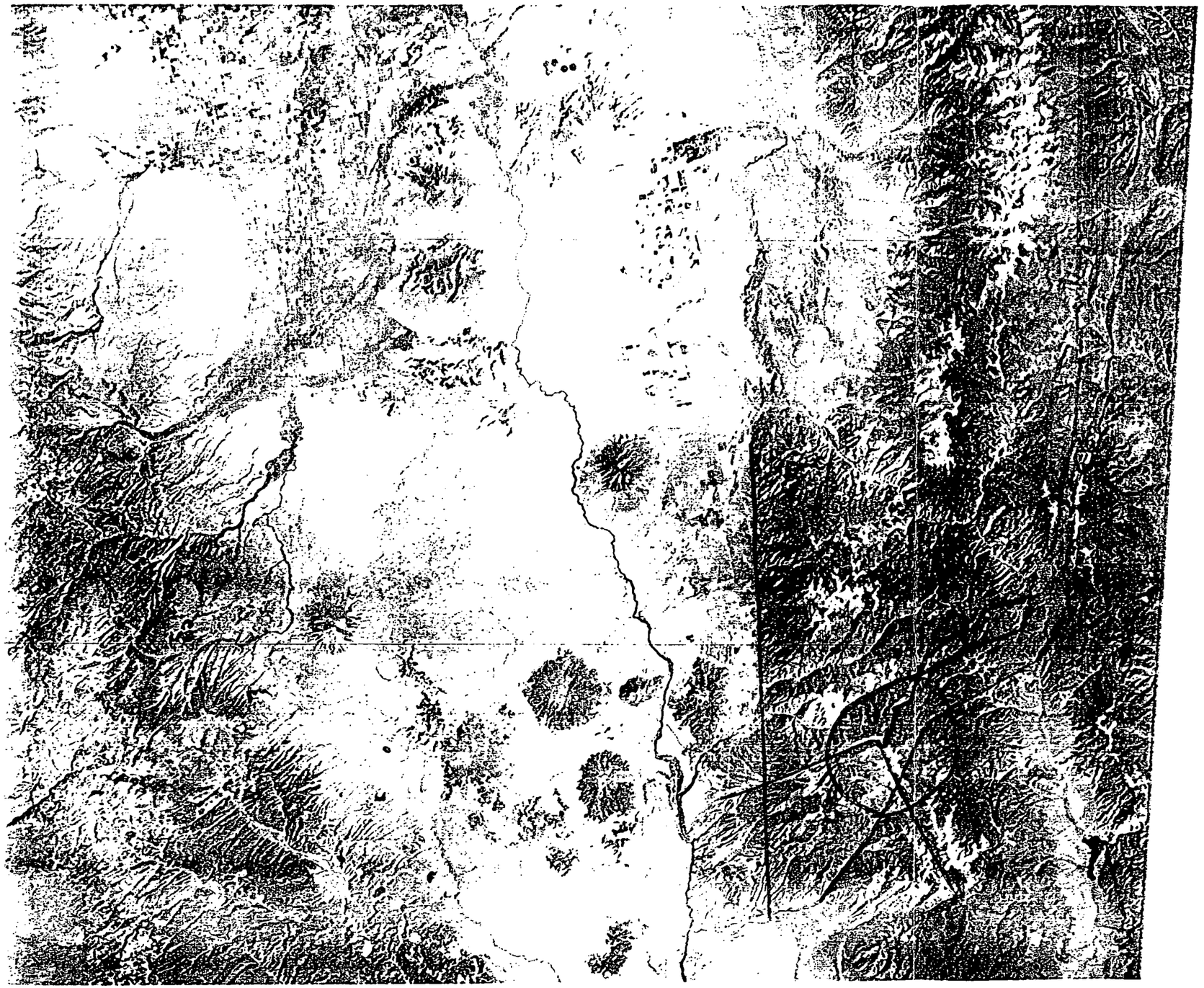
FIGURE 1.

* 1935/36 mine site

RECEIVED
APR 12 1996

John —

Here is the [illegible] map we discussed. It looks oddly like an "X marks the spot." The Molycorp Mine is on the NW part of the circle showing as a bright white spot. The dark center in that bright spot is hill 9538. Would like to visit the area - Perhaps May or June

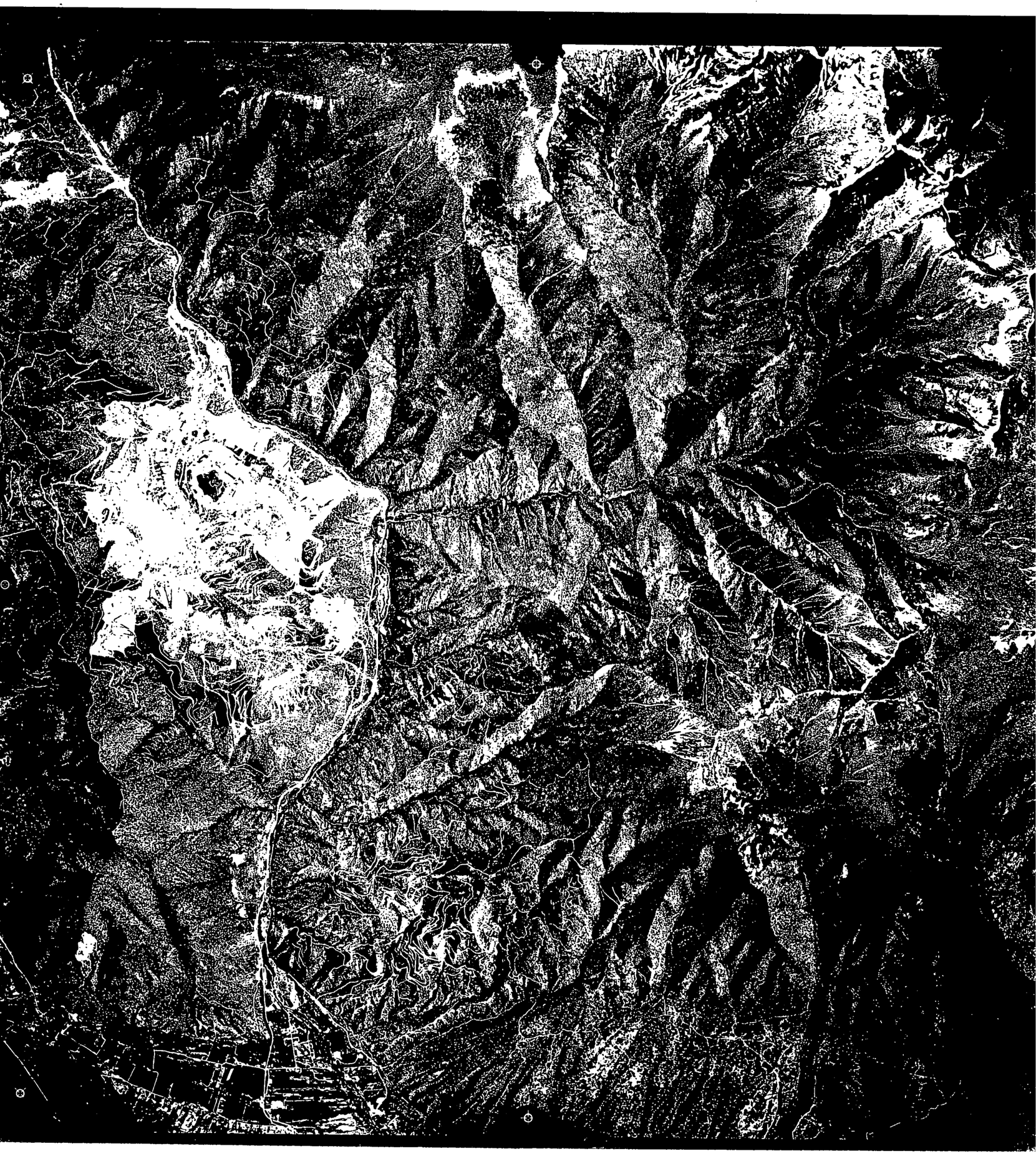


USGS EROS DATA CENTER

1SS 5 SUN EL45 AZ136 191-3346-G-1-N-D-2L NASA ERTS E-2240-17015-5 01

Linear & Curvilinear Map
from 1:1,000,000 LANDSAT MSS
False color image enlarged to
about 1:500,000.

Lines added by Stan Morain
April 9, 1996.



State of New Mexico
ENVIRONMENT DEPARTMENT
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Santa Fe, New Mexico 87502
(505) 827-0187

GARY E. JOHNSON
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SECRETARY

EDGAR T. THORNTON, III
DEPUTY SECRETARY

January 30, 1996

1 - Permit/CD
2 - AO & AO matl
3 - DMR's
4 - Vio. Sum. Log
5 - NOS
6 - Correspondence
7 - CRAS
Date Filed
Clerk's Inits.

Mr. Robert Murphy
Chief, Enforcement Branch
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202-2733

Re: **Molycorp, Inc., NPDES Permit No. NM0022306**

Dear Mr. Murphy:

Recently staff of the New Mexico Environment Department Surface Water Quality Bureau (SWQB) assigned to the New Mexico Mine Act program began a review of Departmental files for the referenced facility. In this review, a September 24, 1993 report entitled *Analysis of Tailings Pond Seepage Flow to the Red River at UNOCAL 76 Molycorp, Inc. Questa Division* by Molycorp's consultant Vail Engineering, Inc. was brought to the attention of the SWQB's Point Source Regulation Section. The report had been submitted to NMED's Ground Water Quality Bureau by Molycorp in support of their discussions on ground water quality impacts and permitting. A copy of the report is enclosed with this letter.

In this report, Molycorp has quantitatively identified subsurface discharges of tailings leachate (volume & quality) to the Red River. Please see the schematic diagram at end of the enclosed report labelled "Analysis of Accretions to Red River." These discharges are not permitted under the current NPDES permit. To the best of our knowledge, Molycorp has never notified EPA of these discharges either through their NPDES permit application or other official correspondence. The current NPDES permit was issued September 10, 1993. Given the time frames, and the fact many of the sample collections were in the Spring of 1993, it appears that Molycorp was aware of these discharges at the time the permit was being processed.

We understand there has been some judicial review[1] regarding propriety of permitting situations where the pollutants move through ground water prior to entering a "water of the United

[1] e.g., **Sierra Club v. Colorado Refining Co.; Washington Wilderness Coalition v. Hecla Mining Co.; McClellan Ecological Seepage Situation v. Defense Department; and Oconomowoc Lake v. Dayton Hudson Corp.**

States. We further understand that the issue, in terms of these cases, may not be fully resolved. However, we believe the situation at Molycorp is clear; the permittee has a professional engineer's report which firmly identifies and quantifies the discharge *vis a vis* the potential for discharge to a water of the United States which was an issue in other cases.

The Red River is classified in the New Mexico *Standards for Interstate and Intrastate Streams* [20 NMAC 6.1, §2119] with the following uses: coldwater fishery, fish culture, irrigation, livestock watering, wildlife habitat, and secondary contact. The discharges are also only a few miles above the portion of the Red River designated as a wild and scenic river by the U.S. Congress under the **Wild and Scenic Rivers Act**. Further, the Red River is included in the New Mexico §305(b) report's list of "Waterbodies with Designated Uses Partially or Not Fully Supported or with Threatened Designated or Attainable Uses" and is a "priority 1" reach on the New Mexico 1994-96 §303(d) list.

Based on the above, the NMED Surface Water Quality Bureau requests your review of this matter and determination of appropriate action. If you have any questions, please contact Glenn Saums of my staff at (505) 827-2827.

Sincerely,

Jim Piatt

Jim Piatt, Ph.D.
Chief
Surface Water Quality Bureau

Enclosure

cc (w/o enclosure):
Jack Ferguson, P.E., USEPA (6WQ-P)
Rip Harwood, NMED OGC
Marcy Leavitt, NMED GWQB

# ANALYSIS OF TAILINGS POND SEEPAGE FLOW TO RED RIVER

AT

UNOCAL 76 MOLYCORP, INC.

QUESTA DIVISION

VAIL ENGINEERING, INC.

SANTA FE, NEW MEXICO

SEPTEMBER 24, 1993

# VAIL ENGINEERING, INC.

PHONE: (505)
-5375

1588 SAN MATEO LANE
SANTA FE, NEW MEXICO
87501

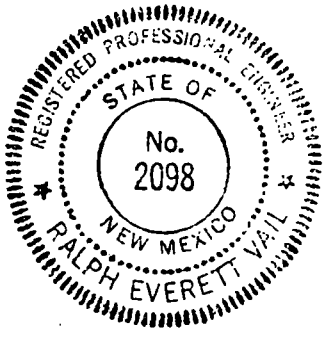

September 24, 1993

Mr. David Shoemaker
Mine Manager
Molycorp, Inc.
P.O. Box 469
Questa, NM 87556

Dear Sir:

Submitted herewith is our report on the stream survey and analysis of accretions to Red River in the vicinity of Molycorp's tailings ponds, Taos County, New Mexico.

Sincerely yours,
VAIL ENGINEERING, INC.




Ralph E. Vail

Chief Engineer
NMPE No. 2098

# ANALYSIS OF TAILINGS POND SEEPAGE FLOW TO RED RIVER

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VAIL ENGINEERING, INC.

PHONE: (505)
3575

1588 SAN MATEO LANE
SANTA FE, NEW MEXICO
87501

# ANALYSIS OF TAILINGS POND SEEPAGE FLOW TO RED RIVER

## OVERVIEW

Molycorp's tailings dams are located primarily in Sections 35 (Dam Nos. 4 & 5) and 36 (Dam No. 1), of Township 29N Range 12E NMPM, one to two miles west of the Town of Questa, Taos County, New Mexico. Red River flows to the west past the tailings ponds at a distance of approximately one-half mile south of the ponds. Leachate from the tailings ponds seeps to the ground water which flows generally in a southwesterly direction and discharges to Red River.

The seepage from the ponds contains elevated concentrations of sulfates (840± mg/l), molybdenum (2± mg/l), manganese (1.4± mg/l), and total dissolved solids (1700± mg/l). Several other elements are present at moderately elevated but below significant levels. It appears that most of the molybdenum is being absorbed during seepage flow in the vadose zone and along the ground water flow path.

During the 1970's Molycorp excavated trenches and installed french drains to intercept the seepage flow south of Dam No. 1 and southeast of Dam No. 4. These seepage barriers appeared to be fairly effective for some time but recently there has been evidence that an increased amount of seepage from the tailings ponds flows past these barriers. This seepage flow is generally in the shallow alluvium and the fairly high constituent concentrations this area.

It is probable that a large percentage of the seepage from section 35 is transported by the ground water flow in the volcanic formations which underlie most of this pond area. It is believed that most of this ground water flow is discharged to Red River at the numerous springs along the Red River Gorge. The accretion to Red River from spring flow between the head of the gorge to the State fish hatchery is on the order of 18 cfs indicating a large amount of ground water flow in the volcanic formation.

In April 1993 a water quality survey was made along Red River between the State Road 3 highway bridge and the Red River Fish Hatchery. The primary purposes for this survey study were:

(1) Determination of the concentration of significant pond seepage water constituents in the ground water and spring water entering Red River.

(2) Determination of the amount of seepage water contained in the ground water and spring flows along specific reaches of Red River.

(3) Determination of the effect on Red River of the pond seepage discharge.

This study was conducted in conjunction with a ground water study, being prepared by South Pass Resources, Inc., to determine the characteristics of the ground water aquifer south of Dam No. 1 and the distribution and concentration of significant tailings pond water constituents in the ground water immediately down gradient of the pond areas.

Both studies were being conducted to determine the desirability and feasibility of further action by Molycorp to reduce the effect of seepage from the pond areas.

## SURVEY OF RED RIVER

The survey was conducted on April 12, 1993 between State Highway 3 and the fish hatchery. Six water samples were collected at selected locations along Red River. Four samples were collected from springs and drainages in the fields south of Dam No. 1 and five samples were collected from springs flowing into Red River along and at the head of the Red River Gorge. Both the warm and cold water fish hatchery supplies were sampled. A sample was collected from the 002 outfall. Samples were taken from the drainage below the 002 metering manhole and from a spring along the irrigation ditch east of that point. Conductivity and temperature measurements were recorded at all of the above and at an additional nine points in Red River and nine more spring or field drainage points. All samples were analyzed for sulfates, dissolved and suspended aluminum, molybdenum and ten other elements or parameters. The flow from many of the springs and field drainages were estimated at the time of the survey.

Subsequently the USGS recorded stream flow data was obtained for April 11, 12 and 13 at Red River near Questa (Ranger Station), Red River below the fish hatchery and Cabresto Creek near Questa. The fish hatchery superintendent was interviewed relative to the amount of cold and warm spring water that was being intercepted.

The following Table No. 1 is a summary of the more significant data obtained during the survey. Table 2 presents the complete data of the laboratory analysis of the water samples collected during the survey.

Drawing No. 1 shows the significant elements of the area and the location of the stream survey stations.

## DATA BASE

### Flow in Red River

USGS stream flow data indicates the following mean daily flows were present at the time of the stream survey.

| Station | 1993 | | |
|---|---|---|---|
| | April 11 | April 12 | April 13 |
| Red River Near Questa (Ranger Station) | 37 | 41 | 46 |
| Cabresto Creek | 11 | 11 | 12 |
| Red River Below Fish Hatchery | 62 | 65 | 70 |

The USGS data indicated measurement conditions were good during this time period. Good conditions under the USGS classification means that about 95% of the reported daily discharges are within 10% of the true value. Historic USGS stream flow data indicates that except for Cabresto Creek, there generally is not a significant amount of gain or loss in Red River between the Ranger Station and the highway bridge when irrigation water is not being diverted and there is not a significant amount of drainage from recent precipitation. The data indicates that there may have been a small amount of irrigation diversion on the date of the stream survey.

Table 3. is a tabulation of the USGS reported daily stream flows for March and April 1993. This table also shows the indicated gain or loss between the Ranger Station (plus Cabresto Creek) and the fish hatchery. Gains in

TABLE 1
LOWER RED RIVER SURVEY 4-12-93
Summary of Survey Data

| SAMPLE POINT | DESCRIPTION | RED RIVER COND | RED RIVER TEMP | RED RIVER SO 4 | SPRINGS & DRAINAGE COND | SPRINGS & DRAINAGE TEMP | SPRINGS & DRAINAGE SO 4 |
|---|---|---|---|---|---|---|---|
| 1. | Below Hwy Bridge | 345 | 8.3 | 119 | | | |
| 2. | Spring in field | | | | 398 | 10.5 | 92 |
| 2A. | Field Drainage | | | | 456 | 8.3 | -- |
| 3. | Field Drainage | | | | 415 | 11.2 | 92 |
| 4. | Field Drainage | | | | 926 | 17.8 | 172 |
| 4A. | RR above 3/4 | 369 | 9.3 | -- | | | |
| 5. | RR above 002 | 376 | 9.1 | 118 | | | |
| 6. | 002 | | | | 1984 | 9.7 | 840 |
| 6A. | Field Drainage | | | | 450 | 9.3 | |
| 6B. | Seepage @ 002 | | | | 1800 | 9.8 | |
| 7. | Field Drainage | | | | 863 | 10.1 | 228 |
| 8. | RR above Big Spr. | 418 | 9.8 | 141 | | | |
| 9. | Big Spring | | | | 1390 | 7.8 | 504 |
| 10. | Pipe @ Big Spr. | | | | 870 | 7.1 | 210 |
| 11. | RR below BS | 412 | 10.3 | 138 | | | |
| 11A. | RR above Pope | 410 | 10.4 | -- | | | |
| 11B. | RR above Pope | 409 | 10.5 | -- | | | |
| 11C. | RR @ Pope | 410 | 10.5 | -- | | | |
| 11D. | RR below Pope | 410 | 10.4 | -- | | | |
| 11E. | RR below Pope | 410 | 10.4 | -- | | | |
| 12. | Spring | | | | 388 | 15.3 | 115 |
| 13. | RR above S12 | 410 | 10.5 | 128 | | | |
| 13A. | Spring | | | | 407 | 15.8 | -- |
| 13B. | Seep | | | | 410 | 14 | -- |
| 13C. | Spring | | | | 436 | 14.5 | -- |
| 13D. | RR | 410 | 10.5 | | | | |
| 14. | South Side Spr. | | | | 450 | 16.9 | 126 |
| 14A. | RR above S14 | 410 | 10.9 | | | | |
| 15. | Spring | | | | 238 | 16.4 | 20 |
| 15A. | RR | | | | 284 | 16.3 | |
| 15B. | RR | 404 | 11.2 | | | | |
| 15C. | Spring | | | | 284 | 16.4 | |
| 16. | RR | 407 | 11 | 129 | | | |
| 16A. | RR @ Div.Dam | 407 | 11 | | | | |
| 17. | Hatchery Cold Spr. | | | | 430 | 8.3 | 80 |
| 18. | Hat-Warm Spr. | | | | 320 | 15.8 | 63 |
| 19. | Irrg. Ditch 002/003 | | | | 1550 | 10.5 | 660 |
| 20. | Drain Below 002/003 | | | | 1520 | 8.9 | 790 |

WATER QUALITY SURVEY ALONG RED RIVER
BETWEEN STATE ROAD 522 AND FISH HATCERY
APRIL 12, 1993

| SAMPLE SOURCE | PH | TOT ALK | F | TDS | SO4 | TSS | DIS. MO | DIS. AL | DIS. CD | SUS. AL | SUS. FE | SUS. PB | SUS. CU | SUS. ZN | SUS. MN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #1 R/R Below Highway Bridge | 7.23 | 38 | 0.84 | 255 | 119 | 31 | <.03 | <.5 | <.005 | 7.8 | 0.594 | <.1 | 0.036 | 0.250 | 0.92 |
| #2 Spring N. Side R/R | 6.76 | 90 | 0.55 | 247 | 92 | 20 | <.03 | <.5 | <.005 | 0.5 | 0.543 | <.1 | 0.007 | 0.021 | 0.02 |
| #3 Field Drainage to R/R 500'E. of 002 | 7.44 | 99 | 0.60 | 246 | 92 | 7 | 0.20 | <.5 | <.005 | <.5 | 0.405 | <.1 | <.005 | 0.047 | 0.05 |
| #4 Field Drainage to R/R 450'E. of 002 | 8.22 | 94 | 0.46 | 648 | 172 | 6 | <.03 | <.5 | <.005 | <.5 | 0.115 | <.1 | 0.008 | 0.012 | 0.05 |
| #5 R/R 300'E. of 002 | 7.60 | 43 | 0.90 | 240 | 118 | 22 | <.03 | <.5 | <.005 | 8.0 | 0.569 | <.1 | 0.028 | 0.222 | 0.88 |
| #6 Outfall 002 | 7.26 | 152 | 1.90 | 1764 | 840 | 2.0 | 1.80 | <.5 | <.005 | <.5 | 0.102 | <.1 | <.005 | 0.010 | 1.40 |
| #7 Field Drainage 75'W of 002 | 7.20 | 165 | 0.80 | 727 | 228 | 39 | 0.20 | <.5 | <.005 | 2.7 | 1.090 | <.1 | 0.009 | 0.017 | 0.03 |
| #8 R/R Above Questa Spring | 7.14 | 50 | 0.88 | 268 | 141 | 21 | <.03 | <.5 | <.005 | 6.2 | 0.573 | <.1 | 0.029 | 0.207 | 0.88 |
| #9 Near Questa Springs SE of Conc.Box | 7.02 | 158 | 0.38 | 1094 | 504 | 88 | <.03 | <.5 | <.005 | 8.5 | 2.940 | <.1 | 0.016 | 0.047 | 0.07 |
| #10 Near Questa Springs End of Old Pipe | 7.50 | 177 | 0.60 | 576 | 210 | 7 | <.03 | <.5 | <.005 | <.5 | <.05 | <.1 | 0.005 | 0.010 | 0.01 |
| #11 R/R 500'W. of Questa Springs | 7.45 | 54 | 0.90 | 269 | 138 | 22 | <.03 | <.5 | <.005 | 3.10 | 0.618 | <.1 | 0.033 | 0.215 | 0.88 |

TABLE NO. 2 (CONT.)

WATER QUALITY SURVEY ALONG RED RIVER
BETWEEN STATE ROAD 522 AND FISH HATCERY
APRIL 12, 1993

| SAMPLE SOURCE | PH | TOT ALK | F | TDS | SO4 | TSS | DIS. MO | DIS. AL | SUS. CD | SUS. AL | FE | PB | CU | ZN | MN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| #12 Spring–N. Side R/R Sta. 47+20 | 6.94 | 82 | 0.80 | 271 | 115 | 47 | <.03 | <.5 | <.005 | 1.70 | 2.36 | <.1 | 0.011 | 0.046 | 0.13 |
| #13 R/R Sta. 47+70 Above Hatchery | 7.45 | 51 | 0.90 | 259 | 128 | 22 | <.03 | <.5 | <.005 | 3.00 | 0.590 | <.1 | 0.026 | 0.206 | 0.8? |
| #14 Spring S. Side R/R Sta. 36+80 | 8.14 | 82 | 0.80 | 304 | 126 | <1 | <.03 | <.5 | <.005 | <.5 | <.05 | <.1 | <.005 | 0.005 | 0.01 |
| #15 Spring N. Side R/R Sta. 36+40 | 7.26 | 80 | 1.10 | 145 | 20 | <1 | <.03 | <.5 | <.005 | <.5 | <.05 | <.1 | <.005 | <.005 | <.0 |
| #16 R/R Sta. | 7.80 | 49 | 0.90 | 247 | 129 | 24 | <.03 | <.5 | <.005 | 3.10 | 0.527 | <.1 | 0.024 | 0.191 | 0.781 |
| #17 Hatchery Inlet Cold Water | 7.14 | 43 | 0.64 | 176 | 80 | | <.03 | <.5 | <.005 | <.5 | 0.138 | <.1 | <.005 | <.005 | <.0 |
| #18 Hatchery Inlet Warm Water | 7.87 | 77 | 1.10 | 284 | 63 | | <.03 | <.5 | <.005 | <.5 | 0.181 | <.1 | <.005 | 0.010 | <.0 |
| #19 Seep Water in Irrigation Ditch Above 002 Line X @ Road | 7.73 | 174 | 0.54 | 1304 | 660 | | <.03 | <.5 | <.005 | <.5 | 0.160 | <.1 | <.005 | 0.013 | 0.05 |
| #20 Molycorp Drain Below Culver Above Ditch | 8.10 | 153 | 1.90 | 1702 | 790 | | 1.70 | <.5 | <.005 | 4.00 | 2.4 | <.1 | 0.016 | 0.010 | 2.00 |

excess of 18 cfs during the first two weeks of March indicate run-off from spring snow melt along the survey reach. During the latter part of April the net gains were generally below 18 cfs because of irrigation diversions.

The USGS data also includes the river stage (gage height) at the stations on an hourly basis. The hourly data was used for determination of the specific probable stream flow at the average time of the stream survey.

Accretions to Red River

Previous studies have established that the accretion to Red River due to natural spring flow between the highway bridge and the mouth of Red River is fairly constant and amounts to approximately 32 cfs. Of this, the data indicates that 18 cfs originates above the fish hatchery. Hydro-geological analysis indicates that the majority of the spring flow is from the north side of Red River.

At the time of the stream survey, the irrigation ditches west of the highway were dry, there were no surface stream flows to the river along the survey reach and there did not appear to be any significant amount of drainage from precipitation. It is believed, therefore, that accretions to Red River at that time consisted essentially of the natural spring flow, the discharge from 002 and 003 and seepage from the tailings pond area which was not being intercepted by the 002 and 003 collection systems.

Fish Hatchery Diversions

The New Mexico Game and Fish Department has constructed facilities which intercept a large portion of the spring flow upstream of the hatchery. The intercepted spring water is transported to the hatchery by two pipelines. One pipeline extends to the large spring complex on the north side of the river at the upper end of the Red River Gorge. Water from this spring complex has a temperature of from 8°

TABLE 3
USGS STREAM FLOW DATA - CFS

| | MARCH 1993 | | | | | APRIL 1993 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY | RANGER STATION | CABR. CREEK | RS & CAB CK | BELOW F HAT | GAIN | RANGER STATION | CABR. CREEK | RS & CAB CK | BELOW F HAT | GAIN |
| 1 | 22 | 6.2 | 28.2 | 54 | 25.8 | 31 | 7.8 | 38.8 | 57 | 18.2 |
| 2 | 20 | 5.7 | 25.7 | 51 | 25.3 | 32 | 8.1 | 40.1 | 59 | 18.9 |
| 3 | 19 | 5.6 | 24.6 | 50 | 25.4 | 32 | 8.2 | 40.2 | 61 | 20.8 |
| 4 | 20 | 5.6 | 25.6 | 50 | 24.4 | 30 | 7.9 | 37.9 | 58 | 20.1 |
| 5 | 20 | 5.6 | 25.6 | 48 | 22.4 | 33 | 8.4 | 41.4 | 60 | 18.6 |
| 6 | 21 | 5.9 | 26.9 | 51 | 24.1 | 34 | 8.5 | 42.5 | 61 | 18.5 |
| 7 | 22 | 6.2 | 28.2 | 53 | 24.8 | 34 | 7.8 | 41.8 | 61 | 19.2 |
| 8 | 22 | 6.2 | 28.2 | 55 | 26.8 | 33 | 8.1 | 41.1 | 60 | 18.9 |
| 9 | 23 | 6.3 | 29.3 | 56 | 26.7 | 33 | 9.5 | 42.5 | 60 | 17.5 |
| 10 | 24 | 6.6 | 30.6 | 55 | 24.4 | 34 | 10 | 44 | 61 | 17 |
| 11 | 24 | 6.6 | 30.6 | 54 | 23.4 | 37 | 11 | 48 | 62 | 14 |
| 12 | 23 | 6.3 | 29.3 | 52 | 22.7 | 41 | 11 | 52 | 65 | 13 |
| 13 | 20 | 5.3 | 25.3 | 47 | 21.7 | 46 | 12 | 58 | 70 | 12 |
| 14 | 22 | 6.1 | 28.1 | 49 | 20.9 | 47 | 12 | 59 | 77 | 18 |
| 15 | 23 | 6.6 | 29.6 | 48 | 18.4 | 46 | 12 | 58 | 79 | 21 |
| 16 | 23 | 6.6 | 29.6 | 49 | 19.4 | 44 | 12 | 56 | 79 | 23 |
| 17 | 24 | 6.7 | 30.7 | 50 | 19.3 | 42 | 11 | 53 | 79 | 26 |
| 18 | 25 | 6.8 | 31.8 | 51 | 19.2 | 42 | 12 | 54 | 70 | 16 |
| 19 | 26 | 6.9 | 32.9 | 52 | 19.1 | 44 | 12 | 56 | 71 | 15 |
| 20 | 27 | 7 | 34 | 52 | 18 | 44 | 12 | 56 | 76 | 20 |
| 21 | 28 | 7.3 | 35.3 | 52 | 16.7 | 48 | 12 | 60 | 75 | 15 |
| 22 | 30 | 7.4 | 37.4 | 53 | 15.6 | 57 | 14 | 71 | 83 | 12 |
| 23 | 30 | 7.7 | 37.7 | 55 | 17.3 | 73 | 16 | 89 | 96 | 7 |
| 24 | 31 | 8 | 39 | 59 | 20 | 78 | 21 | 99 | 107 | 8 |
| 25 | 33 | 8.3 | 41.3 | 59 | 17.7 | 71 | 19 | 90 | 102 | 12 |
| 26 | 34 | 8.5 | 42.5 | 58 | 15.5 | 78 | 20 | 98 | 102 | 4 |
| 27 | 36 | 8.6 | 44.6 | 63 | 18.4 | 95 | 24 | 119 | 119 | 0 |
| 28 | 34 | 8.4 | 42.4 | 58 | 15.6 | 105 | 26 | 131 | 129 | -2 |
| 29 | 34 | 8.3 | 42.3 | 59 | 16.7 | 115 | 29 | 144 | 135 | -9 |
| 30 | 33 | 8.2 | 41.2 | 58 | 16.8 | 122 | 31 | 153 | 147 | -6 |
| 31 | 32 | 7.8 | 39.8 | 57 | 17.2 | | | | | |

to 10°C and is referred to as the hatchery cold water supply. The other pipeline collects water from numerous springs west of the upper end of the gorge. Water from these springs has a nominal temperature of 16°C and is referred to as the warm water supply.

It is believed that the cold water springs are fed by ground water from the alluvial aquifer east of the Guadalupe Mountain volcanic formations which flows primarily along the frontal lobe of the volcanics and/or along the easterly most volcanic formation fault zone.

The warm water springs emanate from the volcanic formations along the Red River Gorge. The higher temperature of this spring water is attributed to heat gains from the volcanic formations.

Flow meters have been installed on both the warm and cold water supplies to the hatchery. At the time of the stream survey, however, neither meter was operating properly. The hatchery superintendent advised that the warm water supply normally ranged from 4600 to 4700 gpm (10.2 to 10.5 cfs) and the cold water supply varied from 900 to 1500 gpm (2.0 to 3.3 cfs). The flow at the time of the stream survey was estimated at 10 cfs for the warm water supply and 2.7 cfs for the cold water supply.

Ambient Ground Water Quality

Table 4 lists the water analysis for a number of springs and wells up gradient or out of the tailings pond seepage flow path. Winograd in Technical Report No. 12, indicated that the quality of water in the volcanics and in the alluvium formations was nearly the same.

TABLE 4

WATER QUALITY OF SPRINGS AND WELLS
IN THE VICINITY OF GUADALUPE MOUNTAINS

| WATER SOURCE | LOCATION Sec | Twp | Rng | AGENCY | DATE | SPEC. COND. umhos | TDS mg/l | pH units | SO4 mg/l | CALCIUM mg/l | MAG-NESIUM mg/l | CHLORIDE mg/l | FLOURIDE mg/l | IRON ug/l | MANGANESE ug/l | MOLY-DENUM ug/l | ZINC ug/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Arsenic Springs | 8 | 28 | 12 | USGS | 10-07-80 | 228 | 161 | 8.2 | 22.0 | 18.0 | 4.8 | 6.9 | --- | <10 | 2 | <10 | --- |
| Big Arsenic Springs | 8 | 28 | 12 | USGS | 08-20-82 | 220 | 159 | 7.9 | 22.0 | 20.0 | 5.1 | 6.8 | 1.2 | 4 | 3 | --- | 13 |
| Big Arsenic Springs | 8 | 28 | 12 | EID | 01-13-83 | 226 | 162 | 7.5 | 23.7 | 18.0 | 5.7 | 8.0 | --- | --- | <10 | --- | <50 |
| Big Arsenic Springs | 8 | 28 | 12 | EID | 07-23-84 | --- | 160 | --- | 24.8 | 16.3 | 5.6 | 6.0 | --- | <50 | <10 | <50 | <50 |
| Big Arsenic Springs | 8 | 28 | 12 | EID | 01-13-83 | 229 | 163 | 7.5 | 23.7 | 19.4 | 5.4 | 8.0 | --- | --- | --- | <10 | <50 |
| Big Arsenic-North Springs | 8 | 28 | 12 | EID | 01-13-83 | 192 | 163 | 7.5 | 23.7 | 19.4 | 5.4 | 8.0 | --- | --- | <10 | --- | <50 |
| Big Arsenic-Meadow Springs | 8 | 28 | 12 | EID | 11-08-84 | --- | 154 | --- | 29.6 | 22.4 | 7.8 | 6.3 | 1.2 | <100 | <50 | <10 | <50 |
| Big Arsenic-Meadow Springs | 8 | 28 | 12 | EID | 05-30-85 | --- | 165 | --- | 24.5 | 24.0 | 8.3 | 8.6 | --- | 110? | <50 | <10 | <10 |
| Big Arsenic-Meadow Springs | 8 | 28 | 12 | EID | 11-08-84 | --- | --- | --- | --- | 21.6 | 3.9 | --- | 1.08 | 480? | <50 | <10 | --- |
| Big Arsenic-High Springs | 8 | 28 | 12 | EID | 05-30-85 | 247 | 170 | --- | 24.5 | 11.2 | 20.0 | 6.8 | --- | <50 | <50 | <10 | --- |
| Big Arsenic-High Springs | 8 | 28 | 12 | EID | 05-30-85 | 218 | --- | --- | 26.6 | 22.5 | 17.6 | 7.0 | --- | --- | --- | --- | --- |
| Chiflo Springs | 9 | 28 | 12 | USGS | 08-20-82 | 220 | 156 | 7.9 | 20.0 | 19.0 | 5.0 | 7.0 | 1.2 | 7 | 3 | --- | 48 |
| BLM Visito Center Well | 9 | 28 | 12 | USGS | 08-20-82 | 220 | 158 | 8.0 | 23.0 | 19.0 | 5.2 | 6.9 | 1.3 | 3 | 10 | --- | 97 |
| BLM Chiflo Wells | 9 | 28 | 12 | USGS | 08-19-82 | 220 | --- | 7.5 | --- | --- | --- | --- | --- | 3 | 8 | 6 | <3 |
| Mottle Spring-Red River | 9 | 28 | 12 | EID | 02-21-84 | --- | 164 | --- | 21.7 | 24.0 | 5.9 | 9.7 | --- | --- | <10 | --- | <100 |
| Warm Spring-Red River | 22 | 29 | 12 | MC | 12-87 | --- | 167 | 7.5 | 50.1 | 20.5 | 4.9 | 8.7 | 1.1 | 5 | 2 | <2 | 150 |
| MC Guadalupe Well 4 (Average of 7 samples) | 33 | 29 | 12 | MC | 11-85 | --- | 167 | --- | 18.8 | 20.4 | 5.4 | 7.6 | 1.1 | 3 | 14 | <2 | 40 |
| MC Guadalupe Well 5 (Average of 5 samples) | | | | | | | | | | | | | | | | | |
| **ALLUVIUM WELLS** | | | | | | | | | | | | | | | | | |
| Top of World Farm | 35 | 1 | 74 | | 1955 | 217 | 136 | 7.7 | 8.8 | 24 | 5.7 | 5.0 | 0.8 | --- | --- | --- | --- |
| Anderson Well | 16 | 12 | 30 | | 1954 | 194 | --- | 7.2 | --- | --- | --- | 4.5 | --- | --- | --- | --- | --- |
| Carter Farm | 24 | 12 | 30 | | 1954 | 190 | --- | --- | 43 | 36 | 2 | 18 | --- | --- | --- | --- | --- |
| **WATERS APPEARING TO BE ABOVE NATURAL AMBIENT** | | | | | | | | | | | | | | | | | |
| Fish Hatch. Cold Springs | 1 | 28 | 12 | EID | 10-18-84 | --- | 306 | --- | 70.6 | 50.4 | 7.9 | 5.7 | 0.73 | <50 | <50 | 10 | <50 |
| Spr. Across from STP | 1 | 28 | 12 | EID | 10-15-84 | --- | 320 | 7.2 | 81.3 | 50.0 | 8.2 | 6.0 | 0.67 | <100 | <50 | 15 | --- |
| Fish Hatch Spr. Coll. Box | 2 | 28 | 12 | EID | 10-16-84 | --- | 460 | --- | 152. | 84.6 | 14.0 | 7.0 | 0.73 | <100 | <50 | 22 | <50 |
| Fish Hatch.Warm Springs | 3 | 28 | 12 | EID | 10-16-84 | --- | 158 | --- | 43.2 | 19.0 | 6.7 | 10.3 | --- | <100 | <50 | 14 | <50 |

Where analysis was made all samples had concentrations of cadmium, copper and lead near or below the detection limit.

Tailings Seepage Water Quality

For the analysis and this report it was assumed that the concentrations reported in Table 2 for sampling point No. 6 (002 outfall) reflected the quality of the tailings pond seepage flow.

## ANALYSIS

A large part of the analysis was based on the following selected values:

Table 5

Selected Analytical Values

| Element | Flow CFS | Sulfate mg/l |
|---|---|---|
| Red River @ Hwy.Bridge | 46.0 | 119 |
| Total Natural Spring Flow | 18.0 | 20 |
| Hatchery Warm Water Supply | 10.0 | 63 |
| Hatchery Cold Water Supply | 2.7 | 80 |
| Tailings Pond Seepage | --- | 840 |
| Red River Below Fish Hatchery | 66.29 | --- |

The selected value for the flow in Red River below the fish hatchery was based on the USGS reported hourly stage reading at the estimated average time when the flow during the survey was passing by the station. The flow at the highway bridge was derived by subtracting the assumed and calculated accretions above the hatchery from the flow in Red river at the station below the hatchery. The sum of the Red River flow at the Ranger Station plus Cabresto Creek was approximately 49 cfs at that time indicating a nominal difference in the flow measurements and/or that there may have been a small amount of irrigation diversion from the reach above the highway bridge.

The ambient concentration of sulfate for the natural ground water flow was conservatively selected at 20 mg/l which is slightly below the average of the concentrations

for the springs and wells listed in Table 5. If a higher value had been used, the calculated amount of tailings pond seepage flow would have been slightly less.

Other values for the analysis were taken from the data base set forth herein and/or laboratory data for the survey water samples.

Additional mathematical analyses, not included herein, were made using changes in water temperature, conductivity and concentrations of other constituents. These analyses in general supported the results of the analysis based on sulfates. The results, however, appeared to be less precise.

(a.) Calculations of Total Seepage Flow.

| Inflow | CFS | Mg/l $SO_4$ |
|---|---|---|
| RR @ Hwy | 46.0 | @ 119 |
| Natural Spring Flow | 18.0 | @ 20 |
| Tailing Seepage | S | @ 840 |

Outflow

| | | | |
|---|---|---|---|
| Red River above Hatchery | + 46.0 | | |
| (Nat.Spring Flow | + 18.0 | | |
| (F.H. Warm Water) | - 10.0 | | |
| (F.H. Cold Water) | - 2.7 | | |
| (Seepage Flow) | + S | | |
| | = | (51.3+S) | @ 129 |
| F.H. Warm Water | | 10 | @ 63 |
| F.H. Cold Water | | 2.7 | @ 80 |

Multiplication CFS X Conc:

$$5474 + 360 + 840S = 6618 + 129S + 630 + 216$$

by Subtraction:

$$711S = 1630$$

by Division:

$$S = \text{Total tailings seepage flow} = 2.29 \text{ cfs.}$$

(b.) Warm Water Spring Flow

The stream survey found several springs along the upper part of the Red River Gorge which had sulfate concentrations somewhat higher than the ambient natural ground water. It was presumed that these springs were in the flow path of and included tailings pond seepage. An $SO_4$ concentration of 120 mg/l was selected as being representative of these springs.

No springs with elevated $SO_4$ concentrations were detected downstream of sampling point 14 indicating that this was the westerly limit of the tailings pond seepage flow path. An $SO_4$ concentration of 20 mg/l was assumed for spring flow below Station 14. This value was also used for spring flow to Red River from the south. (Some of the springs along the south side of Red River had elevated $SO_4$ concentrations indicating that ground water from the north was flowing beneath Red River with discharge at fissures along the south shoreline).

Based on $SO_4$ concentrations of 20 mg/l for the natural ground water and 840 mg/l for seepage water, the spring water which had a concentration of 120 mg/l consisted of 87.8% of natural ground water and 12.2% seepage water.

The warm water supply to the fish hatchery is composed of both spring water from the flow path down gradient of the tailings ponds (120 mg/l) and spring water west of the flow path and from the south (20 mg/l). The laboratory analysis of the combined hatchery warm water supply

indicated a $SO_4$ concentration of 63 mg/l. Mathematical calculations therefore indicate that 43% of the warm water supply consisted of spring flow within the pond seepage flow path (120 mg/l) and 57% from spring flow outside the seepage path (20 mg/l).

The estimated warm water hatchery supply was 10 cfs. Calculations indicated that this consisted of 5.70 cfs of spring water from outside the seepage path (20 mg/l) and 2.27 cfs of spring flow within the seepage path (120 mg/l).

The 2.27 cfs of spring flow within the seepage path was composed of:

1.99 cfs of natural ground water flow

0.28 cfs pond seepage flow.

(c.) Hatchery Cold Water Supply

The hatchery cold water supply is obtained from the spring complex on the north side of Red River near the upper end of the Red River Gorge. The cold water supply was estimated to be 2.7 cfs at a $SO_4$ concentration of 80 mg/l. Based on the selected values of 20 mg/l for natural ground water flow and 840 mg/l for pond seepage water, the cold water supply consists of 2.50 cfs of natural ground water flow and 0.20 cfs of seepage flow.

(d.) Balance of Accretions to Red River

Subtraction of the determined discharges (F.H. warm and cold water supplies and discharge from 002) from the total calculated accretion (18.0 cfs spring flow plus 2.29 cfs seepage flow) leaves a balance of 6.99 cfs at an average $SO_4$ concentration of 133.8 mg/l to be accounted for. The assumed sources of the unaccounted for accretion were:

(1.) Warm spring flow direct to Red River from west of the pond seepage path and from the south side.

(2.) Warm spring flow within the pond seepage path direct to Red River.

(3.) Cold spring flow direct to Red River from the spring complex near the upper end of the gorge.

(4.) Field drainage and alluvial ground water flow upstream of the Red River Gorge.

It was found that there were too many variables for mathematical determination of the distribution of the remaining amount of accretion to the various sources. Calculations based on assumed allocations, however, revealed that there was a fairly narrow range of possible flows from each source which would total 6.99 cfs at an average concentration of 133.8 mg/l $SO_4$.

Assumptions used to arrive at the most probable allocation included:

(1.) The warm water spring flow direct to Red River probably consisted of spring water flow outside the pond seepage path approximately in the same ratio to spring flow within the seepage path as contained in the warm water supply line (i.e. 57% - 43%) and that the $SO_4$ concentrations were probably nearly the same.

(2.) The cold water spring flow direct to Red River probably has the same $SO_4$ concentration as the cold water supply to the hatchery. (Water samples from stations 9 and 10 are believed to be from field drainage and shallow alluvial ground water flow rather than from the main cold water spring flow.)

(3.) The significant increases in river water temperature indicates that a large part of the unaccounted for accretion is from warm water spring flow.

(4.) There is a significant amount of field drainage and shallow ground water flow from the alluvial formation upstream from the large spring complex at the upper end of the Red River Gorge. Such is evidenced by the fairly significant indicated increase in the

indicated $SO_4$ concentration in the vicinity of sampling point No. 8. The average $SO_4$ concentration of the field sampling points (Stations 3, 4, 7, 9 and 10) is 240 mg/l. This value was assumed to be representative of the field drainage and flow from the shallow alluvium.

(5.) Accretions with a $SO_4$ concentration in excess of 134 mg/l must be present to offset the accretions from the cold and warm water springs which have concentrations of less than 134 mg/l.

Based on the above assumptions and other valid considerations, the most probable distribution of the unaccounted for accretions appeared to be as follows:

(a.) Warm water spring flow from the north side of Red River west of the pond seepage path plus spring flow from the south side of Red River. ---2.81 cfs @ 20 mg/l $SO_4$.

(b.) Warm water spring flow direct to Red River within the seepage path of the tailings pond area --- 1.65 cfs @ 120 mg/l $SO_4$. (This flow would consist of about 1.45 cfs of natural ground water and 0.20 cfs of seepage water.)

(c.) Cold water spring flow direct to Red River -- 0.40 cfs @ 80 mg/l $SO_4$. (Composed of .37 cfs of natural ground water and 0.03 cfs seepage flow.)

(d.) Field drainage and shallow alluvial flow east of the cold water spring complex -- 2.67 cfs @ 240 mg/l $SO_4$. (Composed of 2.02 cfs natural ground water flow and 0.74 cfs of seepage flow).

A schematic diagram showing the above distribution of accretion flow and all of the other measured and derived spring and river flows and $SO_4$ concentrations is included at the end of this report.

## SUMMARY AND CONCLUSIONS

At the time of the stream survey (April 12, 1993) the quality of the water in Red River (relative to constituents associated with Molycorp's operations) was better below the fish hatchery than at the State Highway bridge. The sulfate concentration was nearly the same. The concentrations of aluminum, iron, copper, zinc and manganese were all lower at the downstream point. Concentrations of molybdenum, cadmium and lead at both the upstream and downstream ends of this reach, were all below the detection limits for the laboratory methods used. Except for manganese, all constituents analyzed were below drinking water and stream water quality standards. The high manganese concentration are due to concentrations in the river upstream of the tailings pond area.

The quality of the natural ground water in the area is excellent. The average sulfate concentration is low at only slightly more than 20 mg/l.

Except for TDS and $SO_4$; the seepage flow from the tailings ponds compares favorably with Red River water quality.

The majority of the natural spring flow along the survey reach is intercepted by the fish hatchery water supply system. Analysis of the hatchery water supply indicates a moderate increase in sulfate; however, the concentration (63 - 80 mg/l) is still far below drinking and ground water standards. The maximum $SO_4$ concentration found for any individual spring was 126 mg/l. (Sampling

points 9 and 10 are believed to be field drainage and shallow alluvium aquifer flow rather than spring flow.)

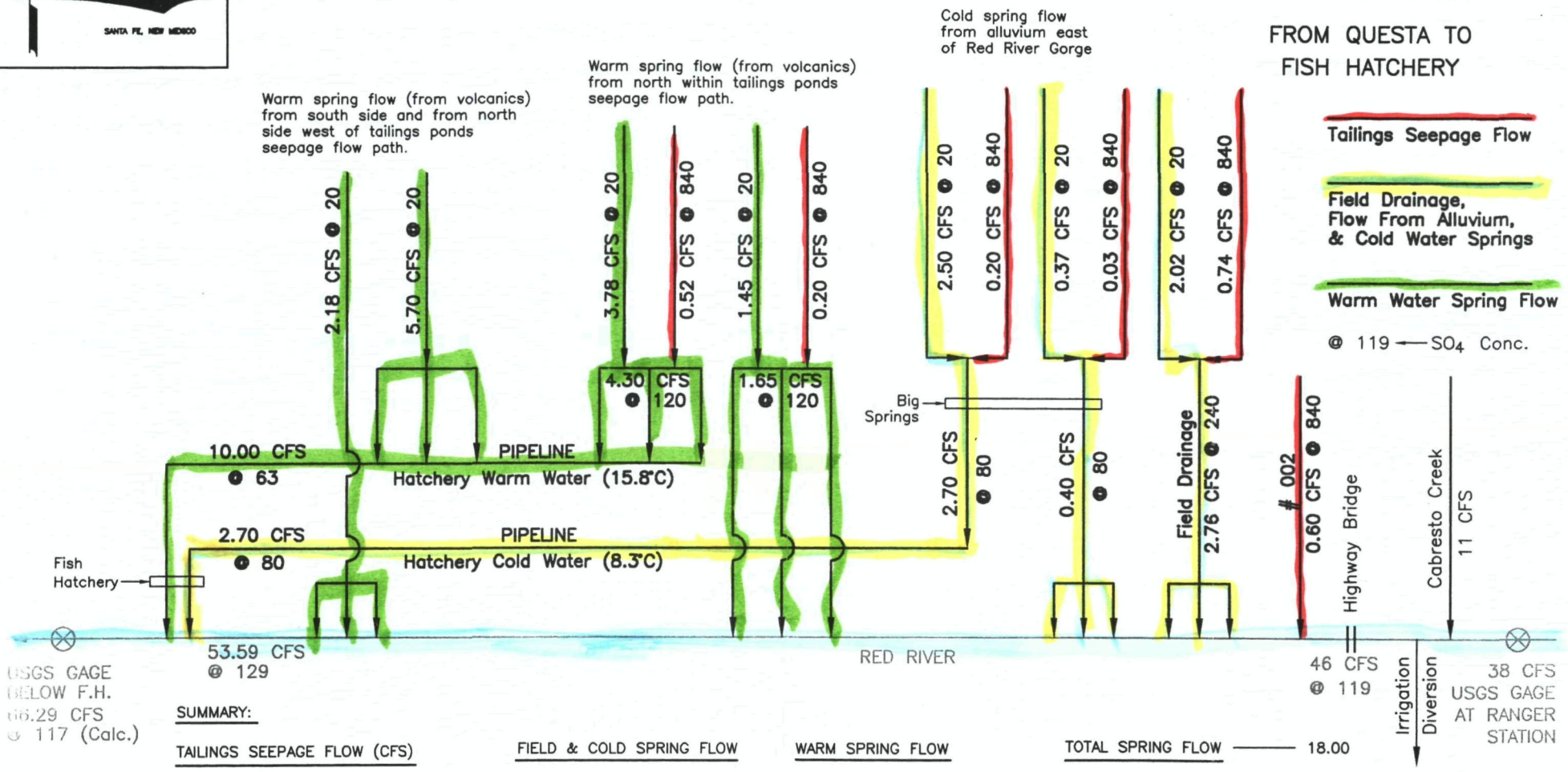
High concentrations of sulfate (660 - 690 mg/l) were found down gradient of the junction manhole from 002 and 003 which is located in the natural drainage channel below Dam No. 1. and about 1/4 mile north of Red River. Other data indicates elevated $SO_4$ concentrations in some monitor and private wells in and down gradient of this area. The highest $SO_4$ concentration detected near the river was 504 mg/l at Station No. 9. We believe that the field drainage below Dam No. 1 and 003 is concentrated at this location. Molycorp is presently investigating the feasibility of constructing additional seepage barriers and/or other facilities to substantially reduce the seepage flow down gradient of the tailings ponds in this area.

Data from the stream survey indicates that at that time, the total tailings pond seepage flow entering Red River (including the fish hatchery supply) was about 2.29 cfs (including discharge from 002 and 003). Of this about 0.6 cfs was flowing from 002 and 003. 0.7 cfs were in the field drainage and shallow alluvium aquifer flow east of the volcanic formations. These seepage flows are presumably from the tailings ponds in Section 36 and the easterly part of the tailings ponds in Section 35. An additional seepage flow of about one cfs was indicated to be contained in the cold spring flow at upper end of the gorge and in the warm springs along the gorge. It is believed that this seepage flow is from the west side of the pond area in Section 35 and from the pond area above Dam No. 5. Survey data indicates that the seepage path from these areas extends downstream to within about 1/2 mile east of the fish hatchery.

VAIL ENGINEERING, INC.
SANTA FE, NEW MEXICO

# ANALYSIS OF ACCRETIONS TO RED RIVER

## FROM QUESTA TO FISH HATCHERY




SUMMARY:

TAILINGS SEEPAGE FLOW (CFS)

| | |
|---|---|
| 002 | 0.60 |
| Field Drainage | 0.74 |
| Big Springs to River | 0.03 |
| Big Springs to Pipeline | 0.20 |
| Warm Water Springs to River | 0.20 |
| Warm Water Springs to Pipeline | 0.52 |
| TOTAL | 2.29 |

FIELD & COLD SPRING FLOW

| | |
|---|---|
| Field Drainage | 2.02 |
| Big Springs to River | 0.37 |
| Big Springs to Pipeline | 2.50 |
| TOTAL COLD | 4.89 |

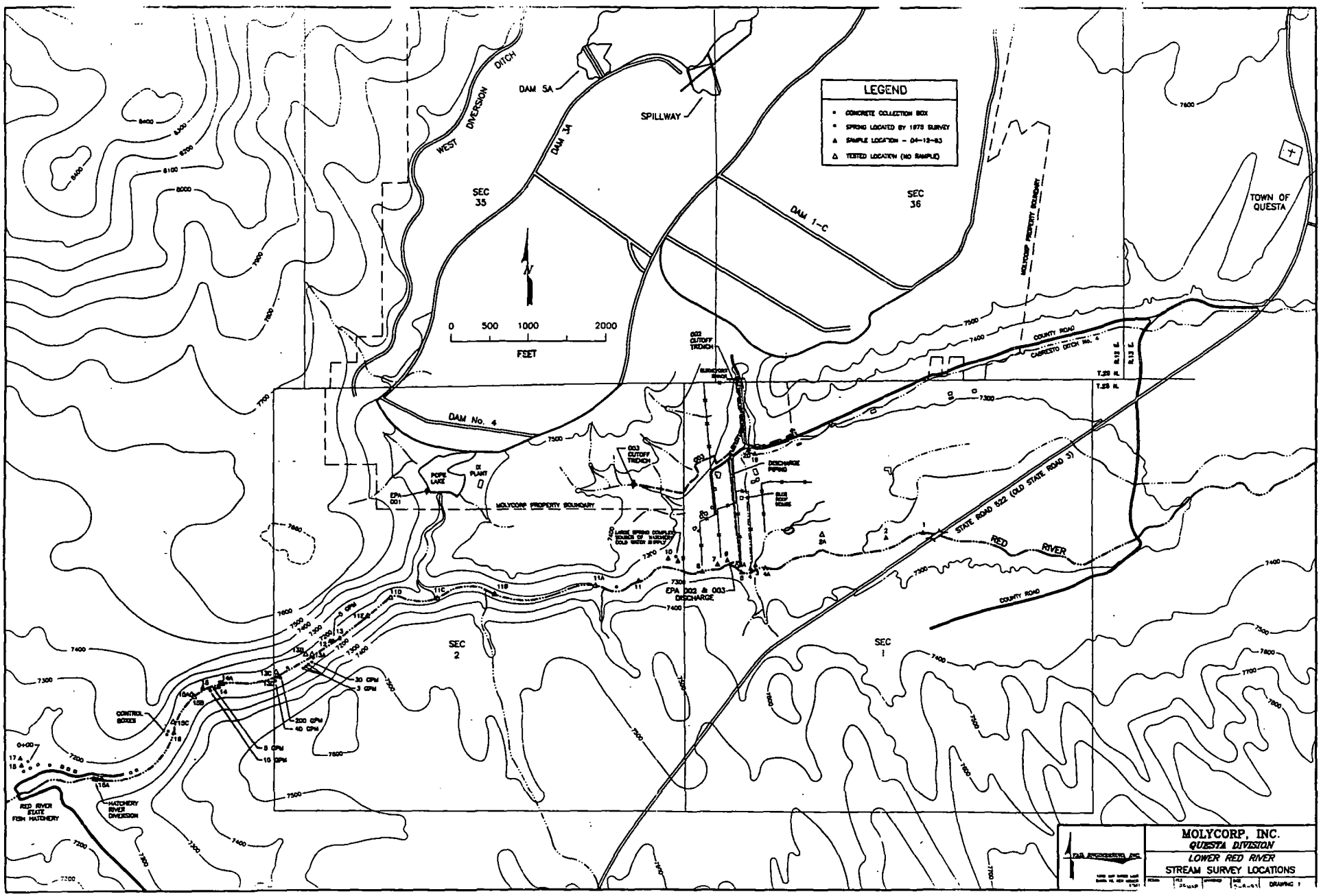
WARM SPRING FLOW

| | |
|---|---|
| In Seepage Path | |
| To River | 1.45 |
| To Pipeline | 3.78 |
| From South & to West of Seepage Path | |
| To River | 2.18 |
| To Pipeline | 5.70 |
| TOTAL WARM | 13.11 |

TOTAL SPRING FLOW — 18.00

RIVER FLOW

| | |
|---|---|
| Red River @ Ranger Sta. | 35.00 |
| Cabresto Creek | 11.00 |
| Field & Cold Spring Flow | 4.68 |
| Warm Spring Flow | 13.11 |
| Tailings Ponds Seepage | 2.29 |
| TOTAL | 66.29 |


LEGEND
CONCRETE COLLECTION BOX
SPRING LOCATED BY 1978 SURVEY
SAMPLE LOCATION - 04-12-83
TESTED LOCATION (NO SAMPLE)
WEST DIVERSION DITCH
DAM 5A
DAM 3A
SPILLWAY
DAM 1-C
DAM No. 4
SEC 35
SEC 36
SEC 2
SEC 1
TOWN OF QUESTA
MOLYCORP PROPERTY BOUNDARY
COUNTY ROAD
CABRESTO DITCH No. 2
002 CUTOFF TRENCH
003 CUTOFF TRENCH
POND LINER
EPA 001
DISCHARGE PIPING
BLUE BOX HOUSE
STATE ROAD 522 (OLD STATE ROAD 3)
RED RIVER
EPA 002 & 003 DISCHARGE
CONTROL BOXES
RED RIVER STATE FISH HATCHERY
HATCHERY RIVER DIVERSION
0 500 1000 2000
FEET
MOLYCORP, INC.
QUESTA DIVISION
LOWER RED RIVER
STREAM SURVEY LOCATIONS

NM 22306

DRAFT

# Expanded Site Inspection Report
on
Molycorp Inc, Questa Division
Taos County, New Mexico

(CERCLIS ID# NMD0022899094)

Prepared by
Stuart Kent
New Mexico Environment Department,
Groundwater Protection and Remediation Bureau-
Superfund Program
October 20, 1995

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Molycorp Inc., Questa Division
Taos County, New Mexico

Expanded Site Inspection

New Mexico Environment Department
October 20, 1995

# I. INTRODUCTION

Molycorp Inc., Questa Division (or Molycorp Site) is a molybdenum mine and tailings disposal site in Northern New Mexico. It is currently under review by the New Mexico Environment Department (NMED), Superfund Program to determine whether the site is a potential candidate for inclusion on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980. To further evaluate the site, an Expanded Site Inspection (ESI) was conducted to obtain information critical for this assessment.

## A. Expanded Site Inspection Objectives

This Expanded Site Inspection (ESI) was performed to obtain information relevant to the evaluation of the Molycorp Site using the Hazard Ranking System (ref. 1). The purpose of the ESI is to determine whether Molycorp Site poses a potential threat to human health and the environment. The information collected involved sampling various environmental media and review of records to more accurately determine the presence and distribution of CERCLA hazardous substances (listed in the Superfund Chemical Data Matrix, ref. 2) along the air, soil, surface water and groundwater migration/exposure pathways. Environmental media sampled included mining waste, soil, sediment and water. Air was not sampled during this investigation since recent monitoring data from NMED showed no exceedances of any ambient air quality standards.

## B. Site Description

The Molycorp Site is situated in Taos County near Questa, New Mexico (Fig. 1) and consists of two separate areas: the mine and the tailings ponds (Fig. 2). The Molycorp Site and surrounding area are located on the following USGS 7½' quadrangle maps: Sunshine NM, Cerro NM, Latir Peak NM, Guadalupe Mountain NM, Questa NM and Red River NM (ref. 3). The mine, surrounded by Carson National Forest, occupies approximately three square miles on patented land owned by Molycorp, Inc. The mine, located at 36° 42' 30" N latitude and 105° 30' 30" W longitude (ref. 3), lies along the Red River and several side drainages including Sulphur Gulch,

Spring Gulch, Goathill Gulch and Capulin Canyon (Fig. 2). The mine consists of both underground and open pit operations, a mill and two waste disposal areas (Fig. 3). Other features present in the mine area of the site are several groundwater seeps along the Red River, catchment basins to control run-off, a network of mining-related roads and several areas of erosion subsequently referred to as hydrothermal scars (ref. 4, photos 1, 3, 5). In the vicinity of the Molycorp mine, precipitation varies from about 16 inches per year at elevations of 8,000 feet to approximately 35 inches per year at elevations up to 11,000 feet (ref. 5, p. 33). Mean annual temperature near the mine is about 40° F.

Tailings ponds occupy approximately 1 square mile and consist of two large ponds (designated by Molycorp as Ponds 1 & 4) and two smaller ponds (Ponds 2 and 5A; Fig. 2). These tailings ponds are located 1-2 miles west of Questa, NM and 5-6 miles west of the mine on land owned by Molycorp, Inc. The coordinates of the tailings ponds are 36° 42' 30" N latitude and 105° 37' 0" W longitude. A series of pipelines transported the tailings from the mill site to the ponds until Molycorp became inactive in 1992. In the vicinity of the tailings ponds, annual precipitation is approximately 12.5 inches with average annual temperature of 45° F (ref. 6, p. III-8, 9).

The Red River is located immediately south of the Molycorp mine and tailings ponds and flows in a westerly direction (Fig. 2). The drainage area covers approximately 190 square miles and ranges in elevation from the top of Wheeler Peak (elev. 13,161 feet) to the confluence with the Rio Grande (elev. 6,500 feet) (ref. 7, p. 14, 15). Two tributaries to the Red River in the vicinity of the mine and tailings ponds are Columbine Creek and Cabresto Creek (Fig. 2). Four to five miles below the tailings ponds, the Red River enters the Rio Grande.

## C. Operational History

Molybdenum Corporation of America (MCA) acquired mining rights to Sulphur Gulch, a side drainage to the Red River, in 1920. They conducted small-scale mining operations until 1923 when a mill was constructed. The old underground workings consisted of adits, winzes and raises which followed the irregular vein system. In 1941, a haulage adit approximately one mile long was constructed to facilitate ventilation and drainage (ref. 8, p. 8). By 1954 this underground complex contained over 35 miles of workings at 14 production levels ranging in elevation from 7764 to 8864 feet. By 1954 all but the lowest three working levels were designed to drain by gravity out a mile-long service portal (known as the Moly Tunnel) located above the elevation of the Red River. The lower three working levels gathered drainage in a sump and this water was pumped to the service portal where it was allowed to drain by gravity to the Red River. This original underground Molycorp mine continued to grow until the open pit mine was developed. In 1965, MCA switched to an open pit operation which required the transport of tailings via a pipeline approximately eight miles downstream to tailings ponds located 1-2 miles west of the town of Questa. Dam # 1 is located in Section 36 of T 29 N, R 12 E. Decant water from the associated pond was discharged to the Red River via culvert tunnels through the dam. To ensure integrity of Dam #1, a smaller dam was constructed in 1969 just north of Dam # 1 which contained overflow weir structures to keep waste water from the dam face (ref. 9, Table 1).

Waste water was conveyed to a small holding pond (called Pope Lake) for further settling before discharge to the Red River. Molycorp referred to this discharge point as outfall # 001 of their permit under the National Pollution Discharge Elimination System (NPDES) (ref. 10). In 1971, a second large dam (Dam # 4) was constructed southwest of Dam # 1 (in Section 35 of T 29 N, R 12 E) with an impermeable membrane on the dam face. Surface water diversion ditches were installed in 1974 on the north, east and west sides of the ponds to divert surface water run-on around the ponds (ref. 9). The following year, interceptor trenches (called seepage barriers) were constructed below Dam # 1 and east of Dam # 4 to collect leachate from the tailings ponds. This waste water is diverted around dwellings below the dams and discharged to the Red River through NPDES outfall # 002.

In 1978, Unocal 76 Corporation purchased Molybdenum Corporation of America and shortened the name to Molycorp, Inc. Molycorp constructed an ion exchange plant near Pope Lake in 1983 to treat the waste water prior to discharge. After extensive mineral exploration in Goathill Gulch during the 1970's and early 1980's, Molycorp ceased open pit operations in 1985 and reverted back to underground mining techniques. The recent mining activity is referred to as the new underground workings. Production declined significantly in 1989 due to decreased value of molybdenum. The number of employees at this time shrank from a maximum of over 1,000 to approximately 200. Low production continued until December 1991 when operations stopped (ref. 11, p. 3). There are currently only 16 employees who are preparing the mine for potential re-opening (ref. 11, p.2). In 1994 Molycorp began pumping the water that had been flooding the mine, and discharges this mine water via the tailings pipelines to the tailings ponds at Questa (ref. 12, p. 6).

## D. Regulatory History

### 1. Other Agency Involvement

In 1966, the U.S. Department of Health, Education and Welfare (HEW), Federal Water Pollution Control Administration, conducted a baseline water quality survey of the Red River. A moderate increase of sulfate in the downstream direction was noted but metal concentrations varied little (ref. 13, p. V-1,2). The most significant effects observed were increased coliform counts from the town of Red River and the Red River Fish Hatchery (ref. 13, p. V-10). The overall quality of the river, including the segment adjacent to the Molycorp mine site, was determined to be high (ref. 13, p. II-1).

In November 1971, EPA conducted a study of the Red River in which they concluded that the chemical quality and biological conditions of the Red River water remained very good but that occasional breaks in the tailings pipeline resulted in some degradation of stream quality and biota (ref. 14, p. 4). During this same period of the late 1960s and early 1970s, however, the New Mexico Game and Fish Department discovered in the course of routine population studies that fish were conspicuously absent in the middle reach of the Red River where thriving populations

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had once existed (ref. 15). Fish census data of 1960 indicate that approximately 572 fish per mile were estimated in the river. The 1988 fish census found no fish in this same reach (ref. 16).

In 1982, EPA evaluated the Red River for potential impairment from metal loading (ref. 17). Among the findings were that concentrations of ambient total arsenic, cadmium, and silver exceeded EPA-recommended acute criteria; that 'Control' stations contained higher concentrations of all metals except zinc; and bioassay results from tests with Red River water suggested some biological toxic response may be occurring in the Red River (ref. 17, p. 35).

In 1983, the Red River and the Rio Grande in the vicinity of the confluence were designated a Wild and Scenic River (ref. 18, p. 49). In response to the designation the BLM published results of its study of water quality in the Red River and Rio Grande between 1978 and 1983. This study documented pollution sources and found a downstream increase in concentrations of various constituents, at times exceeding water quality standards, and found that the major impacts were due to mining and related activities. Nonpoint sources were found to be a major cause of elevated trace element concentrations (ref. 18, p. 49).

The U.S. EPA Superfund program (Region VI, Dallas, TX) conducted a Preliminary Assessment (PA) of the Molycorp site in May, 1980 and a Site Inspection (SI) in June, 1981. The conclusions of these reports, respectively, were for no further remedial action and placing the site at a lower priority (ref. 19). However, EPA funded field investigation teams (FIT) to investigate Molycorp in 1983 and 1985 (refs. 20, 21). Part of these investigations was an assessment of the Molycorp waste disposal area ("landfill") located near the head of Spring Gulch (above the mill area). This landfill was described as a mine rubble pile more than 100 feet thick that was also used as a disposal area for discarded equipment and parts. Some unrinsed reagent drums from the mill were the only "hazardous" wastes observed (ref. 20, p. 4). Soil samples were collected and analyzed for metals and organics in these EPA FIT investigations of the area, but were inconclusive, in part because appropriate background soil samples were not collected for comparison. The 1985 inspection observed a small oil spill (not sampled) and commented that the area was still active as a dump for empty drums and old equipment. Conclusions from the 1985 investigation included the recommendation for further study of this landfill under RCRA authority (ref. 21, p. 4). Molycorp has had two landfills (in Spring and Goathill Gulches) which are exempted from NM Solid Waste Management Regulations since they received only demolition and construction debris (ref. 22). The Spring Gulch site is inactive, having been covered with several hundred feet of overburden during subsequent mining operations that filled Spring Gulch.

In 1992, a report was submitted to the Congress of the United States by the New Mexico Water Quality Control Commission (WQCC) which reported an increase concentration in the Red River in the vicinity of the Molycorp Mine of several metals including cadmium, copper, lead, silver and zinc (ref. 23). Because these metals are listed CERCLA hazardous substances, the Molycorp Site was re-opened for investigation under CERCLA authority.

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During 1994, another newly created state agency became involved in regulatory investigations at the Molycorp site. The NM Office of Natural Resource Trustee (ONRT) is investigating natural resource damages from Molycorp in the Red River area and has participated in sampling activities and review of Molycorp reports and workplans (ref. 24, p. 46, 47). A natural resource damage assessment (NRDA) is being conducted.

2. Involvement by New Mexico Environment Department (NMED)

Water quality concerns relating to the Molycorp site have been studied by several programs within NMED, predominantly by the Nonpoint Discharge Section of the Surface Water Quality Bureau and the Groundwater and Superfund Sections of the Ground Water Protection and Remediation Bureau. Point source discharges from the tailings ponds at Questa have been monitored through an NPDES permit issued by the U.S. Environmental Protection Agency. Renewal of the permit in 1993 (permit # NM0022360) included two additional discharge points for stormwater runoff from the mining site (ref. 10).

Groundwater monitoring data presented by Molycorp to NMED-Groundwater Section in April 1987 revealed contamination in one private well downgradient from the tailings ponds. The data, covering 1985 and 1986, showed an average lead concentration of 0.056 ppm (N = 8) in the water from this well (ref. 25). This level was greater than three times the reported background concentration of 0.016 ppm and above the WQCC standard of 0.05 ppm (ref. 25, p. 4). The maximum and minimum concentrations reported were 0.12 ppm and 0.01 ppm, respectively (ref. 25, p. 6). Comparing the results to the New Mexico State WQCC standards, Molycorp concluded the violation of the standard for lead on four different occasions (ref. 25 p. 12). Analytical results from seven private wells sampled in 1987 and 1988 by NMED, which included the well previously showing a violation, showed no detectable levels of lead or cadmium (Attachment A). Use of groundwater from this well for drinking had stopped by 1988 (ref. 24, p. 18).

Two studies conducted by the NMED-Surface Water Quality Bureau (SWQB) in 1986 and 1988 confirmed high metal loading of the Red River by periodic storm events, but found that metal concentrations in surface water and stream sediments were not elevated to the point of causing aquatic toxicity (refs. 26, 27). In these studies, the major elements which became elevated between the Red River Waste Water Treatment Plant and the Questa (USFS) Ranger Station were iron and aluminum. A portion of this segment abuts Molycorp property where mining operations have occurred. One conclusion drawn from these surface water surveys was that episodic run-off events may erode oxidized sulfide-rich soils from barren slopes and mining scars (ref. 26, p. 4; ref. 27, p. 3). This process generates acidic run-off, which mobilizes and transports trace elements, including heavy metals, to the Red River. The acidic run-off temporarily reduces the pH of the river. Metals precipitate out of solution downstream as the pH becomes more neutral. These surveys also concluded that biomonitoring in the Red River generally showed no chronic or acute toxicity but that biological indices were reduced in the area below the Molycorp mine (ref. 27, p. 3).

Groundwater seeps have been observed emerging and entering Red River in the vicinity of Molycorp Mine (ref. 24, p. 14-17; ref. 4, photo 3). Within this stretch of the Red River, the 1988 study by NMED-SWQB detected over a three-fold increase in manganese concentrations (ref. 27, p. 43, 51). Concentrations of zinc and total aluminum were elevated two to three times over this same reach of the river. Other reports have determined that there is a general increase in the loading of sulfate, manganese, iron, zinc and aluminum in the downstream direction, with those seeps located below Capulin Canyon being the major contributors (ref. 28, p. 31, 33).

A number of other investigations of Molycorp have been generated by the regulatory involvement of NMED-Groundwater Section. During 1987-90 Molycorp was proposing to build a new tailings impoundment area in the Guadalupe Mountain saddle area located on BLM lands several miles north of the existing ponds. Molycorp directed a number of hydrogeologic studies of the area as part of the requirements for an Environmental Impact Statement but never built the proposed new tailings facility because the mine operations ceased in 1992. In 1993, the GWPRB-Groundwater Section required Molycorp to submit an application for a Ground Water Discharge Plan for the tailings impoundments (application # 933). A similar request was made for the mine waste dumps in 1994 (application # 1055; ref. 29). While site investigation and monitoring processes are ongoing, approval of either Discharge Plan application is pending.

## II. EXPANDED SITE INSPECTION

Molycorp was evaluated along four migration or exposure pathways: groundwater, surface water, air and soil. Environmental media sampled included the following: 1) waste samples from the mining waste rock piles and tailings ponds; 2) soil samples near the tailings ponds to identify the area of contamination; 3) groundwater samples from wells and seeps/springs to determine if a release from the waste sources has occurred; and 4) surface water and sediment samples from the Red River to identify a release of CERCLA hazardous substances and determine level of contamination.

### A. Waste Source Characteristics

1. Source Identification and Quantity

Two areas of the Molycorp Site have been identified as potential waste sources for CERCLA hazardous substances: the mine waste dumps and the tailings ponds. While there are separate sub-units within each area (eg. multiple mine waste dumps and tailings ponds), these sub-units were considered collectively as mine waste dumps and tailings ponds due to their similarity of respective waste types.

The development of the open pit between 1965 and mid 1980's resulted in the deposition of mine waste rock in Capulin Canyon, Goathill, Sulphur and Spring Gulches and adjacent to the Red

River in areas referred to as Sugar Shack (Figs. 2, 3). A recent report has estimated the amount of waste material in each of the disposal areas (ref. 30, p. 45). The total amount of waste material at the mine waste dumps is 328 million tons (ref. 30, p. 45). While most of the dump material in Capulin Canyon and Goathill Gulch consists of altered volcanics, those dumps south and east of the pit consist primarily of andesite, aplite and granite (ref. 30, p. 7, 36). Prior to conducting the ESI and completion of a preliminary waste dump characterization study directed by Molycorp, little information was available regarding CERCLA constituents in the mine waste dumps. One field test performed by NMED-Surface Water Quality Bureau demonstrated the acid generating potential in several waste samples in which the pH of test water was reduced when samples of waste were shaken with water over a several minute period (ref. 31).

Tailings Ponds at Molycorp consist of fine-grained tailings and waste water located in a series of ponds west of Questa (Figures 2, 4). No bottom liner is present in any of four ponds (ref. 9, p. 3). Transmission of waste water from the tailings ponds to groundwater may be slowed by the deposition of fine-grained sediment on the bottom of the ponds. The amount of tailings in these ponds is estimated to be 95 million tons (ref. 30, p. 7). One split sample of the tailings analysis conducted by Molycorp and the Questa Board of Education in 1982 detected lead, copper and zinc at concentrations ranging from 90 ppm (lead) to 240 ppm (zinc) (ref. 32, p. B-13).

2. Waste Characteristics-Methods

Seven waste source samples were collected from the mine dumps during June 1994 to determine the presence of CERCLA hazardous substances. Sample locations were selected to evaluate the waste characteristics from each dump area (Fig. 3). Specific locations were initially intended to be selected based upon high relative readings of metal concentrations by x-ray fluorescence (XRF). Failure of the XRF resulted in visual selection of sampling points at more highly discolored locations (ref. 24, p. 51), which may be indicative of acid generation.

To assess whether the hydrothermal scar areas surrounding the mine waste dumps also could be a potential source of CERCLA hazardous substances, three composite soil samples (including one duplicate) were collected from the Eagle Rock and Hanson Creek scar areas (Fig. 3). Samples collected for analysis were homogenized in a designated plastic bag or in place prior to their transfer into two 4-oz. or one 8-oz. sample jar equipped with a Teflon-lined cap. All samples were split with Molycorp's consultant and analyzed for Target Analyte List metals under EPA's Contract Laboratory Program (CLP).

Collection of waste material in the tailings ponds occurred during April 1994 (Fig. 4). Eight waste samples from the four tailings ponds (including one duplicate sample) were collected and analyzed to identify the presence of CERCLA hazardous substances, with at least two samples from each of the two larger ponds (Ponds 1 and 4; Fig. 4). Because different tailings ponds were utilized at different times, samples from each pond, or various locations within a pond, may reflect changes in composition of the tailings over the period of operation.

At each sampling location within the tailings ponds, three waste locations 100 feet to 200 feet apart were screened for metal concentrations using x-ray fluorescence (Spectrace 9000). Selection of sampling location for waste source identification was based upon those screening locations which demonstrated higher XRF readings. Results for iron, barium and molybdenum were generally used as the basis for determining metal concentrations at each XRF screening location (ref. 24, p. 32-37). Results from the screening procedure are presented in Attachment B. Sample collection of the waste material from the tailings ponds involved the removal of the soil cap material (where present) with a hand auger, and collection of the upper 3 to 6 inches of tailings with a stainless steel hand auger (ref. 24, p. 32). Decontamination of the hand auger between waste samples was performed using deionized water. Samples collected for analysis were homogenized in a designated plastic bag prior to their transfer into two 4-oz. or one 8-oz. sample jar equipped with a Teflon-lined cap. All samples were split with Molycorp's consultant and analyzed for Target Analyte List metals under EPA's Contract Laboratory Program.

3. Waste Characteristics-Results

Analytical results of the average metal concentrations and the range of concentrations in the mine waste dumps are presented in Table 1 (ref. 65). Results indicate that most metals included in EPA's Target Analyte List were detected in the mine waste samples above the detection limits. Metals detected at the highest concentrations are those which are most abundant in the earth's crust including aluminum, calcium, iron, magnesium and potassium. Other metals ranged in concentrations from non-detectable levels (e.g. mercury) to over 1,000 mg/kg (e.g. manganese; Table 1). The large ranges of metal concentrations seen for most metals (e.g. cadmium, silver, zinc) demonstrates the heterogeneous nature of the mine waste dumps. This variation can be measured relative to the average concentration by calculating the coefficients of variation for each metal (Table 1). These values ranged between 50 and 245 % for all detected metals (Table 1).

Results of waste sampling at the tailings ponds is presented in Table 2 (ref. 65). Most metals on EPA's Target Analyte List were detected. Concentrations are fairly consistent as shown by coefficients of variation which are generally less than 50% (Table 2). Most metals demonstrating higher concentrations are those which are most abundant in the earth's crust such as aluminum, calcium, iron and magnesium.

Most metals on EPA's Target Analyte List were detected in the mine waste dumps and the tailings ponds with higher average concentrations generally noted in the tailings (iron, lead, zinc excluded; ca. Tables 1 and 2). While finding CERCLA hazardous substances in the waste sources does not require a comparison to background, evaluation of their potential to impact the surrounding environment should take into account effects from other potential sources. In the vicinity of the mine, hydrothermal scar areas represent another source of metal loading to groundwater and the Red River. Several composite soil samples from three of these scar areas (Eagle Rock, Goathill Gulch and Hanson Creek) were collected and analyzed for TAL metals. Results for the average concentration for each metal are presented in Table 3 (ref. 65). Variation in metal concentrations noted in the mine waste dumps is also apparent in the scar material.

4. Waste Characteristics-Discussion

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Detecting differences between the mine waste dumps and hydrothermal scar areas is important in assigning attribution of any potential effects to groundwater and the Red River. To assist in detecting differences between the mine waste dump and scar material, ratios of average metal concentrations between the two sources were calculated (Table 4; ref. 65). Any dissimilarities in metal concentrations between the two areas are reflected in concentration ratios which deviate from unity. The mine waste dumps exhibited greater average concentrations (e.g. 2 to 5 times) of molybdenum, zinc, copper and manganese, while hydrothermal scar material had higher average levels of iron, alkali metals (potassium and sodium) and silver (Table 4).

Average metal concentrations of the tailings in the impoundments were also determined and compared to that of two surrounding soil types by calculating concentration ratios similar to those for the mine waste dumps (Table 4). Concentration ratios show that several metals exhibiting the highest average metal concentrations in tailings relative to surrounding soil are copper, calcium, magnesium, chromium and nickel (Table 4). Comparing these concentration ratios at the mine area and tailings ponds demonstrate that the tailings are more easily distinguishable from the surrounding soil (i.e. have higher ratios) than the mine waste dumps are from the hydrothermal scar areas (Tables 4).

## B. Groundwater Migration Pathway

1. Geology and Aquifer Description

1.1 General Geology

The Molycorp mine is located along the Red River drainage in the Taos Range of the Sangre de Cristo Mountains where complex geologic history stems from Tertiary magmatism and regional block-faulting of the Rio Grande Rift (ref. 33, p. 3, 5, 7, 9). The Red River is located along a normal fault and is the southern boundary of a down-faulted area known as the Red River Graben (ref. 34, p. 94, 95, 99). North of the Red River fault but within the Red River drainage, there is a line of hydrothermal alteration scars marking a parallel fault (ref. 34, p. 95). A series of high angle normal faults which trend north has caused significant segmentation of this graben (ref. 34, p. 95).

The lithology in the vicinity of Molycorp mine is comprised of a Precambrian basement of igneous rock (granite) and metamorphic rock (amphibolites, quartzites and schists) which is overlain by Tertiary volcanics (ref. 8, p. 11). The volcanics consist of flows, breccias and tuffs of andesite, latite and rhyolite. These formations were intruded by a granitic stock of Miocene age (23 m.y.) and later by quartz and monzonite porphyries. Most of these intrusions, along with mineralizations associated with hydrothermal fluids, centered along the Red River Graben.

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The town of Questa and the tailings ponds are located 5 miles to the west of the mine on the Taos Plain. This plain is situated within the Rio Grande Basin, a deep basin which was created through Miocene uplifting of the Taos Range (ref. 35, p. 12). This downfaulted area has received alluvial sediment from the Taos Range. Intermittent extrusion of basalt and andesite flows from the Guadalupe Mountains during late Pliocene and early Pleistocene (approximately 1.6 m.y.) resulted in interbedding of lava with alluvium. These lithologies, together with occasional lake deposits, comprise the Santa Fe Group (ref. 35, p. 15).

## 1.2 Hydrogeologic Setting

### Mine Area

The principle aquifer in the vicinity of the mine is comprised of fractured igneous and volcanic bedrock (subsequently referred as Fractured-Bedrock Aquifer) and a second, overlying aquifer within the alluvium of the Red River channel and side channels (called Alluvial Aquifer) (ref. 12, p. 5). [For the purposes of this ESI, the "valley-fill mudflow and alluvial valley-fill aquifers" outlined in reference 12 were combined into the Alluvial Aquifer.] The depth of the alluvium within the Red River channel is as much as 150 feet thick (ref. 12, fig. 5). The placement of 12 new monitoring wells drilled in the Molycorp mine area in 1994 evaluated each of these aquifers (ref. 12, p. 3). Based upon pump tests of wells in the mine area, the aquifers are considered interconnected (ref. 12, p. 12). The hydraulic conductivity of the fractured bedrock was recently reported between 5.1 gallons/day/ft$^2$ and 629 gallons/day/ft$^2$ (.00024 cm/sec to .03 cm/sec; ref. 12, p. B-10); whereas that of the alluvium was 1.141 gallons/day/ft2 (.0539 cm/sec) (ref. 12, p. B-9). The variability seen in the fractured bedrock depends upon the degree of fracturing present at a given location.

A number of seepage studies have demonstrated that the Red River is a gaining stream in the vicinity of both the mine area and tailings area. In the middle reach of Red River (the reach from Red River to Questa, which includes the Molycorp mine area) seepage studies have documented accretion from groundwater into the Red River at average rates of 4 cubic feet per second (cfs) (ref. 36, p. 84, 85). As an approximation, this recharge rate could be assumed to be equally apportioned to each side of the river. Therefore, a portion of the 2 cfs from the north side originates from the drainage area of the Molycorp Mine. Other studies estimated groundwater recharge to the Red River from the Molycorp Mine drainage area to be between 1.45 and 2.56 cfs (ref. 12, p. B-6).

### Tailings Ponds

The Santa Fe Group, underlying Questa and the tailings ponds, is the major water-bearing unit in the Rio Grande Basin of Taos County (ref. 35, p. 15). Depth to water in the Questa area is generally in the range of 60 to 160 feet (ref. 35, p. 22). The groundwater gradient in the vicinity of Questa is approximately 100 feet per mile (ref. 35, Plate 2). Groundwater flow near the town of Questa and the tailings ponds is generally southwest away from the mountains, and recharges

the Red River and Rio Grande by numerous springs which generally emerge from a basalt layer. The lower reach of Red River (from Cabresto Creek to mouth of Red River, Fig. 2) has been measured as having an average accretion rate from groundwater of approximately 33 cfs (ref. 35, p. 40). Those springs which recharge the Red River are located southwest of the tailings ponds toward the confluence of the Red River and Rio Grande (ref. 37, p. 20, 23). Some of these springs are hydrologically connected to the waste water which leaches through the tailings ponds (ref. 37, p. 19, 24).

2. Groundwater Use

Mine Area

The Fagerquist's Cottonwood Park is a small, 12 unit resort approximately 1/3 mile south of the Molycorp mine and 100 feet below the confluence of Columbine Creek and the Red River (Fig. 3; ref. 65). The resort's well is the well nearest the mine which supplies drinking water. Other supply wells which provide drinking water in the vicinity of the mine are the U.S. Forest Service wells located in Columbine, Fawn Lakes, Elephant Rock and Junebug Campgrounds (Fig. 3). With a depth of 56 feet (ref. 65, p. 1), the Fagerquist well taps the Alluvial Aquifer which is in hydraulic communication with the Fractured-Bedrock Aquifer. With the Fagerquist well located on the south side of the Red River, much of the recharge may be from the Columbine Creek area. This is suggested by the low concentrations of metals and sulfate and high alkalinity detected in the well as compared to Molycorp monitoring wells north of the Red River (Table 5).

Drinking water wells in the vicinity of Questa include private wells and community wells (ref. 38). These wells are west of the regional blockfault which created the Taos Range. While on the opposite side of the fault from the mine, nothing is known to preclude inter-communication among the Santa Fe Group Aquifer and the Fractured-Bedrock and Alluvial Aquifers near the mine. Therefore, most of the wells west of the regional block fault, including the Questa community supply wells, are potentially impacted by groundwater in the vicinity of the mine. The population served by groundwater wells within four miles of the mine is presented below:

| Distance from Mine (mi.) | # Private Wells (ref. 39) | Population Served by Private Wells | # Community Wells (ref. 38, 40) | Population Served by Community Wells | Total Population |
|---|---|---|---|---|---|
| 0-1/4 | 0 | 0 | 0 | 0 | 0 |
| 1/4-1/2 | 1 | 2* | 0 | 0 | 2 |
| 1/2-1.0 | 0 | 0 | 0 | 0 | 0 |
| 1.0-2.0 | 0 | 0 | 0 | 0 | 0 |
| 2.0-3.0 | 4 | 12 | 1 | 44 | 56 |
| 3.0-4.0 | 10 | 30 | 4 | 1733** | 1763 |
| | Total Population: | | | | 1,821 |

* Fagerquists (Nearest Well; ref. 65)

** Includes Questa population or 1,644 persons (ref. 38)

Tailings Ponds

Several private wells located below the tailings ponds were used by residents for drinking water purposes until Molycorp offered to switch their drinking water supply to the Questa community well system (ref. 41). The basis for this switch was due to elevated concentrations of Total Dissolved Solids (TDS) and sulfate (personal communication, Dave Shoemaker, Site Manager). The switch from private wells to the Questa community well system began in approximately 1976 (ref. 24, p. 19). Several families refused to have their water supply switched; by November 1993, all but three wells had been switched (ref. 42).

Groundwater analysis submitted September 1993 by Molycorp, Inc. used an off-gradient well to reflect background conditions. This well, labelled MW-CH, is screened in the middle to lower units of the Santa Fe Group Aquifer (ref. 43, p. 15). Results from this sampling event show elevated levels above background of iron, manganese and zinc in several monitoring wells and detected levels of chromium and lead in one monitoring well (ref. 43, p. 23). Three private wells were also sampled during September 1993 with results showing no exceedances of New Mexico WQCC Standards (ref. 44); however, comparison of the reported concentrations of zinc in the private wells to the background value reported in the September 1993 report demonstrates over a three-fold increase in zinc in each private well (ca. ref. 43, p. 23 and ref. 44). Upon presenting the results from the sampling of private wells to the owners, Molycorp continued to offer to switch residents below the tailings ponds to Questa community water supply (ref. 44, p. 2). The Feliciano Rael well (Fig. 4) is believed to be the only private well currently used for drinking purposes (ref. 45; ref. 24, p. 43).

The population served by groundwater was evaluated within 4 miles of the tailings ponds. Locations for the Questa Community Wells, other community wells and the Rael well are shown in Reference 3. Location of drinking water wells were determined using well information from the New Mexico State Engineer's Office (ref. 39) and information provided by the Superintendents of the towns of Questa (ref. 38) and Red River (ref. 40). The two community supply wells for the town of Questa, with roughly equal pumping rates, provide water for 1,644 persons (ref. 38). Three additional community wells identified near Questa are an unnamed well near the offices for the Town of Questa, Eagle Lake Trailer Park and Cerro de Oro (ref. 38). Each have 10 - 15 service connections. Population served by each well was calculated by multiplying the number of connections and the number of persons per household (i.e. 2.95; ref. 46, Questa Village). The population of Cerro was estimated to be 396 (ref. 46, 47) and was assumed to be serviced equally from each of two community supply wells (Cerro East and West, ref. 40). Total population served by groundwater within 4 miles of the tailings ponds is presented below:

| Distance from Tailings Ponds (mi.) | # Private Wells (ref. 39) | Population Served by Private Wells | # Community Wells (ref. 38, 40) | Population Served by Community Wells | Total Population |
|---|---|---|---|---|---|
| 0-1/4 | 1 | 1 | 0 | 0 | 1 |
| 1/4-1/2 | 0 | 0 | | 0 | 0 |
| 1/2-1.0 | 2 | 6 | 3 | 882* | 888 |
| 1.0-2.0 | 20 | 59 | 2 | 852* | 911 |
| 2.0-3.0 | 5 | 15 | 1 | 198** | 213 |
| 3.0-4.0 | 22 | 61 | 1 | 198** | 259 |
| | Total Population: | | | | 2,272 |

* Includes ½ of Questa population or 822 persons (ref. 38)

** Includes ½ of Cerro population or 198 persons (ref. 46, 47)

3. Groundwater Pathway-Methods

The purpose of evaluating groundwater in the mine area and tailings ponds is to determine whether a release of CERCLA hazardous substances from the site has occurred. A release is observed where contaminant concentrations in downgradient groundwater exceed three times the upgradient or background concentration for a particular analyte. An alternative definition for a release is the detection of an analyte in downgradient samples when undetected in the background sample(s). Therefore, field sampling focused upon the collection and analysis of groundwater from both background and downgradient locations within each aquifer.

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In the area of the mine where elevated concentrations of metals in seeps, springs and the Red River have been previously noted (refs. 12, 24, 28), much attention focused upon the attribution of these elevated contaminants to Molycorp operations above any contribution from hydrothermal scar areas. During this ESI, attempts to distinguish site-related discharge from that of background conditions were used to identify and attribute the release of hazardous substances to the mining activities.

Much of the sampling for the groundwater pathway involved the sampling of seeps/springs. [For this ESI, these terms will be interchangeable]. Because the seeps and springs most likely reflect groundwater quality and ultimately reach a surface water body, they were also evaluated through the groundwater-to-surface water pathway. A release of any CERCLA hazardous substances from a seep or spring to surface water can only be achieved if a release to groundwater has first been established.

Mine Area: Alluvial Aquifer

In the vicinity of the mine, background groundwater quality is highly variable and likely depends, in part, on the degree to which it has been impacted by mineralized areas of the lithology. To address the variability of the Alluvial Aquifer, four groundwater sampling locations were chosen to reflect background conditions: one of the Molycorp Mill wells, U.S. Forest Service wells at Elephant Rock and Junebug Campgrounds and the wastewater treatment plant (WWTP) for the town of Red River (Fig. 3). The first three wells are screened in the alluvium of the Red River channel while the well at the WWTP is screened in a mudflow (alluvium) representing a fan delta from a side channel (Attachment C). For the purposes of this ESI, the highest reported concentration of each analyte from any of the four background wells was used to represent the background condition.

A release to the Alluvial Aquifer was determined by sampling six seeps along the Red River in the vicinity of Molycorp haulage adit, Goathill Gulch, Capulin Canyon and Old Eagle Rock Campground (called Cliff Seep) (Fig. 3; ref. 24, p. 46-47, 64). Collection included both filtered and unfiltered samples to distinguish between dissolved and total metals. Comparisons of metal concentrations in downgradient groundwater locations to background were restricted to samples of similar fractions (dissolved or total).

Mine Area: Fractured-Bedrock Aquifer

No background well for the Fractured-Bedrock Aquifer was located. Those wells screened in the alluvium (Red River channel or tributaries) are not representative of background for this aquifer. The only water which may serve this function is within the mine workings. Although the mine workings may be impacting the water quality, mine water provides the best available approximation for background water quality in the Fractured-Bedrock Aquifer. Numerous groundwater locations within the mine workings have been sampled by Molycorp (ref. 30, Table 1.4; ref. 12, Table D-4). While their data does not include all Target Analyte List metals,

their data best addresses temporal and spatial representativeness of this aquifer and was used for background water quality within the Fractured-Bedrock Aquifer. Cabin Spring also represents fractured bedrock flow since it is located where mudflows from hydrothermal scars are absent (ref. 12, figure 4) and emerges directly from bedrock (ref. 24, p. 71). For the purposes of this ESI, the highest metal concentrations within the mine workings was used as background to identify releases of CERCLA hazardous substances to Cabin Spring and the 4 monitoring wells which are screened in the fractured bedrock.

Identifying a release to groundwater focused upon downgradient monitoring wells (which were installed after completion of the ESI workplan) and seeps/springs. A total of four monitoring wells and six seeps were sampled and analyzed for total and dissolved metal concentrations and general chemistry (Cabin Spring excluded). Location of all monitoring wells and seeps sampled are presented in Figure 3. Four 1-liter high density polyethylene (HDPE) bottles were needed at each sampling location for total (unfiltered) and dissolved (filtered) metals and general chemistry. The latter required both a preserved and unpreserved sample. Water samples requiring filtering were initially collected in 4-liter containers. Samples were acidified to pH 2 with nitric acid (sulfuric for general chemistry) and kept on ice until arrival at the analytical laboratory. Samples were split with Molycorp's consultant and analyzed for Target Analyte List (TAL) metals under EPA's Contract Laboratory Program (CLP). Selected samples were also analyzed for general chemistry parameters under either CLP or the program of the New Mexico State Laboratory Division (SLD). SLD was used for latter sampling events due to the discontinuation of the applicable contract under EPA. In accordance with SLD's operating procedures, general chemistry samples were not filtered.

Tailings Ponds

Ten monitoring wells located below (south - southwest) the tailings ponds were sampled to identify a release of CERCLA hazardous substances from the ponds to the Santa Fe Group Aquifer. Analyses conducted on samples from each well included total metals, dissolved metals and general chemistry parameters. Results from these downgradient wells were compared to that from the Change House well which represented background conditions. Locations of all wells sampled are presented in Figure 4.

Five seeps, labelled A through E, were identified between the tailings ponds and the Red River Fish Hatchery (Fig. 4). Those seeps which demonstrated higher relative readings of conductivity (eg. seeps A, D, E) were assumed to have a higher metal content and samples were collected for laboratory analysis (ref. 24, p. 40). Water from a seep identified along Embargo Road below tailings pond #1 and Molycorp's discharge (Outfall #002) was collected along with the warm and cold water springs which provide water to the Red River Fish Hatchery and the hatchery's abandoned cold water spring collection point (Fig. 4).

Four 1-liter HDPE bottles were needed at each sampling location for total (unfiltered) and dissolved (filtered) metals and general chemistry. The latter required both a preserved and

unpreserved sample. Water samples requiring filtering were initially collected in 4-liter containers. Samples were acidified to pH 2 with nitric acid (sulfuric for general chemistry) and kept on ice until arrival at the analytical laboratory. Samples were split with Molycorp's consultant and analyzed for Target Analyte List (TAL) metals under EPA's Contract Laboratory Program (CLP) (ref. 24, p. 62).

4. Groundwater Pathway-Results

Mine: Alluvial Aquifer

Analytical results of the four background wells sampled during this ESI are presented in Table 6 (ref. 65). The metal concentration used as background groundwater quality to which downgradient seeps were compared is the highest concentration reported among the four wells. Results of metal analyses of various groundwater seeps and their comparison to background is presented in Table 7 (ref. 65). Results show that metal concentrations were generally the same for filtered (dissolved) and unfiltered (total) samples. Two CERCLA metals (beryllium and copper) were elevated above three times background in at least one downgradient seep of the Alluvial Aquifer (Table 7). Copper demonstrated a 7 to 30-fold increase over background whereas Be showed up to a 4-fold increase (Table 7). Also, the non-CERCLA metals aluminum and manganese were elevated in at least a single seep. The highest concentrations of all four metals were noted in the Capulin Channel Seep.

Mine: Fractured-Bedrock Aquifer

Analytical results of metal concentrations (total and dissolved) in downgradient monitoring wells and Cabin Spring are presented in Table 8 (ref. 65). Representing background for the Fractured-Bedrock Aquifer are the highest metal concentrations reported from Molycorp mine workings (Table 8). Data show that several metals were elevated in at least one downgradient well and/or Cabin Spring including three CERCLA metals--arsenic, cadmium and copper (Table 8). All metals reported were most elevated in MW-7. Cabin Spring, represented by an unfiltered sample only, demonstrated copper and aluminum concentrations which were elevated 14 and 28-fold, respectively.

Tailings Ponds: Santa Fe Group Aquifer

Groundwater from three private wells located south of the tailings ponds were sampled for metals and general chemistry parameters. Of the three wells, only one is currently used for drinking purposes (ref. 45). Analytical results of the groundwater in private wells near the tailings ponds is presented in Table 9 (ref. 65). The results show that arsenic, chromium and lead (CERCLA hazardous substances) were detected in either the filtered or unfiltered sample from one of the private wells while undetected in the background sample. Arsenic was detected in the filtered sample from the Duran well at 4.7 ug/L (Table 9). This level is below EPA's Maximum Contaminant Level (MCL) of 50 ug/L. Groundwater results from the Herrera well show

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detectable amounts of lead (estimated at 8.5 ug/L in the filtered sample only) and chromium (16.6 ug/L in the unfiltered sample only). The levels at which these metals were detected are also below their respective MCL (Table 9). Groundwater from the Rael well showed detectable levels of zinc in both the filtered and unfiltered samples (Table 9). The estimated zinc concentration of 260 ug/L observed in the unfiltered sample is over three times the background concentration of 75 ug/L but well below the MCL of 5,000 ug/L (Table 9). Concentrations of several non-CERCLA metals were elevated in both filtered and unfiltered samples from private wells (downgradient) at least three times the background concentration (at Change House Well; Table 9). Elevated concentrations of sulfate were noted in both the Rael and Herrera wells.

Analytical results of groundwater from the monitoring wells, presented in Tables 10 and 11, reveal that most of the elevated concentrations of metals were detected in unfiltered samples whereas only a few non-CERCLA metals (e.g. calcium, magnesium and manganese) were consistently elevated in filtered samples (Table 11). Two CERCLA metals were detected in both filtered and unfiltered samples but were not elevated above background in both fractions. These include lead in MW-3 and MW-4 and copper in MW-7b (Tables 10, 11). Lead was noted in the filtered samples from MW-3 and MW-4 at elevated concentrations of 8.3 ug/L and 4.2 ug/L, respectively (Table 11). The respective lead concentrations of 1.5 ug/L and 2.4 ug/L in the unfiltered samples were not elevated above the background concentration of 2.5 ug/L (Table 10). Lead concentrations in these wells are below EPA's Maximum Contaminant Level (MCL) of 15 ug/L. Copper was detected at 3.5 ug/L and 38.9 ug/L in the filtered and unfiltered samples from MW-7b while undetected in background samples (Tables 10, 11). The concentration of copper from both filtered and unfiltered samples is below the MCL of 1,300 ug/L (Tables 10, 11).

Analytical results of the seeps sampled near the tailings ponds are presented in Table 12 (ref. 65). Several seep samples along the Red River (e.g. Seeps A, D and E), the North Irrigation Ditch (near Embargo Road) and Outfall #002 were compared to background groundwater at the Change House Well to determine whether a release of CERCLA hazardous substances to groundwater had occurred. Results show elevated concentrations of arsenic in both filtered and unfiltered samples from the Warm Spring (Table 12). Several non-CERCLA hazardous substances were also elevated in at least one seep, including aluminum, manganese, sulfate and Total Dissolved Solids (TDS) (Table 12). Other than aluminum and sulfate, which were observed at the Embargo Road seep at the highest concentrations, all other parameters were most elevated in Outfall #002 (Table 12).

5. Groundwater Pathway-Discussion

Mine Area

One area of uncertainty when evaluating groundwater quality downgradient from the mine area is the selection of a background sample. Two different aquifer types can be distinguished at Molycorp Mine: Fractured-Bedrock and Alluvium. Seeps along Red River are likely influenced

by both aquifers since nothing precludes hydrologic communication between the two aquifers. Since the seeps are located within the alluvium (Cabin Spring excepted), the selection of background focused within this aquifer. Water quality of the Alluvial Aquifer is highly variable as demonstrated by the analysis of groundwater from the WWTP and Molycorp Mill well (Table 6). The probable reason for this difference is that the Red River WWTP well is screened in the alluvium of a side channel (Hot-N-Tot Creek) which is more greatly influenced by drainage from a hydrothermal scar area. Because the WWTP well and portions of the Molycorp mine area are likely impacted by drainage from hydrothermal scars, the water quality observed from the WWTP well represents the most conservative selection of background water quality for the Alluvial Aquifer. Comparison of downgradient seeps to this background demonstrated a release of CERCLA hazardous metals (beryllium and copper) to this aquifer.

A second method of identifying a release to the seeps below the Molycorp Mine focused upon the comparison to an upgradient seep near Hanson Creek. This seep most probably drains Hanson Creek where one of the largest hydrothermal scars is located (ref. 28, figure A). Previously reported data show over a 3-fold increase between Hanson Creek Seep (or Spring) and downstream seeps in aluminum, copper, lead, manganese and zinc (ref. 28, Appendix 1). Except for beryllium which was not reported, the three metals defining a release to the seeps (aluminum, copper and manganese) during the ESI were also elevated in this previous report. Furthermore, aluminum, beryllium, copper and manganese were detected at greater concentrations in the leachate from mine waste than hydrothermal scars (Table 13; ref. 65). A similar result is seen with data from another study which used a greater number of samples (Table 14; ref. 30, Table 1.2). Copper and manganese were also detected at twice the concentrations in soil samples from the waste dumps than the scar areas (Table 4). The consistency with which increased concentrations of beryllium, copper and manganese were detected in the mine waste dumps, the leachate from the dumps and in the seeps provides sufficient evidence for partially attributing to Molycorp the release of CERCLA hazardous metals to the Alluvial Aquifer.

All downgradient monitoring wells sampled during this ESI are screened in bedrock and represent the Fractured-Bedrock Aquifer. Evaluation of data from this aquifer resulted in a release of CERCLA metals (arsenic, cadmium and copper) in at least a single monitoring wells and/or Cabin Spring (Table 8). Because cadmium and copper were detected at greater concentrations in the soil and leachate samples from mine waste dumps as compared to hydrothermal scars (Tables 4, 13, 14), the release of CERCLA hazardous metals to the Fractured-Bedrock aquifer is partially attributable to Molycorp. This conclusion is supported by another study which demonstrated, through tritium dating, similarities between the water from MW-11 and Cabin Spring and that from mine waste leachate (ref. 12, p. D-8).

Tailings Ponds

Increased metal concentrations were noted primarily in the unfiltered (total metals) samples of private wells located downgradient from the tailings ponds (Table 9). These elevated levels, however, may not be representative of the aquifer they tap (Santa Fe Group Aquifer). Unfiltered

samples can be affected by well construction and are less likely to be representative of groundwater characteristics than filtered samples. Although purging of a well is supposed to alleviate problems from well construction and completion, the difference in metal concentrations between the filtered (dissolved fraction) and unfiltered (total metals) samples seen for aluminum, iron and manganese in the Herrera well (Table 9) suggests that the unfiltered sample may be incorporating particulates and may not be providing a true reflection of the aquifer. Contrarily, arsenic and lead were detected solely in the filtered (dissolved fraction) sample from the Duran and Herrera wells, respectively. If either metal truly exists at their reported level, one would expected similar results from the unfiltered samples. However, arsenic and lead were not detected in the unfiltered sample from the Duran and Herrera well, respectively. This inconsistency most likely reflects analytical variability. Further proof that As and Pb are not elevated in these wells is provided by Molycorp's data (from split sampling) which showed undetected levels of these metals in the Duran and Herrera wells (ref. 48, p. 2-4). For the purposes of this ESI, a release to groundwater required at least a three-fold increase of an analyte in both the filtered and unfiltered samples. Using this definition, no release of CERCLA hazardous substances to private wells was observed. While the concentration of zinc was elevated in the unfiltered sample from the Rael Well, it was not elevated above three times background for the filtered sample (Table 9). Therefore the Rael well, which remains as the only private well for drinking water purposes, is subject to potential contamination from the ponds rather than actual contamination.

Analytical results from the monitoring wells downgradient from the tailings ponds showed several metals including aluminum (Al), calcium (Ca), magnesium (Mg), manganese (Mn) and potassium (K) which are elevated in both filtered and unfiltered samples (Tables 10, 11). These metals, however, are not listed as CERCLA hazardous substances. Copper was detected in both filtered and unfiltered samples from MW-7b while remaining undetected in background samples (Tables 10, 11). The sample detection limit for copper in the background sample, however, is greater than the level detected in the filtered sample for MW-7b (6 ug/L vs. 3.5 ug/L, respectively). It is uncertain whether the level detected in MW-7b (dissolved fraction) is truly greater than the concentration (though undetected) in the background sample. Due to this uncertainty, copper is not considered elevated in MW-7b. No other metal listed as a CERCLA hazardous substance is elevated in both filtered (dissolved fraction) and unfiltered (total metals) samples in downgradient monitoring wells. Therefore, a release of CERCLA hazardous substances to monitoring wells has not been established in the vicinity of the tailings ponds.

Seeps and springs which were sampled during this ESI flow directly into the Red River (Seeps A, D, E, Old Cold Spring Collection), into the North Irrigation Ditch (Embargo Road Seep) or are collected by the Red River Fish Hatchery (Warm and Cold Springs). They represent locations where groundwater enters a surface water body. Arsenic was detected in both filtered and unfiltered samples from Warm Spring while remaining undetected in the background well (MW-CH; Table 12). However, arsenic was detected in only three of the eight tailings samples and at levels slightly greater than the detection limit (Table 2). With arsenic concentrations in background soil which equal or exceed those in the tailings (Table 4), the elevated level in Warm Spring cannot be attributed to the tailings ponds. The elevated concentrations of other metals

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noted in the seeps (e.g. Al, Ca, Mg, Mn and K) are restricted to parameters which are not defined as CERCLA hazardous substances.

Laboratory results of groundwater (from private wells, monitoring wells and seeps) near the tailings ponds demonstrated elevated concentrations of non-CERCLA hazardous substances such as aluminum, iron and manganese in both filtered and unfiltered samples from at least one downgradient groundwater sampling location (Tables 10-12). An elevated level of arsenic (a CERCLA metal) was detected at a single location, but is unlikely attributable to the tailings due to the virtual absence of As in the tailings. Therefore, a site-related release of CERCLA hazardous substances to groundwater in the vicinity of the tailings ponds has not been established.

## C. Surface Water Migration Pathway

### 1. Surface Water Flow Characteristics

The Red River is located immediately south of the Molycorp mine and tailings ponds and flows in a westerly direction (Fig. 2). The average annual flow of the Red River at Questa Ranger Station (located between the mine and the tailings ponds) is approximately 41 cubic feet per second (cfs. ref. 28. Fig. B). Two tributaries to the Red River are Columbine and Cabresto Creeks which enter the Red River between the Molycorp mill area and the tailings ponds. Additional inflows to the Red River include seeps and springs, NPDES discharges from Molycorp, Inc. and return water from the Red River Fish Hatchery, which is located one-and-a quarter mile below Molycorp's most downstream NPDES discharge point (called outfall #001; ref. 10). Three miles below the hatchery, the Red River enters the Rio Grande (Fig. 2).

Drainage (via overland flow) from Molycorp first enters the Red River at the uppermost outfall of their NPDES permit (outfall #005) located near the mill area (Fig. 2). This location is the first probable point of entry (PPE-1). Approximately one-third mile below PPE-1, drainage from Molycorp's mine waste in Sulphur Gulch also enters the Red River through groundwater migration (ref. 4, photo 2). The bottom or toe of this dump was constructed in a manner which purposely conveys any collected water to the Red River via the alluvium of the river channel (ref. 24, p. 24). This location is the first where groundwater enters the Red River (called PPE-g). The furthest downstream location where drainage from Molycorp is known to enter the Red River (called PPE-2) occurs at outfall #001 (NPDES discharge point; ref. 10; Fig. 2). Between PPE-1 and PPE-2 are other known and potential drainage inputs from Molycorp to the Red River such as additional NPDES discharge points and seeps/springs (see Groundwater Pathway).

### 2. Surface Water Use

The Red River is a popular recreational area supporting activities such as skiing, hiking and fishing. The stream reach between the mine and State Highway 522 near Questa (a length of approximately 5 miles) is often referred to as the "Dead Zone" as it no longer supports a natural

fishery (ref. 49). The last fish survey within this reach reported zero fish (ref. 16). Anecdotes persist regarding the presence of abundant fish in the Red River in the 1960's. This is substantiated by the decrease in fish counts in the Red River over time (ref. 15).

Although a self-supporting fishery is lacking, Eagle Rock Lake, which is within the "Dead Zone", is heavily stocked by the New Mexico Department of Game & Fish (ref. 49). Red River is stocked bi-weekly between May and September with fish which can be caught (> 9 inches). The annual production of fish stocked in this area is 11,000 pounds, all of which is assumed to be caught (ref. 50). Water from the Red River is used at the Red River Fish Hatchery where it provides about 40% of the water for the raising of fish (ref. 51). The supplement of water comes from the collection of groundwater at Warm and Cold Water Springs (ref. 51). The total fish production at the Red River Fish Hatchery is approximately 300,000 pounds (ref. 50).

Numerous wetlands have been delineated by the US Fish & Wildlife Service along the Red River (ref. 63). Below the uppermost probable point of entry (PPE-1) where Molycorp's Outfall #005 for their NPDES permit is located, at least ten wetlands have been identified (ref. 63). The length of these wetlands varies between 0.1 and 0.5 mile. The total length of all the wetlands along the Red River below Molycorp Mine was estimated to be 1.8 miles (ref. 63).

The Red River also provides water for irrigation purposes near the town of Questa. Four surface water diversions are located below the mine: Questa Forest Service Ranger Station (North Irrigation Ditch); near the Old Eagle Rock Campground area (South Irrigation Ditch); and two within the town of Questa (Middle and Molino Ditches; Fig. 2). These diversion structures provide water for approximately 700 acres of agriculture (ref. 52). Water in the ditches or in the Red River is not used for drinking purposes (ref. 53).

Two miles below Outfall #001, the Red River has been designated as a Wild and Scenic River (Fig. 2); This designation extends down the Red River and Rio Grande for at least 15 miles (Fig. 2). Included within the Wild and Scenic designation (approx. 12 miles below Outfall #001) is the Canon del Rio Grande Recreation Area which extends approximately two miles down the Rio Grande. (Fig. 2).

Several species may occur at the Molycorp Site which are either threatened or endangered (as designated by US Fish & Wildlife) (ref. 54). Species include the Bald Eagle, American Peregrine Falcon and Southwestern Willow Flycatcher (ref. 54). The list of state threatened or endangered species which may occur in the area also includes the Baird's Sparrow and Meadow Jumping Mouse (ref. 55). Only the Bald Eagle has been verified by New Mexico Department of Game & Fish within four miles of Molycorp and 12 miles downstream (ref. 55). A single sighting of a Southwestern Willow Flycatcher along the Red River has been recorded, but the Red River is generally considered poor habitat for this species as it requires slow meandering waters with willow overgrowth (ref. 49). While unverified by the New Mexico Department of Game & Fish, the American Peregrine Falcon represents a (State) threatened species whose range is known to include the Red River (ref. 49). American Peregrine Falcon has a foraging range of up to 20

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miles, and may be present at either the mine area or the tailings ponds where its range overlaps that of the Prairie Falcon (ref. 49). With the American Peregrine Falcon having such a large range, the Molycorp site (mine and tailings ponds) may account for a small proportion of it; however, one was sighted on the mine waste dumps during ESI field activities (ref. 24, p. 52).

3. Surface Water Pathway-Methods

A release of CERCLA hazardous substances from waste sources to the Red River was evaluated by the collection and analysis of surface water and streambed sediment samples upstream and downstream from the mine area. Near the tailings ponds, a release to North Irrigation Ditch was also evaluated for potential impact to surface water. Discharges by Molycorp to the Red River which may have exceeded those permitted under NPDES were also examined by direct sampling (at outfall #002).

Mine Area

Twenty-one sampling locations along the Red River near the mine area were selected to determine whether CERCLA hazardous substances have migrated into the river from the mine site (Fig. 3). The selection of sampling locations were based upon the presence of various inputs to the Red River such as creeks, seeps and springs. Media sampled included surface water, seeps and streambed sediments. Samples taken within the Red River were generally collected in a progressively upstream direction to minimize the possibility of disturbance of previous sampling from upstream locations. Samples were collected on three separate sampling events and analyzed for Target Analyte List (TAL) metals under EPA's Contract Laboratory Program (CLP). Selected samples were also analyzed for general chemistry parameters under either CLP or the New Mexico State Laboratory Division (SLD). SLD was used for latter sampling events due to the discontinuation of general chemistry analyses under CLP.

Water samples were collected prior to sediment samples to prevent elevated amounts of suspended sediment in the water samples caused by sediment sampling. Four 1-liter HDPE bottles were needed for total and dissolved metals and general chemistry. A preserved and unpreserved sample of filtered water were needed for general chemistry. Water samples requiring filtering were initially collected in 4-liter containers. All water samples were collected upstream from where the sampler was standing. Samples were acidified to pH 2 with nitric acid (sulfuric for general chemistry) and kept on ice until arrival at the analytical laboratory. Sediment samples were collected with an individually wrapped (sterile) plastic scoop to a depth of 1 to 2 inches so as to collect the maximum precipitate which may have formed on the streambed. Samples were collected in a plastic bag and homogenized prior to their transfer to either one 8-oz. or two 4-oz. jars equipped with a Teflon-lined cap. All samples were split with Molycorp's consultant.

Tailings Ponds

Determining a release of CERCLA hazardous substances to surface water near the tailings ponds followed three lines of investigation: input of groundwater directly to the Red River by seeps and springs; input of a particular seep near the tailings ponds to the North Irrigation Ditch; and exceedances of Molycorp's NPDES permit at outfall #002 (Fig. 4). Media sampled included surface water and seeps.

Four 1-liter HDPE bottles were needed for total and dissolved metals and general chemistry. A preserved and unpreserved sample of filtered water were needed for general chemistry. Water samples requiring filtering were initially collected in 4-liter containers. Samples were acidified to pH 2 with nitric acid (sulfuric for general chemistry as appropriate) and kept on ice until arrival at the analytical laboratory. Samples were split with Molycorp personnel and were analyzed for Target Analyte List (TAL) metals and general chemistry parameters under EPA's Contract Laboratory Program (CLP).

4. Surface Water Pathway- Results

Mine Area

Results from the analyses of Red River water samples show a general downstream increase of both total and dissolved metals (Table 15, 16; ref. 65). Using a sampling location above Molycorp property as the background surface water quality (sampling location #16, Fig. 3), an increase of at least three-fold was observed for both manganese and zinc (Table 16). This 3-fold increase first occurred for zinc at Goathill Gulch whereas that for manganese occurred below Capulin Canyon Seeps (sampling locations #7 and #3, respectively; Fig. 3). The highest reported concentration of either occurred where the Molycorp tailings pipeline crosses the Red River (Old Eagle Rock Campground; sampling location #2, Fig. 3). Elevated concentrations of manganese and zinc were also noted in this reach of the Red River during an earlier ESI sampling event (Table 17; ref. 65).

A release of CERCLA hazardous substances to the river is also documented by streambed sediment samples. Analytical results of the metal contents for 13 sediment samples are presented in Table 18 (ref. 65). This contamination may be due to suspended sediment deposition or precipitation of metal oxides originating from groundwater seeps. Using the data from the Red River above Molycorp property as background condition, several metals were elevated at various locations along the 8 downstream sampling locations (Table 18). Beryllium (Be), copper (Cu), lead (Pb), manganese (Mn) and zinc (Zn) were elevated above three times the background concentration in at least one-half of these locations (locations A through D and I, Fig. 3). Except for Mn, these metals are listed as CERCLA hazardous substances. Be, Cu and Zn demonstrated at least a five-fold increase at the location reporting the highest concentration. While the elevated concentrations generally increased in a downstream direction, the highest value was not necessarily at the farthest downstream location (Red River above Pipeline Crossing).

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Tailings Ponds

Results for all seeps which may affect the Red River and the North Irrigation Ditch near Embargo Road are presented in the Groundwater Migration Pathway (Table 12). Impacts from the Embargo Road Seep to the adjacent irrigation ditch was evaluated by the collection of surface water in the irrigation ditch both above and below the inflow of the seep (Fig. 4; Table 19; ref. 65). While the concentration of several parameters increased below the input of the seep, including aluminum, manganese, sulfate and TDS, none of the elevations resulted in at least a three-fold increase (Table 19). A third sample from this ditch was taken above its return to the Red River and incorporates field drainage between Embargo Road and the river (Fig. 4). Data from this sample show that several metals increased dramatically. Calcium was documented at a 3-fold increase and magnesium, at a 20-fold increase for this location. Aluminum and manganese decreased in this sample (Table 19).

5. Surface Water Pathway-Discussion

Mine Area

Two sets of surface water data obtained during the ESI show a general increase in metal concentrations below the mine (Tables 15-17). The first set of data (June 26, 1994) documents over a three-fold increase in Mn and Zn concentrations between Columbine Creek and the USGS gaging station at the US Forest Service Ranger station near Questa (locations #9 and #1, Fig. 3; Table 17). Although a background sample was collected above Hanson Creek during this sampling event (location #18, Fig. 3), it did not adequately characterize surface water quality at the Molycorp property boundary since contributions of metals from Hanson Creek are unknown. Analysis from the second sampling event (Nov. 1994) demonstrates at least a three-fold increase of Mn and Zn between Molycorp property boundary (representing background) and where the Molycorp pipeline crosses the river (locations #16 and #2, respectively, Fig. 3; Tables 15, 16). The concentration at which Zn was detected in the Red River above the pipeline crossing (159 ug/L at location #2; Table 16; Fig. 3) exceeds the Ambient Water Quality Standard of 110 ug/L (ref. 2, p. B-54). The dilution effect from Columbine Creek may preclude the three-fold increase of other metals between these two sampling locations.

Analytical results from sampling events prior to this ESI have also shown elevated concentrations of Zn in the Red River below the Molycorp Mine and in Eagle Rock Lake (ref. 28, Appendix 2, p. 1, 2). During both sampling events the concentration of Zn in Eagle Rock Lake exceeded the Ambient Water Quality Standard of 110 ug/L.

The increase in metal concentrations in surface water is not uniform throughout the Red River between Molycorp property boundary and the pipeline crossing (locations # 16 and #2, respectively, Fig. 3). The largest gain of sulfate, Mn and Zn during ESI sampling was generally between Columbine Creek and Goathill Gulch (Table 20). This finding is consistent with two other data sets which focused on sulfate gain (Table 21; ref. 28, Appendices 2, 3). The data set

from 10-22-92 shows a much larger contribution from the upper reach (Molycorp mill to Columbine Creek). This is likely the result of discontinued surface flow from the mine waste dumps in Capulin Canyon due to the installation of the leachate collection system in 1992. The reach which demonstrated the second largest increase from the 10-22-92 data set is between Columbine Creek and Goathill Gulch.

The increase in manganese and zinc concentrations in surface water samples of the Red River near the Molycorp Mine is at least partially attributable to Molycorp's mining activities. Manganese and zinc were both elevated in the seeps along the Red River as well as waste source and leachate samples from the mine waste dumps. The consistency with which these two metals are elevated in waste material and drainage from mine dumps and downgradient water samples provides strong qualitative data to impart at least partial attribution of these increases to Molycorp activities. Supporting evidence of partial attribution was noted as changes over time of sulfate gain in the Red River were examined near the Molycorp mine (Attachment D). Results suggest that Molycorp operations have increased the proportion of sulfate gain contributed by the lower reach (i.e. Columbine Creek to Questa Ranger Station). Because sulfate gain in the Red River has ostensibly changed by Molycorp activities, partial attribution of this increase (and hence, Mn and Zn) to Molycorp operations is demonstrated.

Analytical results of streambed sediment sampling along the Red River near the Molycorp Mine demonstrated at least a three-fold increase in metal concentrations above background at several downstream locations (A through I, Fig. 3; Table 18). Metals exhibiting an increase in sediments include Be, Co (cobalt), Cu, Pb, Mn and Zn with all demonstrating at least a three-fold increase in the sediment sample below the mine at the pipeline crossing (location #2, Fig. 3; Table 18). These same metals were most elevated in soil samples from mine waste dumps relative to scar material (Table 4) lending support that the release of metals to the Red River in the vicinity of the mine is partially attributable to Molycorp.

The concentrations of metals in the Red River reflect contributions from various sources including drainage from the hydrothermal scars and from Molycorp mining activities. Other sources above Molycorp property likely include development near the town of Red River and grazing in the upper areas of the watershed (ref. 23, p. 210-211). Through surface water and streambed sediment sampling, a release of CERCLA hazardous substances to the Red River in the vicinity of the mine has been established and that the release is partially attributable to Molycorp activities.

Tailings Ponds

The sample collected from the outflow of the irrigation ditch (located approximately 50 feet west of outfall #002) includes seeps or field drainage in the area between Embargo Road and the Red River. This field is used primarily for grazing. Impacts from this field drainage should be reflected in any changes in water quality of the irrigation ditch below Embargo Road Seep and its inflow into the Red River. Several parameters increased due to the input of the field drainage with only sodium and chloride demonstrating at least a three-fold increase (Table 19); however,

none of these parameters are listed as CERCLA hazardous substances.

One study which evaluated contribution of leachate from Molycorp tailings to various seeps in the area of the ponds found increased concentrations of sulfate which was attributed to Molycorp activities (ref. 37, p. 19, 24). The seep at Embargo Road likely represents a fugitive release from Pond #1 which is not collected by the seepage barrier system. This conclusion is supported by the concentrations of calcium, magnesium, sulfate and TDS in the Embargo Road Seep which most closely parallels that of outfall #002 (Table 19).

Evaluation of impacts to the Red River initially included sample collection and analysis for metals and general chemistry parameters in river water samples. At the time of field collection of the water from seeps/springs and the irrigation ditch near the tailings ponds, the flow in the Red River was determined to be too high to safely sample. The high run-off would likely have diluted or masked any potential impacts to the Red River from the seeps and springs. Review of the analytical data from the seeps and springs, however, failed to establish a release of CERCLA hazardous substances in the seeps and springs; the absence of a documented release to these seeps and springs (which reflects the lack of impacts of CERCLA hazardous substances to groundwater), precluded the need to sample the Red River for potential impacts.

The surface water standards for the State of New Mexico include several use designations for the Red River in the vicinity of the Molycorp mine and tailings ponds including a coldwater fishery designation (ref. 56, sec. 3119). Acute and chronic standards exist which are relevant to coldwater fisheries. Comparison of chronic water quality standards to Outfall #002 and Embargo Seep provides a measure to evaluate potential effects of Molycorp discharge to aquatic systems. The sole metal elevated in waste water from the ponds (e.g. Outfall #002 and Embargo Road Seep) for which a chronic standard exists is aluminum. However, aluminum is not listed as a CERCLA hazardous substance. Embargo Road Seep had dissolved aluminum concentration of 119 ug/L (Table 19) which exceeds the State standard of 87 ug/L. While aluminum in the receiving surface water body (North Irrigation Ditch) increased due to the input from this seep, this increase was not significant. Fortunately, the concentration of dissolved aluminum in this irrigation ditch decreases to below the standard upon re-entering the Red River. The concentration of aluminum in Molycorp's discharge to the Red River is 148 ug/L which, while above the chronic standard of 87 ug/L, is a permitted discharge under their NPDES permit (permit # NM00222360; ref. 10, Part I, p. 3, 4).

A release of CERCLA hazardous substances to the Red River was evaluated through the groundwater-to-surface water pathway by examining seeps along the river. One seep entering an irrigation ditch was also evaluated. A release to the Red River also focused on the waste water discharged by Molycorp to the Red River. Comparing the seeps (and Molycorp waste water) to background groundwater quality failed to identify elevated concentrations of CERCLA hazardous substances. Therefore a release to surface water in the vicinity of the tailings ponds has not been established.

## C. Soil Exposure Pathway

Soil sampling surrounding the tailings ponds was conducted to identify any elevated concentrations of CERCLA hazardous substances in residential soils which are attributable to the site. Determining areas of soil contamination required the comparison of soil constituents in residential yards to that of background soil locations.

### 1. Soil Exposure Pathway- Methods

Eight waste samples, including one duplicate, were collected from the tailings ponds to identify the presence of CERCLA hazardous substances. Soil samples were collected from residential yards south, east and north of the ponds and from Questa Jr. High School to the north of the ponds (Fig. 4). Soils from these residential areas represent two soil classifications as determined by the U.S. Soil Conservation Service: Sedillo series (residences to the south) and Silva Series (residences and school to the east and north) (Fig. 6). Background soil sampling locations were chosen for similarity in soil type to residential sampling areas and were generally upwind (south) from the tailings ponds (Fig. 4). The Silva soil type present at the eastern and northern residences and the junior high school is not present south (i.e. upwind) of the ponds; a location representing background was chosen further downwind (north). Sampling locations for waste (i.e. tailings) and soil are shown on Figure 6.

Generally, soil samples at each sampling location were first screened using x-ray fluorescence (XRF) for metal concentrations (ref. 24, p. 36, 37; Attachment B). Those with the highest metal content were chosen for laboratory analysis. This screening was abandoned due to time constraints; no XRF screening was conducted at background sampling locations (ref. 24, p. 38). Soil samples were collected from the top 1 or 2 inches with emphasis toward finer grain-sized particles. Sieving of samples was not conducted. Samples were homogenized in a designated plastic bag prior to their transfer into two 4-oz. or one 8-oz. sample jar equipped with a Teflon-lined cap. All samples were split with Molycorp's contractor and were analyzed under EPA's Contract Laboratory Program for Target Analyte List (TAL) metals.

### 2. Soil Exposure Pathway-Results

Analytical data of the metal concentrations in residential soil and the comparison to background concentrations is presented in Tables 22 and 23 (ref. 65). Results from residential areas to the south of the ponds and near the Change House area east of the ponds show concentrations of three metals which exceed three times the highest background concentration, namely chromium (Cr), copper (Cu) and nickel (Ni; Table 23). Only Ni was elevated in each of soils from the residential and Change House areas. Two of the three metals have soil benchmarks associated with them: Cr at 2,900 mg/kg; and Ni at 12,000 mg/kg (Table 22, ref. 2, p. B-59, B-66). The concentrations seen in residential or Change House soils are at least two orders of magnitude less than their respective benchmarks.

A release of CERCLA hazardous substances to the soil involves the evaluation of the top 2 feet of potentially contaminated areas. Because the capped portions of the tailings ponds have only one foot of soil (ref. 57), the entire tailings ponds were included in the soil exposure pathway. Chromium, copper and nickel, which were elevated in residential areas south of the ponds, was also elevated in the tailings ponds. Average concentrations of Cr, Cu and Ni in the tailings ponds were 40 mg/kg, 188 mg/kg and 30 mg/kg, respectively (Table 2). These concentrations were 7 to 26 times greater than that seen in the highest background soil (Table 22).

Soils found at the Trujillo and Martinez residences were initially interpreted as the Fernando Series and several background soil samples from this soil type were collected. Further study of the U.S. Soil Conservation Service map correctly identified the soil type at these residences as the Silva Series. Soil samples from the Fernando Series likely would misrepresent background for these residential areas. Therefore, the one soil sample collected approximately 1/4-mile north of Questa Jr. High School, which was initially intended to represent background conditions for samples collected at the school, also would provide background conditions for the Trujillo and Martinez residences. Analytical results of the soil metal concentrations using this single sample for background is presented in Table 23. Results show a single incident of a metal concentration being elevated, namely zinc at the Martinez residence. To determine whether this single background sample was sufficiently far from the tailings ponds to be representative of background conditions of this soil type, three additional soil samples (including one duplicate) was collected further north (i.e. downwind) from the tailings ponds (Fig. 4). Results using the latter sampling locations as background (near the road to Cerro) failed to define any release to soil (Table 23).

3. Soil Exposure Pathway-Discussion

Tailings Ponds

A release of CERCLA hazardous substances to soils surrounding the tailings ponds is defined by any metal concentration which exceeds three times background and is attributable to the waste source (e.g. tailings ponds). Elevated metal concentrations have been determined; to prove likely attribution of these hazardous substances to the tailings ponds, metal concentrations from the tailings were compared to that in background soil for the same soil types sampled in residential yards. A ratio of average analyte concentrations in the tailings to the highest concentration in background soil was calculated (Table 22). With ratios exceeding one, the tailings were found to have higher concentrations of most metals than in the Sedillo soil type sampled in background locations. Three CERCLA hazardous metals demonstrated at least a seven-fold increase in the tailings: Cr, Cu and Ni (Table 22). Each of these metals was elevated in at least two of the four soil sampling locations within the Sedillo soil type and thus providing justification of attribution of the elevated metals concentrations to the tailings ponds (Table 22).

Zinc was elevated in the soil of the Martinez residence (Fig. 7) when compared to the initial background sample (location #23, Table 23). Using the highest background concentration from subsequent sampling failed to identify a release. Because the average and highest zinc

concentrations in the tailings ponds (Table 23 and Table 4, respectively) are below the concentration noted at the Martinez residence, the elevated level of zinc noted at the Martinez residence is not likely attributable to the tailings and does not define an area of soil contamination.

The current extent of soil contamination has been shown to include the tailings ponds and several residential areas south of the tailings ponds (Fig. 7). No soil contamination to the east and north has been identified. Areas between residences which demonstrate an observed release are inferred to lie within the area of soil contamination. The total area of soil contamination is 20,635,000 $ft^2$ of which 35,000 $ft^2$ is beyond the extent of the tailings ponds (ref. 24, p. 5, 73). The number of persons residing within the area of soil contamination and the respective level of contamination is presented below:

| Residence Sampled | Additional # of Residences w/in Obs. Release | # of Persons | CERCLA Substance Defining Release | Soil Benchmark Exceeded (metal)? |
|---|---|---|---|---|
| Herrera | | 2 | Cr, Cu, Ni | No |
| | 2 (ref. 24, p. 37, 72 ) | 6* | Cr, Cu, Ni | No |
| Rael | | 1 | Cr, Cu, Ni | No |
| Clines | | 1 | Cr, Cu, Ni | No |

* calculated from number of houses within area of soil contamination and number of persons per household (ref. 46)

The total number of persons residing in areas of soil contamination is 10. No schools or daycares are present within 200 feet of the area of contamination.

Mine Area

Soil contamination in the vicinity of the mine was not examined past the extent of the mine waste dumps. While physically accessible (i.e. no fence exists), the dumps are private property and provide no public recreational use. The owners of the Fagerquist Cottonwood Park (2 persons) are the nearest residents and live within a half-mile of the mine waste dumps at Sugar Shack South (Fig. 3). Molycorp workers and terrestrial sensitive environments are potentially exposed to the mine waste dumps. It is assumed that the 16 persons currently employed by Molycorp (ref. 11) work within 200 feet of the mine waste dumps.

During waste source sampling for this ESI, a Peregrine Falcon was seen perched on the waste dump near the open pit (ref. 24, p. 52). Conversation with the Wildlife Biologist for the Questa Ranger Station has confirmed that the Red River valley is included within the range of a nesting pair (ref. 49). The appearance of the Peregrine Falcon on the waste dumps suggests its range likely includes the entire mining site. Whether the waste dumps present a health risk to Peregrines

is unknown. No other endangered species or other species representing sensitive environments are present in areas of waste source material or contaminated soils.

## D. Air Migration Pathway

1. Existing Data

Several incidents of exposure to tailings dust at Questa Jr. High School, located 0.3 mile NE of the northern edge of the tailings ponds (Fig. 2), have been recorded with the New Mexico Environment Department (ref. 58, p. 1, 5). During the spring months, the school is predominantly downwind from the tailings ponds. Numerous incidents of impaired health of students have been recorded by the school nurse (ref. 59). Since the installation of a sampling device at Questa Jr. High School (formerly, the high school) in 1979 (ref. 58, p. 4), NMED has conducted ambient air measurements of total suspended particulates. While information concerning the heavy metal concentrations in these particulate samples is not abundant, several sampling events had measurable concentrations of Pb (average of 0.09 $ug/m^3$). Although detected, Pb concentrations were below the National Ambient Air Quality Standard of 1.5 $ug/m^3$ (ref. 58, Table II). In response to potential releases of airborne particulates from the tailings ponds, Molycorp has implemented the use of soil stabilizers and a temporary soil cap of approximately one foot over much of the ponds (ref. 57; ref. 4, photo 4). Current dewatering of the mine has resulted in rewatering a portion of the tailings ponds. An automated continuous air monitoring device, which has recorded total particulates at the school since June 1993, has shown no violation of air quality standards at Questa Jr. High School (ref. 60). The number of incidents of impaired health at the school is likely to have decreased since the installation of the tailings cap (ref. 59).

Since the temporary capping of the tailings ponds, no release of hazardous substances via air migration pathway has been reported. One sensitive environment initially identified for the air migration pathway was a federally designated Wild and Scenic River (Fig. 2). The Wild and Scenic River designation of the Red River begins 1 to 2 miles downstream (southwest) from the tailings pond and is administered by US Bureau of Land Management. With the prevailing winds in the Questa area heading north, the Wild and Scenic River portion of the Red River (and Rio Grande) are not likely to be significantly impacted by airborne tailings; however, its receipt of airborne particulates is not precluded.

Two other potential habitats for species under consideration for their federally endangered or threatened status which were initially identified were the Southwestern Willow Flycatcher and Small-headed Goldenweed (ref. 51). The Red River is generally considered poor habitat for the Southwestern Willow Flycatcher despite a single sighting. The Small-headed Goldenweed can be removed from consideration as potential sensitive habitat near the Molycorp site as its only reported location is west of the Rio Grande (ref. 61). The range for the Peregrine Falcon, however, is certain to include the tailings ponds as it travels up to 20 miles to forage (ref. 49).

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## III. SUMMARY AND CONCLUSIONS

The Molycorp Site was evaluated under CERCLA authority for the presence and distribution of CERCLA hazardous substances along the groundwater, surface water, soil exposure and air pathways. Both mine waste dumps and tailings ponds contain CERCLA hazardous substances. In the vicinity of the mine, a release has been determined to groundwater (in both Alluvial and Fractured-Bedrock Aquifers) and the Red River. Evaluation of sulfate gain to the Red River over time suggest partial attribution of the releases of CERCLA hazardous substances by Molycorp activities. No such release has been established at the tailings ponds.

The Questa community water supply system consists of two wells which are approximately one mile east of the tailings ponds and four miles west of the mine site. The system provides drinking water for 1644 residents of Questa. The number of people served by other community wells and private wells and is 486 and 142, respectively. All wells, including the Questa community system, are subject to potential contamination from both the tailings ponds and mine waste.

A release of CERCLA hazardous metals to the Red River has been observed in the vicinity of the Molycorp Mine. Several areas or habitats which are of concern or have protected status were identified near the Molycorp Site. These include fisheries at Eagle Rock Lake and below the Red River Fish Hatchery, the Wild and Scenic River designation of the Lower Red River and Rio Grande, wetlands along the Red River and the habitat of the American Peregrine Falcon. Sampling conducted prior to this ESI identified levels of contamination at Eagle Rock Lake which exceeded Ambient Water Quality Standards. Fisheries or habitats below Eagle Rock Lake are subject to potential contamination from the site via surface water.

Soil sampling near the tailings ponds identified areas of soil contamination which include residential yards. At least ten residents have been identified who live within the area of contamination. Concentrations of metals which defined the area of soil contamination are far below health-based standards.

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# Table 1. Metal Concentrations in Mine Waste Dumps (mg/kg)

| Map Location | P Capulin Waste Dump #1 | Q Capulin Waste Dump #2 | R Goathill Waste Dump | S Sugar Shack West Dump | T Sugar Shack South Dump | U Along Truck Shop Road | V Along Lower Bench Road | Average Waste Dump Concentration (# of samples=7) | Coefficient of Variation (%) |
|---|---|---|---|---|---|---|---|---|---|
| Date Sampled | 6/27/94 | 6/27/94 | 6/27/94 | 6/28/94 | 6/28/94 | 6/28/94 | 6/28/94 | | |
| Field ID # | SS-4 | SS-5 | SS-6 | SS-7 | SS-8* | SS-9 | SS-10 | | |
| CLP # | SF5804 | SF5805 | SF5806 | SF5816 | SF5819 | SF5817 | SF5818 | | |
| Analyte (mg/Kg) | | | | | | | | | |
| Al | 1910 | 2730 | 5860 | 6190 | 18900 | 9130 | 5810 | 7219 | 73 |
| Sb | nd | nd | nd | nd | nd | nd | nd | nd | na |
| As | 2.6Jv | 2.5Jv | 11.4Jv | 1.6Jv | 0.96Jv | na | 1.1Jv | 3 | 124 |
| Ba | 45.2 | 171 | 46.2 | 27.5 | 246 | 41.2 | 4 | 83 | 100 |
| Be | 0.25 | 0.27 | 0.27 | 0.59 | 0.63 | 0.89 | 1.3 | 1 | 60 |
| Cd | nd | nd | nd | nd | nd | nd | 3.9 | 1 | 245 |
| Ca | 195 | 1350 | 2280 | 8860 | 18400 | 8670 | 15100 | 7836 | 83 |
| Cr | nd | 4.6 | 17.5 | 10.4 | 81.7 | 17 | nd | 19 | 142 |
| Co | nd | 2.4 | 3.5 | 5.6 | 9 | 13.3 | 2.9 | 5 | 80 |
| Cu | 26.3 | 45.4 | 41.6 | 126 | 140 | 222 | 92.5 | 99 | 65 |
| Fe | 13800 | 16800 | 27700 | 22700 | 46000 | 25400 | 7830 | 22890 | 50 |
| Pb | 431 | 40.2 | 91 | 61 | 31.1 | 40.8 | 275 | 139 | 103 |
| Mg | 265 | 1800 | 3610 | 4300 | 18700 | 4700 | 1250 | 4946 | 118 |
| Mn | 64.5 | 155 | 473 | 432 | 362 | 293 | 1080 | 409 | 75 |
| Hg | nd | nd | nd | nd | nd | nd | nd | nd | na |
| Ni | nd | 5.5 | 12.7 | 12.2 | 26.9 | 21.7 | 3.7 | 12 | 76 |
| K | 1620 | 2180 | 2550 | 2540 | 12300 | 2550 | 1020 | 3537 | 102 |
| Se | na | 1.5J | 0.43J | 0.35J | nd | nd | nd | 3 | 69 |
| Ag | 3.2J^ | 2.9J^ | 4 | nd | 4.6 | 3J^ | nd | 1 | 159 |
| Na | 27.5 | 40.5 | 67 | 99.9 | 183 | 56.1 | 43.8 | 74 | 67 |
| Tl | na | na | na | na | 2.4Jv | na | na | 2 | 0 |
| V | 1.3 | 5.9 | 12.7 | 14.9 | 83.3 | 16.2 | 3.4 | 20 | 135 |
| Zn | 86.5 | 20.8 | 53.3 | 66.3 | 35.4 | 43.3 | 569 | 125 | 146 |
| Mo | 9.3 | 6.1 | 24 | 10.8 | 168 | 176 | 207 | 86 | 100 |

nd = not detected
J = estimated value;
^ = value biased high; v = value biased low
na = not available (data unusable or value cannot be calculated)
* Sample was labelled SS-11 on chain of custody

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Table 2. Metal Concentrations in Tailings (mg/kg)

| MapLocation | 6 | 7 | 8 | 4 | 5 | 3 | 1 | 2 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tailings Pond | TP-1 | TP-1 | TP-2 | TP-5A | TP-5A(dupl) | TP-4 | TP-4 | TP-4 | Average | Coefficient |
| Date Sampled | 4/18/94 | 4/18/94 | 4/18/94 | 4/18/94 | 4/18/94 | 4/18/94 | 4/18/94 | 4/18/94 | | |
| Field Station | S-12 | S-13 | S-14 | S-10 | S-10A | S-11 | S-8 | S-9 | Conc. | of Variation |
| CLP ID# | MFT923 | MFT924 | MFT925 | MFT926 | MFT927 | MFT928 | MFT929 | MFT930 | (mg/kg) | |
| Analyte (mg/Kg) | | | | | | | | | | |
| Al | 6190 | 16300 | 3850 | 5620 | 6220 | 11000 | 8150 | 7070 | 8050 | 45.7 |
| Sb | nd | nd | nd | nd | nd | nd | nd | nd | nd | na |
| As | nd | nd | 1.2^J | nd | 1.4^J | nd | 1.1^J | nd | 0.78 | 46.9 |
| Ba | 70.4 | 153 | 29.9 | 73.9 | 90.6 | 125 | 78.1 | 74.8 | 87.0 | 40.1 |
| Be | 0.59 | 2.4 | 0.46 | 0.47 | 0.56 | 1.3 | 0.79 | 0.72 | 0.9 | 67.7 |
| Cd | nd | nd | nd | nd | 1.2 | nd | nd | nd | 0.2 | 265 |
| Ca | 14500 | 17900 | 10200 | 18800 | 19700 | 17700 | 15700 | 15500 | 16250 | 17.4 |
| Cr | 32.9 | 77.1 | 19.4 | 28.5 | 31 | 55.8 | 40.5 | 36.3 | 40.2 | 42.4 |
| Co | 8.1 | 7.9 | 3.6 | 14.7 | 16.2 | 7.4 | 12.9 | 12.4 | 10.4 | 38.6 |
| Cu | 136 | 169 | 37.7 | 262 | 274 | 324 | 196 | 109 | 188 | 47.2 |
| Fe | 13100 | 19700 | 8640 | 19400 | 20800 | 16600 | 18500 | 16800 | 16693 | 22.6 |
| Pb | 31.3 | 51.8 | 33.2 | 82.2 | 82.8 | 67.8 | 71.4 | 40.7 | 57.7 | 34.4 |
| Mg | 6300 | 14300 | 3870 | 5730 | 6180 | 10100 | 8330 | 7130 | 7743 | 39.0 |
| Mn | 352 | 692 | 515 | 386 | 413 | 546 | 461 | 406 | 471 | 21.9 |
| Hg | nd | nd | nd | nd | nd | nd | nd | nd | nd | na |
| Ni | 24.6 | 42 | 10.5 | 30.5 | 34.9 | 35.4 | 31.2 | 29.8 | 29.9 | 29.2 |
| K | 4010 | 8490 | 1910 | 3680 | 3970 | 6230 | 5340 | 4460 | 4761 | 38.6 |
| Se | nd | nd | nd | nd | nd | nd | nd | nd | nd | na |
| Ag | nd | nd | nd | nd | nd | nd | nd | nd | nd | na |
| Na | 118 | 222 | 78.6 | 119 | 117 | 173 | 130 | 140 | 137 | 29.5 |
| Tl | 0.42 | 0.82 | ND | 0.42 | 0.53 | 0.64 | 0.58 | 0.42 | 0.5 | 46.4 |
| V | 30.2 | 61.8 | 13.6 | 26.5 | 30.4 | 46.2 | 37.9 | 33.8 | 35.1 | 38.1 |
| Zn | 85.1J | 115J | 111J | 156J | 148J | 140J | 158J | 104J | 127 | 19.9 |

J - estimated value; ^ value biased high

nd - undetected; na - not available or calculable

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# Table 3. Metal Concentrations in Hydrothermal Scars (mg/kg)

| Map Location | M Eagle Rock Scar Area | N Eagle Rock (duplicate) | O Goathill Scar | W Hanson Crk Scar | Average Scar Concentration (# of samples=4) | Coefficient of Variation (%) |
|---|---|---|---|---|---|---|
| Date Sampled | 6/27/94 | 6/27/94 | 6/27/94 | 6/26/94 | | |
| Field ID# | SS-1 | SS-2 | SS-3 | SS-12 | | |
| CLP ID# | SF5897 | SF5899 | SF1801 | SF5860 | | |
| Analyte (mg/Kg) | | | | | | |
| Al | 10300 | 7770 | 2220 | 8210 | 7125 | 42 |
| Sb | nd | nd | nd | nd | nd | na |
| As | na | na | 21.2Jv | 11.5Jv | 16.4 | 30 |
| Ba | 147 | 131 | 106 | 248 | 158 | 34 |
| Be | 0.52 | 0.44 | 0.12J^ | 0.42 | 0.4 | 41 |
| Cd | nd | nd | nd | nd | nd | na |
| Ca | 5590 | 7680 | 81.9 | 8810 | 5540 | 61 |
| Cr | 47 | 44.8 | nd | 12.8 | 26 | 78 |
| Co | 2.4 | 2.4 | 3.7 | 4.6 | 3 | 28 |
| Cu | 31.4 | 31.3 | 52.4 | 35.1 | 38 | 23 |
| Fe | 40200 | 43500 | 156000 | 61500 | 75300 | 63 |
| Pb | 42.5 | 45.9 | 134 | 138 | 90 | 51 |
| Mg | 4140 | 3370 | 192 | 7100 | 3701 | 66 |
| Mn | 200 | 173 | 17.7 | 258 | 162 | 55 |
| Hg | nd | nd | nd | nd | nd | na |
| Ni | 12.6 | 9.1 | nd | 12.4 | 9 | 60 |
| K | 6250 | 5630 | 23700 | 3300 | 9720 | 84 |
| Se | 3.6J | 3.7J | 3.4J | 2.2J | 3 | 19 |
| Ag | 3.8J^ | 4.1 | 12.5 | 6 | 6 | 80 |
| Na | 908 | 1200 | 1200 | 689 | 999 | 22 |
| Tl | 2.1Jv | na | 2.9Jv | na | 3 | 16 |
| V | 43 | 37.7 | 16.2 | 18.6 | 29 | 40 |
| Zn | 31.4 | 27.5 | 23.9 | 55.9 | 35 | 36 |
| Mo | 7.5 | 9.6 | 35.6 | 16.6 | 17 | 64 |

nd = not detected
J = estimated value;
^ = value biased high; v = value biased low
na = not available (data unusable or value cannot be calculated)

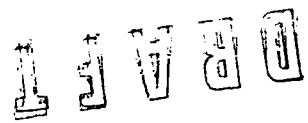

Table 4. Ratio of Metal Concentrations between Waste Sources and Hydrothermal Scars or Background Soil

| Analyte (mg/kg) | Average Metal Concentration: Waste Dumps (N=7) | Average Metal Concentration: Scars (N=4) | Ratio of Concentrations (waste dump/scar) | Average Metal Concentration: Tailings (N=8) | Average Metal Concentration: Background Soil Sedillo Soil Type* (N=3) | Ratio of Concentrations (tailings/backgroud) Sedillo Soil Type | Average Metal Concentration: Background Soil Silva Soil Type* (N=3) | Ratio of Concentrations (tailings/backgroud) Silva Soil Type |
|---|---|---|---|---|---|---|---|---|
| Al | 7219 | 7125 | 1.0 | 8050 | 2887 | 2.8 | 10813 | 0.7 |
| Sb | nd | nd | na | 0 | 2.4 | na | nd | na |
| As | 3 | 16.4 | 0.2 | 0.78 | 0.78 | 1.0 | 4.9 | 0.2 |
| Ba | 83 | 158 | 0.5 | 87.0 | 48.7 | 1.8 | 167 | 0.5 |
| Be | 1 | 0.4 | 1.6 | 0.9 | 0.18 | 5.0 | 0.8 | 1.1 |
| Cd | 1 | nd | na | 0.2 | nd | na | 0.4 | 0.4 |
| Ca | 7836 | 5540 | 1.4 | 16250 | 1111 | 14.6 | 2477 | 6.6 |
| Cr | 19 | 26 | 0.7 | 40.2 | 3.5 | 11.5 | 14.8 | 2.7 |
| Co | 5 | 3 | 1.6 | 10.4 | 3.0 | 3.4 | 12.1 | 0.9 |
| Cu | 99 | 38 | 2.6 | 188 | 6.3 | 29.9 | 23.6 | 8.0 |
| Fe | 22890 | 75300 | 0.3 | 16693 | 7177 | 2.3 | 20633 | 0.8 |
| Pb | 139 | 90 | 1.5 | 57.7 | 12.6 | 4.6 | 22.9 | 2.5 |
| Mg | 4946 | 3701 | 1.3 | 7743 | 1051 | 7.4 | 2787 | 2.8 |
| Mn | 409 | 162 | 2.5 | 471 | 298 | 1.6 | 783 | 0.6 |
| Hg | nd | nd | na | 0.0 | nd | na | nd | na |
| Ni | 12 | 9 | 1.4 | 29.9 | 3.8 | 7.9 | 12.3 | 2.4 |
| K | 3537 | 9720 | 0.4 | 4761 | 1049 | 4.5 | 2330 | 2.0 |
| Se | 3 | 3 | 1.1 | 0.0 | nd | na | 1.1 | 0.0 |
| Ag | 1 | 6 | 0.2 | 0.0 | nd | na | nd | na |
| Na | 74 | 999 | 0.1 | 137 | 38.5 | 3.6 | 90 | 1.5 |
| Tl | 2 | 3 | 1.0 | 0.5 | nd | na | nd | na |
| V | 20 | 29 | 0.7 | 35.1 | 7.9 | 4.5 | 36.8 | 1.0 |
| Zn | 125 | 35 | 3.6 | 127 | 33.5 | 3.6 | 66.4 | 1.9 |

*ref. 5; nd - not detected; na - not available (cannot be calculated)
N = Number of Samples

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Table 5. Metal Concentrations in Fagerquist Well (Nearest to Mine) and Surrounding Surface/Ground Waters

| Date Sampled<br>Side from Red River<br><br>Analyte (mg/L) | Fagerquist Well*<br>9/9/93<br>south | Columbine Creek<br>11/7/94<br>south | Columbine C.G. Well*<br>8/24/93<br>south | Molycorp MW-8b**<br>11/8/94<br>north | Molycorp MW-10a**<br>11/8/94<br>north | Molycorp MW-10c**<br>11/8/94<br>north |
|---|---|---|---|---|---|---|
| Al | <0.1 | 0.05 | <0.1 | 0.44 | 33.4 | 31.1 |
| Sb | na | <0.003 | na | <0.05 | <0.05 | <0.05 |
| As | <0.005 | <0.0012 | <0.005 | <0.05 | <0.05 | <0.05 |
| Ba | <0.1 | 0.042 | <0.1 | 0.016 | <0.01 | 0.014 |
| Be | <0.1 | <0.0004 | <0.1 | 0.008 | 0.008 | 0.007 |
| Cd | <0.001 | <0.004 | <0.001 | <0.0005 | 0.03 | 0.03 |
| Ca | 24 | 23 | 26 | 206 | 275 | 204 |
| Cr | <0.005 | <0.004 | <0.005 | <0.01 | <0.01 | <0.01 |
| Co | <0.05 | <0.005 | <0.05 | <0.01 | 0.15 | 0.11 |
| Cu | <0.05 | <0.003 | <0.05 | <0.01 | 0.56 | 0.38 |
| Fe | <0.1 | 0.05 | <0.1 | <0.05 | <0.05 | <0.05 |
| Pb | <0.005 | <0.0009 | 0.01 | <0.002 | <0.002 | <0.002 |
| Mg | 2 | 2.3 | 2.6 | 55.5 | 77.9 | 75.2 |
| Mn | <0.05 | <0.002 | <0.05 | 0.2 | 13.8 | 16.3 |
| Hg | <0.0005 | <0.0002 | <0.0005 | <0.0002 | <0.0002 | <0.0002 |
| Ni | <0.1 | <0.017 | <0.1 | 0.06 | 0.33 | 0.03 |
| K | 1 | 0.8 | 2 | 2.9 | 2.8 | 2.8 |
| Se | <0.005 | <0.001 | <0.005 | <0.005 | <0.005 | <0.005 |
| Ag | <0.1 | <0.004 | <0.1 | <0.1 | <0.1 | <0.1 |
| Na | 2 | 2.1 | 3 | 33.9 | 26.5 | 20.2 |
| Tl | na | <0.004 | na | <0.005 | <0.005 | <0.005 |
| V | <0.1 | <0.0009 | <0.1 | <0.01 | <0.01 | <0.01 |
| Zn | <0.05 | 0.003 | 1.6 | 0.2 | 2.3 | 3.2 |
| | | | | | | |
| pH | 8.15 | 7 | 7.51 | 6.4 | 5.8 | 4.7 |
| Conductivity (umhos) | 142 | 80 | 169 | 1780 | 2400 | 2000 |
| Depth of Well (feet) | 52 | na | 80 | 129 | 144 | 50 |

* unfiltered sample collected by NMED-Surface Water Quality Bureau

** filtered sample collected by South Pass Resources, Inc. (ref. 12)

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Table 6. Background Metal Concentrations for Determining a Release to Alluvial Aquifer via Seeps

| Map Location | 21 Red River WWTP | 15 Molycorp Mill Well | 20 Elephant Rk Campground | 22 Junebug Campground | Highest Conc. for Background Purposes | 21 Red River WWTP | 15 Molycorp Mill Well | 20 Elephant Rk Campground | 22 Junebug Campground | Highest Conc. for Background Purposes |
|---|---|---|---|---|---|---|---|---|---|---|
| CLP ID# | MFQ267 | MFQ270 | MFQ268 | MFQ269 | | MFQ262 | MFQ265 | MFQ263 | MFQ264 | |
| Temp (C) | | | | | | 11 | 6 | 5.5 | 6 | |
| pH | | | | | | 3.85** | 6 | 5.5 | 6 | |
| Cond. (umhos) | | | | | | 1200 | 202 | 150 | 163 | |
| | Filtered | Filtered | Filtered | Filtered | Filtered | Unfiltered | Unfiltered | Unfiltered | Unfiltered | Unfiltered |
| Analyte (ug/L) | | | | | | | | | | |
| Al | 36500 | 144 | nd | nd | 36500 | 36700 | 716 | nd | nd | 36700 |
| Sb | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| As | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ba | 11.1 | 21 | 32.9 | 34.4 | 34.4 | 5.3 | 22.2 | 34.1 | 39 | 39 |
| Be | 5.1 | nd | nd | nd | 5.1 | 5.2 | nd | nd | nd | 5.2 |
| Cd | 6.1J | nd | nd | nd | 6.1 | 7.8J | nd | nd | nd | 7.8 |
| Ca | 151000 | 43700 | 33900 | 34200 | 151000 | 151000 | 45700 | 34300 | 36600 | 151000 |
| Cr | 5.8 | nd | nd | nd | 5.8 | 8.5 | nd | nd | nd | 8.5 |
| Co | 97.4 | nd | nd | nd | 97.4 | 101 | nd | nd | nd | 101 |
| Cu | 58.3 | 4.9 | 5 | | 58.3 | 60.8 | 21.6 | 12.4 | 54.7 | 60.8 |
| Fe | 30100 | nd | 97.1J^ | 128 | 30100 | 30200 | 273 | 610 | 4850 | 30200 |
| Pb | 3.7J^ | nd | nd | nd | 3.7 | 3.6J^ | 3.1J^ | 1.5J^ | 5.6J^ | 5.6 |
| Mg | 51500 | 8880 | 6600 | 6920 | 51500 | 52200 | 9190 | 6710 | 7620 | 52200 |
| Mn | 5700 | 110 | 5.6 | 82.6 | 5700 | 5720 | 108 | 6.1 | 78.5 | 5720 |
| Hg | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ni | 227 | nd | nd | nd | 227 | 232 | nd | nd | nd | 232 |
| K | 2540 | 771 | 792 | 732 | 2540 | 2910 | 941 | 535 | 585 | 2910 |
| Se | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ag | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Na | 15100 | 5140 | 3870 | 4180 | 15100 | 14900 | 4810 | 3720 | 4060 | 14900 |
| Tl | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| V | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Zn | 2090 | 41 | 107 | 252 | 2090 | 2090 | 46.1 | 109 | 404 | 2090 |

nd - not detected
*ref. 12
J^ - estimated value biased high

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Table 7. Release of CERCLA Hazardous Substances to Downgradient Seeps of Alluvial Aquifer

| Map Location | Background Concentrations for Determining a Release in Alluvial Aquifer | | S-1 Cliff Seep (Old Eagle Rock CG) | | S-2 Capulin Channel Seep | | S-3 Capulin Canyon Seep: Lower | | S-3 (Duplicate) Capulin Canyon Seep: Lower | | S-4 Capulin Canyon Seep: Upper | | S-5 Goathill Seep | | S-7 Adit Seep | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date Sampled<br>CLP ID#<br>Analyte (ug/L) | filtered | unfiltered | filtered 6/26/94 SF5831 | unfiltered 6/26/94 SF5832 | filtered 6/26/94 SF5823 | unfiltered 6/26/94 SF5827 | filtered 6/26/94 SF5824 | unfiltered 6/26/94 SF5828 | filtered 6/26/94 SF5825 | unfiltered 6/26/94 SF5829 | filtered 6/26/94 SF5826 | unfiltered 6/26/94 SF5830 | filtered 6/26/94 SF5839 | unfiltered 6/26/94 SF5842 | filtered 6/26/94 SF5840 | unfiltered 6/26/94 SF5843 |
| Al | 36500 | 36700 | 43100 | 43500 | 127000 | 120000 | 104000 | 108000 | 105000 | 105000 | 113000 | 114000 | 28500 | 28800 | 13700 | 17500 |
| Sb | nd | nd | nd | nd | nd | nd | 32.1 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| As | nd | nd | nd | nd | 1.8J | 1.0J | 1.1J | nd | 1.1J | 1.3J | 2.1J | 1J | nd | nd | nd | nd |
| Ba | 34.4 | 39 | 12.8 | 13.5 | 8.1 | 7.9 | 9.8 | 12.2 | 13.6 | 13.9 | 8.2 | 8.1 | 20.1 | 25 | 62.5 | 58.1 |
| Be | 5.1 | 5.2 | 13.1 | 13.1 | 25.6 | 21.3 | 19.6 | 20.4 | 20 | 19.9 | 17.6 | 17.6 | 5.5 | 5.5 | 3.6 | 4.2 |
| Cd | 6.1 | 7.8 | 17.7J | 23J | nd | 5.7 | 9.2J | 12.1J | 13.1J | 15.2J | 6.8J | nd | 11.1J | 15.1J | 13J | 51.4J |
| Ca | 151000 | 151000 | 79800 | 79500 | 224000 | 218000 | 199000 | 206000 | 201000 | 202000 | 216000 | 216000 | 275000 | 273000 | 206000 | 210000 |
| Cr | 5.8 | 8.5 | 2.9 | nd | 3.3 | 3.8 | 4 | 3.4 | 3.8 | 3.9 | 5 | 3.9 | nd | 4.6 | nd | nd |
| Co | 97.4 | 101 | 127 | 125 | 216 | 202 | 179 | 185 | 183 | 183 | 195 | 194 | 113 | 115 | nd | nd |
| Cu | 58.3 | 60.8 | 361 | 363 | 1010 | 916 | 741 | 775 | 755 | 753 | 1130 | 1140 | 233 | 234 | 22 | 37.9 |
| Fe | 30100 | 30200 | 47 | 146 | 4730 | 6010 | 7550 | 7860 | 7430 | 7900 | 14600 | 17500 | 27.9 | 602 | 18.4 | 59.1 |
| Pb | 3.7 | 5.6 | 2.1J | 2.5J | 4.0J | 4.9J | 4.4J | 3.8J | 5J | 5.1J | 3.6J | 4.4J | 3.4J | 6.8J | 1.7J | 1.4J |
| Mg | 51500 | 52200 | 44100 | 44000 | 63000 | 58100 | 50800 | 53000 | 51500 | 51900 | 55500 | 55900 | 104000 | 103000 | 80300 | 87000 |
| Mn | 5700 | 5720 | 19000 | 18900 | 19200 | 17000 | 14700 | 15200 | 14800 | 14900 | 15900 | 16000 | 4270 | 4250 | 6350 | 9450 |
| Hg | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ni | 227 | 232 | 368 | 353 | 430 | 409 | 357 | 373 | 367 | 364 | 393 | 412 | 412 | 414 | 342 | 413 |
| K | 2540 | 2910 | 1650 | 1980 | 2770 | 3000 | 3290 | 3000 | 3210 | 3220 | 2460 | 3200 | 3270 | 3360 | 3150 | 3000 |
| Se | nd | nd | na | na | na | na | na | na | na | na | na | na | 1.3J | na | 1.4J | 1.5J |
| Ag | nd | nd | nd | nd | nd | nd | 3.9 | 3.6 | nd | 3.2 | nd | 5.4 | nd | nd | nd | nd |
| Na | 15100 | 14900 | 10700 | 10500 | 26500 | 25500 | 22200 | 23000 | 22500 | 22300 | 27100 | 27100 | 32200 | 31600 | 22200 | 22400 |
| Tl | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| V | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Zn | 2090 | 2090 | 4560 | 4570 | 4890 | 4370 | 3790 | 3940 | 3840 | 3880 | 4230 | 4290 | 1650 | 1650 | 2470 | 3100 |

J - estimated value; nd - not detected; na - not available
Shaded data indicate concentrations which exceed 3 x background.
Note: Only Be and Cu represent CERCLA Hazardous Substances

Table 8. Release of CERCLA Hazardous Substances to Fractured Rock Aquifer at Molycorp Mine

| | Highest Background Concentration* | Capulin Canyon (MW-3)** | Sugar Shack West (MW-7)** | Sugar Shack South (MW-10b)** | Sugar Shack South (MW-11)** | Sugar Shack South (MW-11 dup.)** | Cabin Spring** |
|---|---|---|---|---|---|---|---|
| CLP ID# | | MFQ252 | MFQ251 | MFQ250 | MFQ249 | MFQ248 | MFQ266 |
| | F | F | F | F | F | F | UF |
| | | | | | | | |
| Analyte (ug/L) | | | | | | | |
| Al | 1200 | 876 | 77000 | 6720 | 43800 | 45900 | 34500 |
| As | <10 | 1.4J^ | 462J | nd | nd | nd | nd |
| Cd | 19 | nd | 97.4 | 23.3J | 30.3J | 32.3 | 28.8 |
| Cu | 30 | 16.7 | 4220 | 111 | 832 | 787 | 424 |
| Fe | 39000 | 121J^ | 329000 | 227 | nd | nd | nd |
| Mn | 43600 | 28400 | 54700 | 7640 | 24900 | 23600 | 20100 |
| Zn | 25600 | 1190 | 8750 | 1120 | 4330 | 4090 | 3540 |

* ref.12, Table D4; ref. 30, Table 1.4 (highest reported value)
** ref. ~~65~~ 64
F = filtered; UF = unfiltered
J - estimated value; ^ - datum biased high; nd - not detected
Shaded data indicate concentrations which exceed 3 x background.
Note: Only As, Cd and Cu represent CERCLA Hazardous Substances which have been released.

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Table 9. Metal Concentrations and General Chemistry Parameters in Private Wells below the Tailings Ponds

| Map Location | A | | C | | D | E | | N | | MCL |
|---|---|---|---|---|---|---|---|---|---|---|
| Field Station | CHANGE HOUSE WELL* W-1 (Background) | | DURAN WELL* W-5 | | Duplicate W-5.5 | RAEL WELL* W-5** | | HERRERA WELL* W-6.5 | | |
| CLP ID# | MFT996 | MFT995 | MFQ072 | MFQ071 | MFQ073 | MFQ998 | MFQ997 | MFQ982 | MFQ981 | |
| | Filtered | Unfiltered | Filtered | Unfiltered | Unfiltered | Filtered | Unfiltered | Filtered | Unfiltered | |
| Date Sampled | 4/18/94 | | 4/18/94 | | | 4/18/94 | | 4/19/94 | | |
| Used for Drinking? | | | No | | | Yes | | No | | |
| | | | | | | | | | | |
| Analyte (ug/L) | | | | | | | | | | |
| Al | <34 | 108 | nd | nd | nd | nd | 55.8 | nd | 3210 | 50-200 |
| Sb | <50 | <50 | nd | nd | nd | nd | nd | nd | nd | 6 |
| As | <1.0 | <1.0 | 4.7 | nd | nd | nd | nd | nd | 1.4J | 50 |
| Ba | 44.1 | 44.7 | 54 | 54.9 | 54.9 | 65.7 | 70 | 34.5 | 295 | 2000 |
| Be | <1.0 | <1.0 | nd | nd | nd | nd | nd | nd | nd | 4 |
| Cd | <5.0 | <5.0 | nd | nd | nd | nd | nd | nd | nd | 5 |
| Ca | 28200 | 28000 | 47400 | 46100 | 46000 | 80800 | 84000 | 231000 | 232000 | |
| Cr | <9.0 | <9.0 | nd | nd | nd | nd | nd | nd | 18.5 | 100 |
| Co | <9.0 | <9.0 | nd | nd | nd | nd | nd | nd | nd | |
| Cu | <6.0J | <6.0J | nd | nd | nd | nd | nd | nd | 7.2J | 1300al |
| Fe | 19 | 360 | nd | 1220 | 1420 | 13.5 | 849 | 184 | 17900 | 300 |
| Pb | <1.0 | 2.5 | nd | ND | 3.1 | nd | ND | 8.5N | 2.5 | 15al |
| Mg | 5260 | 5180 | 10400 | 10100 | 9970 | 14600 | 15600 | 44300 | 44400 | |
| Mn | 3.1 | 6.8 | 146 | 158 | 157 | 3.3 | 4.1 | 22 | 215 | 50a |
| Hg | <0.2 | <0.2 | nd | nd | nd | nd | nd | nd | nd | 2 |
| Ni | <11 | <11 | nd | nd | nd | nd | nd | nd | nd | 100 |
| K | <667 | <667 | 867 | 877 | 873 | <667 | 766 | 2840 | 2940 | |
| Se | <2.0 | 2.6 | nd | nd | nd | nd | nd | nd | nd | 50 |
| Ag | <5.0 | <5.0 | nd | nd | nd | nd | nd | nd | nd | 50 |
| Na | 66300 | 66400 | 15800 | 15100 | 14900 | 26100 | 26900 | 71400 | 69900 | |
| Tl | <2.0J | <2.0J | nd | nd | nd | nd | nd | nd | nd | 2 |
| V | <7.0 | <7.0 | nd | nd | nd | nd | nd | nd | 7.2 | |
| Zn | 75.4J | 75.1J | 101J | 150 | 165 | 206J | 266 | nd | 8.5J | 5000a |
| | | | | | | | | | | |
| | SF1386 | | SF1389 | | SF1390 | SF1387 | | SF1385 | | |
| Gen. Chem. (ug/L) | | | | | (filtered) | | | | | |
| Alk | 190000 | | 103000 | | 104000 | 112000 | | 154000 | | |
| COD | ND | | nd | | nd | nd | | nd | | |
| TDS | 292000 | | 288000 | | 277000 | 454000 | | 1290000 | | 500000a |
| TSS | ND | | nd | | nd | nd | | nd | | |
| NH3 | ND | | nd | | nd | nd | | nd | | |
| Cl | <2000 | | 6140 | | 6140 | 8420 | | 18300 | | 250000a |
| NOX | 400 | | 260 | | 280 | 400 | | 1040 | | |
| TOC | 5340J | | nd | | nd | 2460J | | 5820J | | |
| TPO4 | 120 | | nd | | nd | 120 | | 170 | | |
| SO4 | 58000 | | 72000 | | 84000 | 209000 | | 752000 | | 250a |

* ref. 65; ** Sample inadvertently labelled as W-5; nd - not detected; J - estimated value; ^ - value biased high

MCL - EPA Maximum Contaminant Level; a - aesthetic standard; i - irrigation standard

Stippled data are > 3 x background (or detected when undetected in background); additional shading for CERCLA Hazardous Substances

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Table 10. Total Metal Concentrations in Selected Monitoring Wells near Tailings Ponds (ref. 65)

| Map Location | A Change House Well (Background) | B MW-4 | F MW-9a | K MW-3 | L MW-1 | M MW-1 (Duplicate) | G MW-2 | H MW-C | I MW-7b | J MW-7c | MCL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date Sampled | 4/21/94 | 4/21/94 | 4/25/94 | 4/21/94 | 4/21/94 | 4/21/94 | 4/21/94 | 4/21/94 | 4/25/94 | 4/25/94 | |
| pH (paper) | 6.5 | 6.5 | 7.7* | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 | 7.6* | 7.3* | |
| Conductivity (umhos) | 328 | 1280 | 710 | 1120 | 1190 | - | 1340 | 1390 | 1180 | 1080 | |
| Field ID# | W-1 | W-2 | W-4 | W-6 | W-7 | W-7.5 | W-8 | W-9 | W-11 | W-12 | |
| CLP ID# | MFT995 | MFT969 | MFQ076 | MFQ979 | MFT975 | MFT977 | MFT971 | MFT973 | MFQ074 | MFQ069 | |
| Analyte (ug/L) | UF | UF | UF | UF | UF | UF | UF | UF | UF | UF | |
| Al | 108 | 36 | 78800 | 115 | 179 | 161 | 3690 | 94.3 | 53200J | 2540J | 50-200 |
| Sb | <50 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 6 |
| As | <1J | nd | 23.7 | nd | nd | nd | nd | nd | 15.2 | nd | 50 |
| Ba | 44.7 | 36.1 | 570 | 35.8 | 40 | 26.4 | 152 | 35 | 514 | 53.7 | 2000 |
| Be | <1.0 | nd | 4.7 | nd | nd | nd | nd | nd | 4.6 | nd | 4 |
| Cd | <5.0 | nd | nd | nd | nd | nd | nd | 9.1 | nd | nd | 5 |
| Ca | 28000 | 157000 | 197000 | 255000 | 224000 | 195000 | 222000 | 311000 | 274000 | 248000 | |
| Cr | <9.0 | nd | 109 | 13.1 | nd | nd | 22 | nd | 88.1 | nd | 100 |
| Co | <9.0 | nd | 32.1 | nd | nd | nd | nd | nd | 15.8 | 3.7 | |
| Cu | <6J | nd | 65.7 | nd | nd | nd | nd | nd | 39.9 | 7.8 | 1300al |
| Fe | 360 | 643 | 69500 | 455 | 612 | 562 | 25200 | 170 | 38600 | 1900 | 300 |
| Pb | 2.5 | 2.4 | 65.6 | 1.5 | nd | nd | 4.4vJ | nd | 44.9 | 5.3 | 15al |
| Mg | 5180 | 31800 | 49900 | 46500 | 46000 | 40500 | 50000 | 53200 | 60500 | 45700 | |
| Mn | 6.8 | 43.5 | 1880 | 14.9 | 24.2 | 19 | 774 | 2420 | 743 | 37.3 | 50a |
| Hg | <0.2 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 2 |
| Ni | <11 | nd | 82.2 | nd | nd | nd | 22.7 | nd | 65.3 | nd | 100 |
| K | <667 | nd | 11000 | 1240 | 2770 | 2470 | 3150 | 3420 | 13800 | 3250 | |
| Se | 2.6 | nd | nd | nd | nd | nd | nd | nd | nd | 2.6 | 50 |
| Ag | <5.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 50 |
| Na | 66400 | 65700 | 41100 | 67600 | 61100 | 52300 | 92100 | 87900 | 42300 | 39600 | |
| Tl | <2J | nd | nd | nd | nd | nd | nd | nd | nd | nd | 2 |
| V | <7.0 | nd | 91.7 | nd | nd | nd | nd | nd | 48.8 | 3.9 | |
| Zn | 75.1J | nd | 288 | nd | nd | nd | nd | nd | 177 | 16.4 | 5000a |

* pH measured by laboratory

UF - unfiltered sample; nd - not detected; J - estimated value; v - value biased low

MCL - EPA Maximum Contaminant Level; a - aesthetic std.; i - irrigation std.

Stippled data are > 3 x background (or detected when undetected in background); additional shading for metals representing CERCLA hazardous substances

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Table 11. Dissolved Metal Concentrations and General Chemistry Parameters in Selected Monitoring Wells near Tailings Ponds (ref. 64)

| Map Location | A Change House Well (Background) | B MW-4 | F MW-9a | K MW-3 | L MW-1 | M MW-1 (Duplicate) | G MW-2 | H MW-C | I MW-7b | J MW-7c | MCL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Field ID# | W-1 | W-2 | W-4 | W-6 | W-7 | W-7.5 | W-8 | W-9 | W-11 | W-12 | |
| CLP ID # | MFT996 | MFT970 | MFQ077 | MFQ980 | MFT976 | MFT978 | MFT972 | MFT974 | MFQ075 | MFQ070 | |
| Analyte (ug/L) | F | F | F | F | F | F | F | F | F | F | |
| Al | <34 | 55.7 | nd | nd | nd | 48 | 128 | 135 | nd | nd | 50-200 |
| Sb | <50 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 6 |
| As | <1J | nd | nd | nd | nd | nd | nd | nd | nd | nd | 50 |
| Ba | 44.1 | 36 | 92.7 | 31.4 | 26.2 | ND | 22.4 | 35.4 | 57.5 | 34 | 2000 |
| Be | <1.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 4 |
| Cd | <5.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 5 |
| Ca | 28200 | 158000 | 144000 | 243000 | 225000 | 222000 | 204000 | 307000 | 231000 | 237000 | |
| Cr | <9.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 100 |
| Co | <9.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | |
| Cu | <6J | nd | nd | nd | nd | nd | nd | nd | 3.5 | nd | 1300al |
| Fe | 19 | 31.3 | ND | 40.1 | nd | nd | 290 | nd | nd | nd | 300 |
| Pb | <1.0 | 4.2 | ND | 8.3^J | nd | nd | nd | nd | nd | nd | 15al |
| Mg | 5260 | 30900 | 28100J | 45000 | 46900 | 45800 | 45200 | 53800 | 43600 | 43400 | |
| Mn | 3.1 | 1.7 | 573J | 1.9 | 3.2^J | 3^J | 550 | 2400 | 12 | ND | 50a |
| Hg | <0.2 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 2 |
| Ni | <11 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 100 |
| K | <667 | 945 | 1420J | 973 | 2630 | 2690 | 2900 | 3620 | 5770 | 2670 | |
| Se | <2.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 50 |
| Ag | <5.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | 50 |
| Na | 66300 | 66600 | 40700J | 65900 | 61300 | 59800 | 89200 | 89300 | 40600 | 38200 | |
| Tl | <2J | nd | nd | nd | nd | nd | nd | nd | nd | nd | 2 |
| V | <7.0 | nd | nd | nd | nd | nd | nd | nd | nd | 2.6 | |
| Zn | 75.4J | nd | 37J | nd | nd | nd | nd | nd | 26.1J | 7.8J | 5000a |
| | | | | | | | | | | | |
| Gen. Chem. | | | | | | | | | | | |
| CLP ID# | SF1386 | SF1368 | SF1392 | SF1384 | SF1382 | SF1383 | SF1380 | SF1381 | SF1391 | SF1388 | |
| | | | | | | | | | | | |
| Alk | 190000 | 188000 | 162000 | 179000 | 152000J | 150000J | 67500J | 179000J | 134000 | 131000 | |
| COD | nd | nd | nd | nd | nd | 7200 | nd | 5860 | 6600 | nd | |
| TDS | 292000 | 928000 | 81400 | 1340000 | 1162000 | 1313000 | 1314000 | 1690000 | 1330000 | 1280000 | |
| TSS | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | |
| NH3 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | |
| Cl | 1000 | 8340 | 23500 | 18400 | 18300 | 18300 | 15600 | 17900 | 15200 | 16200 | |
| NOX | 400 | 320 | 360 | 370 | 710 | 710 | nd | nd | 330 | 340 | |
| TOC | 5340J | 7370J | 2150 | 5970J | 3030J | 4770J | 1990J | 5310J | 2280 | 1390 | |
| TPO4 | 120 | 120 | nd | 120 | 150 | 160 | nd | 120 | nd | nd | |
| SO4 | 58000 | 521000 | 384000 | 779000 | 701000 | 749000 | 825000 | 1013000 | 818000 | 740000 | |

F - filtered sample; nd - not detected; J - estimated value; ^ - value biased high; v - value biased low
MCL - EPA Maximum Contaminant Level
Stippled data are > 3 x background (or detected when undetected in background); additional shading for metals representing CERCLA hazardous substances

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Table 12. Total and Dissolved Metal Concentrations In Discharges below Tailings Ponds (ref. 64)

| Map Location | A Change House Well (Background) | | W Seep A | | V Seep D | | U Seep E | | O Embargo Rd. Seep | | R Outfall #002 | | X Warm Spring | | Y Cold Spring | | T Old Coldwater Spring Collection | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLP ID# | MFT996 | MFT995 | MFT955 | MFT954 | MFT953 | MFT952 | MFT952 | MFT951 | MFT959 | MFT958 | MFT963 | MFT962 | MFT947 | MFT946 | MFT949 | MFT948 | MFT967 | MFT966 |
| Analyte (ug/L) | F | UF | F | UF | F | UF | F | UF | F | UF | F | UF | F | UF | F | UF | F | UF |
| Al | <34 | 108 | nd | 480 | nd | 658 | 50.3 | 66.9 | 119 | 248 | 148 | 135 | 35.5 | nd | nd | nd | nd | 44.5 |
| Sb | <50 | <50 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| As | <1J | <1J | 1.2vJ | 2.2vJ | 1.3vJ | 2.1vJ | 2.1vJ | 2.7vJ | nd | nd | nd | nd | 2.9vJ | 2.9vJ | 1.6vJ | nd | nd | nd |
| Ba | 44.1 | 44.7 | 66.4 | 73.8 | 27.7 | 41.8 | 28.1 | 27.6 | 13.5 | 16.2 | 27.1 | 27.3 | 20.1 | 18.3 | 45.1 | 44.8 | 52.6 | 54.3 |
| Be | <1.0 | <1.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Cd | <5.0 | <5.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ca | 28200 | 28000 | 33600 | 33100 | 30800 | 30800 | 31200 | 31200 | 265000 | 269000 | 277000 | 291000 | 22200 | 21600 | 50900 | 50400 | 101000 | 105000 |
| Cr | <9.0 | <9.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Co | <9.0 | <9.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Cu | <6J | <6J | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Fe | 19 | 360 | nd | 494 | nd | 900 | nd | nd | nd | nd | nd | 19.9 | nd | nd | nd | nd | nd | nd |
| Pb | <1.0 | 2.5 | nd | 5 | nd | 2.7 | nd | nd | 1.1 | 1.7 | nd | nd | nd | nd | nd | nd | nd | nd |
| Mg | 5260 | 5180 | 10800 | 10700 | 9770 | 10000 | 9960 | 9850 | 45400 | 47200 | 46400 | 47400 | 6830 | 6730 | 8790 | 9120 | 16700 | 17400 |
| Mn | 3.1 | 6.8 | 3.7vJ | 8.6 | nd | 56.8 | 2.8vJ | 4.8vJ | 669 | 650 | 1820 | 1860 | 1vJ | nd | nd | nd | nd | nd |
| Hg | <0.2 | <0.2 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ni | <11 | <11 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| K | <667 | <667 | 3670 | 3490 | 2740 | 3140 | 2960 | 2690 | 4140 | 4350 | 3520 | 4010 | 2390 | 2280 | 1120 | 1210 | 1860 | 2130 |
| Se | <2.0 | 2.6 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ag | <5.0 | <5.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Na | 66300 | 66400 | 41200 | 41100 | 33000 | 33800 | 31800 | 31700 | 90100 | 92000 | 91700 | 91600 | 24900 | 24300 | 25100 | 24700 | 46000 | 48000 |
| Tl | <2J | <2J | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| V | <7.0 | <7.0 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Zn | 75.4J | 75.1J | nd | nd | nd | 11.8 | nd | nd | nd | 8.3 | nd | nd | nd | nd | nd | nd | nd | nd |
| | | | | | | | | | | | | | | | | | | |
| Gen. Chem. | | | | | | | | | | | | | | | | | | |
| | SF1386 | | SF1373 | | SF1371 | | SF1372 | | SF1375 | | SF1377 | | SF1369 | | SF1370 | | SF1379 | |
| Alk | 190000 | | 92900J | | 80200J | | 80200J | | 160000 | | 158000J | | 84400J | | 158000J | | 184000J | |
| COD | nd | | nd | | nd | | nd | | nd | | nd | | nd | | nd | | nd | |
| TDS | 292000 | | 320000 | | 287000 | | 281000 | | 1633000 | | 1580000 | | 199000 | | 266000 | | 563000 | |
| TSS | nd | | nd | | nd | | nd | | nd | | nd | | nd | | nd | | nd | |
| NH3 | nd | | nd | | nd | | nd | | nd | | nd | | nd | | nd | | nd | |
| Cl | <2000 | | 12000 | | 10300 | | 9610 | | 16000 | | 15600 | | 6880 | | 6080 | | 9530 | |
| NOX | 400 | | 210 | | 300 | | 390 | | nd | | nd | | 350 | | 630 | | 370 | |
| TOC | 5340J | | 1780J | | 1090J | | nd | | 3430J | | 2560J | | nd | | 1660J | | 2780J | |
| TPO4 | 120 | | 170 | | 170 | | 170 | | 130 | | 160 | | 160 | | 100 | | nd | |
| SO4 | 58000 | | 127000 | | 68000 | | 105000 | | 1005000 | | 973000 | | 54000 | | 67000 | | 254000 | |

F - filtered sample; UF - unfiltered sample
nd - not detected; J - estimated value; v - value biased low
Stippled data are > 3 x background (or detected when undetected in background); additional shading for metals representing CERCLA hazardous substances

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Table 13. Ratio of Metal Concentrations in Leachate or Drainage from Mine Dumps to Hydrothermal Scars

| Analyte (ug/L) | Average Mine Leachate Concentration (# of Samples=2) | Average Scar Leachate Concentration (Goathill & Hanson Crk) (# of Samples=2) | Ratio Mine Dump/Hydrothermal Scar |
|---|---|---|---|
| Al | 1245000 | 162850 | 7.6 |
| Sb | nd | 24 | na |
| As | 51 | 11 | 4.8 |
| Ba | na | na | na |
| Be | 439 | 57 | 7.7 |
| Cd | 490 | 11 | 43.8 |
| Ca | 383500 | 234500 | 1.6 |
| Cr | 320 | 11 | 29.0 |
| Co | 2910 | 286 | 10.2 |
| Cu | 12150 | 2445 | 5.0 |
| Fe | 663500 | 484435 | 1.4 |
| Pb | 10 | 4 | 2.7 |
| Mg | 952500 | 57900 | 16.5 |
| Mn | 603500 | 41905 | 14.4 |
| Hg | nd | 0.2 | na |
| Ni | 6550 | 559 | 11.7 |
| K | 801 | 3605 | 0.2 |
| Se | 7 | 8 | 1.0 |
| Ag | 80 | 35 | 2.3 |
| Na | 25150 | 8915 | 2.8 |
| Tl | 3 | 3 | 1.1 |
| V | 8 | 16 | 0.5 |
| Zn | 133000 | 8835 | 15.1 |
| Mo | 34 | 16 | 2.1 |

nd - not detected; na - not available or not calculable

Note: one half detection limit was used in calculating average when detected in the other sample.

Table 14 . Ratio of Metal Concentrations in Leachate from Mine Waste Dumps and Hydrothermal Scars*

| Analyte (mg/L) | Mine Waste Mean (n=9) | Scar Mean (n=8) | Ratio |
|---|---|---|---|
| Al | 471 | 230 | 2.1 |
| Cd | 0.14 | 0.03 | 5.4 |
| Cr | 1.24 | 0.48 | 2.6 |
| Co | 0.16 | 0.08 | 2.1 |
| Cu | 3.89 | 2.19 | 1.8 |
| Fe | 230 | 317 | 0.7 |
| Mn | 210 | 31 | 6.7 |
| Ni | 2.54 | 1.20 | 2.1 |
| Pb | 0.18 | 0.10 | 1.8 |
| Zn | 36.0 | 7.2 | 5.0 |

* ref.30, Table 1.2

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Table 15. Total Metal Concentrations in Surface Water near Molycorp Mine (ug/L)

| Map Location | 18 Red River above Hanson Creek | 17 Red River below Hanson Creek | 16 Red River above Molycorp (Background) | 12 Red River below (30') Adit Seep | 11 Red River above Columbine Creek | 10 Columbine Creek | 9 Red River below Columbine Creek | 7 Red River @ Goathill Gulch Seep | 6 Red River above Capulin Seeps | 5 Red River between Capulin Seeps | 3 Red River below (20') Capulin Seeps | 3 (duplicate) Red River below (20') Capulin Seeps | 2 Red River above Pipeline Crossing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | RR-12 | RR-11 | RR-10 | RR-9 | RR-8 | RR-7 | RR-6 | RR-5 | RR-4a | RR-4 | RR-3 | RR-2 | RR-1 |
| CLP ID# | MFQ393 | MFQ392 | MFQ272 | MFQ271 | MFQ243 | MFQ199 | MFQ198 | MFQ197 | MFQ196 | MFQ195 | MFQ194 | MFQ193 | MFQ192 |
| | | | | | | | | | | | | | |
| Date Sampled | 11/8/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 |
| Temp (C) | na | 4.5 | 5 | 5 | 6 | 4.5 | 5.5 | 6 | 4.5 | 6 | 6 | 6 | 7 |
| pH | 6 | 6 | 6 | 6.5 | 6.5 | 7 | 7 | 7 | 6.5 | 6.5 | 7 | 6.5 | 6.5 |
| Cond. (umhos) | na | 160 | 178 | 190 | 195 | 80 | 172 | 230 | 222 | 235 | 250 | 250 | 261 |
| | UF | UF | UF | UF | UF | UF | UF | UF | UF | UF | UF | UF | UF |
| | | | | | | | | | | | | | |
| Analyte (ug/L) | | | | | | | | | | | | | |
| Al | 347 | 612 | 1070 | 1290 | 1080 | 49.7 | 856 | 1270 | 1540 | 1690 | 2050 | 2050 | 2590 |
| Sb | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| As | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ba | 40.9 | 40.5 | 41.1 | 39.6 | 36.5 | 41.8 | 37.4 | 37.1 | 36.7 | 36.1 | 36.5 | 36.7 | 36.9 |
| Be | 0.35 | 0.35 | 0.34 | nd | 0.35 | nd | 0.45 | 0.59 | 0.45 | 0.54 | 0.45 | 0.55 | 0.7 |
| Cd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ca | 33300 | 34200 | 36900 | 40700 | 39800 | 23000 | 36600 | 44600 | 46000 | 46100 | 46900 | 46600 | 47000 |
| Cr | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Co | nd | nd | nd | nd | nd | nd | nd | 6.8 | nd | nd | nd | 7.9 | 7.4 |
| Cu | 13.1 | 11.2 | 14.3 | 15.9 | 15.6 | | 10 | 16.2 | 21.8 | 20.5 | 24.3 | 26.1 | 29.8 |
| Fe | 294 | 376 | 394 | 557 | 320 | 49.7 | 263 | 265 | 269 | 279 | 386 | 355 | 407 |
| Pb | - | - | 1.1 | - | 0.93 | - | - | 1.1 | 1 | nd | nd | nd | 1.3 |
| Mg | 7090 | 7240 | 8220 | 9200 | 9070 | 2290 | 7670 | 10100 | 10500 | 10500 | 10700 | 10600 | 11000 |
| Mn | 109 | 138 | 208 | 299 | 267 | - | 208 | 495 | 531 | 553 | 607 | 603 | 851 |
| Hg | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ni | nd | nd | nd | nd | nd | nd | nd | nd | nd | 18.7 | nd | 23 | nd |
| K | 1200 | 1140 | 1030 | 999 | 1210 | 810 | 983 | 1320 | - | 1090 | 668 | 1130 | 971 |
| Se | nd | nd | nd | nd | nd | nd | nd | nd | 873 | nd | nd | nd | nd |
| Ag | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Na | 5260 | 5120 | 5430 | 5230 | 5530 | 21000 | 4830 | 5250 | 5620 | 5610 | 5660 | 5550 | 5490 |
| Tl | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| V | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Zn | 32.1 | 48.7 | 60.9 | 92.8 | 75.3 | 3.3 | 56.5 | 123 | 132 | 136 | 153 | 149 | 205 |

nd - not detected

Shaded data is > 3 x background; only Zn is a listed CERCLA hazardous substance

1 5 7 8 0

Table 16. Dissolved Metal Concentrations and General Chemistry Parameters in Surface Water near Molycorp Mine

| Map Location | 18 Red River above Hanson Creek | 17 Red River below Hanson Creek | 16 Red River above Molycorp (Background) | 12 Red River below (30') Adit Seep | 11 Red River above Columbine Creek | 10 Columbine Creek | 9 Red River below Columbine Creek | 7 Red River @ Goathill Gulch Seep | 6 Red River above Capulin Seeps | 5 Red River between Capulin Seeps | 3 Red River below (20') Capulin Seeps | 3 (duplicate) Red River below (20') Capulin Seeps | 2 Red River above Pipeline Crossing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | RR-12 | RR-11 | RR-10 | RR-9 | RR-8 | RR-7 | RR-6 | RR-5 | RR-4a | RR-4 | RR-3 | RR-2 | RR-1 |
| CLP ID# | MFQ397 | MFQ396 | MFQ395 | MFQ394 | MFQ253 | MFQ254 | MFQ255 | MFQ256 | MFQ257 | MFQ258 | MFQ259 | MFQ260 | MFQ261 |
| | F | F | F | F | F | F | F | F | F | F | F | F | F |
| | | | | | | | | | | | | | |
| Analyte (ug/L) | | | | | | | | | | | | | |
| Al | 115 | 48.4 | 115 | 51.5 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Sb | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| As | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ba | 44.2 | 40.2 | 36.7 | 33.6 | 37 | 43.4 | 37 | 36.1 | 35.4 | 35 | 36.3 | 35.2 | 36.5 |
| Be | nd | 0.3 | nd | 0.3 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Cd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ca | 33400 | 34300 | 36900 | 38800 | 42200 | 24600 | 38400 | 46500 | 48600 | 48800 | 49200 | 49000 | 49900 |
| Cr | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Co | nd | nd | nd | nd | nd | nd | nd | nd | nd | 5.1 | nd | nd | 6.7 |
| Cu | 6.8 | 3.7 | 3.7 | 4.4 | 4.3 | nd | 3.1 | 3.7 | 3.1 | 5.6 | 4.9 | 6.2 | 6.8 |
| Fe | 29.5 | 12.7 | 19.3 | 29 | nd | nd | nd | 211 | nd | nd | nd | nd | nd |
| Pb | nd | nd | 1.9 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Mg | 7050 | 7260 | 8140 | 8760 | 9540 | 2540 | 8080 | 10800 | 11200 | 11100 | 11200 | 11200 | 11600 |
| Mn | 106 | 130 | 195 | 250 | 275 | - | 216 | 513 | 550 | 573 | **630** | **628** | **875** |
| Hg | nd | nd | nd | nd | 0.22J^ | 0.2J^ | nd | nd | nd | nd | nd | nd | nd |
| Ni | nd | nd | nd | nd | nd | nd | nd | nd | 22.1 | 19.5 | 28.7 | 20.4 | 33 |
| K | 868 | 775 | 1320 | 1220 | 720 | 697 | 1170 | 613 | 1020 | 1110 | 1080 | 1190 | 1070 |
| Se | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ag | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Na | 5400 | 5270 | 5640 | 5750 | 5250 | 2160 | 4660 | 5290 | 5560 | 5480 | 5480 | 5410 | 5600 |
| Tl | nd | nd | nd | nd | nd | nd | nd | nd | nd | 1.4 | nd | nd | nd |
| V | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Zn | 22.1 | 28.8 | 29.9 | 62 | 49.4 | 6.6 | 45.1 | **103** | **103** | **110** | **125** | **126** | **159** |
| Gen. Chem. | | | | | | | | | | | | | |
| (mg/L)* | | | | | | | | | | | | | |
| Ca | 41 | 42 | 45 | 48 | 49 | 26 | 40 | 49 | 51 | 50 | 52 | 53 | 54 |
| Mg | 7 | 7 | 8 | 9 | 9 | 3 | 8 | 11 | 11 | 11 | 12 | 12 | 12 |
| K | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Na | 5 | 5 | 6 | 6 | 6 | - | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| Hardness | 131 | 134 | 145 | 154 | 157 | 74 | 135 | 166 | 175 | 171 | 176 | 179 | 184 |
| Alkalinity | 64 | 62 | 58 | 56 | 56 | 64 | 58 | 52 | 50 | 49 | 47 | 46 | 42 |
| HCO3 | 78 | 76 | 72 | 69 | 68 | 78 | 71 | 64 | 61 | 60 | 57 | 57 | 52 |
| Cl | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| SO4 | 55 | 59 | 74 | 88 | 89 | 10 | 71 | 106 | 112 | 114 | 117 | 118 | 122 |
| TDS | 200 | 206 | 220 | 246 | 234 | 98 | 224 | 256 | 262 | 266 | 282 | 284 | 283 |
| TSS | 4 | 6 | 9 | 9 | 10 | - | 5 | 9 | 8 | 10 | 10 | 13 | 8 |

F = filtered sample

- not detected; J^ - estimated value which is biased high

* New Mexico State Laboratory Division data

Shaded data is > 3 x background of which only Zn is a listed CERCLA hazardous substance

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Table 17. Metal Concentrations and General Chemistry Parameters in the Red River near Molycorp Mine: 6/26/94

| | Red River above Hanson Creek | | Red River below Columbine Creek | | Red River at USFS Ranger Station | |
|---|---|---|---|---|---|---|
| Date Sampled<br>CLP ID# | 6/26/94<br>SF5850<br>F | 6/26/94<br>SF5852<br>UF | 6/26/94<br>SF5841<br>F | 6/26/94<br>SF5844<br>UF | 6/26/94<br>SF5861<br>F | 6/26/94<br>SF5862<br>UF |
| Analyte (ug/L) | | | | | | |
| Al | 73.3 | 286 | 84.1 | 284J^ | nd | 1360 |
| Sb | nd | nd | 31.7 | nd | nd | nd |
| As | nd | nd | nd | na | na | na |
| Ba | 25.6 | 29.4 | 32.3 | 38J | 26.9J | 39.8J |
| Be | nd | nd | nd | nd | nd | nd |
| Cd | nd | nd | nd | nd | nd | nd |
| Ca | 21500 | 21200 | 21200 | 21700J | 29000J | 29800J |
| Cr | nd | nd | nd | nd | nd | nd |
| Co | nd | nd | nd | nd | 5.4J | 5.9J |
| Cu | nd | nd | nd | nd | nd | nd |
| Fe | 40.3 | 331 | 15.3 | nd | nd | nd |
| Pb | nd | nd | nd | 2.5J | na | 2J |
| Mg | 3520 | 3510 | 2850 | 2960 | 5890 | 6210 |
| Mn | 29.4 | 37.1 | 33.3 | 55.8 | 369 | 407 |
| Hg | 0.2 | nd | nd | nd | nd | 0.22 |
| Ni | nd | nd | nd | nd | nd | nd |
| K | 796 | nd | nd | nd | nd | nd |
| Se | na | na | na | nd | nd | nd |
| Ag | nd | nd | nd | nd | nd | nd |
| Na | 2210 | 2070 | 1900 | nd | nd | nd |
| Tl | nd | nd | nd | nd | nd | nd |
| V | nd | nd | nd | nd | nd | nd |
| Zn | 18.3 | 10.1 | 10.1 | 25.7 | 62.8 | 95.2 |
| | | | | | | |
| | | | | | | |
| Gen. Chem. | | | | | | |
| | SF5854 | | SF5848 | | SF5863 | |
| Alk | 57000 | | 63300 | | 45400 | |
| COD | nd | | nd | | nd | |
| TDS | 102000 | | 92000 | | 156000 | |
| TSS | 10000 | | 12000 | | 14000 | |
| NH3 | nd | | nd | | nd | |
| Cl | nd | | nd | | nd | |
| NOX | 150 | | 100 | | 160 | |
| TOC | 2650 | | 2550 | | 2700 | |
| TPO4 | 240 | | 140 | | nd | |
| SO4 | 21000 | | 12600 | | 53700 | |

Shaded data are > 3 x concentration below Columbine Creek

Note: of the elevated parameters, only Zn is a CERCLA Hazardous Substance

nd - not detected; na - not usable; F - filtered sampled; UF - unfiltered sample

J - estimated value; ^ - value biased high

Table 18. Metal Concentrations in Sediments from the Red River near Molycorp Mine Area

| Map Location | L Red River above Hanson Crk. | K Red River below Hanson Crk. | J Red River above Molycorp Property (Background) | I Red River below (30') Adit Seep | H Red River above Columbine Creek | G Columbine Creek | F Red River below Columbine Creek | E Red River below Goathill Seep | D Red River above Capulin Seeps | C Red River between per and low Capulin Seeps | B Red River below (20') Capulin Seeps (duplicate) | B Red River below (20') Capulin Seeps | A Red River above Pipeline Crossing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date Sampled: | 11/8/94 | 11/8/94 | 11/8/94 | 11/8/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 | 11/7/94 |
| Field ID # | S-12 | S-11 | S-10 | S-9 | S-8 | S-7 | S-6 | S-5 | S-4a | S-4 | S-3 | S-2 | S-1 |
| CLP ID# | MFQ696 | MFQ695 | MFQ399 | MFQ398 | MFQ191 | MFQ190 | MFQ189 | MFQ187 | MFQ188 | MFQ186 | MFQ185 | MFQ184 | MFQ182 |
| Analyte (mg/kg) | | | | | | | | | | | | | |
| Al | 15000 | 4510 | 5250 | 12200 | 12600 | 10500 | 10500 | 10900 | 13900 | 24200 | 19500 | 16000 | 12600 |
| Sb | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| As | 10Jv | 5.6Jv | 4Jv | 8.5Jv | 11.2Jv | 1.2Jv | 8.4Jv | 6.1Jv | 7.4Jv | 9.2Jv | 8.8Jv | 6.1Jv | 11Jv |
| Ba | 787 | 262 | 439 | 694 | 601 | 78.5 | 567 | 406 | 537 | 578 | 569 | 508 | 499 |
| Be | 1.1 | 0.34 | 0.43 | 1.3 | 1.2 | 0.46 | 1.1 | 1.1 | 2.0 | 2.4 | 1.8 | 1.5 | 1.6 |
| Cd | nd | nd | nd | nd | nd | nd | nd | nd | 2.3 | nd | nd | nd | nd |
| Ca | 3690 | 1190 | 1470 | 2340 | 2900 | 2490 | 3020 | 2210 | 3230 | 1860 | 2150 | 1980 | 2990 |
| Cr | 23.5 | 6.5 | 8.8 | 22.1 | 20.5 | 12.5 | 16.8 | 20.3 | 18.7 | 22.3 | 23.9 | 20.7 | 18.5 |
| Co | 12.9 | 4 | 6.9 | 13.2 | 14.1 | 13.1 | 12.7 | 13.3 | 19 | 13.5 | 14.6 | 12.2 | 21.6 |
| Cu | 142 | 22 | 25.1 | 135 | 78.8 | 21.2 | 71.1 | 104 | 126 | 152 | 110 | 95.3 | 116 |
| Fe | 45800 | 14800 | 17600 | 40600 | 38400 | 26700 | 33600 | 31300 | 33700 | 47600 | 41800 | 38000 | 34400 |
| Pb | 163 | 21.4 | 29.3 | 94.4 | 130 | 118 | 106 | 91.1 | 97.6 | 144 | 119 | 102 | 132 |
| Mg | 6110 | 1700 | 2210 | 5310 | 5300 | 7420 | 4560 | 5090 | 4640 | 5400 | 5680 | 4970 | 4670 |
| Mn | 636 | 115 | 165 | 534 | 538 | 701 | 550 | 466 | 1080 | 553 | 501 | 468 | 1310 |
| Hg | nd | nd | nd | nd | nd | 0.13 | nd | nd | 0.22 | nd | nd | nd | nd |
| Ni | 23.2 | 8.6 | 13.9 | 24 | 31.2 | 7.4 | 30.9 | 18.1 | 50.3 | 29.4 | 32.5 | 27.3 | 53.6 |
| K | 5290 | 1980 | 1700 | 3640 | 3980 | 1030 | 3130 | 2540 | 3080 | 4330 | 3960 | 3390 | 2890 |
| Se | 1.8 | 0.44 | nd | 1.1 | 1.6 | nd | 1.1 | 1.4 | 1.6 | 1.4 | 1.3 | 0.94 | 1.9 |
| Ag | 3.3 | nd | nd | nd | nd | 1.9 | 1.9 | 2.3 | 12.5 | nd | nd | 1.6 | 1.6 |
| Na | 292 | 76.5 | 122 | 297 | 277 | 54.4 | 238 | 245 | 254 | 326 | 290 | 241 | 232 |
| Tl | nd | nd | nd | nd | nd | nd | nd | nd | nd | 0.69 | nd | nd | nd |
| V | 24.8 | 6.5 | 7.9 | 20.5 | 20.6 | 43.6 | 16.8 | 22.2 | 18.9 | 21.2 | 24.7 | 21.6 | 18.6 |
| Zn | 274 | 44.5 | 93.9 | 190 | 237 | 136 | 221 | 182 | 548 | 208 | 250 | 220 | 469 |

nd - not detected; Jv - estimated value is biased low
Stippled data are > 3 x background concentration (or detected when undetected at background location)
Additional shading for those metals representing CERCLA hazardous substances

Table 19. Metal Concentrations in Selected Seeps and Surface Water Bodies near the Tailings Ponds

| Map Location | ~~18~~ O Embargo Rd. Seep | | ~~19~~ P Irrigation Ditch above Seep | | ~~20~~ Q Irrigation Ditch below Seep | | ~~21~~ R #002 OUTFALL | | ~~22~~ S 50' W of 002 OUTFALL | |
|---|---|---|---|---|---|---|---|---|---|---|
| CLP ID# | MFT959 | MFT958 | MFT961 | MFT960 | MFT957 | MFT956 | MFT963 | MFT962 | MFT965 | MFT964 |
| Analyte (ug/L) | F | UF | F | UF | F | UF | F | UF | F | UF |
| Al | 119 | 248 | 111 | 971 | 136 | 1050 | 148 | 135 | 40 | 149 |
| Sb | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| As | nd | nd | nd | nd | 1.2 | nd | nd | nd | nd | nd |
| Ba | 13.5 | 16.2 | 27.4 | 32 | 26 | 37.7 | 27.1 | 27.3 | 57.5 | 60.8 |
| Be | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Cd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ca | 265000 | 269000 | 49100 | 46800 | 45700 | 52900 | 277000 | 291000 | 123000 | 119000 |
| Cr | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Co | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Cu | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Fe | nd | nd | 109 | 963 | 116 | 1160 | nd | 19.9 | 33.4 | 251 |
| Pb | 1 | 1.7 | nd | nd | nd | 1.4vJ | nd | nd | nd | nd |
| Mg | 45400 | 47200 | 9190 | 8970 | 8500 | 9910 | 46400 | 47400 | 20700 | 20800 |
| Mn | 569 | 650 | 8.8vJ | 36.4 | 15.8 | 65 | 1820 | 1860 | 11 | 10.9vJ |
| Hg | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ni | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| K | 4140 | 4350 | 863 | 1110 | 791 | 1390 | 3520 | 4010 | 1060 | 1370 |
| Se | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ag | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Na | 90100 | 92000 | 15400 | ND | 14700 | ND | 91700 | 91600 | 48000 | 46700 |
| Tl | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| V | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Zn | nd | 8.3 | nd | nd | nd | nd | nd | nd | nd | nd |
| | | | | | | | | | | |
| Gen. Chem. | | | | | | | | | | |
| (ug/L) | | | | | | | | | | |
| CLP ID# | SF1375 | | SF1376 | | SF1374 | | SF1377 | | SF1378 | |
| | | | | | | | | | | |
| Alk | 160000 | | 71800J | | 71800J | | 158000J | | 167000J | |
| COD | nd | | 8410 | | 6840 | | nd | | nd | |
| TDS | 1633000 | | 273000 | | 304000 | | 1580000 | | 679000 | |
| TSS | nd | | nd | | nd | | nd | | nd | |
| NH3 | nd | | nd | | nd | | nd | | nd | |
| Cl | 16000 | | 3630 | | 3860 | | 15600 | | 12300 | |
| NOX | nd | | 130 | | 130 | | nd | | nd | |
| TOC | 3430J | | 3000J | | 2890J | | 2560J | | 2840J | |
| TPO4 | 130 | | nd | | 110 | | 160 | | 100 | |
| SO4 | 1005000 | | 121000 | | 127000 | | 973000 | | 290000 | |

F - filtered sample; UF - unfiltered sample
nd - not detected; J - estimated value; v - value is biased low

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Table 20. Loading of Sulfate and Selected Metals into the Red River by Stream Segment during ESI Sampling

| Location: | Flow (cfs)* | SO4 conc. | SO4 gain | Mass gain | % of total gain | |
|---|---|---|---|---|---|---|
| | | mg/l | (flow x conc) | | | |
| Abv. Molycorp Mill | 18 | 74 | 1332 | 499.8 | 31.8 | Moly Mill to Columbine Ck. |
| Below Columbine Crk. | 25.8 | 71 | 1832 | 1030.2 | 65.6 | Columbine to Goathill Gulch |
| Goathill Gulch | 27 | 106 | 2862 | 418.4 | 26.6 | Goathill to Blw Capulin Cyn |
| Blw Capulin Canyon | 27.8 | 118 | 3280 | 196.6 | 12.5 | Blw Capulin Cyn to Eagle Rk CG |
| Eagle Rock CG | 28.5 | 122 | 3477 | | | |
| FS Ranger St. | 29 | | | | | |
| | | | Total Gain = | 2145 | | |
| | | | | | | |
| | | | | | | |
| Location: | Flow (cfs) | Al conc. | Al gain | Mass gain | % of total gain | |
| | | mg/l | (flow x conc) | | | |
| Abv. Molycorp Mill | 18 | 1.07 | 19.3 | 2.8 | 5.2 | Moly Mill to Columbine Ck. |
| Below Columbine Crk. | 25.8 | 0.856 | 22.1 | 12.2 | 22.4 | Columbine to Goathill Gulch |
| Goathill Gulch | 27 | 1.27 | 34.3 | 22.7 | 41.6 | Goathill to Blw Capulin Cyn |
| Blw Capulin Canyon | 27.8 | 2.05 | 57.0 | 16.8 | 30.8 | Blw Capulin Cyn to Eagle Rk CG |
| Eagle Rock CG | 28.5 | 2.59 | 73.8 | | | |
| FS Ranger St. | 29 | | | | | |
| | | | Total Gain = | 54.6 | | |
| | | | | | | |
| Location: | Flow (cfs) | Mn conc. | Mn gain | Mass gain | % of total gain | |
| | | mg/l | (flow x conc) | | | |
| Abv. Molycorp Mill | 18 | 0.195 | 3.5 | 1.9 | 8.9 | Moly Mill to Columbine Ck. |
| Below Columbine Crk. | 25.8 | 0.208 | 5.4 | 8.0 | 38.6 | Columbine to Goathill Gulch |
| Goathill Gulch | 27 | 0.495 | 13.4 | 3.4 | 16.4 | Goathill to Blw Capulin Cyn |
| Blw Capulin Canyon | 27.8 | 0.603 | 16.8 | 7.5 | 36.1 | Blw Capulin Cyn to Eagle Rk CG |
| Eagle Rock CG | 28.5 | 0.851 | 24.3 | | | |
| FS Ranger St. | 29 | | | | | |
| | | | Total Gain = | 20.7 | | |
| | | | | | | |
| Location: | Flow (cfs) | Zn conc. | Zn gain | Mass gain | % of total gain | |
| | | mg/l | (flow x conc) | | | |
| Abv. Molycorp Mill | 18 | 0.061 | 1.098 | 0.4 | 7.9 | Moly Mill to Columbine Ck. |
| Below Columbine Crk. | 25.8 | 0.057 | 1.4706 | 1.9 | 39.0 | Columbine to Goathill Gulch |
| Goathill Gulch | 27 | 0.123 | 3.321 | 0.9 | 19.7 | Goathill to Blw Capulin Cyn |
| Blw Capulin Canyon | 27.8 | 0.153 | 4.2534 | 1.6 | 33.5 | Blw Capulin Cyn to Eagle Rk CG |
| Eagle Rock CG | 28.5 | 0.205 | 5.8425 | | | |
| FS Ranger St. | 29 | | | | | |
| | | | Total Gain = | 4.7 | | |

* Flow was estimated by applying flow rates from Vail 1993 to gauged flow of 29 cfs.

Shaded data represents reach of Red River demonstrating highest gain

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Table 21. Sulfate Gain Observed in Red River between Molycorp Property and USFS Ranger Station

| Nov. 7, 1994 | flow (cfs) | SO4 conc. (mg/l) | SO4 gain | Gain w/in stream reach | % of total gain | |
|---|---|---|---|---|---|---|
| Blw Hanson Crk | 13.9 | 59 | 820 | 246 | 13.5 | Hanson Crk to Moly Mill |
| Abv Moly Mill | 14.4 | 74 | 1066 | 314 | 17.3 | Moly Mill to Columbine Ck. |
| Abv Col. Crk | 15.5 | 89 | 1380 | 794 | 43.7 | Columbine to Goathill G. |
| Goathill Gulch | 20.5 | 106 | 2173 | 317 | 17.5 | Goathill to Blw Capulin Cyn |
| Blw Cap. Cyn | 21.1 | 118 | 2490 | 145 | 8.0 | Blw Capulin Cyn to Eagle Rk C |
| Eagle Rock CG | 21.6 | 122 | 2635 | | | |
| FS Ranger St. | 25 | | 0 | | | |
| | | | | 1815 | | |

| Feb. 16, 1993 (ref. 28, App. 2, 3) | flow (cfs) | SO4 conc. (mg/l) | SO4 gain | Gain w/in stream reach | % of total gain | |
|---|---|---|---|---|---|---|
| Blw Hanson Crk | 13.9 | 33.81 | 470 | 180 | 7.9 | Hanson Crk to Moly Mill |
| Abv Moly Mill | 14.4 | 45.17 | 650 | 234 | 10.2 | Moly Mill to Columbine Ck. |
| Abv Col. Crk | 15.5 | 57.06 | 884 | 1276 | 55.5 | Columbine to Goathill G. |
| Goathill Gulch | 20.5 | 105.38 | 2160 | 206 | 9.0 | Goathill to Blw Capulin Cyn |
| Blw Cap. Cyn | 21.1 | 112.13 | 2366 | 401 | 17.5 | Blw Capulin Cyn to Ranger St. |
| FS Ranger St. | 22 | 125.77 | 2767 | | | |
| | | | | 2297 | | |

| Oct. 22, 1992 (ref. 28, App. 2, 3) | flow (cfs) | SO4 conc. (mg/l) | SO4 gain | Gain w/in stream reach | % of total gain | |
|---|---|---|---|---|---|---|
| Blw Hanson Crk | 15.8 | 66 | 1043 | 326 | 11.7 | Hanson Crk to Moly Mill |
| Abv Moly Mill | 16.1 | 85 | 1369 | 638 | 22.9 | Moly Mill to Columbine Ck. |
| Abv Col. Crk | 17.6 | 114 | 2006 | 1069 | 38.4 | Columbine to Goathill G. |
| Goathill Gulch | 23.3 | 132 | 3076 | 284 | 10.2 | Goathill to Blw Capulin Cyn |
| Blw Cap. Cyn | 24 | 140 | 3360 | 465 | 16.7 | Blw Capulin Cyn to Ranger St. |
| FS Ranger St. | 25 | 153 | 3825 | | | |

| Nov. 29, 1988 (ref. 28, App. 2, 3) | flow (cfs) | SO4 conc. (mg/l) | SO4 gain | Gain w/in stream reach | % of total gain | |
|---|---|---|---|---|---|---|
| Blw Hanson Crk | 10.7 | 46 | 492 | 216 | 11.8 | Hanson Crk to Moly Mill |
| Abv Moly Mill | 10.9 | 65 | 709 | 468 | 25.5 | Moly Mill to Columbine Ck. |
| Abv Col. Crk | 12 | 98 | 1176 | 499 | 27.2 | Columbine to Goathill G. |
| Goathill Gulch | 15.8 | 106 | 1675 | 297 | 16.2 | Goathill to Blw Capulin Cyn |
| Blw Cap. Cyn | 16.3 | 121 | 1972 | 357 | 19.4 | Blw Capulin Cyn to Ranger St. |
| FS Ranger St. | 17 | 137 | 2329 | | | |
| | | | | 1837 | | |

| Nov. 25, 1988 (ref. 28, App. 2, 3) | flow (cfs) | SO4 conc. (mg/l) | SO4 gain | Gain w/in stream reach | % of total gain | |
|---|---|---|---|---|---|---|
| RR@Elephant CG | 16 | 46 | 736 | 564 | 16.7 | Hanson Crk to Moly Mill |
| Abv Moly Mill | 20 | 65 | 1300 | 562 | 16.7 | Moly Mill to Columbine Ck. |
| Abv Col. Crk | 19 | 98 | 1862 | 1000 | 29.6 | Columbine to Goathill G. |
| Goathill Gulch | 27 | 106 | 2862 | 647 | 19.2 | Goathill to Blw Capulin Cyn |
| Blw Cap. Cyn | 29 | 121 | 3509 | 601 | 17.8 | Blw Capulin Cyn to Ranger St. |
| FS Ranger St. | 30 | 137 | 4110 | | | |
| | | | | 3374 | | |

Shaded data represent reach of Red River demonstrating highest SO4 gain

Table 22. Metal Concentrations in Residentials Areas near Tailings Ponds: South

| Map Location<br><br>CLP ID#<br>Soil Type*<br><br>Analyte (mg/kg) | Average Metal Conc. in Tailings (N=8) | Highest Metal Conc. in Background Soil<br><br>Sedillo Soil Type* | Ratio of Conc. (tailings/bckgrd) | 17 Change House<br><br>MFT934<br>Sedillo | 15 Feliciano Rael<br><br>MFT937<br>Sedillo | 14 Roger Herrera<br><br>MFT938<br>Sedillo | 16 Cecil Clines<br><br>MFT939<br>Sedillo | Benchmark (ref. 2) |
|---|---|---|---|---|---|---|---|---|
| Al | 8050 | 3180 | 2.5 | 8290 | 7140 | 7070 | 8300 | |
| Sb | nd | 7.3 | na | nd | nd | nd | nd | |
| As | 0.78 | 0.84 | 0.9 | 1.9 | 1.5 | 1.3 | 1.4 | |
| Ba | 87 | 54.1 | 1.6 | 157 | 108 | 156 | 121 | |
| Be | 1 | 0.21 | 4.3 | 0.63 | 0.56 | 0.58 | 0.49 | |
| Cd | 0.2 | nd | na | nd | nd | nd | nd | |
| Ca | 16250 | 1230 | 13.2 | 5360.0 | 2490.0 | 8670.0 | 3060 | |
| Cr | 40 | 4.2 | 9.6 | 12.8 | 16.4 | 14 | 17.5 | 2900 |
| Co | 10 | 3.3 | 3.2 | 7.3 | 9.1 | 7.1 | 8.7 | |
| Cu | 188 | 7.0 | 26.9 | 31.7 | 20.1 | 20.3 | 22.7 | na |
| Fe | 16693 | 7780 | 2.1 | 11700 | 14200 | 11300 | 15400 | |
| Pb | 58 | 13.5 | 4.3 | 33.7 | 17.3 | 21.7 | 15.7 | |
| Mg | 7743 | 1120 | 6.9 | 3520.0 | 3350.0 | 3710.0 | 3830.0 | |
| Mn | 471 | 317 | 1.5 | 527 | 541 | 548 | 469 | |
| Hg | nd | nd | na | nd | nd | nd | nd | |
| Ni | 30 | 4.0 | 7.5 | 13.6 | 15.5 | 15.4 | 15.6 | 12000 |
| K | 4761 | 1100 | 4.3 | 1650 | 1650 | 2960 | 1650 | |
| Se | nd | nd | na | nd | nd | nd | nd | |
| Ag | nd | nd | na | nd | nd | nd | nd | |
| Na | 137 | 45.8 | 3.0 | 56.7 | 49.4 | 97.8 | 89.9 | |
| Tl | 0.5 | nd | na | nd | nd | nd | nd | |
| V | 35 | 8.7 | 4.0 | 18.6 | 19.3 | 14.8 | 21.9 | |
| Zn | 121 | 38.4 | 3.1 | 63.7J | 57.8J | 80.8J | 52.4J | |

* ref.5

** Cancer Risk Screening Concentration (ref. 2)

Shaded data are CERCLA hazardous substances which are > 3 x background concentrations.

J - estimated value; nd - not detected; na - not available or calculable

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Table 23. Metal Concentrations in Residentials Areas near Tailings Ponds: North

| Map Location | Average Metal Concentration in Tailings | 23 1/4-mile north of Questa Jr. High (initial background) | 24 Cerro Rd. # 1 (background) | 25 Cerro Rd. # 2 (background) | 26 Cerro Rd. # 2 (duplicate) | Average Background Concentration | Ratio of Concentrations (tailings/bckgrd) | 22 Questa Jr. High School-2 | 20 Questa Jr. High School-3 | 21 Questa Jr. High School-3 (duplicate) | 18 Arch Trujillo | 19 Romolo Martinez |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLP ID# | (N=8) | MFT945 | MFQ-082 | MFQ-083 | MFQ-084 | | | MFT931 | MFT932 | MFT933 | MFT935 | MFT936 |
| Soil Type* | | Silva | Silva | Silva | Silva | Silva Soil Type | | Silva | Silva | Silva | Silva | Silva |
| Analyte (mg/kg) | | | | | | | | | | | | |
| Al | 8050 | 13600 | 9790 | 8950 | 13700 | 11510 | 0.7 | 12300 | 8000 | 10900 | 8710 | 8650 |
| Sb | nd | nd | nd | nd | nd | nd | na | nd | nd | nd | nd | nd |
| As | 0.78 | nd | 4.7 | 4.4 | 5.5 | 3.7 | 0.2 | 2.3 | 2 | nd | 2.5 | 1.5 |
| Ba | 87 | 187 | 156 | 159 | 185 | 172 | 0.5 | 218 | 196 | 195 | 167 | 192 |
| Be | 1 | 0.75 | 0.72 | 0.79 | 0.97 | 0.81 | 1.1 | 0.88 | 0.67 | 0.69 | 0.62 | 0.62 |
| Cd | 0.2 | 0.98 | nd | 0.57 | 0.65 | 0.55 | 0.4 | nd | nd | 1.2 | nd | nd |
| Ca | 16250 | 4670 | 2570 | 2280 | 2580 | 3025 | 5.4 | 9970 | 7680 | 7010 | 13700 | 14000 |
| Cr | 40 | 13.2 | 13.1 | 13.7 | 17.7 | 14.4 | 2.8 | 11.8 | 8.2 | 11.5 | 9 | 14.5 |
| Co | 10 | 7.1 | 10 | 12 | 14.3 | 10.9 | 1.0 | 8.7 | 7.7 | 6.7 | 6.6 | 7.8 |
| Cu | 188 | 14.4 | 17.4 | 24.3 | 29.2 | 21.3 | 8.8 | 19.5 | 16.9 | 16 | 16.4 | 30.2 |
| Fe | 16693 | 17200 | 17500 | 19400 | 25000 | 19775 | 0.8 | 15000 | 10700 | 14300 | 13200 | 12500 |
| Pb | 58 | 16.2vJ | 20.3 | 23.5 | 24.9 | 21.2 | 2.7 | 18.7 | 15.8 | 3.3vJ | 16.4 | 48.4 |
| Mg | 7743 | 4100 | 2550 | 2590 | 3220 | 3115 | 2.5 | 4100 | 3100 | 3700 | 3980 | 4280 |
| Mn | 471 | 493 | 655 | 789 | 904 | 710 | 0.7 | 589 | 504 | 518 | 457 | 542 |
| Hg | nd | nd | nd | nd | nd | nd | na | nd | nd | nd | nd | nd |
| Ni | 30 | 12.4 | 11 | 11.6 | 14.3 | 12.3 | 2.4 | 12.6 | 9.2 | 11.2 | 11.5 | 14.3 |
| K | 4761 | 2650 | 1850 | 2230 | 2910 | 2410 | 2.0 | 3040 | 1700 | 2070 | 2090 | 2630 |
| Se | nd | 0.21J | 1.1J | 0.92 | 1.4J | 0.23 | 0.0 | nd | nd | nd | nd | nd |
| Ag | nd | nd | nd | nd | nd | nd | na | nd | nd | nd | nd | 0.81 |
| Na | 137 | 86.9 | 86.2 | 79.6 | 105 | 89.4 | 1.5 | 104 | 61.6 | 73.5 | 93.7 | 85.6 |
| Tl | nd | nd | nd | nd | nd | nd | na | nd | nd | nd | nd | nd |
| V | 35 | 24.8 | 36.1 | 33 | 41.3 | 33.8 | 1.0 | 19.8 | 19.9 | 22.4 | 24.5 | 21 |
| Zn | 121 | 49.3 | 48.5 | 65.3 | 85.3 | 62.1 | 1.9 | 60.7J | 42.1J | 44.1 | 52.6J | [illegible] |

* ref. 5

J = estimated value; v - value biased low

nd = not detected; na = not available or calculable

Note: Shaded datum is > 3 x background but also > average concentration in tailings

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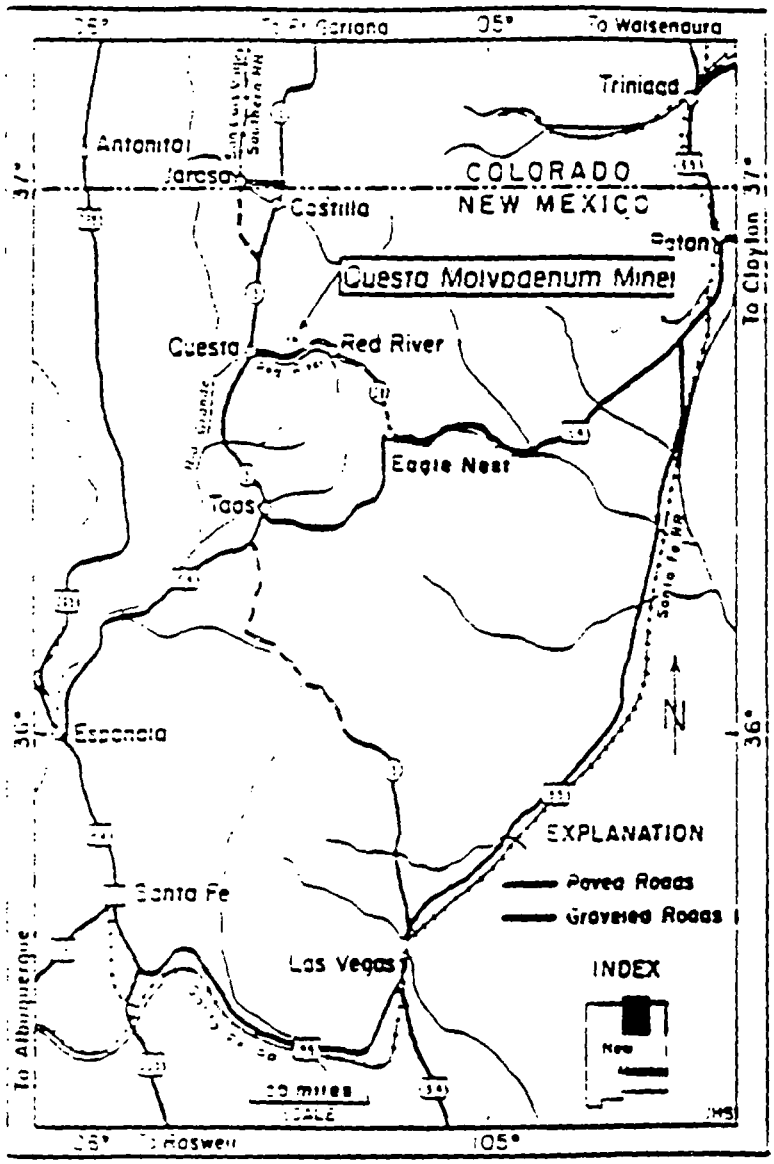


INDEX MAP SHOWING THE LOCATION OF THE QUESTA MOLYBDENUM MINE.

Figure 1 (from Ref. 8)

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LATIR PEAK AND WHEELER PEAK WILDERNESSES

CARSON NATIONAL FOREST

NEW MEXICO

1990

MAP LEGEND

- Forest Service Land
- Pueblo de Taos Indian Reservation
- Other Land
- Cañon del Rio Grande Wilderness
- Cañon del Rio Grande Recreation Area
- National Forest Boundary
- National Forest Administrative Boundary
- Wilderness Boundary
- Wilderness Study Area Boundary
- County Boundary
- Primary Highway
- Secondary Highway
- Improved Dirt or Gravel Road
- Unimproved Dirt Road
- Trail
- U.S. Highway
- State Highway
- Forest Service Road
- Forest Service Trail
- Ranger District Office
- Forest Service Recreation Site
- Other Recreation Site
- Designated Campsites
- Mine
- Locked Gate
- Fenceline
- Powerline
- Perennial Stream
- Intermittent Stream
- Spring

Tailings Ponds

#5A

#2

#1

#4

Mine Waste Dumps

North Ditch

Middle Ditch

South Ditch

Molino Ditch

Red River

BLM Wild & Scenic River

Rio Grande

CARSON NATIONAL

LATIR PEAK WILDERNESS

N

1-mile

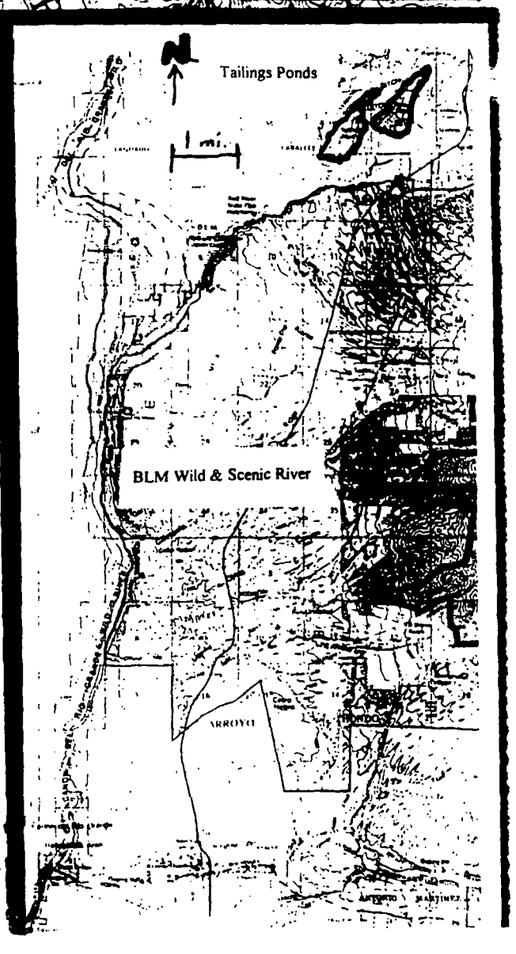


Figure 2. Molycorp Site Map

INSERT
COLOR / OVERSIZED
IMAGE

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Figure 4. Sampling Locations near the Tailings Ponds

| SOIL SAMPLES | | | WATER SAMPLES | | |
|---|---|---|---|---|---|
| Map ID# | Location | Date Sampled | Map ID# | Location | Date Sampled |
| 1 | Tailings Pond (TP)-4 | 4-18-94 | A | Change House Well | 4-21-94 |
| 2 | TP-4 | 4-18-94 | B | MW-4 | 4-21-94 |
| 3 | TP-4 | 4-18-94 | C | Duran Well | 4-25-94 |
| 4 | TP-5A | 4-18-94 | D | Duran Well (dupl.) | 4-25-94 |
| 5 | TP-5A (dupl.) | 4-18-94 | E | Rael Well | 4-21-94 |
| 6 | TP-1 | 4-18-94 | F | MW 9a | 4-25-94 |
| 7 | TP-1 | 4-18-94 | G | MW 2 | 4-21-94 |
| 8 | TP-2 | 4-18-94 | H | MW C | 4-21-94 |
| 9 | Along USFS Rd. 493 | 4-19-94 | I | MW 7b | 4-25-94 |
| 10 | Along USFS Rd. 493 | 4-19-94 | J | MW 7c | 4-25-94 |
| 11 | Along USFS Rd. 493 | 4-19-94 | K | MW 3 | 4-21-94 |
| 12 | 300' E of Fenceline | 4-19-94 | L | MW-1 | 4-21-94 |
| 13 | 700' E of Fenceline | 4-19-94 | M | MW-1 (dupl.) | 4-21-94 |
| 14 | Roger Herrera | 4-19-94 | N | Herrera Well | 4-20-94 |
| 15 | Feliciano Rael | 4-19-94 | O | Embargo Road Seep | 4-20-94 |
| 16 | Cecil Clines | 4-19-94 | P | Irrigation Ditch abv "O" | 4-20-94 |
| 17 | Change House | 4-19-94 | Q | Irrigation Ditch blw "O" | 4-20-94 |
| 18 | Arch Trujillo | 4-19-94 | R | Outfall #002 | 4-20-94 |
| 19 | Romolo Martinez | 4-19-94 | S | Irrigation Ditch @ Red R. | 4-20-94 |
| 20 | Questa Jr. High-2 | 4-18-94 | T | Old Coldwater Spr. Collectio | 4-20-94 |
| 21 | Questa Jr. High-3 | 4-18-94 | U | Seep "E" @ Red R. | 4-20-94 |
| 22 | Questa Jr. High-3 (dupl | 4-18-94 | V | Seep "D" @ Red R. | 4-20-94 |
| 23 | 1/4 mi. N of Jr. High | 4-19-94 | W | Seep "A" @ Red R. | 4-20-94 |
| 24 | Cerro Road #1 | 5-9-95 | X | Warm Spring @ Hatchery | 4-20-94 |
| 25 | Cerro Road #2 | 5-9-95 | Y | Cold Spring @ Hatchery | 4-20-94 |
| 26 | Cerro Rd. #2 (duplicate | 5-9-95 | | | |

2-mile radius

1-mile radius

1/2-mile radius

1/4-mile radius

N

Probable Point of Entry-final (PPE 2)

Boundary of Federally Designated Wild and Scenic River

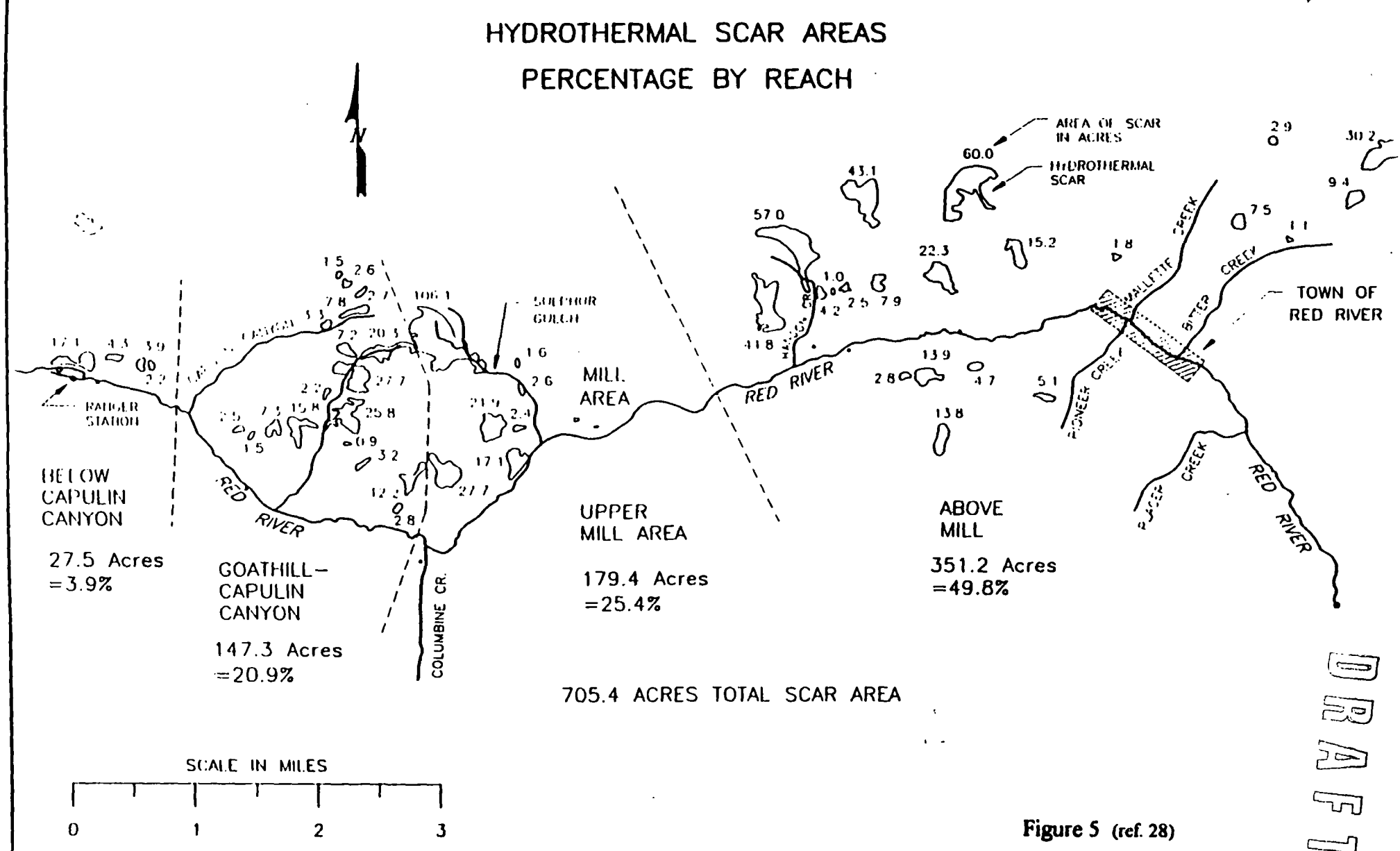


**Figure 5** (ref. 28)

HYDROTHERMAL SCAR AREAS

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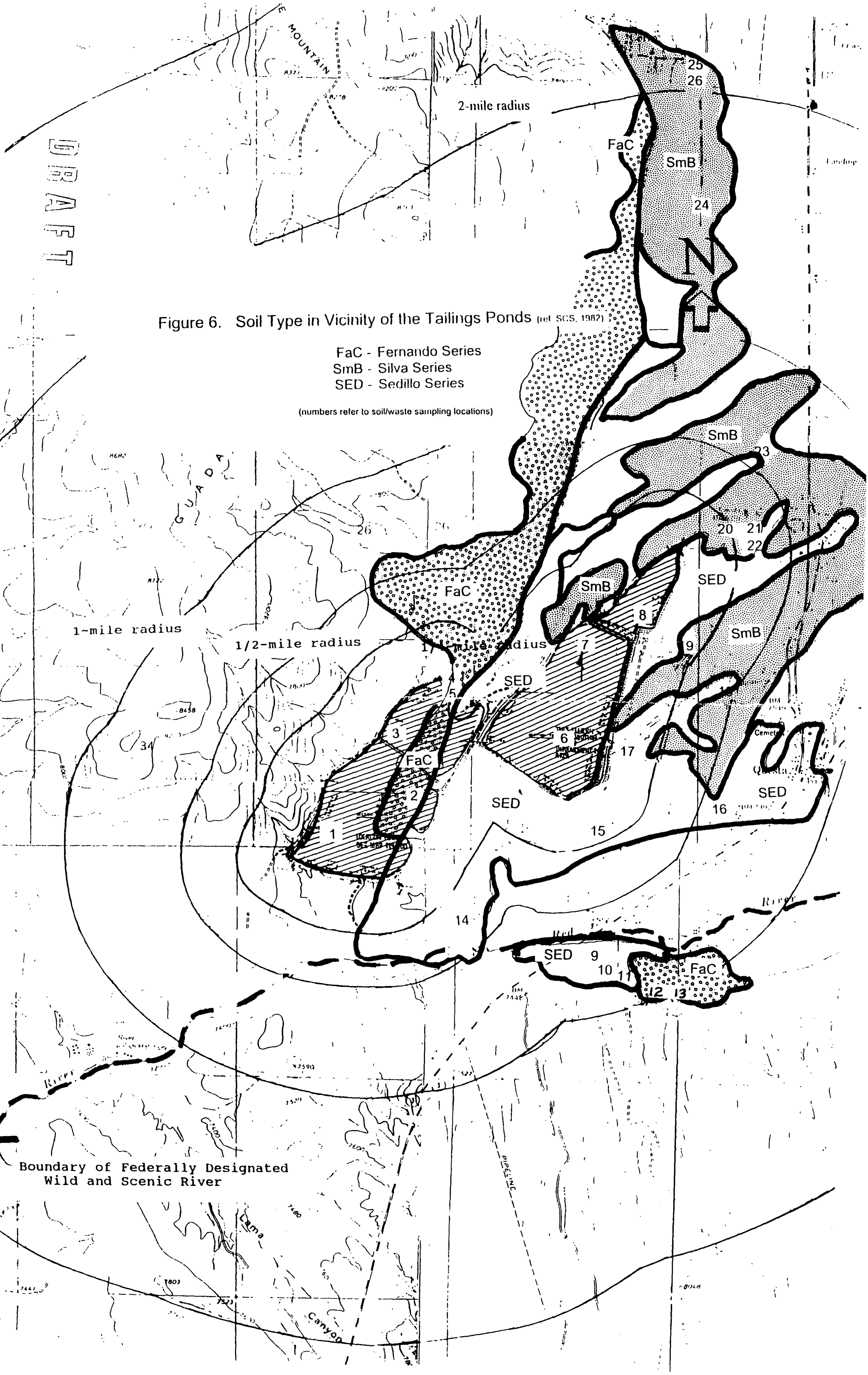


Figure 6. Soil Type in Vicinity of the Tailings Ponds (ref. SCS, 1982)

FaC - Fernando Series
SmB - Silva Series
SED - Sedillo Series

(numbers refer to soil/waste sampling locations)

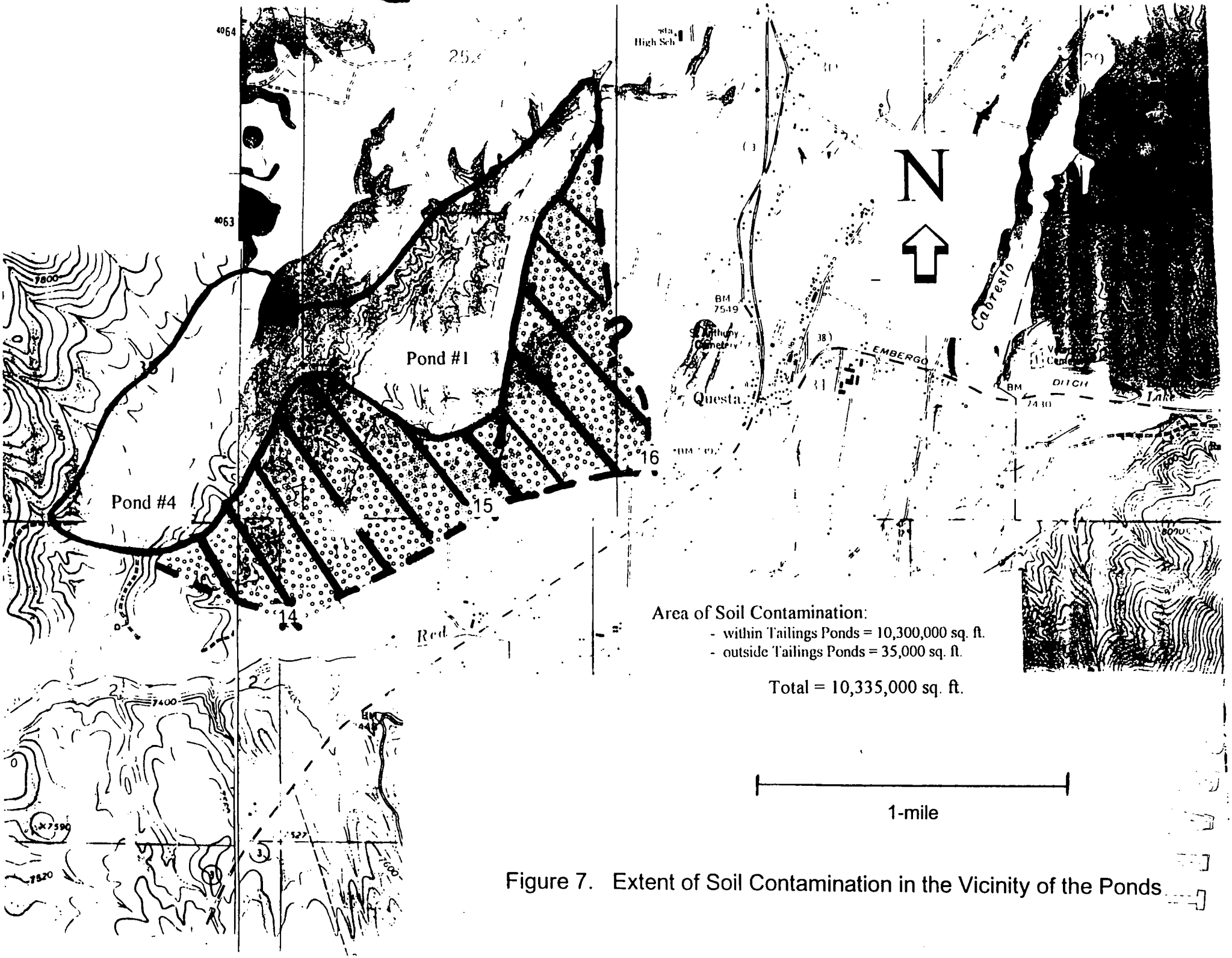


Figure 7. Extent of Soil Contamination in the Vicinity of the Ponds

#18

SOUTH PASS RESOURCES, Inc.
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NM 22306

# PROGRESS REPORT ON THE GEOLOGY, HYDROGEOLOGY, AND WATER QUALITY OF THE MINE AREA
## Molycorp Facility
## Taos County, New Mexico

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# Progress Report on the Geology, Hydrogeology, And Water Quality of the Mine Area

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# 1.0 INTRODUCTION AND SUMMARY

## 1.1 INTRODUCTION

The Molycorp molybdenum mine is located on the western slope of the Taos Range of the Sangre de Cristo Mountains, Taos County in north-central New Mexico (Figure 1). The Mine Area lies north of the Red River and State Highway 38 which connects the mine area with the Town of Red River (6 miles to the east) and the Town of Questa (6 miles to the west). For the purposes of this report, the study area has been defined as the ***Mine Area,*** which consists of extraction, processing, and rock-waste deposition activities. The significant features associated with the Mine Area are shown on Figure 2.

Mining for molybdenum began in the Questa area between 1916 to 1920. The nature of mining activities progressed form the original underground workings to open-pit operations (beginning in 1964-65), and back to the more recent underground mining (beginning in 1979-1983). Mine waste-rock dumps were emplaced during the 1970s and 1980s when the open pit was excavated. The mine went on temporary standby status in 1986 until economic conditions improve for the molybdenum market. Mine dewatering resumed in July 1994 in anticipation of potential reactivation of mining activities.

The Molycorp mining operations have been both extractive in nature (the Mine Area) and simultaneously depositional (the Mine Area waste-rock dumps and the Tailings Area). Large-scale extractive or depositional activities normally will have an impact on a natural environment. Molycorp has been both proactive and responsive to examination of the environmental impacts resulting from their activities. In the Mine Area, any adverse water-quality impacts are exacerbated, if not exceeded, by natural impacts (e.g.-acid runoff from hydrothermal scars). Water-quality data from several sources, including the Red River sewage treatment plant well, Hanson Creek, and Hot-N-Tot Creek indicate significant natural contributions to surface-water and ground-water quality degradation.

In 1989, Molycorp retained the services of South Pass Resources, Inc. (*SPRI*) to evaluate impacts of past and present Molycorp operations on ground-water and surface-water quality. The dominant environmental concerns are two-fold:

- What impacts, if any, have mining operations had on surface-water (Red River) or ground-water quality?
- What percentage of any surface-water or ground-water quality degradation is from natural (versus mining-related) sources?

These issues are under study by consultants currently retained by Molycorp (including SPRI, Vail Engineering, and Steffen Robertson & Kirsten). Previous studies by SPRI, Dames and Moore, Harding-Lawson, Water Resource Associates, Geocon, Vail and Associates, ENSR, and others have focused on definition of the geologic, hydrogeologic, water quality, and hydrologic characteristics in and about the Molycorp facilities. Of particular emphasis has been definition of those naturally-occurring physical and chemical parameters that control real or potential contaminant migration pathways and concentrations.

SPRI's most recent (Summer and Fall 1994) activities have involved the design, installation, and testing of 12 new monitor wells in the Mine Area. This report presents a detailed discussion of the results of the 1994 investigation, and of previous investigations, and an evaluation of recent geologic, hydrogeologic, and water-quality data.

## 1.2 SUMMARY OF FALL 1994 AND PREVIOUS INVESTIGATIONS

Beginning on July 11, 1994, SPRI overviewed the design, installation, and testing of 12 new monitor/extraction wells in the Mine Area. The purpose of this investigation was to:

- characterize the water quality of naturally occurring ground water and seeps and compare these data to seepage from mining activities; and
- characterize the geologic controls on fluid movement.

In addition, the drawdown associated with the cone of depression from dewatering of the mine is being monitored within the newly-installed wells. It will take a year or more of monitoring before drawdown rates can be quantified; some additional monitor wells may be required.

The wells that were installed during the 1994 investigation, and the details of their installation and testing, are summarized below. The locations of these wells and other wells installed in the Mine Area are shown on Figure 2.

| Monitor/Extraction Wells Installed in Mine Area<br>July/August 1994 | | | |
|---|---|---|---|
| **Well No.** | **Total Depth (feet)** | **Screened Interval (feet)** | **Well Completed In** |
| MMW-2 | 68 | 38 - 58 | mudflow |
| MMW-3 | 145 | 65 - 115 | andesite bedrock |
| MMW-7 | 161 | 86 - 161 | andesite bedrock |
| MMW-8A | 161 | 125 - 161 | andesite bedrock |
| MMW-8B | 129 | 67 - 117 | mudflow |
| MMW-10A | 144 | 79 - 130 | alluvial gravel/ sand overlying quartz monzonite bedrock |
| MMW-10B | 189 | 133 - 189 | quartz monzonite bedrock |
| MMW-10C | 50 | 31.5 - 50 | mudflow |
| MMW-11 | 185 | 145 - 185 | quartz monzonite bedrock |
| MMW-13 | 148 | 105 - 148 | sandy gravel, gravelly sand overlying quartz monzonite |
| MMW-14 | 75 | 48 - 75 | sandy gravel gravelly sand |
| MMW-16 | 98 | 45 - 98 | sandy gravel gravelly sand overlying light grey granite |

A partial listing of the other monitor and extraction wells in the Mine Area that pre-date SPRI field activities are summarized below. (Note: a complete list of all wells located in the study area is unknown at this time.)

| Other Wells Located in the Mine Area<br>(Partial Listing) | | |
|---|---|---|
| **Well No.** | **Total Depth (feet)** | **Year Installed** |
| Mill Well 1A-1 | 176 | 1977 |
| Mill Well No. 1 | 150 | 1962 |
| Columbine No. 1 | 89 | 1965 |
| Columbine No. 2 | 140 | 1965 |
| Columbine No. 1 redrill | 153 | 1971 |

# 2.0 GEOLOGY AND HYDROGEOLOGY

## 2.1 GENERAL GEOLOGIC SETTING

The major sources of geologic data for the Questa Mine area are Schilling (1956), Rehrig (1969), Lipman (1981), Bookstrom (1981), and numerous unpublished maps, cross-sections, and reports by Molycorp geologists. A common thread to all of these geologic studies is that the mineralization at Questa was related to Tertiary magnetism and hydrothermal solutions focused along an east- to northeast-trending structural zone. This structural zone is variously interpreted as part of a graben (Schilling, 1956); as a zone of intense faulting (called the Red River Structural Zone by Rehrig, 1969); and the southern part of the outer ring fracture zone that formed the outer wall of the Questa caldera (Lipmann, 1981; Bookstrom, 1981).

The development of the caldera and the associated volcanic and intrusive rocks was a late Oligocene to Middle Miocene event (27.2 to 22 million years before present) that was concurrent to and overlapped the regional rifting associated with the Rio Grande Rift System. The range-bounding high-angle fault along the west side of the Sangre de Cristo Mountains (about 5 miles west of the mine) is related to regional extension across the Rio Grande Rift and the uplift of the range in Mid-Tertiary time. At least the later movements along this range-front fault are younger than the caldera structure because the outer ring fracture zone is truncated by the range-front fault.

## 2.2 MINE AREA GEOLOGY AND HYDROGEOLOGY

*Geology*

The Mine Area is composed of Pre-Cambrian igneous, metasedimentary, metavolcanic, and other metamorphic rocks, overlain by a thick sequence of Tertiary ashflow tuffs and andesitic lava flows. These rock types have been intruded by granitic rocks, forming dikes, and elongated intrusions. Mineralized quartz veins in the Mine Aplite (i.e., finely crystalline granite) and in the adjacent intruded volcanics were formed during a late magmatic, post-caldera hydrothermal stage. The Mine Area is within a northeast- to east-trending structural rift zone that forms the south side of the Questa caldera. This structural rift zone contains numerous dikes and mineral veins. Fractures and fault discontinuities are widely varied, as illustrated on a geologic cross-section (Figure 3), and include:

- high-angle faults and joints;
- low-angle faults; and

- contact-zone fractures between different rock units.

The mined ore deposits consist of molybdenite-bearing quartz veins.

*Hydrogeology*

In the Mine Area, the most significant controls to fluid movement appear to be preferred channels within mud flows, location and degree of geologic discontinuities (faults, joints, fractures), man-made fluctuations of the water table north of the Red River, and hydraulic conductivity differences between mine waste-rock, bedrock, and valley-fill (mudflow or alluvium). Water-quality degradation of the Red River in the Mine Area has been found to be heavily controlled by natural processes and is influenced locally from byproducts of mining.

Hydrogeologic units include a basement (Pre-Cambrian) aquitard, overlain by volcanics and sedimentary rock aquifers, and/or valley-fill mudflow and alluvial valley-fill aquifers. Hydrothermal scar materials of low hydraulic conductivity are scattered over the area. Mine waste dumps contain perched aquifers.

The natural ground-water gradients are toward the Red River. Mine dewatering operations have created a cone of depression around the underground mine workings. The primary hydrologic linkage between up-gradient sources and the river is the fan delta deposits at the mouths of tributary canyons at Capulin Canyon and Sugar Shack South. The 12 monitor/extraction wells installed by SPRI in Fall 1994 were screened in fan delta and bedrock aquifers, and were constructed at sites near the mouths of tributary canyons to evaluate these linkages. Water-quality sampling and water-level measurements were made in cooperation with the New Mexico Environmental Improvement Department (EID) in November 1994.

In the Mine Area, low pH, high total dissolved solids (TDS), and high sulfate characterize the natural springs and seeps as well as surface water in drainages crossing hydrothermal scar areas. Analytical results of water quality sampling along and adjacent to the Red River indicates both natural and mine-related seepage affect the water quality of the Red River. Deep underground mine water has a slightly alkaline pH plus slightly elevated levels of TDS and sulfate.

Water in the unsaturated zone, water in the perched-water zones, and ground water move from sources to discharge points. Sources of this water are both natural and mine-related: infiltration, surface run-off, and seepage from natural springs and mine-constructed waste-rock piles. The discharge points consist of the deep underground mine, the Red River, and (via slurry line) the Tailings Area ponds. Water that arrives at the discharge points

consists of natural acidic drainage mixed with varying amounts of waste-rock dump-related water.

Naturally acidic waters have been in transit through the same system, excluding seepage barriers, for thousands of years as is evident from limonite-cemented alluvial and mudflow deposits.

Perched water can form near the base of the waste-rock dumps. Perched water can also form in zones of fractured bedrock above the main water table and above clay intervals in the valley-fill. Bedrock seeps, such as the seeps at Cabin Springs near the river, may be from a perched bedrock zone.

Dewatering of the new underground mine (1979 to 1992 and resumed in July 1994) has created a cone of depression that appears to extend in some places to the Red River. The original cone of depression may have captured much of the natural and mine-related discharge. However, Capulin Canyon appears to lie outside the zone of influence of dewatering. Also, the Cabin Spring seepage (which may be perched) may not be impacted by the dewatering cone of depression.

The impact of the current mine dewatering on recharge of mine-related seepage to the Red River cannot be properly evaluated until after at least one year of data collection including monthly water-level measurements and quarterly water-quality analysis (similar to data collection of November 1994). Bladder pumps were used to collect water-quality samples at all of the mine monitor/extraction wells because (with some exception) the wells appear to be low yield (less than a few gallons per minute). The known exceptions are MMW-11 (bedrock well in a fracture zone), which pumped at a rate of more than 60 gpm, and MMW-10A (valley-fill well), which pumped at 140 gpm with 3 feet of drawdown. Because the existing extraction wells in the Mine Area tend to be low-yield wells, their capacity to control seepage by pumping is limited.

Appendices A and B contain more detailed discussions of the Mine Area geology and hydrogeology. Appendix C contains geologic logs for wells emplaced during SPRI's 1994 investigation. Appendix D contains data and discussions on water quality.

# 3.0 RESULTS AND DISCUSSION OF SPRI SUMMER/FALL 1994 FIELD ACTIVITIES

## 3.1 WELL EMPLACEMENTS

To identify and evaluate the presence of potential hydrogeologic connections between the waste-rock dumps, down-gradient aquifers, and the Red River, aerial photographs were used to locate the monitor/extraction wells as close as possible to the pre-1963 valley bottom. [In a number of areas, waste-rock dumps and/or mine cut-and-fill operations have subsequently covered these drainages. The fan delta deposits (alluvial sediments and mudflow deposits, collectively called the *valley-fill aquifer*) occur at the mouths of tributary valleys to the Red River (see Figure 4).]

The equipment used to drill the monitor/extraction wells consisted of a casing drive system using 8-inch and 12-inch inside diameter (ID) threaded drive casing. A casing drive shoe was attached to the base of the casing driver and remained at the bottom of the cased hole after hydraulic jacks extracted the drive casing. Well construction and placement of annular materials were accomplished inside the drive casing, limiting the well casing to 8 inches or less inside the 12-inch drive casing and 6 inches or less inside the 8-inch drive casing. A downhole air hammer and hammer bit were used to drill through boulders and bedrock. The drill equipment consisted of a 15W Gardner Denver Tophead drive chain pulldown drill rig, water truck, pipe truck, air compressor truck (primary), tag-along air compressor (secondary), and hydraulic jacks' truck.

All wells that had water in the borehole were developed by either pneumatic downhole bladder pump, bailing, or electric submersible pump. Low-yield wells were pumped using the pneumatic bladder pumps (for their design protections against pump burnup). The medium-yield wells were pumped by continuous bailing with an 18-gallon bailer. The bailing operation used a hydraulic powered 5T Smeal pump truck to raise and lower the bailer. Bailing rates were adjusted to fit each well's yield so as to allow for baildown without undue interruption of the extraction rate. High-yield wells were pumped with either one horsepower (hp) or 5 hp electric submersible well pumps. The actual high-end pumping rate varied with head considerations, but the 5 hp pump would usually pump up to 50 gallons per minute.

When the locations of the monitor wells were established and surveyed for elevation by Molycorp staff, elevations for wells with protruding casing vaults were taken at the top of the casing and elevations for wells with flush-mounted vaults were taken at the top of the cement pad. All measuring point elevations have been corrected to read from the top of the cement pad.

## 3.2 WATER LEVELS AND HYDRAULIC CONNECTIONS

SPRI overviewed the installation of 12 new monitor wells during the 1994 investigation (refer to Figures 2 and 10 for locations). These wells and their hydrologic characteristics are described below.

### Wells MMW-14 and MMW-16

These wells, which are located in the fan delta or valley-fill deposits and the immediately underlying bedrock opposite the Sulphur Gulch and Spring Gulch area, are dry. The open pit (Sulphur Gulch) and the decline that passes under lower Sulphur Gulch may capture most of the discharge from the drainage basin. (These wells are not deep enough to intersect the cone of depression if it extends into this area.)

### Well MMW-13

This well was drilled opposite the Middle Dump and extended initially into bedrock (25 feet); it was completed as a valley-fill well since the bedrock was dry. It is difficult to distinguish reworked valley-fill from in-situ valley-fill by drill cuttings alone. Berms were constructed across the lower parts of some tributary valleys prior to dump construction. Using elevations for the pre-berm surface from the 1963 USGS topographic map (Questa, NM 7.5 Minute Quadrangle Map) and more recent mine topographic maps, the upper 50 to 70 feet of sandy gravel at MMW-13 appear to be berm material. The lower 15 feet of the valley-fill was saturated. The water-level elevation at this well is low (7,963 feet) when compared to the stream bed elevation opposite the well (7,990 to 8,000 feet). This water-level elevation has changed less than 1.0 foot over the five-month period since construction. The water level will continue to be monitored for evidence of additional drawdown related to the mine cone of depression.

### Wells MMW-10A, B, C

These wells are located below the toe of Sugar Shack South Dump. The elevation of the Red River opposite these wells is between 7,910 and 7,920 feet. The water quality of Portal Springs (a series of river bank seeps along the north side of the river) is commensurate with natural acidic sources and/or waste-rock dumps. The eastern most seep (located just west of the MMW-10 wells) has an estimated elevation of 7,915 feet. As discussed later in this section, these seeps are believed to represent the top of the potentiometric surface at the river. Water-level elevations at the three MMW-10 wells are slightly above 7,917 feet.

Monitor well MMW-10A is screened in the lower part of the valley-fill, immediately above bedrock. The borehole log indicates that the fill here is a mixture of fluvial sands and gravel and mudflow deposits. Clay beds interbedded in the valley-fill probably resulted from deposition in lakes formed behind contemporaneous mudflows that blocked the Red River Valley. The aquifer test results discussed in Section 3.3 indicate that this well, if fully stressed, may produce several hundred gallons per minute from the saturated sands and gravels.

MMW-10B is screened in bedrock just below the valley-fill, but the water-level elevation (7,917 feet) is 112 feet above the contact, indicative of a strong upward gradient. This water-level elevation is close to that of the two valley-fill wells which, since the bedrock is highly fractured below the fill, could also be interpreted to mean that the fill and the shallow bedrock are in hydraulic continuity. As discussed in Section 3.3, the aquifer test at MMW-10A established some hydraulic connection between the valley-fill aquifer and the underlying bedrock aquifer (MMW-10B) because both wells gave drawdown effects during the test. The head relationship between the valley-fill and the bedrock aquifers may have a seasonal component with higher heads in the bedrock during spring recharge.

MMW-10C is screened in the upper part of the valley-fill, just above a thick clay bed. It is conceivable that MMW-10C intercepts a perched zone, and the configuration of the perched water table is not dependent on the main water table. A more likely explanation is that the clay beds (just below the total depth for MMW-10C) retarded vertical flow and, because of the short duration of the aquifer test (100 minutes), there was very little drawdown at MMW-10C. An interpretation is that MMW-10C and MMW-10A are part of a continuous zone of saturation and that the clay bed is the cause of the lack of response during the aquifer test.

Well MMW-11

MMW-11 was completed in the upper part of the bedrock aquifer, just south of the toe of Sugar Shack South Dump. During the drilling of this well, the lower part of the dump material was described as moist, but free water (described as dark turbid water) did not appear until 93 feet. This description corresponds with the base of the dump material. Immediately underlying the dump material is a thin sandy gravel followed by 10 feet of gravelly clay. Small amounts of water [a few gallons per minute (gpm)] were reportedly produced throughout the valley-fill, but because a mixture of foam and water was being injected during drilling, the extent of saturation in the valley-fill is unknown. It is possible that the water at 93 feet infiltrated from the overlying dump material and represents a thin perched zone. The water-level elevation for the bedrock aquifer at MMW-11 is 7,915 feet, or 58 feet above the valley-fill and

bedrock contact. This indicates a strong upward gradient which would be expected near the zone of discharge in the Red River valley. The water-level elevation for the valley-fill aquifer at MMW-11 is not known.

During the development (using air lift) of MMW-11, the bedrock aquifer had a pumping rate (Q) of 60 gpm with less than one (1) foot of drawdown (s). According to Huntley et al. (1992), the use of specific capacity formulas based on alluvial aquifer studies can be used to estimate transmissivity (T) for fractured rock. Using the equation:

$$T = K\left(\frac{Q}{s}\right)^{1.18}$$

where Q = 60 gpm
s = 1 foot, and
K = 38.9 [a conversion factor from Table 1 (Huntley et al., 1992); NOTE: This K is not equal to permeability]

a transmissivity (T) of 4,877 $ft^2$/day (36,479 gpd/ft) was calculated. (NOTE: The factor to convert from $ft^2$/day to gpd/ft is 7.48 gallons/foot.) This value contrasts with 90,000 gpd/ft based on the standard alluvial equation estimate:

$$T = \left(\frac{Q}{s}\right)1500$$

It is difficult to estimate hydraulic conductivity since the actual thickness of the aquifer is not known. If the thickness of bedrock aquifer open to the screen (40 feet) is used, a maximum value for K would be 912 gpd/$ft^2$. This value is close to the upper limit for fractured igneous rock (Freeze and Cherry, 1979) and could be a significant overestimation.

MMW-11 may be located near the outer edge of the cone of depression. Over the last five months, corresponding with dewatering of the underground mine, the water level at this well has shown fluctuations of less than 0.5 foot.

Figure 5 is a cross-section illustrating hydrogeologic relationships in the area of Sugar Shack South.

Wells MMW-8A and -8B

Monitor well MMW-8A (screened in bedrock) and MMW-8B (screened in valley-fill) are located on a fan delta deposit that filled an unnamed tributary valley in the area of Shaft No. 1. These wells are close to the river (within 250 feet). Water-level elevations for both wells are within the contour interval (10 feet) along the Red River opposite the well. It is not clear that the MMW-8 wells are within the cone of depression. Recharge from ground water beneath the river may balance discharge to the dewatering center, keeping water levels at about the same elevation. Additional monthly water-level measurements may help resolve the issue. The bedrock well (MMW-8A) has a slightly higher water level than the valley-fill well (MMW-8B), indicating a weak upward gradient.

Well MMW-7

This well (north of Shaft No. 1) was drilled to a depth of 161 feet and screened in bedrock. The water level here is 8,029 feet, which is approximately 550 feet or more above the current cone of depression. This well is screened in andesitic flow rock characterized by a series of low-angle north-dipping faults (Figure 3). Drill cuttings and drilling conditions indicated that the andesite is highly fractured. The potentiometric water level here is above the valley-fill/bedrock contacts. Valley-fill appeared to be unsaturated at MMW-7, and no perched zone within the fill was noted. MMW-7 appeared to have intercepted a perched zone within bedrock. This perched zone is confined to an interval of fractured rocks apparently associated with a series of low-angle structures. Figure 6 is a cross-section illustrating hydrogeological relationships at the MMW-7 and MMW-8 wells.

Upper Goathill Gulch drainage flows into the caved area. With the level of dewatering maintained below the elevation of the Red River, no monitor wells were constructed in the lower part of Goathill Gulch.

Wells MMW-2 and MMW-3

Well MMW-2 (in valley-fill) and MMW-3 (in bedrock) were drilled in the fan delta area in lower Capulin Canyon. Figure 7 is a cross-section illustrating the hydrogeologic relationships at MMW-2 and -3. Water-level elevations of these two wells are 90 to 100 feet above the level of the Red River at the mouth of the canyon. These elevations, if connected to a stream bed elevation farther upstream, are indicative of gaining conditions along the Red River. Based on the number of springs and seeps issuing from cutbanks along the river, the water table is likely to be at the stream bed. There is a weak upward gradient from the bedrock to the valley-fill; however, the

water quality of the valley-fill ground water at MMW-2 is much closer to that of the surface flow in lower Capulin Canyon than to the water quality of the bedrock ground water. It also appears that the seeps near the confluence of Capulin with the Red River contain water that is chemically more similar to the valley-fill than the bedrock. Lower Capulin Canyon may be outside the influence of the dewatering at the mine.

Water Levels and the Red River

A number of the monitor wells show water-level elevations at or slightly below the elevation of the river opposite the well. Construction of a water-level contour map using data collected in November 1994 from both the valley-fill and bedrock wells (head elevations are very close for paired bedrock and valley-fill wells) revealed a cone of depression configuration that included MMW-8A and -8B, MMW-11, and MMW-13. Monitor wells MMW-10A, -10B, and -10C were considered to be outside the cone and related to a water table at or very close to the elevation of the stream bed.

A preliminary potentiometric water-level map (Figure 8) shows a cone of depression centered above the underground mine. (The southern edge of this cone is being monitored by the newly constructed wells.) A schematic of water-level changes in the area of the underground mine is shown on Figure 9.

## 3.3 AQUIFER TESTING

An aquifer test was conducted at MMW-10A at a pumping rate of 140 gpm (the pump was not capable of a higher rate). Although drawdown and recovery tests were completed at this rate, the valley-fill aquifer was not stressed. The drawdown leveled out after 10 minutes of pumping at 10.5 feet, indicating recharge balanced discharge. Transmissivity calculated from the aquifer test was considerably higher (123,200 gallons per day per foot - gpd/ft) than that calculated from the recovery test (32,139.1 gpd/ft). Recharge during the aquifer test strongly reduced the drawdown. The hydraulic conductivity from the recovery results is about 300 gallons per day per square foot ($gpd/ft^2$), which is in the range of values reported for sandy gravel. During the aquifer tests, water levels were monitored at MMW-10B and MMW-10C. Water level declined 6.0 feet in the bedrock well (MMW-10B), which suggests that the fractured bedrock below the valley-fill is in hydraulic continuity with the fill accounting for a common water level. The continuity between the water-level at MMW-10C and the other wells was thought to indicate continuous saturation from MMW-10C (total depth 58 feet) and the deeper wells. MMW-10C did appear to experience some drawdown (less than 1 foot), and it is possible that the change in depth-to-water at MMW-10C was a function of changes in barometric pressure. A perched zone above a clay unit may underlie MMW-10C (with a water table independent of the deeper saturated zone). However, the clay may have

considerably reduced any response from the shallower well at MMW-10A. Our interpretation is that the latter is correct and saturation extends across all three wells.

Data from the aquifer testing are presented in Appendix E.

## 3.4 WATER QUALITY

Table 1 presents the results of the most recent water quality sampling (Fall 1994) for monitor wells located in the Mine Area. Table 2 illustrates selected chemical parameters for the wells and the seep. Water-quality data are provided in Appendix D. [Note: Water from the Portal Springs seep was sampled in May 1994; the other well samples were collected in November 1994].

The chemistry of the monitor well water and river seeps is site-specific. Three river seeps of concern are the Portal Springs seeps, Cabin Springs seeps, and Capulin Canyon seeps. At both Portal Springs and Capulin Canyon, the seep water appears to be more closely aligned (based partly on pH) to ground water in the valley-fill than the underlying bedrock aquifer. Ground-water samples from all of the Mine Area monitor wells have TDS and sulfate concentrations above the concentrations in the Red River. A detailed discussion of water quality is presented in Appendix D.

### Artificial Seepage Conduits

A gas-line utility trench parallels State Route 38 and is a potential lateral conduit for seepage either at the water table (Portal Springs) or possibly from perched zones near the river. If these trenches are carrying seepage, the discharge zone to the river might be considerably lengthened.

# 4.0 RECOMMENDED WORK

Based on SPRI's 1994 field and previous investigations, the geology and hydrogeology of the Mine Area and their relation to water quality and the Red River have been further defined. Any new monitor well placements will be based on pending geophysical work, plus continued sampling and water-level measurements.

## 4.1 SURFACE GEOPHYSICAL SURVEYS

Geophysical surveys would be useful for defining alluvial/bedrock contacts. Such information would then be utilized in selection of any future monitor well emplacements. Potential sites for limited geophysical activity could include:

- the delta at Capulin Canyon,
- Goathill Gulch (including its eastward continuation across the unnamed tributary: MMW-8 wells),
- the Sugar Shack South area, and
- the Cabin Springs area.

Geophysicists advocate the use of a series of east-west seismic refraction lines across the fan deltas. Fan delta deposits (valley-fill sediments) occur at the mouths of the tributary canyons and are an important link between up-valley surface drainage and bedrock aquifer discharge to seepage at the river. The configuration of the bedrock surface beneath the fill, particularly if there is more than one bedrock channel, and the variation in thickness of the fill and related changes in thickness of the saturated portion are important parameters in planning for additional monitor or extraction wells.

## 4.2 MONITOR AND EXTRACTION WELLS

SPRI recommends that monitor/extraction wells be sited in the following areas. Proposed locations are shown on Figure 10.

Capulin Canyon: Sumps at the toe of the Capulin waste-rock dump, the pumpback pond, and monitor wells MMW-2 and -3 are currently available to monitor recharge from natural and man-induced sources. A small diameter (2-inch) monitor well screened in valley-fill and located near the narrows in Capulin Canyon would be a

useful site for collecting water-quality data. This would allow some comparisons between upper canyon and mouth-of-canyon sources.

Sugar Shack South Waste-Rock Dump Area: A valley-fill well west of the road to MMW-11 and north of the powerline is recommended for construction to monitor ground-water flow toward Portal Springs. This well would help to better define flow direction and hydraulic gradient for the valley-fill aquifer at this site.

## 4.3 WATER-QUALITY MONITORING

SPRI recommends that water-quality measurements be performed quarterly using the QA/QC procedures and the equipment (inline filters and bladder pumps for minipurging) developed during the November 1994 sampling period. To facilitate statistical comparisons among samples and statistical discrimination among sources, the set of physical measurements, cations and anions included in the November 1994 work should be continued. To develop models of the chemical loading of surface water and ground water from various sources in the tributary canyons (natural seeps and springs, waste-rock dump sump water) and to the Red River (river seeps and selected river samples), water quality from these sources should be included in the quarterly program. Flow rates from these various sources should be estimated during each sampling period as input for chemical and water balance models. Tributary canyon sampling should focus on Capulin Canyon and, to some extent, on the South Sugar Shack area.

Similar water-quality and flow rate surveys should be conducted in Hanson Creek or Hot-N-Tot tributary canyons. Chemical and water balance models of the natural acidic system can then be compared to modeling results from Capulin Canyon, and an estimate of the proportion of acidic drainage related to natural and waste-rock dump sources evaluated.

Tritium analyses to date appear to distinguish post-1952 ground water ("young water") from mixed ground water (pre-and post-1952 water). Additional "age" data should be obtained from the valley-fill wells and the Portal Springs seeps opposite the Sugar Shack South waste-rock dumps. These data would supplement the hydrogeological model being developed for the area. A tritium value for the perched water at MMW-7 may be useful in better defining recharge sources.

A full complement of QA/QC documents indicating condition of the samples when taken, when received at the laboratory, and when analyzed should be maintained and methods of analysis should be documented.

## 4.4 BASIC DATA COLLECTION

Portrayal of the ground-water conditions in the Mine Area requires, at a minimum, water-level data for a period of a year. Precipitation data, stream gauge measurements, and changes in the river stages over the same period are also useful. It is necessary to look at seasonal relationships as well as any delayed impacts from the mine dewatering. Natural and man-induced discharges for the seeps and for adjacent tributary flows should also be included in the Mine Area data base. Any additional monitor wells would lead to better definition of the ground-water system.

## SUMMARY OF RECOMMENDATIONS

- Perform surface geophysical surveys at the delta at Capulin Canyon and Goathill Gulch (including the unnamed tributary that lies just west of Shaft No. 1) using a seismic refraction technique. The primary purpose is to define the subsurface configuration of the bedrock valley floor and the thickness of the fan delta deposits.

- Perform a surface geophysical survey across the steep south sloping surface north of the Cabin Springs seeps. The primary purpose is to define permeable fracture zones that may be the source of the Cabin Springs seepage.

- Install a shallow (less than 50-foot TD) monitoring piezometer in the valley-fill in the mid-Capulin Canyon area. The purpose is to monitor water quality and to evaluate down-valley changes in quality relative to existing sampling points at the head and the mouth of the canyon.

- Install a valley-fill monitor/extraction well (TD of 130 feet) near the west end of the Sugar Shack South waste-rock dump and west of the existing valley-fill wells. The purposes of this well are to better define the flow system in the valley-fill, and to potentially aid in the extraction of ground water.

- Collect water-quality samples from the monitor wells in the Mine Area (and the tailings facility) using a bladder pump. Additional sampling may include the river and selected river bank seeps along with springs and seepages in the tributary canyons. This sampling should all be conducted at the same time to reflect any seasonal controls on the water quality.

- Conduct limited tritium analyses at MMW-10A, the Portal Springs seeps, and MMW-7.

- Develop a database based on one-year measurements of water levels, stream flow, precipitation, and changes in river stages.

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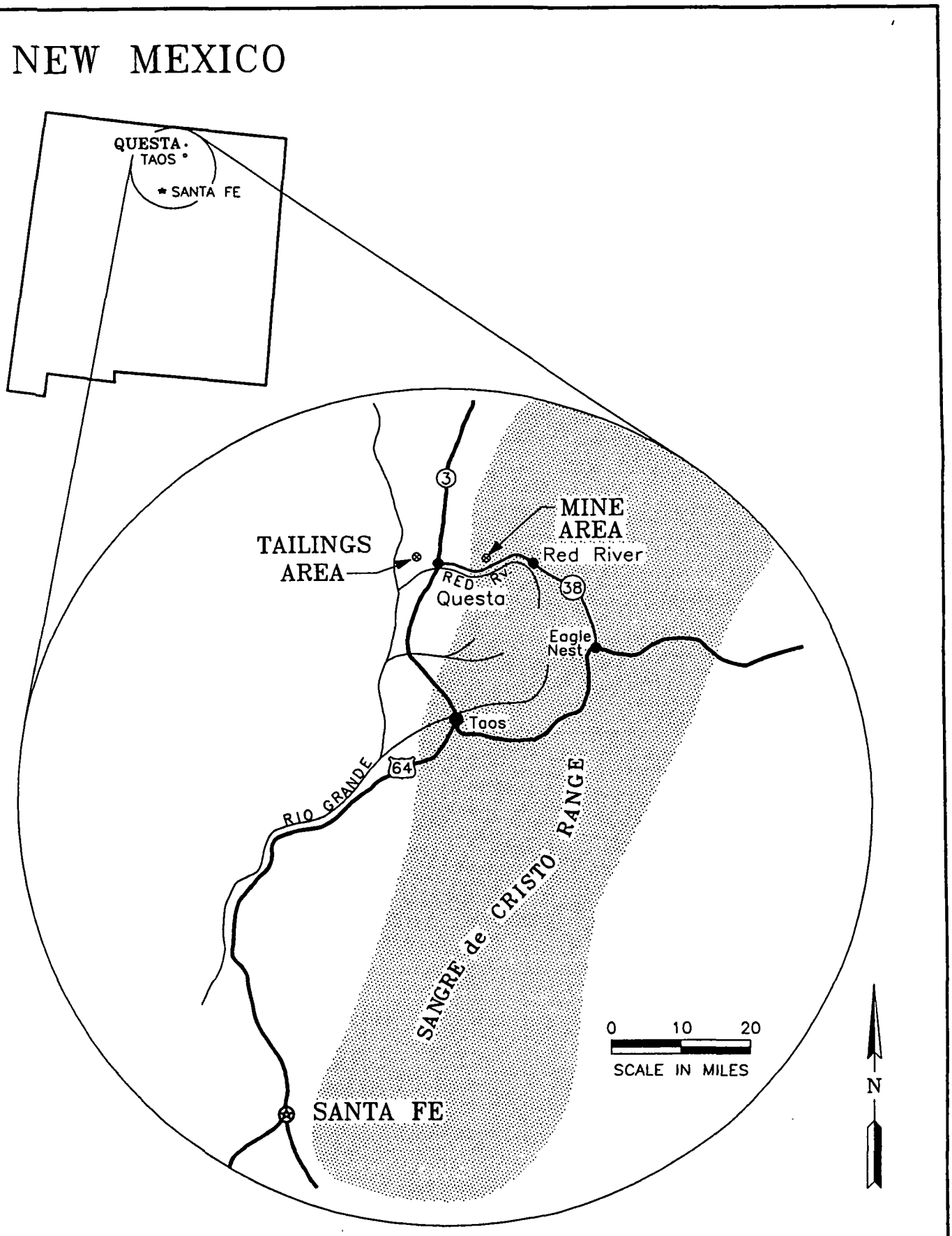
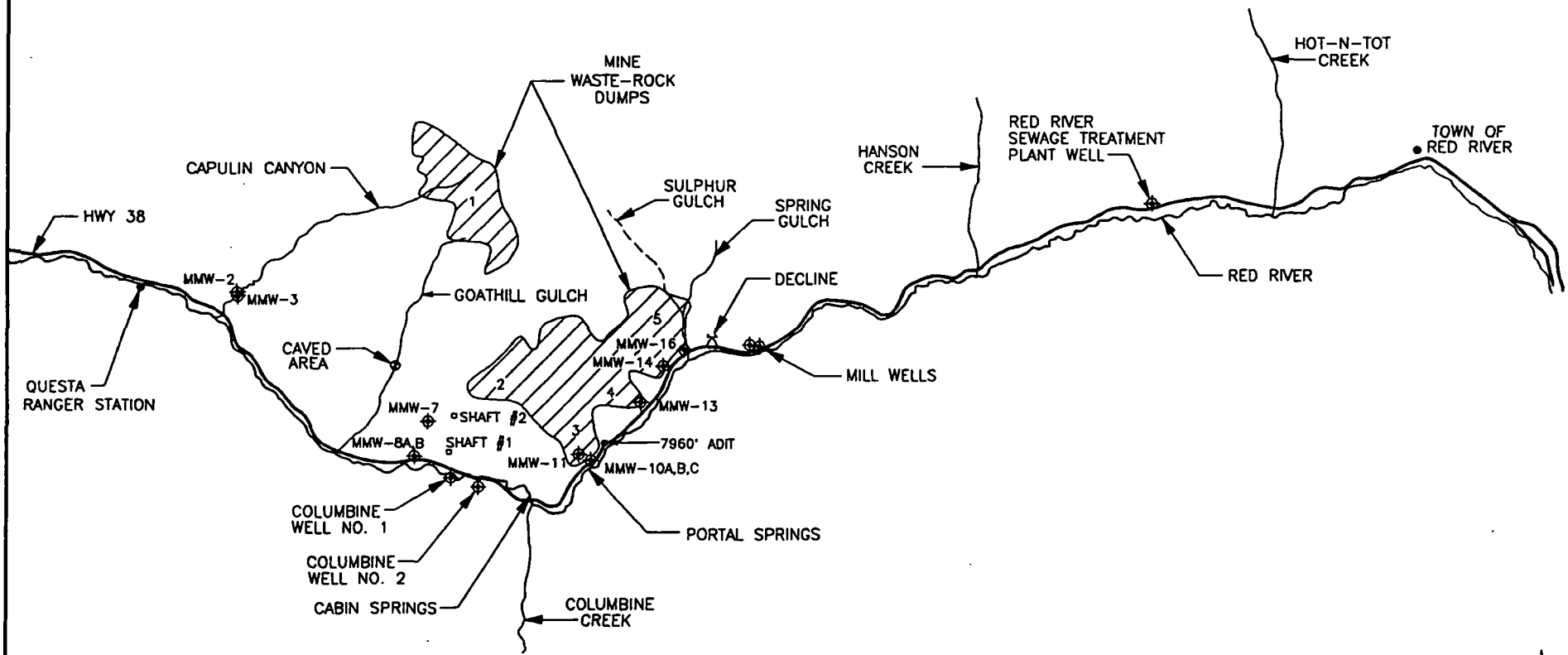
**FIGURES**




| SOUTH PASS RESOURCES, INC. | | | | REGIONAL LOCATION MAP<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: 1 |
|---|---|---|---|---|---|
| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: | | |
| 001-06 | 4/13/95 | | M.O'M. | | |




WASTE-ROCK DUMP AREAS

| | |
|---|---|
| 1 | CAPULIN/GOATHILL |
| 2 | SUGAR SHACK WEST |
| 3 | SUGAR SHACK SOUTH |
| 4 | MIDDLE |
| 5 | SULPHUR/SPRING |

0 0.5 1.0 1.5 2.0

SCALE IN MILES

N

FIGURE: 2

SOUTH PASS RESOURCES, Inc.

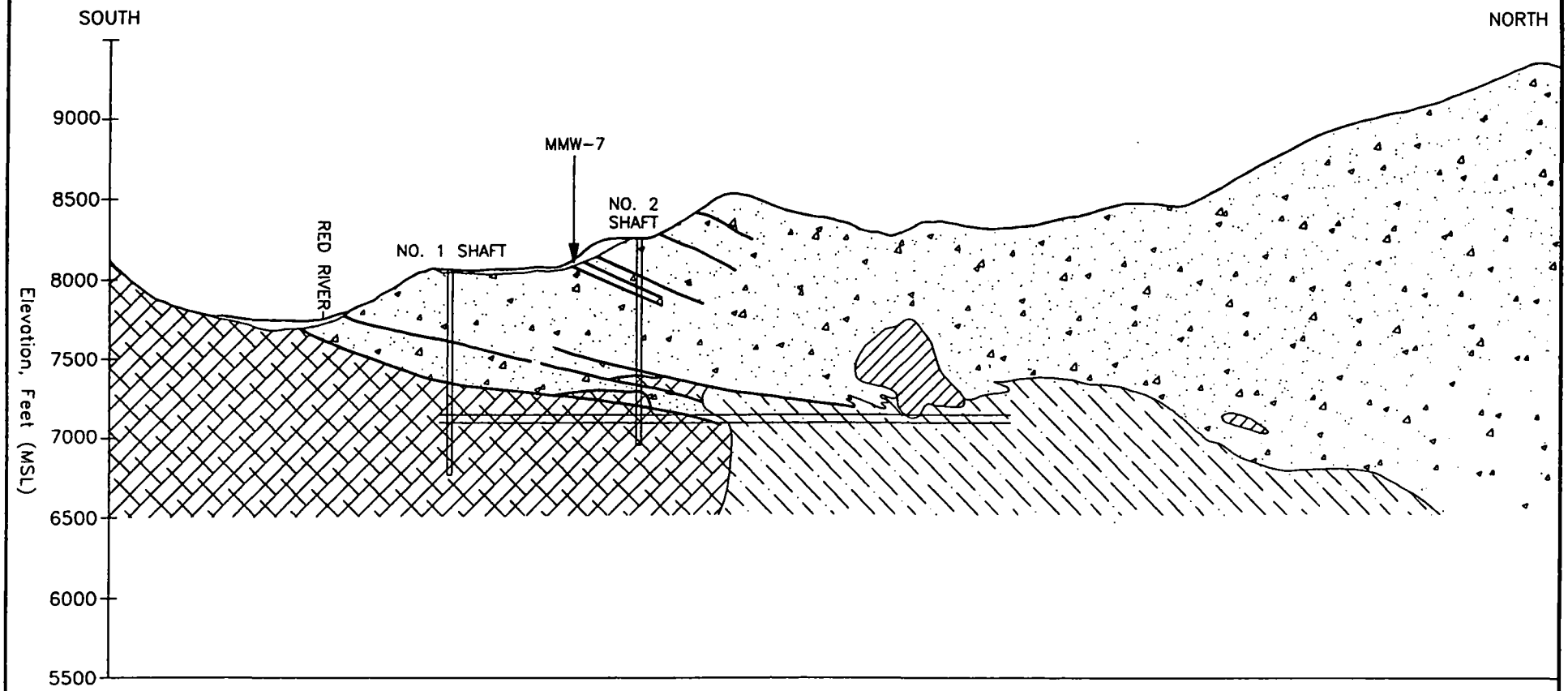
| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | J.C.K | M.O'M. |

# MINE AREA SITE MAP

Molycorp, Inc.

Questa, New Mexico

XSEC-1




LEGEND

- MINERALIZED ZONES
- TERTIARY INTRUSIVE: MINE APLITE AND GRANITE
- TERTIARY VOLCANICS: FLOWS, TUFFS, DIKES
- PRECAMBRIAN ROCKS
- LOW-ANGLE NORTH-DIPPING FAULTS

SEE FIGURE A2 FOR CROSS-SECTION LOCATION

0 500 1000

VERTICAL & HORIZONTAL SCALE IN FEET

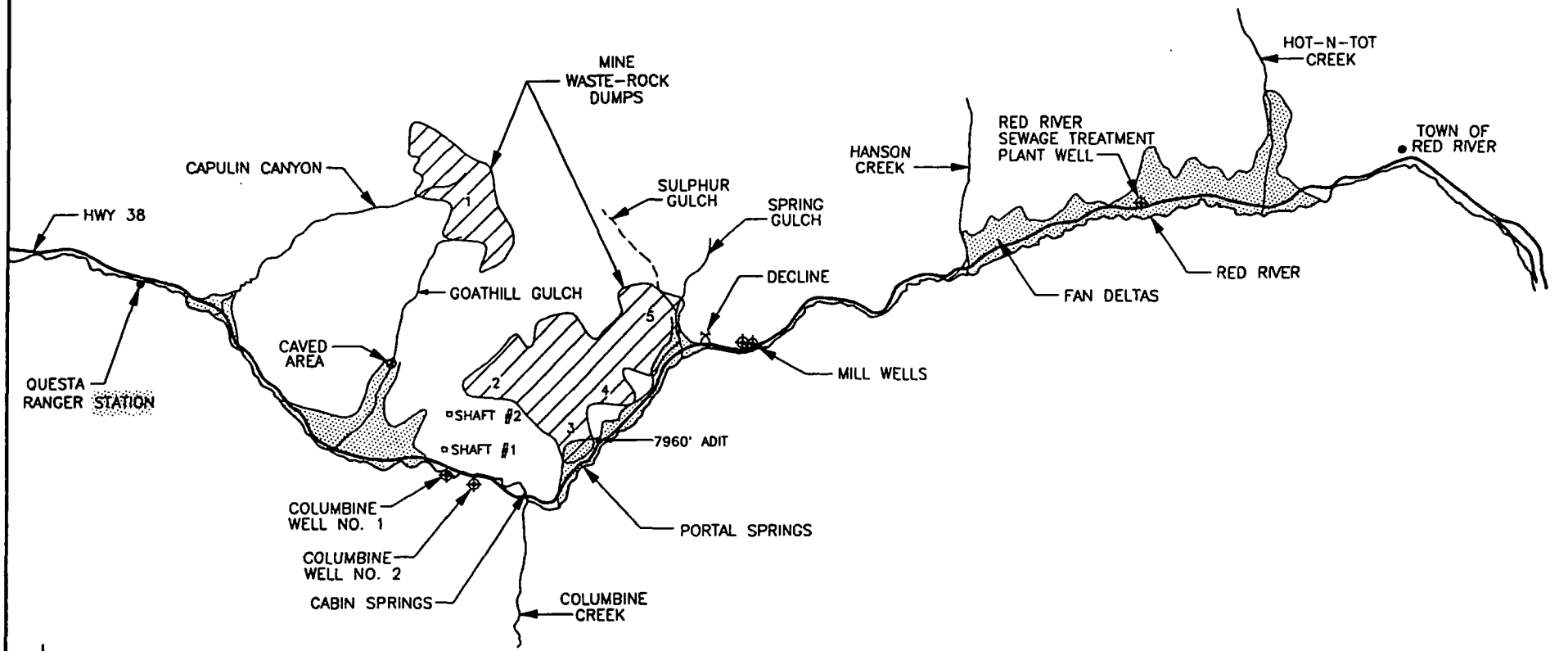
FIGURE: 3

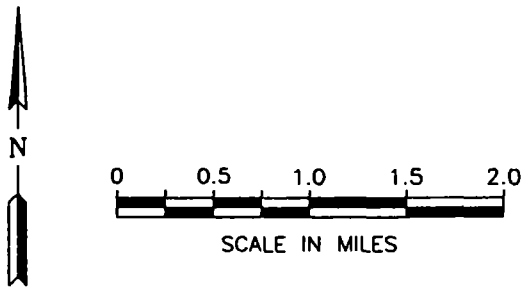
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/21/95 | JCK | M.O'M. |

# GEOLOGIC CROSS-SECTION A - A'

Mine Area - Molycorp, Inc.
Questa, New Mexico




EXPLANATION

- FAN DELTA
- WASTE-ROCK DUMP AREAS
  - 1 CAPULIN/GOATHILL
  - 2 SUGAR SHACK WEST
  - 3 SUGAR SHACK SOUTH
  - 4 MIDDLE
  - 5 SULPHUR/SPRING

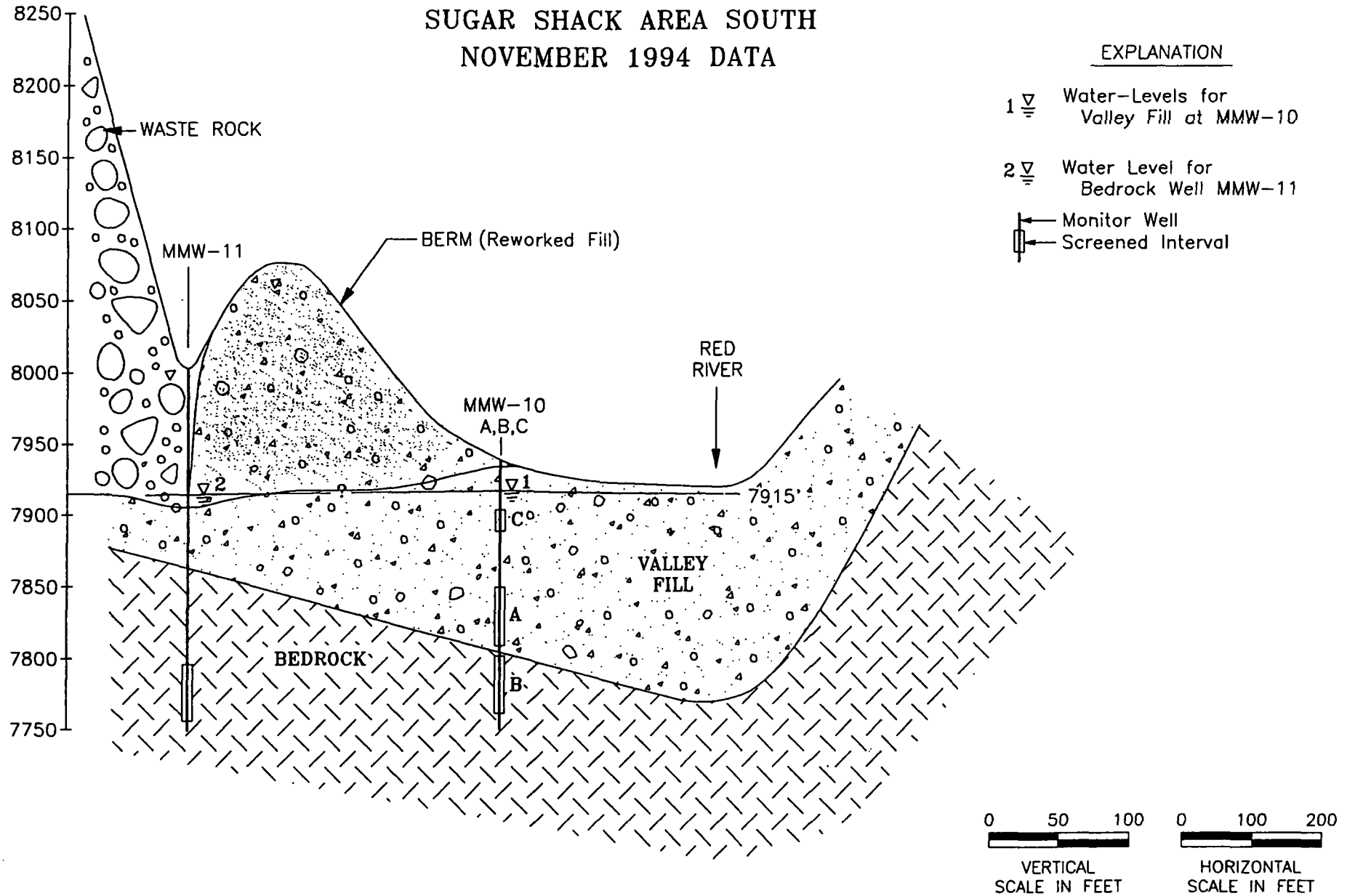
FIGURE: 4

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | J.C.K | M.O'M. |

# FAN DELTA AND MINE WASTE-ROCK LOCATIONS

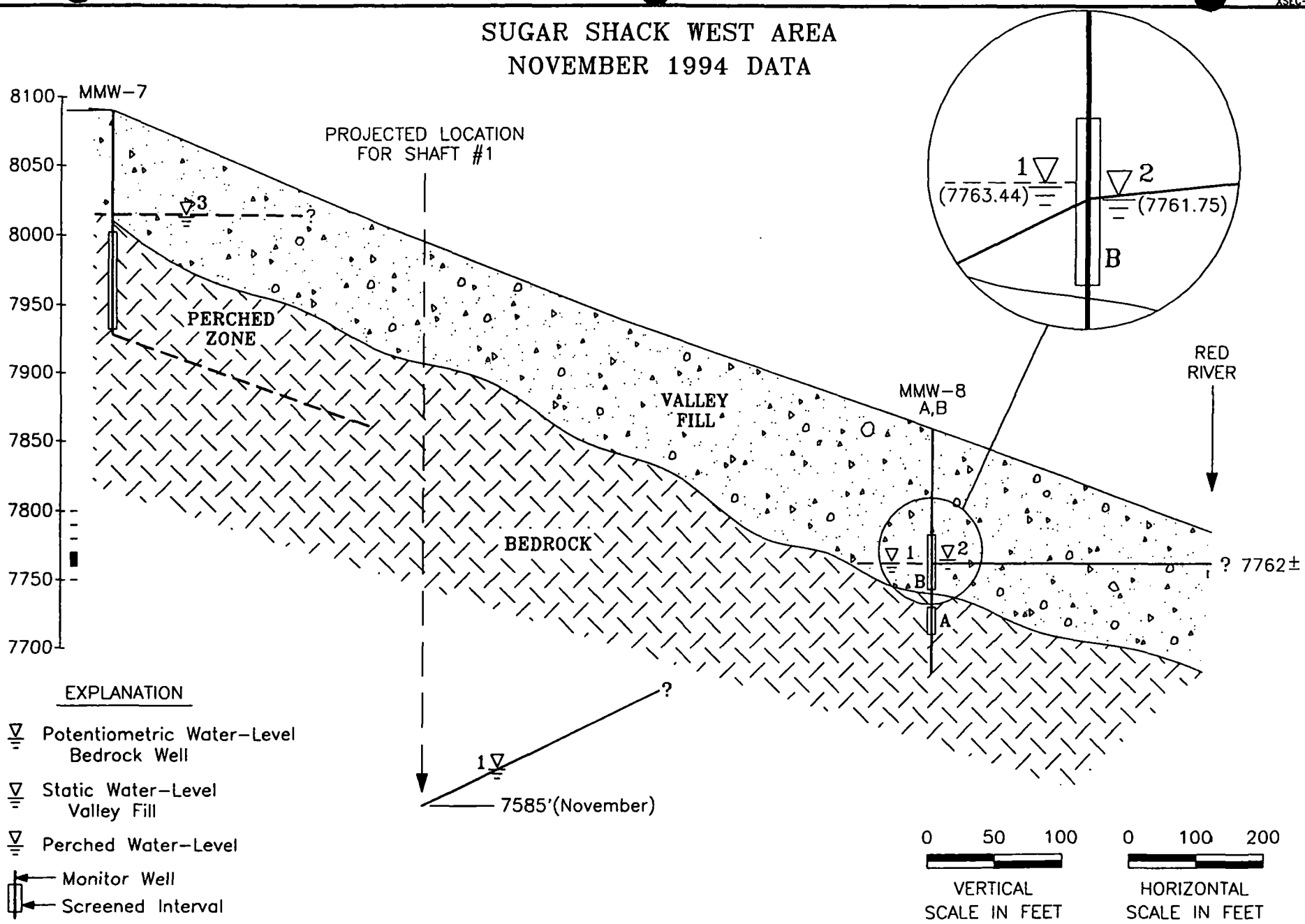
Molycorp, Inc.
Questa, New Mexico




| FIGURE: 5 | SOUTH PASS RESOURCES, Inc. | | | | HYDROGEOLOGIC CROSS-SECTION, SUGAR SHACK SOUTH<br>Mine Area - Molycorp, Inc.<br>Questa, New Mexico |
|---|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | |

XSEC-18

# SUGAR SHACK WEST AREA
# NOVEMBER 1994 DATA




EXPLANATION

1 ▽ Potentiometric Water-Level Bedrock Well

2 ▽ Static Water-Level Valley Fill

3 ▽ Perched Water-Level

Monitor Well

Screened Interval

0 50 100
VERTICAL SCALE IN FEET

0 100 200
HORIZONTAL SCALE IN FEET

FIGURE: 6

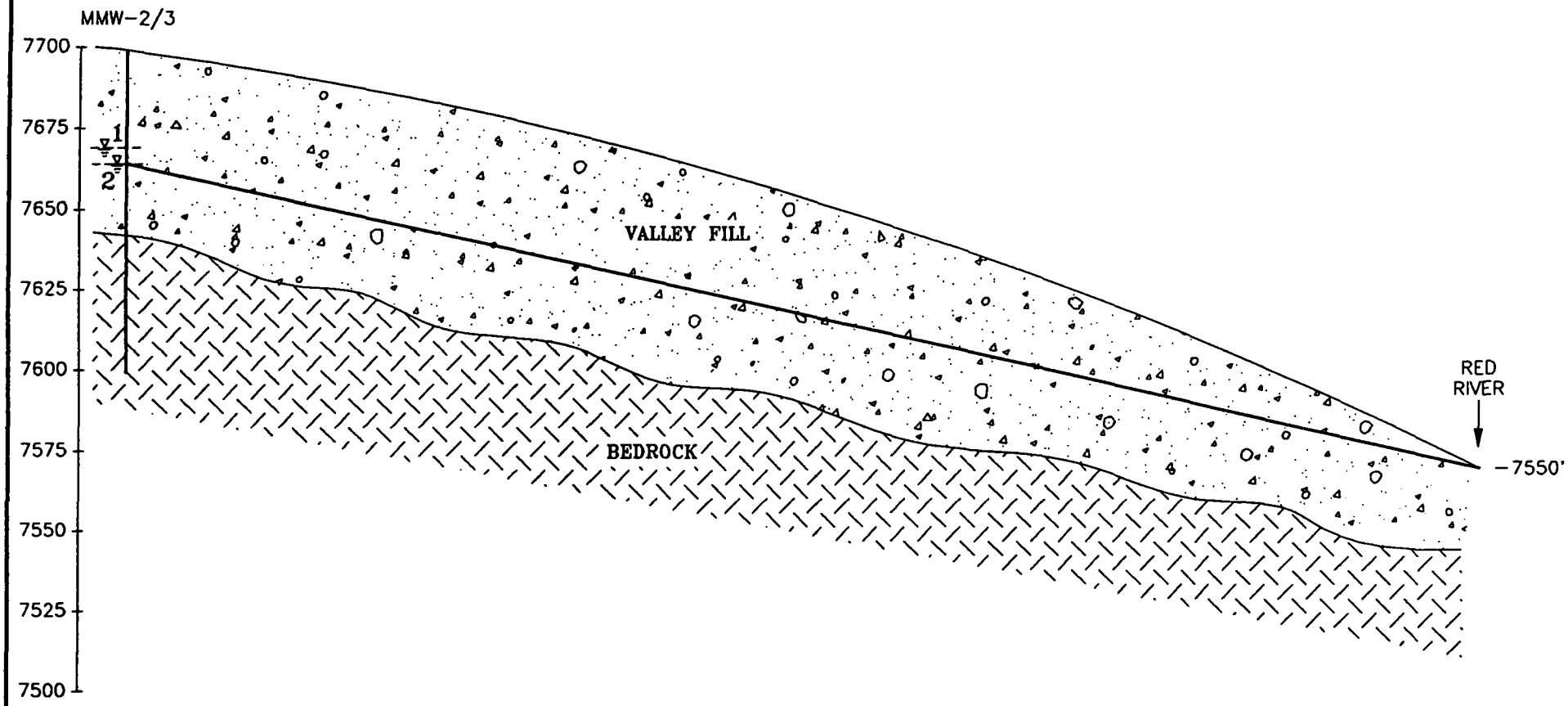
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

HYDROGEOLOGIC CROSS-SECTION, SUGAR SHACK WEST
Mine Area - Molycorp, Questa
New Mexico

XSEC-17

# CAPULIN CANYON




EXPLANATION

▽1 POTENTIOMETRIC WATER-LEVEL FOR BEDROCK WELL MMW-3

▽2 STATIC WATER-LEVEL FOR VALLEY FILL WELL MMW-2

0 25 50
VERTICAL SCALE IN FEET

0 50 100
HORIZONTAL SCALE IN FEET

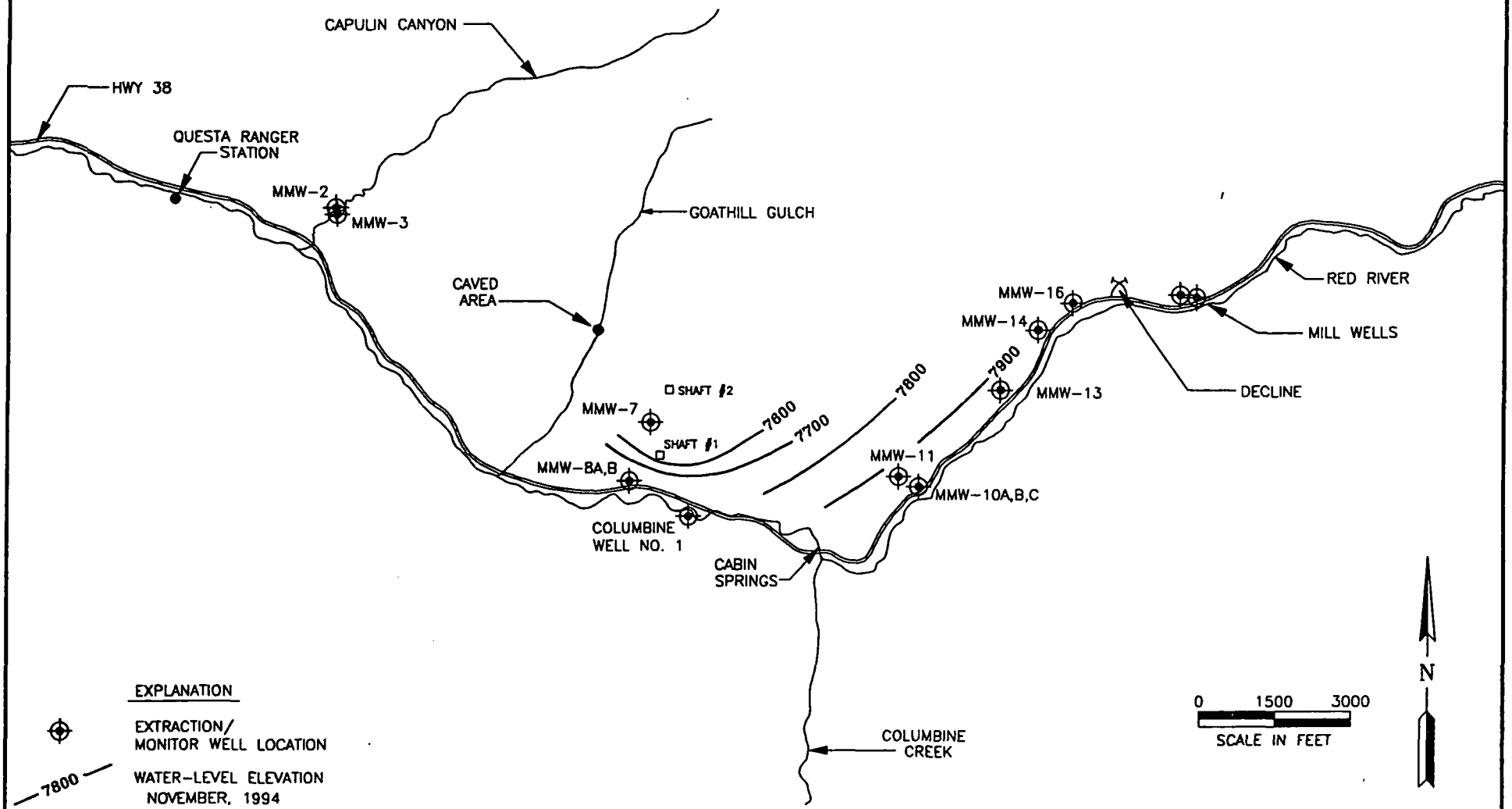
FIGURE: 7

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

HYDROGEOLOGIC CROSS-SECTION, CAPULIN CANYON
Mine Area - Molycorp, Questa
New Mexico

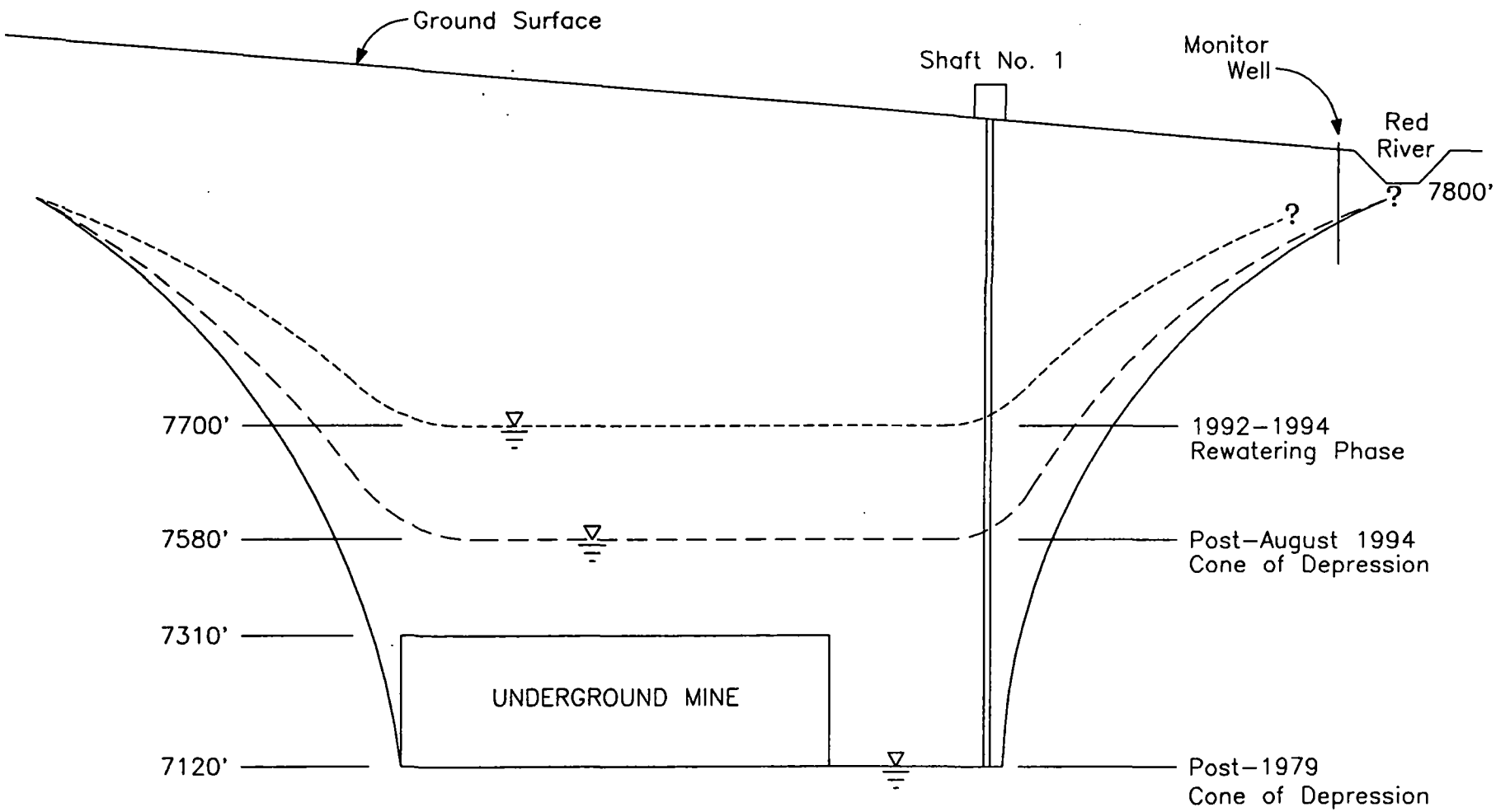
# RED RIVER CANYON




| FIGURE: 8 | SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. |

## GROUND-WATER CONTOURS FOR BEDROCK WELLS

Mine Area - Molycorp, Questa
New Mexico




NOT TO SCALE

FIGURE: 6

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001–06 | 4/13/95 | | M.O'M. |

# SCHEMATIC OF WATER–LEVEL CHANGES IN AREA OF THE UNDERGROUND MINE

MIne Area – Molycorp, Inc., Questa, New Mexico

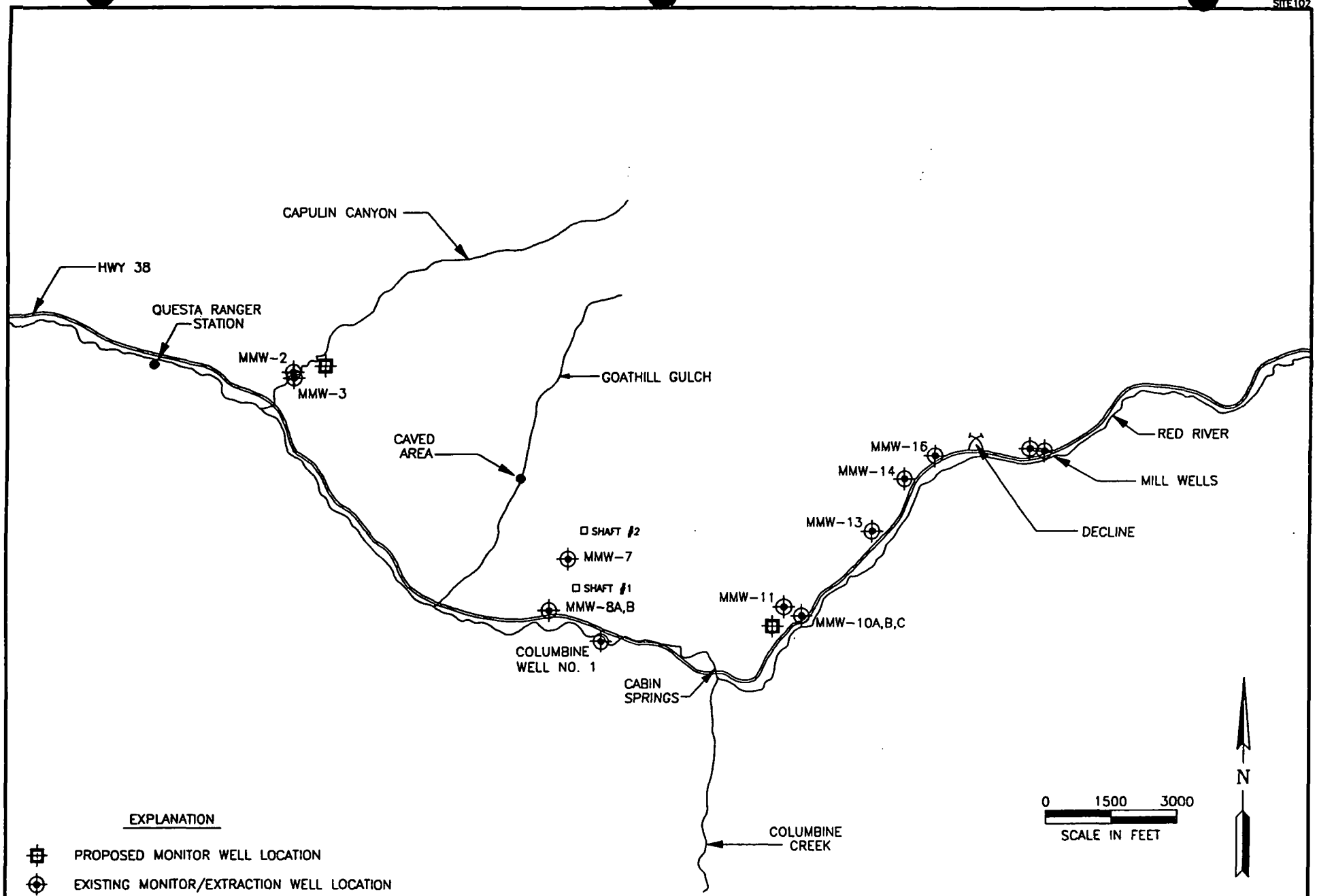



FIGURE: 10

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/21/95 | | M.O'M. |

# EXISTING AND PROPOSED MONITOR WELL LOCATIONS

Mine Area - Molycorp, Questa
New Mexico

**TABLES**

# TABLE 1
## 1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | SAMPLE DATE 1994 | WELL TD (feet) | Corrected DEPTH TO WATER (feet) | DEPTH TO PUMP INTAKE (feet) | pH (1) | CONDUC-TIVITY(1) (uhmos) | TEMP.(1) (°C) | CARBO -NATE (mg/L) | BICARBO -NATE (mg/L) | HYDR-OXIDE (mg/L) | TOTAL ALK (mg/L) | CHLORIDE (mg/L) | FLUORIDE (mg/L) | SULFATE (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MMW-2 | 8-Nov | 68 | 31.69 | 50 | 4.90 | 3,680 | 7.9 | <1 | <1 | <1 | <1 | 6.8 | 24.0 | 2,100 |
| MMW-3 | 7-Nov | 140 | 27.76 | 80 | 7.50 | 3,970 | 10.9 | <1 | 222 | <1 | 222 | 5.8 | 2.59 | 1,700 |
| MMW-7 | 7-Nov | 161 | 61.11 | 120 | 4.40 | 9,490 | 17.2 | <1 | <1 | <1 | <1 | 21 | 1.12 | 10,400 |
| DUP-11A (2) | 7-Nov | NA | NA | NA | NA | NA | NA | <1 | <1 | <1 | <1 | 21 | 0.98 | 10,500 |
| MMW-8A | 8-Nov | 178 | 96.77 | 140 | 7.00 | 2,860 | 8.4 | <1 | 165 | <1 | 165 | 8.7 | 2.72 | 1,300 |
| MMW-8B | 8-Nov | 129 | 96.03 | 112 | 6.40 | 1,780 | 7.1 | <1 | 19 | <1 | 19 | 5.6 | 1.83 | 730 |
| MMW-10A | 8-Nov | 144 | 21.70 | 100 | 5.80 | 2,400 | 7.8 | <1 | <1 | <1 | <1 | 27 | 11.2 | 1,100 |
| DUP-12B (3) | 8-Nov | NA | NA | NA | NA | NA | NA | <1 | <1 | <1 | <1 | 26 | 7.96 | 1,100 |
| MMW-10A (4) | 19-Nov | NA | NA | NA | NA | NA | NA | <1 | <1 | <1 | <1 | 26 | 8.28 | 1,200 |
| MMW-10B | 7-Nov | 189 | 21.57 | 140 | 7.90 | 2,250 | 10.1 | 10 | <1 | 66 | 76 | 28 | 12.2 | 1,100 |
| MMW-10C | 8-Nov | 50 | 21.80 | 40 | 4.70 | 2,000 | 11.8 | <1 | <1 | <1 | <1 | 20 | 15.4 | 880 |
| MMW-11 | 7-Nov | 184 | 86.71 | 150 | 5.60 | 2,450 | 15.7 | <1 | <1 | <1 | <1 | 22 | 17.6 | 1,300 |
| MMW-13 | 8-Nov | 145 | 105.98 | 130 | 7.90 | 2,280 | 8.9 | <1 | 200 | <1 | 200 | 14 | 1.67 | 770 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER AQUIFER TEST

NA - Not Available

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

# TABLE 1
## 1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | TDS (mg/L) | SILVER (mg/L) | ALUMINUM (mg/L) | ARSENIC (mg/L) | BARIUM (mg/L) | BERYLLIUM (mg/L) | CALCIUM (mg/L) | CADMIUM (mg/L) | COBALT (mg/L) | CHROMIUM (mg/L) | COPPER (mg/L) | IRON (mg/L) | MERCURY (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MMW-2 | 3,400 | <0.10 | 63.5 | <0.005 | <0.010 | 0.015 | 501 | 0.024 | 0.280 | <0.010 | 0.088 | 50.8 | <0.0002 |
| MMW-3 | 2,900 | <0.10 | 0.75 | <0.005 | 0.047 | <0.004 | 567 | 0.0024 | 0.089 | <0.010 | <0.010 | 0.076 | <0.0002 |
| MMW-7 | 16,000 | <0.50 | 943 | <0.05 | 0.108 | 0.104 | 544 | 0.096 | 4.91 | 0.193 | 4.84 | 384 | <0.0002 |
| DUP-11A (2) | 16,000 | <0.50 | 961 | <0.05 | 0.074 | 0.122 | 534 | 0.092 | 4.99 | 0.17 | 5.04 | 375 | <0.0002 |
| MMW-8A | 2,200 | <0.10 | <0.05 | <0.005 | 0.103 | <0.004 | 466 | 0.002 | <0.010 | <0.010 | <0.010 | 2.84 | <0.0002 |
| MMW-8B | 1,100 | <0.10 | 0.44 | <0.005 | 0.016 | <0.004 | 206 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MMW-10A | 1,700 | <0.10 | 33.4 | <0.005 | <0.010 | 0.008 | 275 | 0.028 | 0.148 | <0.010 | 0.558 | <0.050 | <0.0002 |
| DUP-12B (3) | 1,700 | <0.10 | 34.2 | <0.005 | <0.010 | 0.008 | 270 | 0.024 | 0.137 | <0.010 | 0.58 | <0.050 | <0.0002 |
| MMW-10A (4) | 1,700 | <0.010 | 31.6 | <0.005 | <0.010 | 0.006 | 245 | 0.0224 | 0.141 | <0.010 | 0.534 | 0.086 | <0.0002 |
| MMW-10B | 1,800 | <0.10 | 8.74 | <0.005 | 0.034 | 0.007 | 347 | 0.025 | 0.074 | <0.010 | 0.179 | 0.101 | <0.0002 |
| MMW-10C | 1,400 | <0.10 | 31.1 | <0.005 | 0.014 | 0.007 | 204 | 0.026 | 0.106 | <0.010 | 0.38 | <0.050 | <0.0002 |
| MMW-11 | 2,000 | <0.10 | 56.3 | <0.005 | 0.016 | 0.013 | 276 | 0.036 | 0.266 | 0.036 | 0.919 | 0.129 | <0.0002 |
| MMW-13 | 1,400 | <0.10 | <0.05 | <0.005 | 0.036 | <0.004 | 316 | <0.0005 | 0.013 | <0.010 | <0.010 | 0.198 | <0.0002 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER PUMP TEST

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

# TABLE 1
## 1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | POTASSIUM (mg/L) | MAGNESIUM (mg/L) | MANGANESE (mg/L) | MOLYBDENUM (mg/L) | SODIUM (mg/L) | NICKEL (mg/L) | LEAD (mg/L) | ANTIMONY (mg/L) | SELENIUM (mg/L) | SILICON (mg/L) | THALLIUM (mg/L) | VANADIUM (mg/L) | ZINC (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MMW-2 | 10.8 | 137 | 52.1 | <0.02 | 64.6 | 0.61 | <0.002 | <0.05 | <0.05 | 20.3 | <0.005 | <0.010 | 9.48 |
| MMW-3 | 7.5 | 96.2 | 34.5 | <0.02 | 103 | 0.236 | <0.002 | <0.05 | <0.005 | 7.6 | <0.005 | <0.010 | 1.36 |
| MMW-7 | 12.0 | 1250 | 72.1 | <0.10 | 175 | 10.5 | 0.10 | <0.25 | <0.025 | 22.7 | <0.005 | 0.104 | 11.7 |
| DUP-11A (2) | 12.1 | 1230 | 73.3 | <0.10 | 178 | 10.7 | 0.06 | <0.25 | <0.025 | 22.6 | <0.005 | 0.106 | 11.9 |
| MMW-8A | 3.8 | 85.6 | 7.15 | <0.02 | 41.5 | <0.020 | <0.002 | <0.05 | <0.005 | 11.1 | <0.005 | <0.010 | <0.050 |
| MMW-8B | 2.9 | 55.5 | 0.202 | <0.02 | 33.9 | 0.059 | <0.002 | <0.05 | <0.005 | 17.3 | <0.005 | <0.010 | 0.211 |
| MMW-10A | 2.8 | 77.9 | 13.8 | <0.02 | 26.5 | 0.325 | <0.002 | <0.05 | <0.005 | 14.3 | <0.005 | <0.010 | 2.29 |
| DUP-12B (3) | 2.5 | 76.7 | 12.8 | <0.02 | 26.4 | 0.293 | <0.002 | <0.05 | <0.005 | 14.0 | <0.005 | <0.010 | 2.07 |
| MMW-10A (4) | 3.7 | 69.7 | 13.1 | <0.02 | 25.6 | 0.279 | 0.004 | <0.05 | <0.005 | 14.1 | <0.005 | <0.010 | 2.68 |
| MMW-10B | 3.5 | 80.3 | 8.55 | <0.02 | 25.8 | 0.201 | 0.021 | <0.05 | <0.05 | 12.8 | <0.005 | <0.010 | 1.5 |
| MMW-10C | 2.8 | 75.2 | 16.3 | <0.02 | 20.2 | 0.0347 | <0.002 | <0.05 | <0.005 | 9.9 | <0.005 | <0.010 | 3.2 |
| MMW-11 | 3.4 | 133 | 31.7 | <0.02 | 25.5 | 0.593 | 0.086 | <0.05 | <0.005 | 14.2 | <0.005 | <0.010 | 5.0 |
| MMW-13 | 5.4 | 38.7 | 1.02 | 0.05 | 30 | <0.020 | <0.002 | <0.05 | <0.005 | 8.8 | <0.005 | <0.010 | 0.222 |

NOTES:

(1) Ph, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER PUMP TEST

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

**TABLE 2**
**COMPARISON OF WATER QUALITY DATA**
**FOR SUGAR SHACK SOUTH and PORTAL SPRINGS**
MOLYCORP, INC. - QUESTA, NEW MEXICO

| MONITOR WELL/ SPRING | pH | TEMPERATURE (°C) | SULFATE (mg/L) | ALUMINUM (mg/L) |
|---|---|---|---|---|
| MMW-10A | 5.80 | 7.8 | 1,100 | 33.4 |
| MMW-10B | 7.90 | 10.1 | 1,100 | 8.74 |
| MMW-10C | 4.70 | 11.8 | 880 | 31.1 |
| MMW-11 | 5.60 | 15.7 | 1,300 | 56.3 |
| Portal Springs | 5.00 | - | 679.8 | 5.3 |

**APPENDIX A**

# APPENDIX A

## Discussion Of Mine Area Site Geology

# APPENDIX A

## Discussion of Mine Area Site Geology

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Table A1: Generalized Section of Rock Units in the Vicinity of the Mine Area

# APPENDIX A

## Discussion of Mine Area Site Geology

### A.1 GENERAL GEOLOGIC SETTING

The major sources of geological data for the Mine Area are Schilling (1956), Rehrig (1969), Lipman (1981), Bookstrom (1981), and numerous unpublished maps, cross-sections, and reports by Molycorp geologists. A common thread to all of these geological studies is that the mineralization in the study area was related to Tertiary magmatism and hydrothermal solutions focused along an east- to northeast-trending structural zone. This structural zone is variously interpreted as part of a graben (Schilling, 1956); as a zone of intense faulting (called the Red River Structural Zone by Rehrig, 1969); and the southern part of the outer ring fracture zone that formed the outer wall of the Questa caldera (Lipmann, 1981; Bookstrom, 1981).

The development of the caldera and the associated volcanic and intrusive rocks was a late Oligocene to Middle Miocene event (27.2 million years to 22 million years before present) that overlapped in time and space with the regional rifting associated with the Rio Grande Rift system. The range-bounding high-angle fault along the west side of the Sangre de Cristo Mountains (about 5 miles west of the mine) is related to regional extension across the Rio Grande Rift and the uplift of the mountain range in Mid-Tertiary time. At least the later movements along this range-front fault are younger than the caldera structure because the outer ring fracture zone is truncated by the range-front fault.

### A.2 ROCK UNITS

The oldest rock units exposed in the vicinity of the Mine Area are Pre-Cambrian amphibolites, quartz-biotite schists, metaquartzites, granite gneisses, and intrusive quartz monzonites. These units are overlain by an Early Tertiary conglomerate and sandstone unit followed by a complex sequence of Oligocene and Miocene rhyolitic to quartz latitic ashflow tuffs, breccias, and lava flows and a sequence of basalt/andesite lava flows. These volcanics are intruded by a number of dikes and small stocks or plutons that range widely in composition (quartz latite, rhyodacite, rhyolite, granite porphyry, and aplite). In the Mine Area, most of the molybdenum mineralization is found in the outer parts of the Mine Aplite (22 million years before present) and adjacent volcanic units. Table A1 presents a brief description of the major rock units in the Mine Area.

| TABLE A1<br>Generalized Section of Rock Units in the Vicinity of the Mine Area | | |
|---|---|---|
| **AGE** | **UNIT (Symbol)** | **DESCRIPTION** |
| Quaternary | Valley-Fill Alluvium<br>(QAL) | Gravel, sand, and silt. Dominantly in Red River floodplain/channel deposits. A minor component of tributary valley-fill. Colluvial material not distinguished on maps, but consists of angular material deposited at the base of slopes. |
| Quaternary | Valley-Fill mudflow<br>(Qmf) | Boulder and finer gravel size material in a medium to coarse silty and clayey sand matrix. Mixture of angular subangular, subrounded material. |
| Quaternary | Valley-fill "limonite" cemented sediment<br>(Qlcq, Qlcs) | Channel gravels and sand, mudflow deposits and spring deposits (near the river) cemented by rust-orange to black "limonite." |
| Tertiary Miocene | Intrusive Units<br>(Tq, Tql, Tqp, Tap, Tri, Tmp) | Variety of intrusions (commonly post-Amalia formation) consisting of: quartz latite, aplite, quartz monzonite, granite, granite porphyry, as stocks, plugs, dikes, and sills. Major intrusions in the Mine Area include:<br>Mine aplite<br>Red River Granite Porphyry<br>Goathill Gulch Granite Porphyry<br>Log Cabin Biotite Granite |
| Miocene | Amalia formation<br>(Trt, Tr) | Rhyolitic ash-flow Tuffs, poorly to densely welded; rhyolitic breccias (fragments of andesite and rhyolite); megabreccia blocks of andesite (outcrop size to blocks on the order of 1,000 feet long) enclosed in the Amalia Formation (often mapped as andesite-Tanbx). Blocks more abundant toward the river area and lower in the section. Estimated intra-caldera thickness: 7,000 to 10,000 feet. Caldera-fill unit. |
| Oligo-Miocene | Basalt<br>(Tb) | Xenocrystic basalt, amygdaloidal basalt contains xenoliths of Pre-Cambrian rock. Occurs as megabreccia blocks in the Amalia Formation. Caldera-fill unit. |
| Oligocene | Porphyritic Quartz latite<br>(Tgl) | Flows and tuffs above andesite. Some of the latite is intrusive. Partly caldera-fill unit. |
| Oligocene | Andesite<br>(Tan fp, Tan mp, Tan cp, Tan bx post-script indicates megabreccia block) | Finely (fp), medium (mp), and coarsely (cp) grained undifferentiated andesite porphyry. Both autobrecciated and monautobrecciated. Found as megabreccia blocks in Amalia Formation. Caldera-fill unit. |
| Oligocene | Andesite<br>(Tan fp) | Medium-grained andesite porphyry. Massive, some autobrecciation. Caldera floor unit. |
| Oligocene | Tertiary sediments<br>(Tcgc, Tcgf, Ts, c= >10 cm, f= <10 cm | Cobble to pebble conglomerate grading up into sandstone and siltstone. Channel structure (100 to 300 ft. thick). Finer grained upper section 50 to 300 ft thick. Consists of sandstone/siltstone with minor conglomeritic. |
| Pre-Cambrian | Pre-Cambrian basement<br>(p€q, p€gn, p€d) | Quartzite, amphibolite schist, quartz-biotite schist, gneisses, granite gneisses intruded by pegmatite and diabase dikes and granite to quartz monzonite plutons. |

## A.3 STRUCTURE

Geological maps of the Mine Area (Figure A1) show a northeast- to east-trending structural zone (see Caldera boundary on Figure A1) along which intrusions of granitic rock and mineralization have occurred. This zone more or less parallels the Red River in the vicinity of the mine but farther to the west, swings to the southwest, away from the river. The structural zone is believed to be the southern part of the outer ring fracture zone (outer wall or rim) for the Questa Caldera. The zone is characterized by a swarm of east-trending dikes, elongated intrusions, and mineral veins that were emplaced in fractures developed parallel to the caldera rim.

South of the structural zone, northeast- and northwest-trending high-angle faults extend throughout the Pre-Cambrian block (Pre-Cambrian rocks and some pre-caldera volcanic rocks). Some of these faults are truncated by the caldera wall. North of the structural zone, the geology is more complex. Fault-bound blocks of Pre-Cambrian rock, pre-caldera volcanics, and younger caldera-related volcanics occur throughout the area. These structural blocks and the outer fracture zone along the caldera wall became the plumbing system through which granites intruded (such as the Mine Aplite) and the later mineralizing hydrothermal waters migrated.

A variety of fractures developed throughout the caldera block. These include:

- high-angle joints (called sheeting in the aplite) and fracture cleavage;
- contact conformable fractures between the intrusions and the volcanic units;
- high-angle northeast-, north-, and northwest-trending faults; and
- low-angle faults both within the Mine Aplite (west- and north-dipping) and as structural contacts between various Tertiary units.

Major northerly-trending high-angle faults that could have an influence on ground-water flow paths include the Goathill Fault, the Neck Fault, and a series of unnamed faults east of the Neck Fault (Figure A2). The low-angle faults are presented in a north-south cross-section on Figure A3. These are probably related to listric (concave-up fault planes), normal faults developed along the caldera boundary, and/or large slide blocks derived from the walls of the caldera. Within the structural zone mine, geologists have mapped volcanic megabreccias that may be representative of slide blocks.

Detailed surface and subsurface mapping (Molycorp files) shows a complex of low- and high-angle faults of different ages. The character of the individual faults ranges from tight mineralized fractures (quartz + sulfide ± calcite ± fluoride) to faults with an abundance of clay

gouge to open structures. Segments of the Neck Fault exposed in the underground mine have been described as "water bearing" by Molycorp staff. Extensive east/west- to west/northwest-striking faults dip northward at an angle varying from nearly horizontal (0°) to vertical (90°). Most of these faults formed early during mid-Tertiary tectonism. The north- to northwest-striking high-angle faults are believed to be normal faults with down to the east separation. Some of these faults have a strike-slip component. Northeast-striking high-angle faults are also present. Some of these are truncated by the early east/west structures, but some are much younger.

## A.4 MINERALIZATION

The mineral deposits in the Mine Area consist of molybdenite-bearing quartz veins. The vein fillings occur in east- to northeast-striking, nearly vertical fractures in the Mine Aplite and in the immediately adjacent andesitic flow rocks intruded by the Aplite. Pyrite (iron sulfide) is fairly abundant in the quartz veins (with or without molybdenite) and in the clay gouges that fill some of the fault zones. It is also widely disseminated in the volcanic and intrusive rocks. Calcite, fluorite, and biotite are commonly associated with the vein minerals. The major alteration mineral in the volcanics outside of the veins is chlorite. Field photographs by Rehrig (1969) indicate that many fractures and small faults are barren of mineralization.

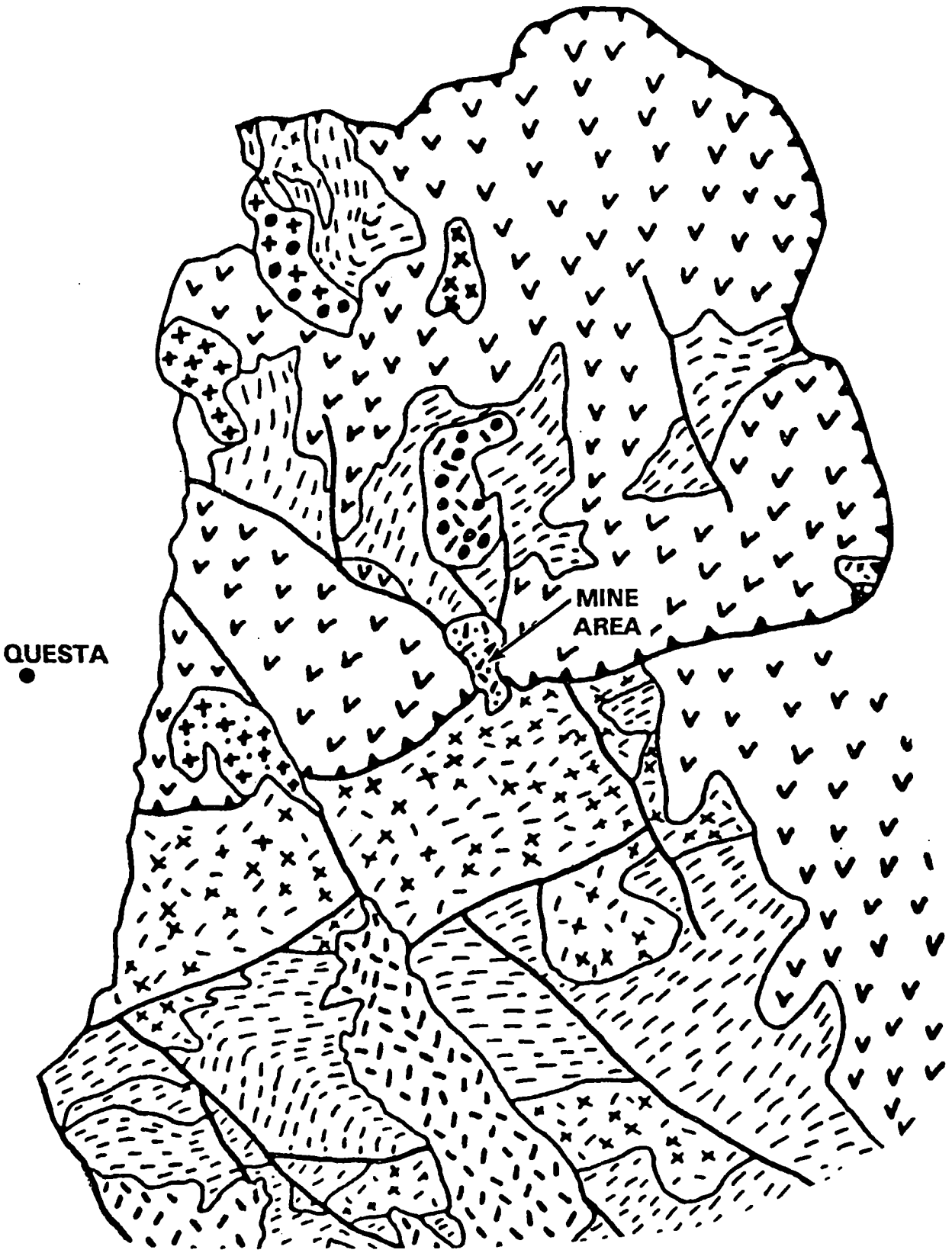
Schilling (1956) described intense zones of alteration associated with hydrothermal pipes (i.e., steeply inclined breccia structures) that probably formed at fault/fracture intersections in the volcanic rocks overlying the intrusion. The alteration minerals in these pipes consist of pyrite, chalcopyrite, quartz, kaolinite, sericite, and carbonates. Subsequent descending oxidizing ground waters reacted with the pyrite and carbonate minerals to form limonite (iron oxide), jarosite (hydrous iron/potassium sulfate), and gypsum (hydrated calcium sulfate) -- creating the yellow- and red-colored hydrothermal scars common throughout the area.

More recent regional mapping [U.S. Soil Conservation Service (USCS), 1982 aerial photograph map sheets 50 and 51] demonstrates that the hydrothermally altered areas (hydrothermal scars or rock outcrop - Badlands Complex - RdG) underlie most of the land between the Cabresto Canyon and Red River Canyon divide and the river. Every tributary canyon north of the river includes large exposures of hydrothermally altered pyritic rock. Two large areas south of the river, Bear Canyon drainage and several drainages west of Pioneer Creed (Town of Red River area), are also underlain by this type of pyritic rock. The USCS describes hydrothermally altered areas as typically sparsely vegetated, steeply-sloped badlands topography characterized by extremely acidic soil material. These steep surfaces are the source of much of the mudflow material deposited in the fan deltas at the mouths of the tributary canyon. Therefore, mudflow debris becomes another source of acidic drainage. The

potential for natural acidic seeps and springs throughout the area, including the mine property, is high. Hanson Creek and Hot-N-Tot natural acidic drainages are an example of these conditions east of the mine property.

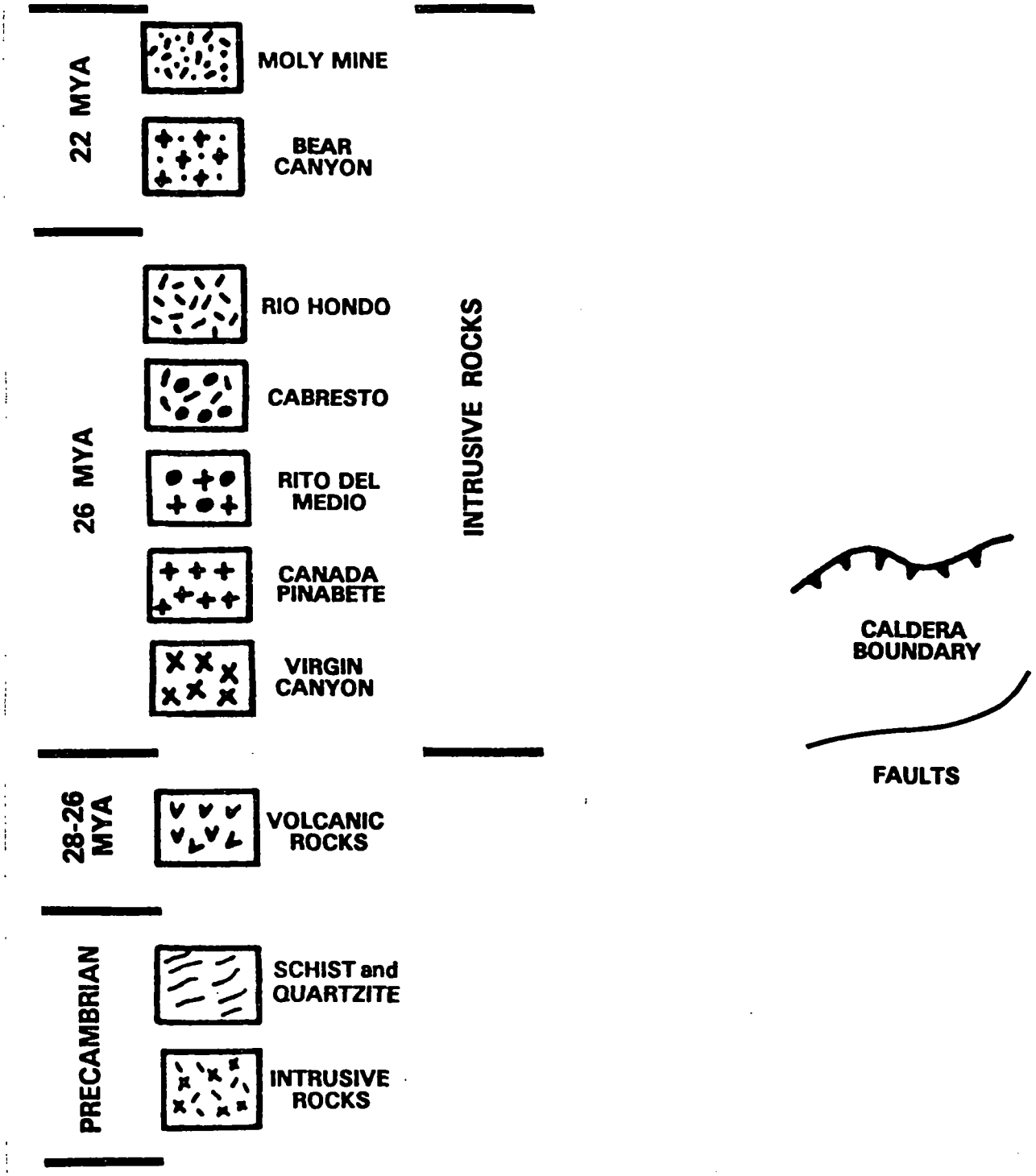
Schilling (1956) reported that iron-enriched mine drainage waters precipitated limonite near the portal to Z Tunnel (old underground workings) and that pre-mine alluvial deposits cemented by limonite occur in the upper Sulphur Gulch drainage above the older workings. During field reconnaissance, SPRI geologists observed that limonite-cemented alluvial material occurs in the lower part of Goathill Gulch near State Route 38, on an outcropping of cemented gravels on the north side of State Route 38, west of the cabins, and throughout a 75-foot thick section of a mudflow deposit just west of lower Hanson Creek near the highway. During the drilling of MMW-16 at Sulpher Gulch, a 10-foot section of limonite-cemented gravel was encountered at a depth of 36 to 46 feet. A thin (less than 1-foot thick) bed of limonitic sediment was exposed a few feet below the recent alluvial surface in bank exposures along the Red River. All of these occurrences indicate that the natural oxidation processes occurring at present have a very long pre-mine history.

GEOLOGY




REFERENCE: MOLYCORP FILES.

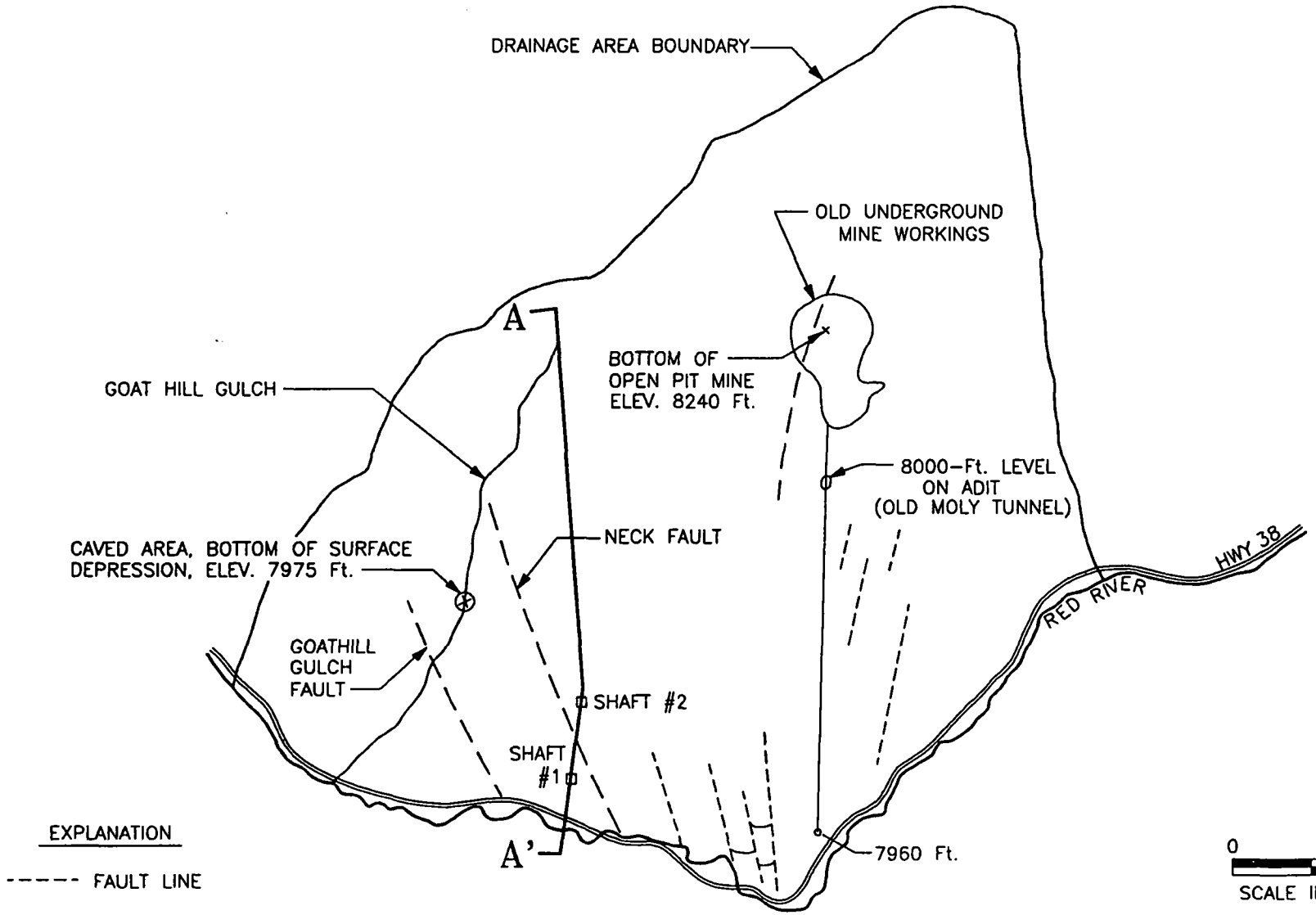
| SOUTH PASS RESOURCES, Inc. | | | | GENERALIZED GEOLOGIC MAP<br>Mine Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: A1 |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | | |




REFERENCE: MOLYCORP FILES.

| SOUTH PASS RESOURCES, Inc. | | | | GENERALIZED GEOLOGIC MAP KEY<br>Mine Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: A1a |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

XSEC-MAP

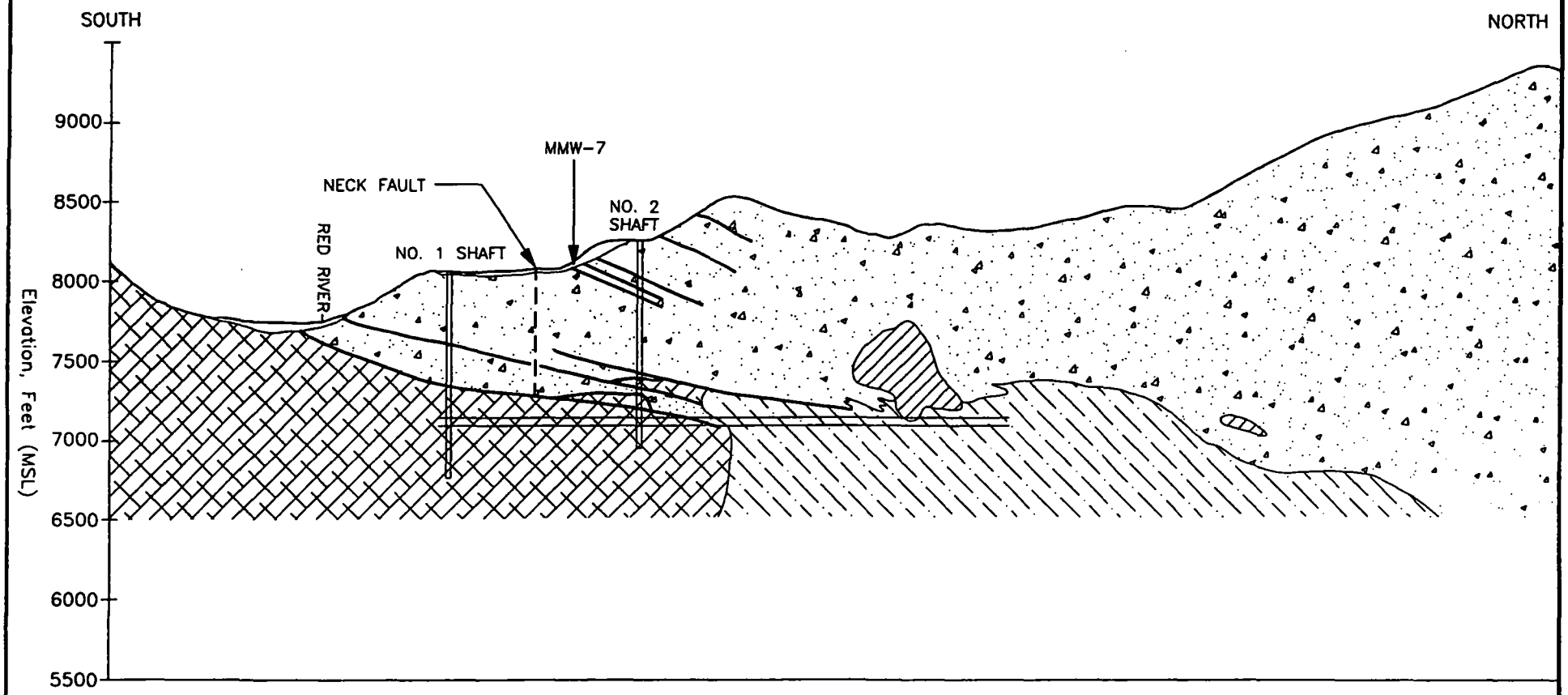



| FIGURE: | SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|---|
| A2 | PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. |

# APPROXIMATE CROSS-SECTION LOCATION

Mine Area - Molycorp, Inc.
Questa, New Mexico

XSEC-4A




LEGEND

- MINERALIZED ZONES
- TERTIARY INTRUSIVE: MINE APLITE AND GRANITE
- TERTIARY VOLCANICS: FLOWS, TUFFS, DIKES
- PRECAMBRIAN ROCKS
- LOW-ANGLE NORTH-DIPPING FAULTS

0 500 1000

VERTICAL & HORIZONTAL SCALE IN FEET

FIGURE: A3

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | JCK | M.O'M. |

# GEOLOGIC CROSS-SECTION A - A'

Mine Area - Molycorp, Inc.
Questa, New Mexico

# APPENDIX B

# APPENDIX B

## Discussion Of Mine Area Hydrogeology

# APPENDIX B

## Discussion Of Mine Area Hydrogeology

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B.3 PRE-MINE WATER-TABLE CONFIGURATION ..... B-7
B.4 AQUIFER TESTS ..... B-9
B.5 GROUND-WATER TRANSPORT ..... B-11

# APPENDIX B

## Discussion Of Mine Area Hydrogeology

## B.1 HYDROGEOLOGIC UNITS

In the Mine Area, the identified hydrogeologic units are:

- Pre-Cambrian/Tertiary Aquitard,
- Tertiary Aquifer,
- Hydrothermal Alteration ("Scar") Aquitard [Note: not a true aquitard because it is not in the saturated zone]
- Valley-Fill/Mudflow Aquifer,
- Valley-Fill/River Alluvium Aquifer, and
- Mine Waste-Rock Dumps (Perched Aquifer).

Each of these units is discussed below.

### Pre-Cambrian/Tertiary Aquitard

The Pre-Cambrian metamorphic and intrusive rocks and the stock-like Tertiary intrusives (Mine Aplite) form a hydrogeological basement or a regional aquitard analogous to the regional lower clastic (Pre-Cambrian/Cambrian quartzites) aquitard identified by Winograd and Thordarson (1975) in central and eastern Nevada. While shallow fracture systems (and in some cases, major through-going faults) allow for some movement of ground water, these rocks are characterized by low hydraulic conductivity and serve as barriers to deep circulation of ground water. Schilling (1956), in characterizing the vertical fracture system in the Mine Aplite, noted that these fractures pinch out downward into the main intrusive mass. These fractures (along with numerous small faults) are also mineralized in the ring fracture fault zone.

### Tertiary Aquifer

The Tertiary volcanics and sedimentary rock units are highly fractured and faulted throughout the caldera block north of the river. (Note: sedimentary units are very thin and do not show on Figure A1 - Appendix A.) The major structural features are high-angle northwest-, north-, and northeast-trending faults and low-angle faults, either parallel to the intrusive/volcanic contact (contact conformable fractures) or along unit contacts. Joints related to some combination of tectonic and volcanic processes are also present in the volcanic units.

Although mineralization and/or clay gouge along faults have sealed some of the fractures, not all are sealed and fracture flow does occur throughout the area. The Tertiary volcanic rock then represents the aquifer in the area and has highly variable hydraulic conductivity depending on the fracture orientation, fracture spacing, and the openness of the fracture system below the water table.

**Hydrothermal Alteration ("Scar") Aquitard**

The hydrothermal scars scattered across the ridges above the mined area are composed of pyrite, clay, quartz, and carbonates altered to iron oxide, gypsum, jarosite, plus residual quartz and clay resulting from near-surface oxidation processes. These masses of altered material are principally located above the natural water table, but they likely have very low hydraulic conductivity and serve to retard infiltration to the fractured Tertiary aquifer system. Several 90-foot deep boreholes drilled by Molycorp into the "scar" material were either dry or produced very small flows (on the order of less than 1 gallon per minute) over time. Because masses of fractured rock are located within the hydrothermal "scars," some of this flow may have been from local perched water zones associated with isolated masses of rock. If the "scar" material extends below the water table, the altered rock might locally create semi-confined conditions.

**Valley-Fill/Mudflow Aquifer**

Schilling (1956) described and mapped mudflow deposits in the Sulphur Gulch area and related these flows to intense storms that periodically flushed valley debris to the Red River Valley. He noted that the mudflows tended to develop in tributary canyons that extend across the hydrothermal scar areas transporting the hydrothermally altered rock toward the main valley. At times, flows blocked the Red River Valley and spread laterally—covering parts of the valley floor. SPRI field observations were that mudflow deposits extend beyond the area mapped by Schilling and are present at Goathill Gulch and Capulin Canyon. These mudflow accumulations, interbedded with alluvial sands and gravels, make up the fan delta deposits that occur at the lower part of many of the tributary canyons. Because hydrothermally altered rock underlies so much of the land north of the river (Appendix A), virtually all of the tributary canyons have some mudflow debris composed of acid-generating rock within the fan delta deposits. The large fan delta complexes at Hanson and Hot-N-Tot Creeks, Sulphur Gulch, Goathill Gulch, and Capulin Canyon are examples of deposits that contain acid-generating mudflow debris.

The mudflow material consists of angular, poorly sorted rock ranging from pebble to boulder sizes in a matrix containing varying amounts of clay, slit, and sand. Field observations of these deposits and borehole logs show that thin layers of sandy, silty clay are present within the mudflow. Drilling has also encountered buried logs in these deposits.

Mudflow sediments from the tributary canyons should interfinger with the river alluvium, but drillers' lithologic logs for the Columbine and Mill wells on or close to the Red River Valley floor are not of sufficient detail to recognize this. Ephemeral flows and seepage from tributary canyons should infiltrate the mudflow sediment and these deposits can serve as a conduit between the tributary canyons and the main valley. Exposure of these mudflow deposits are gypsiferous resulting from precipitation of gypsum from pore waters and/or reactions between acidic pore water and pyritic debris. In either case, the fan delta deposits themselves may become sources of high TDS and sulfate-bearing acidic water. In the main valley, mudflow deposits may be part of the saturated valley-fill.

Valley-Fill/River Alluvium Aquifer

Drillers' logs characterize the river alluvium as rounded gravels (ranging from pebbles to boulder size) and fine to coarse sand. Pumpage at Columbine wells No. 1 and No. 2 was in the 1,000 gpm range (Molycorp files). In the mill area, which was built on a broad flat surface north of the Red River, Mill well No. 1 pumped at 1,200 gpm. Mill well No. 1A initially pumped up to 1,500 gpm, but the well could not sustain this level and was pumped dry shortly after completion. Other wells attempted in the mill area were not productive. Well logs to-date indicate that bedrock lies at depths of 80 to 150 feet below the valley floor.

Mine Waste-Rock Dumps (Perched Aquifer)

The mine waste-rock dumps are fairly permeable relative to the underlying bedrock. The dumps are recharged from snow melt and other precipitation events. That they store water for some period of time is evidenced by the acidic, high TDS and high sulfate waters discharged in some places from the lower part of these rock piles. Recharged water has sufficient residence time to react with available sulfide (chiefly pyrite) to generate acidic conditions. Mine waste-rock dumps function as perched aquifers that discharge water to surface seeps and flows, to valley-fill sediments, and to fractured bedrock.

Mine waste-rock dumps occur at the head of Capulin Canyon and Goathill Gulch. Farther south, the Sugar Shack West dump was built across a small canyon that merges near Shaft No. 2 with a larger canyon tributary to the Red River. Sugar Shack South Dump, the Middle Dump, and the Sulphur Gulch/Spring Gulch Dump were built across drainages tributary to the Red River. These dumps were constructed from rock excavated when the open pit was developed. Berms (to control rock falls and slides from the waste-rock dumps) were constructed from local valley-fill material and extended across the tributary valleys prior to the building of the waste-rock piles. Geologic maps, cross-sections of the pit area, and borehole logs with or without geochemistry indicate that the dominant rock types were andesitic flow rocks and aplite with subordinate amounts of granite porphyry and rhyolitic ash flow tuffs. Virtually all of these rock types (including overburden rock, subeconomic waste rock, and ore)

normally carry some disseminated pyrite. Most of the ore mineralization was in the aplite and the andesite. Mine waste-rock ranges from fresh, weakly altered rock to rock consisting largely of quartz, clay, and pyrite (or its oxidized equivalent). Occasionally, rock fragments at the toe of the dump will disintegrate very easily because of the growth of intergranular gypsum precipitated from dump waters. Qualitative observation of waste-rock piles indicates that dump material ranges from clay to boulder sizes. The dump material shows "angle of repose" layering resulting from variations in time of the size fragments excavated. Downward flow of water in this unsaturated environment should be enhanced by the angle of repose layering.

## B.2 GROUND-WATER RECHARGE

Factors to be evaluated in preparing estimates of ground-water recharge include: topography (elevation, degree of slope); surface material (outcrop, soil sediment); permeability and run-off characteristics of surface material; bedrock conditions in terms of infiltration characteristics, porosity, and hydraulic conductivity; and climate (temperature, precipitation, evaporation). Many of these parameters are not well defined in the Red River drainage area, but there are sufficient data to make some estimates of a hydraulic connection between ground water and the Red River.

The mine operations are located north of the Red River Valley where elevations range from 7,581 feet on the Red River opposite Capulin Canyon to 10,812 feet at the ridge north of the open pit, resulting in a relief of 3,221 feet. Excluding the relatively narrow flat to gently rolling valley floor, most of the topography is composed of steep to very steep slopes that are conducive to high rates of runoff. Major tributary canyons in the Mine Area have gradients on the order of 600 to 800 feet per mile.

The U.S. Soil Conservation Service (1982) defined four soil map units (as part of their soil survey of Taos County) in the Mine Area north of the Red River:

- Two of the soil units (Rock Outcrop/Ustorthentis Complex and Marosa Soil/Rock Outcrop Complex) are described as gravelly and/or sandy loams. These soils are characterized by rapid to moderate run-off with high erosion potential. Infiltration (number of inches per hour that water percolates downward in the soil) ranges from 0.6 to 6 inches. The soil units are described as complex because a significant percentage of the map area consists of outcrops of igneous and metamorphic rocks. Vegetative cover consists of Douglas fir, Engelmann spruce, and Ponderosa pine with an understory of Gambel oak, mountain brome, kinnikinnick, Kentucky bluegrass, Arizona fescue, and whortleberry.

- The third soil unit (Rock Outcrop/Badland Type) is associated with the hydrothermal scars and underlies much of the area north of the Red River

(Appendix A). This soil is described as extremely acidic (pH <4.5). It occurs along portions of all of the major drainages (Capulin, Goathill, Spring & Sulphur Gulch). Typically, slopes are steep and are nearly barren of vegetation. The Soil Conservation Service characterizes this unit as a soil that generates increasing sediment loads to tributary drainage as precipitation increases (very high run-off and erosion potential). Drainages that intersect the hydrothermal scar areas typically have mudflow deposits near their confluence with the Red River.

- The fourth soil unit (Cumulii Hoplobenolls) covers parts of the main valley floor. It generally consists of stratified gravelly sandy loams and gravelly clays. Infiltration of the soil is slow to moderate (0.2 to 2 inches per hour). Periodic flooding is the chief hazard here.

Rainfall estimates related to elevation and soil units in the Mine Area were prepared by the U.S. Soil Conservation Service (1982). For the lower elevation, below 9,000 feet, the annual precipitation is 18 inches; between 9,000 to 11,000 feet, annual precipitation is 35 inches. In its report, the U.S. Soil Conservation Service indicates that annual snowfall can exceed 100 inches in the mountains. Schilling (1956) had estimated 21 inches of annual precipitation for the same area. The bulk of the precipitation is winter snowfall with some thunderstorm contribution during the summer months. The average annual temperature is 40° to 42° Fahrenheit.

Several authors have attempted to estimate the distribution of precipitation among run-off, evapotranspiration, and ground-water recharge. Wilson and Associates (1978) estimated that in the mountainous areas of northern New Mexico, 3 to 10 inches of the precipitation contributed to run-off and the balance was distributed between evapotranspiration and recharge to ground water. Vail Engineering (1989) measured the areas of drainage basins for the major tributary to the Rio Grande, including the Red River, and calculated basin discharges from an equation based on drainage basin area and average annual winter precipitation. For the lower Red River basin (Zwergle Dam east of the Town of Red River to the Questa Ranger Station stream gauge), Vail calculated a discharge of 38.2 cubic feet per second (cfs). A review of flow discharges measured over a 12-year period [U.S. Geological Survey (USGS) data in Molycorp files for 1943 to 1955] shows that discharge ranges from 7.74 cfs to 262.5 cfs. In general, the higher flow rates occur in the April through July period and the lower rates over the balance of the year. Overall, this section of the Red River between the dam and the Ranger Station appears to be a gaining stream with substantially higher flow discharge at the downstream station.

River accretion studies by the USGS (in October 1965 and in 1988) were referenced by Smolka and Tague (1988) in their water quality survey of the Red River between Zwergle Dam and the Fish Hatchery. After correcting for tributary and diversion flows, they estimate

that the net gains from ground water were 9.0 cfs (1965) and 9.1 cfs (1988) between Zwergle Dam and the Ranger Station gauge east of Questa. The Molycorp mill was not in operation in 1965 or 1988 and was not a factor in the diversion calculations. A review of the 1943-1955 flow data (Molycorp files) for these two gauges indicate that base flow (ground-water recharge) conditions ranged from 7.74 cfs to 13.9 cfs (an average of 11.04 cfs). This data set also shows that base flow conditions are typically in December and January, and Smolka and Tague's estimate for net gain to ground water may be too high. Vail (1989) used USGS stream flow data to estimate accretion to the Red River at nine locations from the Zwergle Dam site to the Bear Canyon area (near the Questa Ranger Station gauge). The segment from the Molycorp mill downstream to Bear Canyon is estimated to have an accretion of 6.6 cfs. Of this, 5.0 cfs comes from Columbine Creek, which leaves 1.6 cfs related to recharge from intermittent tributary drainages, seeps, and springs along both sides of the rivers.

Another approach to estimating drainage basin recharge to ground water utilizes the Maxey and Eakien (1949) approach. Their method estimates that 25 percent of the annual precipitation over the Mine Area drainage basin could contribute to recharge. Vail Engineering (1989) calculated areas for the Red River drainage basin and for the lower Red River basin (from Zwergle Dam to the Ranger Station). Using an area of 83.24 square miles at 25 percent of 21 inches annual precipitation (Schilling, 1956), the entire basin would contribute 32.25 cfs to ground water. That part of the entire drainage basin in the Mine Area represents about 6 percent of the total drainage basin. On the assumption of a uniform distribution of ground-water recharge (as an approximation), 1.94 cfs would be recharged to the ground water. Using Vail's (1989) estimate of the square miles for discrete elevation zones and 25 percent of the annual precipitation for each zone as recharge results in a higher estimate of 2.56 cfs ground-water recharge for the Mine Area drainage basin. SPRI (1993b), using a similar approach for the Mine Area drainage basin (Capulin Canyon to Spring & Sulphur Gulch), calculated a ground-water recharge of 1.45 cfs. If a water balance is assumed, this recharge equals accretion to the Red River.

A final approach to estimating recharge from ground water is to use the average of the baseflow from the 1943 to 1955 flow data (11.04 cfs) as an estimate of the total ground-water recharge for the basin. Again, with the assumption of an uniform distribution of recharge throughout the basin, the Mine Area portion of the drainage basin (6 percent of total area) would have contributed 0.66 cfs. This value is considerably lower than the precipitation-based estimates. The lower recharge values will be used here because there may be less error for a recharge estimate based on actual flow data than for estimates based on a precipitation approximation.

Vail Engineering's (1989) accretion study results in an estimate of 1.6 cfs of ground-water recharge in the river from both sides of the segment opposite the mine. This would

result in about 0.8 cfs from the north (mine side) of the river, which is in fairly good agreement with the base flow estimate.

Molycorp records indicate when the deep underground mine was being developed, dewatering required between 250 and 500 gpm (0.57 to 1.14 cfs). The Smolka and Tague (1988) accretion study, during the time of mine development, shows a net accretion to the river from ground water of 9.0 cfs, similar to the pre-mine accretion of 9.1 cfs in 1965. Taken at face value, this suggests that the mine was dewatered from the deeper part of the ground-water flow system and did not appreciably, if at all, reduce accretion to the river from ground water. The explanation for this is that most of the ground-water recharge to the river may have come from the upper part of the ground-water system. In other words, the deep mine was not directly in the recharge zone. Schilling (1956), in his description of fracturing in the Sulphur Gulch area, indicated that many of the fractures (particularly sheeting type of fracturing related to contacts) tend to die out with depth. More water was probably in storage in the shallow, more open, and better interconnected fracture system close to the water table, and mineralization combined with lithostatic pressure effectively sealed much of the deeper level fractures. With lower hydraulic conductivity conditions at depth, a cone of depression (probably steep-sided) would develop over the deep mine. SPRI (1993b, 1994) concluded that the cone probably did not extend to the river.

The stability of the water levels in the monitor wells over the last five months, despite continuous dewatering of the underground mine (several hundred feet decline over the same period), supports the interpretation that a steep cone of depression occurs over the mine, and that the edge of the cone is north of the river. The wells close to the river could possibly be recharged at a rate which balances any loss (discharge) due to dewatering. Water-quality data from 1994 sampling of the river and of the monitor wells, in terms of dilution affect, is inconclusive because there is no historical water-quality data. Concentrations of sulfate in well water ranges from 700 to 1,300 mg/L while river water is typically less than 20 mg/L. As water-quality samples are taken over the next year, it may be possible to evaluate dilution affects, if any.

## B.3 PRE-MINE WATER-TABLE CONFIGURATION

Based on Molycorp data (obtained in 1993), dewatering inflow for the older underground workings and for the open pit ranged from 15 to 30 gpm, which are very low flow rates. However, anecdotal evidence from mine workers active at the open pit indicate that an extensive water control program was in operation during the development of the pit and that these rates may be low. If these areas were below the water table, such rates could only be explained by very tight rock conditions in which virtually all the fractures were sealed.

Schilling's (1956) and Rehrig's (1969) descriptions of the fracture systems and field examination of rock exposures in the same area indicate that open fractures exist (some fracturing can be related to mine activities). It is also likely that these low flow rates can be attributed to perched fracture water above a regional water table. The deeper underground workings dewatered at 250 to 500 gpm. [For comparison, Newmont's Gold Quarry Mine in Nevada is in fractured sedimentary rock and dewaters at 50,000 gpm (Carrillo, 1993).] However, if the fractures in a mineralized zone were partly sealed by mineralization/clay gouge and/or poorly interconnected, then 500 gpm, even below the water table, would not be unreasonable. It is possible that the open pit and most of the older underground workings near Sulphur Gulch (down to 7,800 to 7,900 feet) were above the regional water table and that the inflows were from perched water. Currently, this inflow from the open pit and the older underground mine drains though a borehole into the deeper mine workings.

If the gaining stream model is used with the equipotential lines (contours of equal water-level elevation) nearly normal to the flow direction of the river, such a contour surface would allow for most of the old workings and the pit to be relatively dry and above the regional water table. The Moly Tunnel (7,960 adit) would be at the water table at an elevation of 8,000 feet. Construction of the 7,960 adit did not produce much water and, therefore, the 8,000-foot water-level contour might have curved more to the north. This water-table surface would have a southwesterly gradient of 0.036 foot/foot in this very simplified configuration. If the equipotential lines were parallel to the river, most of the old workings and part of the open pit would have been below the pre-mine water table.

A simplified water-table surface with the equipotential lines at a right angle to the river can be used to estimate the elevation of the water table in various areas of the underground workings. For example, the water level would continue to rise in the caved area above the underground workings in the Goathill Gulch area to an elevation of approximately 7,840 feet. At Shaft No. 1, the elevation would be about 7,820 feet and at Shaft No. 2, it would be closer to 7,850 feet. With respect to the old Moly Tunnel (7,960 adit), a conservative position would place it just below the water table at about 8,000 feet.

Another element in the water-table surface configuration is the additional recharge from seepage barriers to the mine through the caved area. This recharge currently amounts to about 70 gpm captured by the seepage barriers constructed on Capulin and Goathill Gulches. An additional 30 gpm drains from the open pit through a borehole in the old underground mine to the deeper workings. This amount of seepage water is occasionally strongly augmented by surface water related to storm discharge and snow melt such that recharge to the caved area can exceed several hundred gpm. How much of this water actually reaches the caved area is unknown since it is a surface discharge and a certain amount must be lost to evaporation or infiltration to the vadose zone. (In the vadose zone, the water would be bound by surface

tension in intergranular voids or micro-fractures.) It is possible that the additional recharge might cause some mounding of the water table surface, particularly in the caved area, and locally a slightly steeper gradient. A concern here is that water-level mound in the caved area might extend to the valley-fill in Goathill Gulch from which it could more easily reach the river.

Rate of Rise for the Water Table

On May 19, 1994, the water level in the mine workings was at 7,600 feet. According to Molycorp records, the caved area began to fill by October 20, 1992. Using the elevation of the bottom of the caved area (7,226 feet) and the time since filling began (549 days), the rate of rewatering is 0.68 foot/day. The actual daily rate values range from less than 0.68 to as much as 2.0 feet/day, depending on seasonal recharge conditions. However, if the 0.68 foot/day is used as the rate, it would take 147 days (from May 1994) for the water level to rise to the down-gradient elevation (7,700 feet) of the Red River. (This assumes a southwestern gradient based on the normal contour configuration in the caved area at Goathill Gulch). In other words, after 147 days (0.4 year) from May 1994, there would be a slight gradient from the cave area toward the river. Using the same rate of 0.68 foot/day, it would take 0.97 year to reach the postulated water-table elevation of 7,840 feet in the caved area. However, as noted in the previous paragraph, localized high recharge rates in the caved area could cause mounding and water would be higher and at an earlier date than the 0.68 foot/day rate predicts. In the case of the Moly tunnel (7,960 feet), it would require 1.61 years for the water level to reach 8,000 feet and begin to flow down to the adit.

Monitor wells constructed in 1994 were designed to capture tributary discharges to the valley-fill and bedrock aquifers. Not enough wells were sited in a single aquifer to evaluate flow directions or hydraulic gradients.

## B.4 AQUIFER TESTS

An aquifer test conducted in the valley-fill at MMW-10A resulted in a calculated transmissivity of 123,200 gallons per day per foot (gpd/ft) and a hydraulic conductivity of 1,141 gpd/ft$^2$ (based on an aquifer thickness of 108 feet). These are reasonable values for the coarse sand and gravel encountered in this well. However, the maximum pump yield was 140 gpm, and the aquifer was not stressed.

Almost all of the bedrock wells went dry during development (air-lift). Bladder pumps were utilized in sampling these wells, and yields were typically a few gallons per minute or less. The exception to the low yield during development was MMW-11, which yielded 60 gpm with less than one (1) foot of drawdown. The high yield probably resulted from this well

being located close to a north-south fracture zone. An estimate for transmissivity based on the specific capacity:

$$\left(\frac{Q}{s}\right) = \left(\frac{60gpm}{1foot}\right)$$

and utilizing an equation developed by Huntley et al. (1992) for fractured rock

$$T = K\left(\frac{Q}{s}\right)^{1.18}$$ where K is a conversion factor from their Table 1

resulted in a transmissivity of 4,877 $ft^2/d$, or 36,481 gpd/ft. (Note: The factor to convert from $ft^2/d$ to gpd/ft is 7.48.)

The thickness of the bedrock aquifer is unknown. Using the saturated thickness at the well (58 feet), an estimated hydraulic conductivity (K) is 629 $gpd/ft^2$. This is probably close to a maximum value (thickness is too small), but still lies within the upper range of K values for fractured igneous rock (Freeze and Cherry, 1979, Table 2.2).

Another approach to estimating hydraulic conductivity uses the decline in water level at the underground mine during the current dewatering phase and dates of measurement on a time-drawdown plot. Data were plotted on semi-log pager and the Cooper-Jacobs equation was used to calculate transmissivity.

$$T = \left(\frac{264Q}{\Delta s}\right)$$

This calculation resulted in a transmissivity of 2,424 gpd/ft and a hydraulic conductivity of 5.09 $gpd/ft^2$ (the latter is based on a thickness of 476 feet or the difference between the pre-dewatering water-level and the top of the Grizzly level at the underground mine). The Cooper-Jacobs equation was developed for porous media. Its application to bedrock data assumes that over a large enough volume of rock ("large enough" is not specified), fractured rock can be approximated by a porous media formula.

The two values for hydraulic conductivity reported here are at best rough estimates. These results suggest that hydraulic conductivity ranges over two orders of magnitude from fairly tight rock to permeable fracture zones. A compilation of flow velocity based on simple analytical equations using single hydraulic conductivity values does not lead to reliable estimates for travel time. Even if the estimate was close to a true travel time, open fault zones at an angle to the regional gradient can move ground water more rapidly and in a different

direction from the regional flow direction. Estimates of flow velocity and travel time, based on water quality (from known sources) and isotopic data, may have more validity (when the data from such studies become available) than hydrogeological approximations.

## B.5 GROUND-WATER TRANSPORT

With the currently available information, it is not possible to make meaningful quantitative estimates for the velocity of ground water through the fractured bedrock. Tracer tests in sets of nearby boreholes would probably allow for an estimate of ground-water velocity through fractures. For these tests, the distances between boreholes and their relationship to mapped fractured systems would have to be considered. However, as indicated in previous sections, water chemistry combined with isotope data might lead to better estimates for velocity.

Seepage velocity formulas are based on advection in granular material, not fractured rock. Moreover, conceptual models for fracture flow include an equivalent porous media model that treats fractured rock as if it were a granular, porous medium. The rationale is that if the fracture spacing is small (compared to the scale of the system being studied), the model leads to a reasonable estimate of regional flow. The model is not an accurate representation of local conditions (e.g., an open fault that diverts flow at some angle to the regional system).

Using the caved area (located on Goathill Gulch) above the deep underground workings as a source and published values for hydraulic conductivity and porosity for fractured rock (Freeze and Cherry, 1979), rough estimates of travel time from the mine to the river can be made. According to Freeze and Cherry (1979), the range of hydraulic conductivity for fractured igneous and metamorphic rocks is $10^{-1}$ to $10^{3}$ gallons/day/ft$^2$ and for permeable basalt 1 to $10^{5}$ gallons/day/ft$^2$. The porosity range for fractured crystalline rock is 0 to 10 percent, and for fractured basalt 5 to 50 percent.

The seepage velocity formula is:

$$V = \frac{Ki}{7.48 n_e}$$

where:
- V = seepage velocity, in feet/day;
- K = hydraulic conductivity, in gallons/day/square foot;
- i = hydraulic gradient, in feet/feet;
- $n_e$ = porosity, as a percent; and
- 7.48 = gallons per cubic foot.

The hydraulic gradient (0.036 ft/ft) and the down-gradient distance to the river from the caved area (3,500 feet) are based on a "normal" water-table configuration map. Seepage velocity was estimated by using a hydraulic conductivity equal to 10 gallons/day/ft$^2$ and a porosity of 10 percent. These values are in the mid- to upper-range of values for fractured igneous and metamorphic rocks and in the lower range for permeable basalt. The resulting seepage velocity is 0.48 foot/day and the travel time from the caved area to the river is 19.97 years. High-angle faults that cut across the structure of the mineralized zone and the low-angle north- and west-dipping faults may represent preferential pathways for flow to the river at rates less than the calculation indicates. However, estimates of seepage velocity and travel time calculated from formulas *derived from granular or matrix flow* and applied to a setting where hydraulic conductivity is highly variable are not accurate.

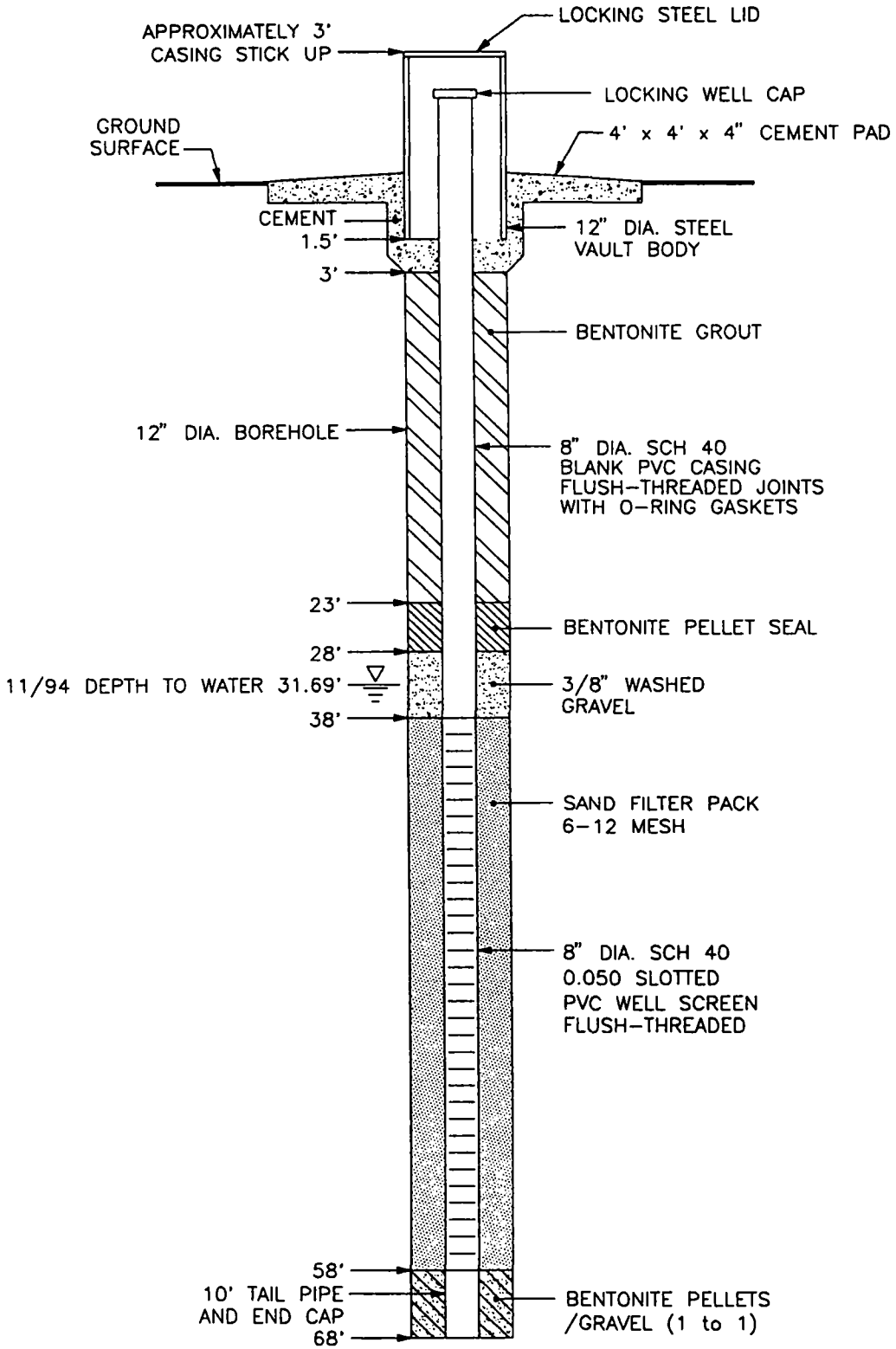
APPENDIX C

# APPENDIX C

## Mine Area Borehole Logs

## (from Fall 1994 Field Investigations)

MMW-2

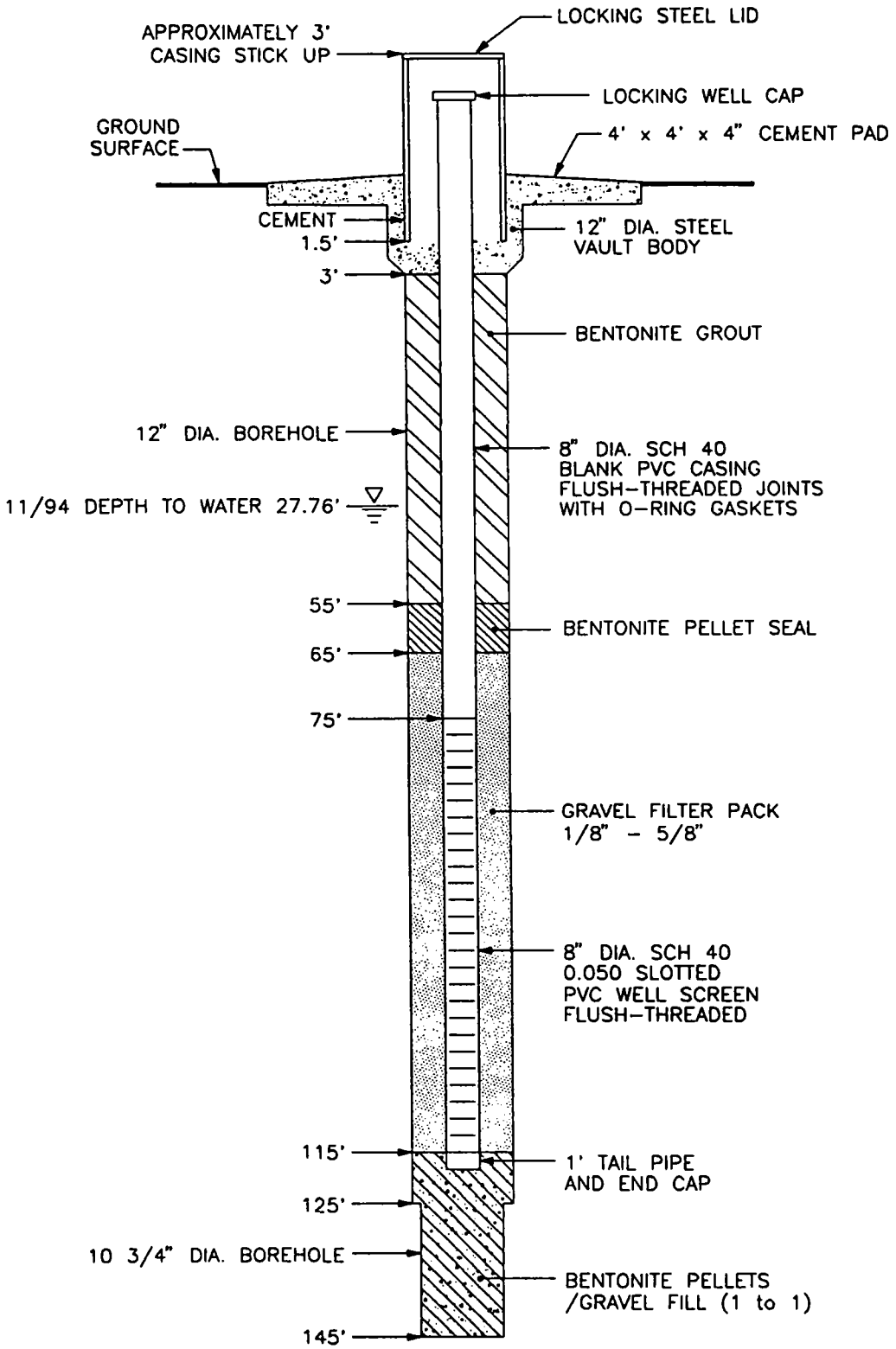



SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL MMW-2<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE:<br>C1 |
|---|---|---|---|---|---|
| PROJECT No.:<br>001-05 | DATE:<br>2/20/95 | AUTHOR: | DRAWN BY:<br>M.O'M. | | |

MMW-3




NOT TO SCALE

## SCHEMATIC OF WELL CONSTRUCTION

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL MMW-3<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C2 |
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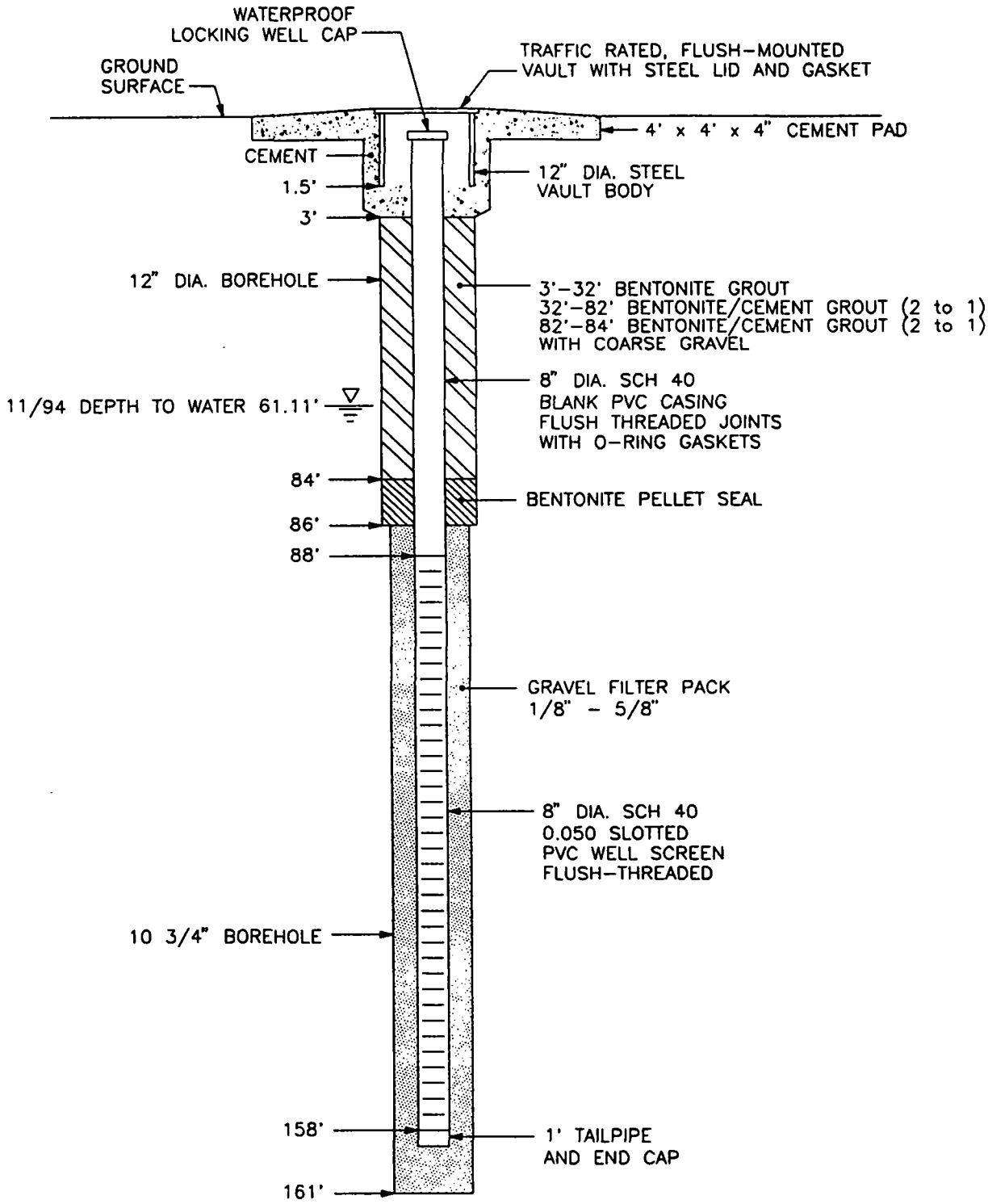
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-7




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, INC. | | | | MONITOR WELL MMW-7<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C3 |
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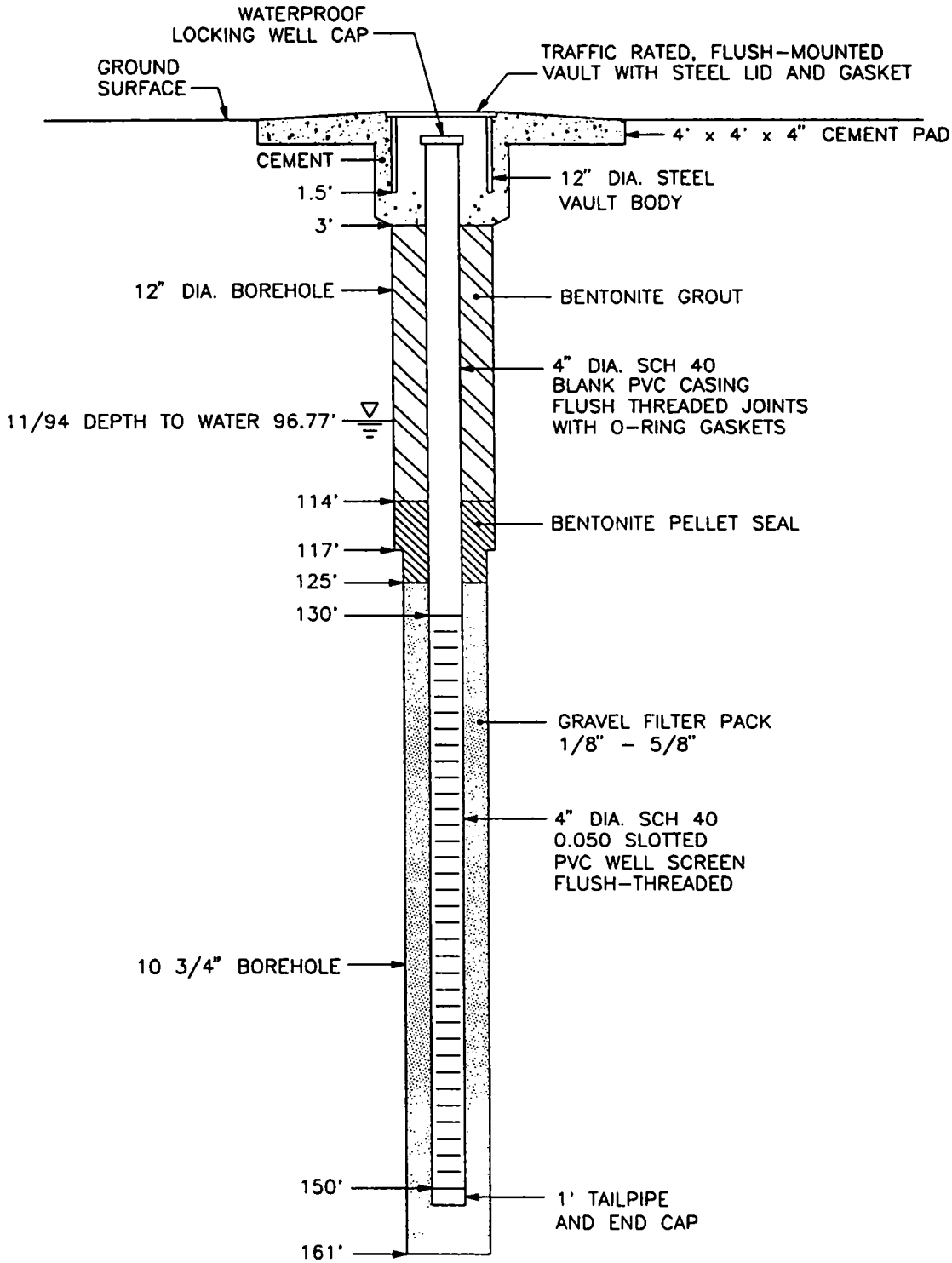
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-8A

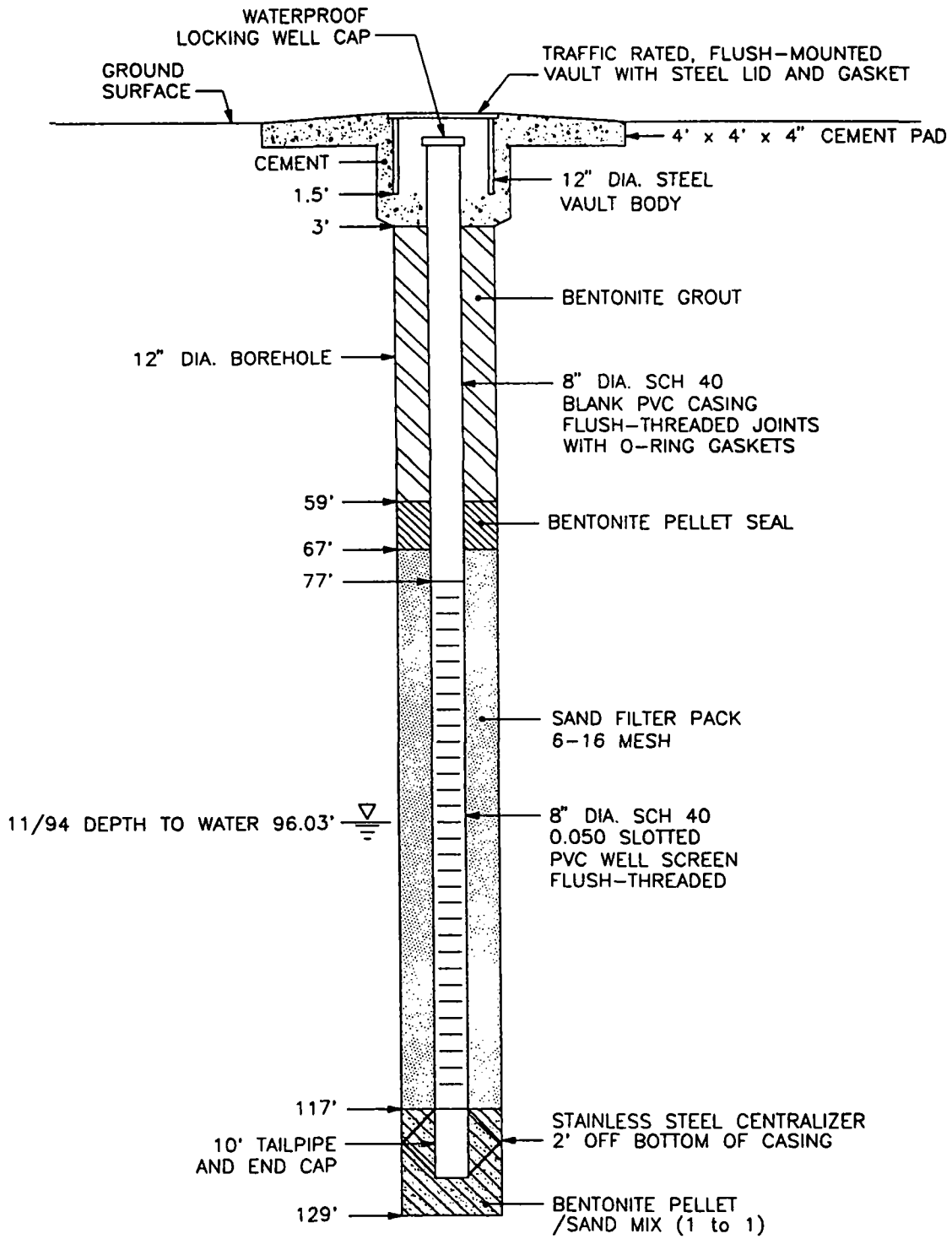



SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, INC. | | | | MONITOR WELL MMW-8A<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE:<br>C4 |
|---|---|---|---|---|---|
| PROJECT No.:<br>001-05 | DATE:<br>2/15/95 | AUTHOR: | DRAWN BY:<br>M.O'M. | | |

MMW-8B




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, INC. | | | | MONITOR WELL MMW-8B<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C5 |
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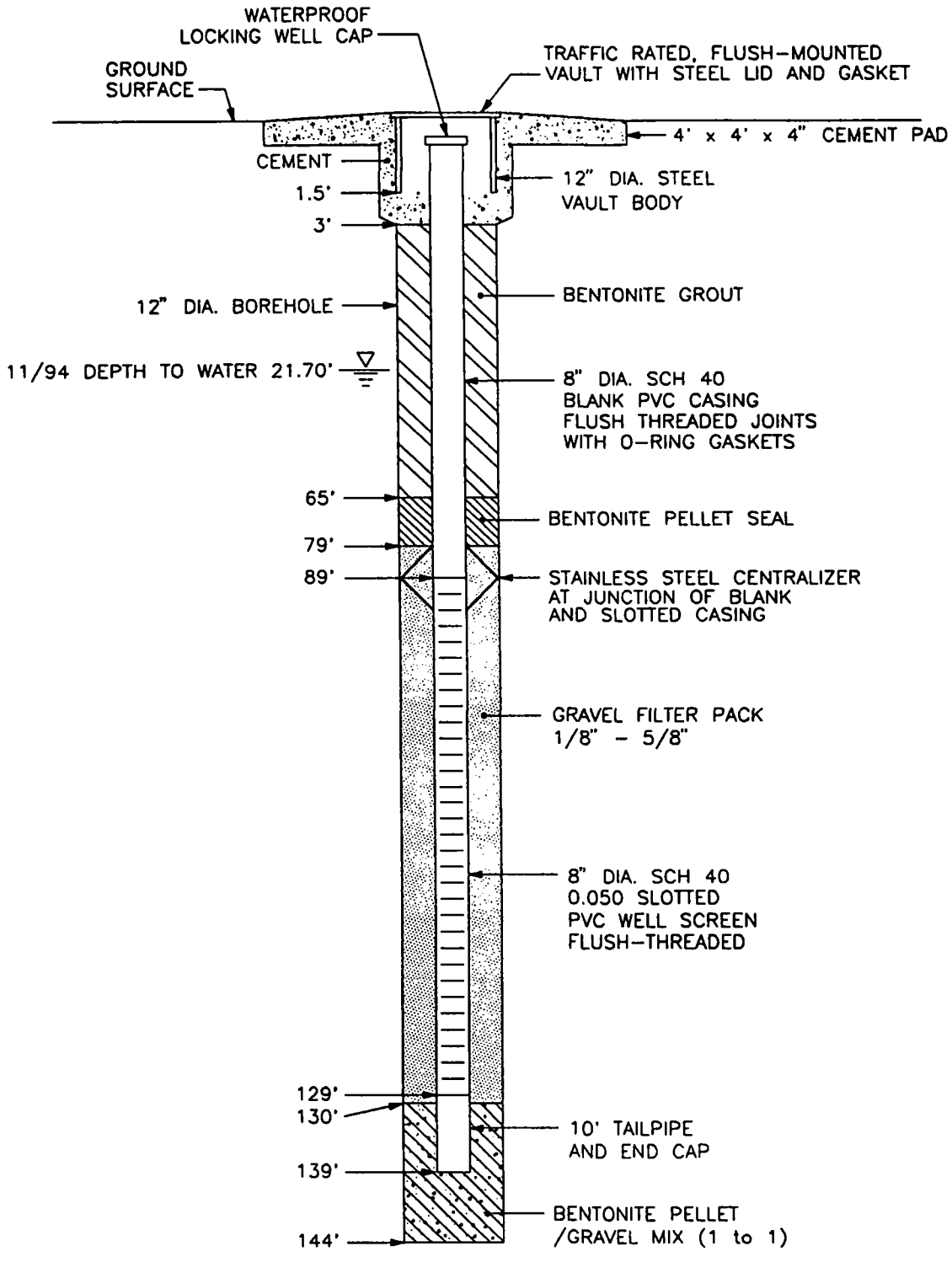
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-10A




## SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

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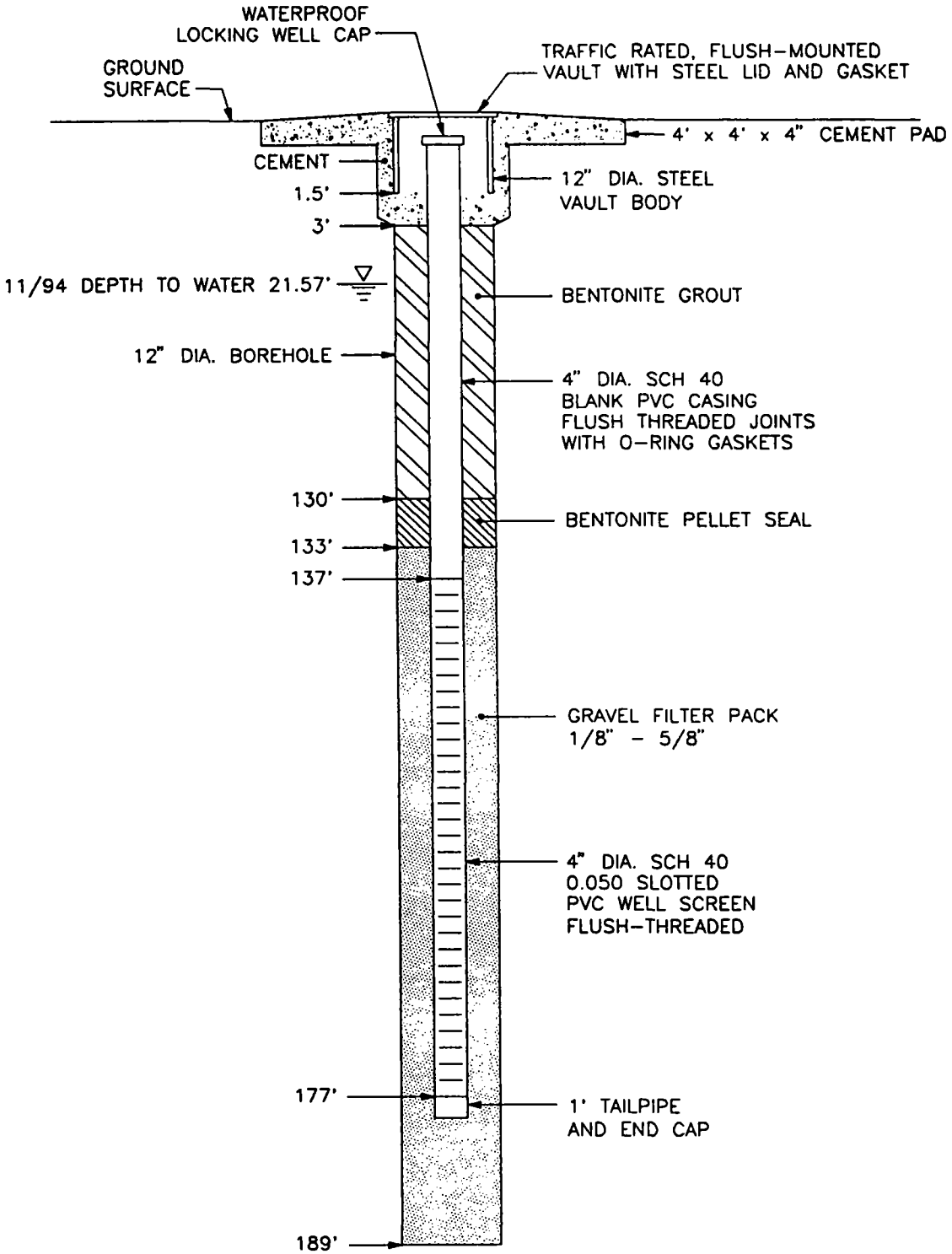
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-10B




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, INC. | | | | MONITOR WELL MMW-10B<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C7 |
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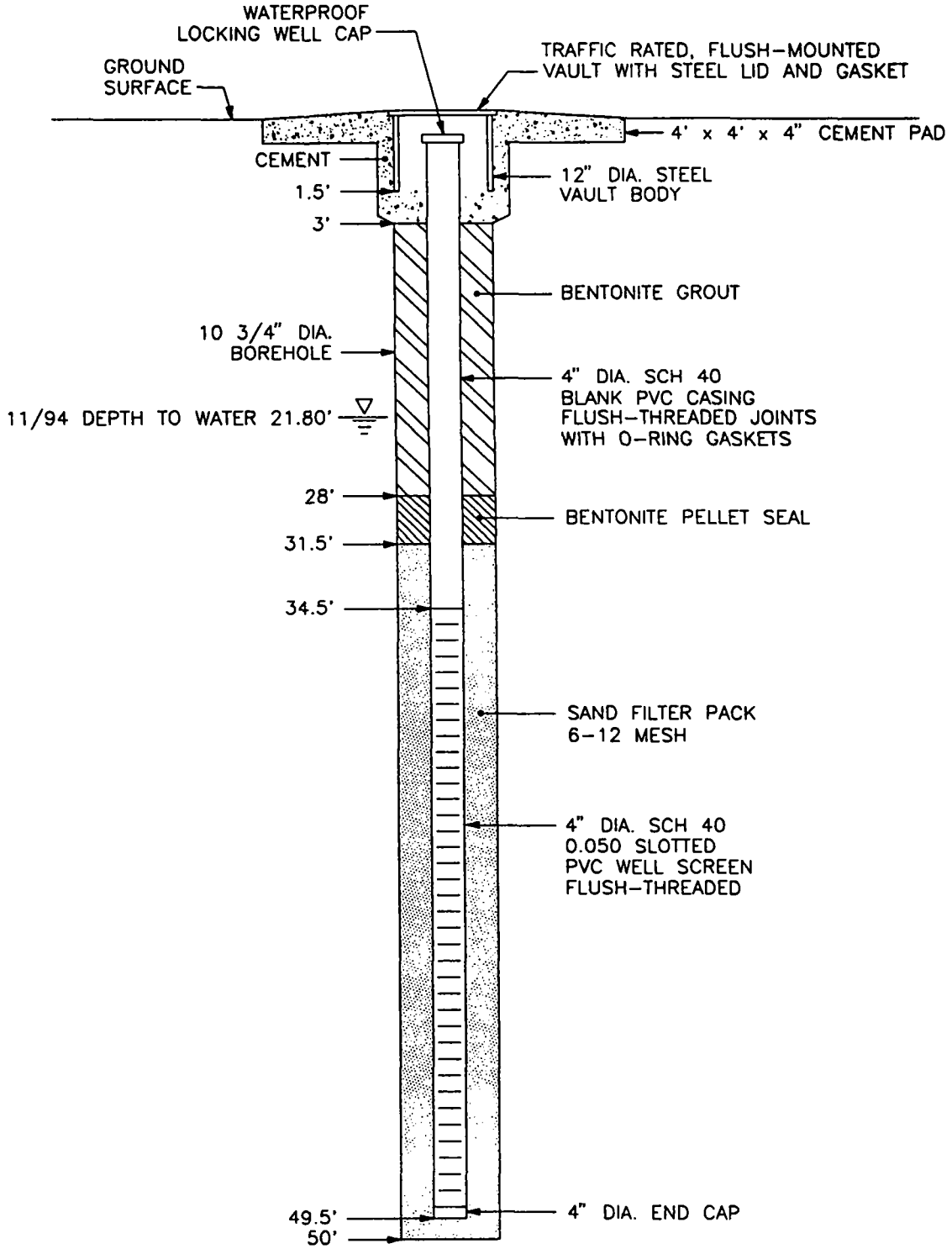
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-10C




## SCHEMATIC OF WELL CONSTRUCTION

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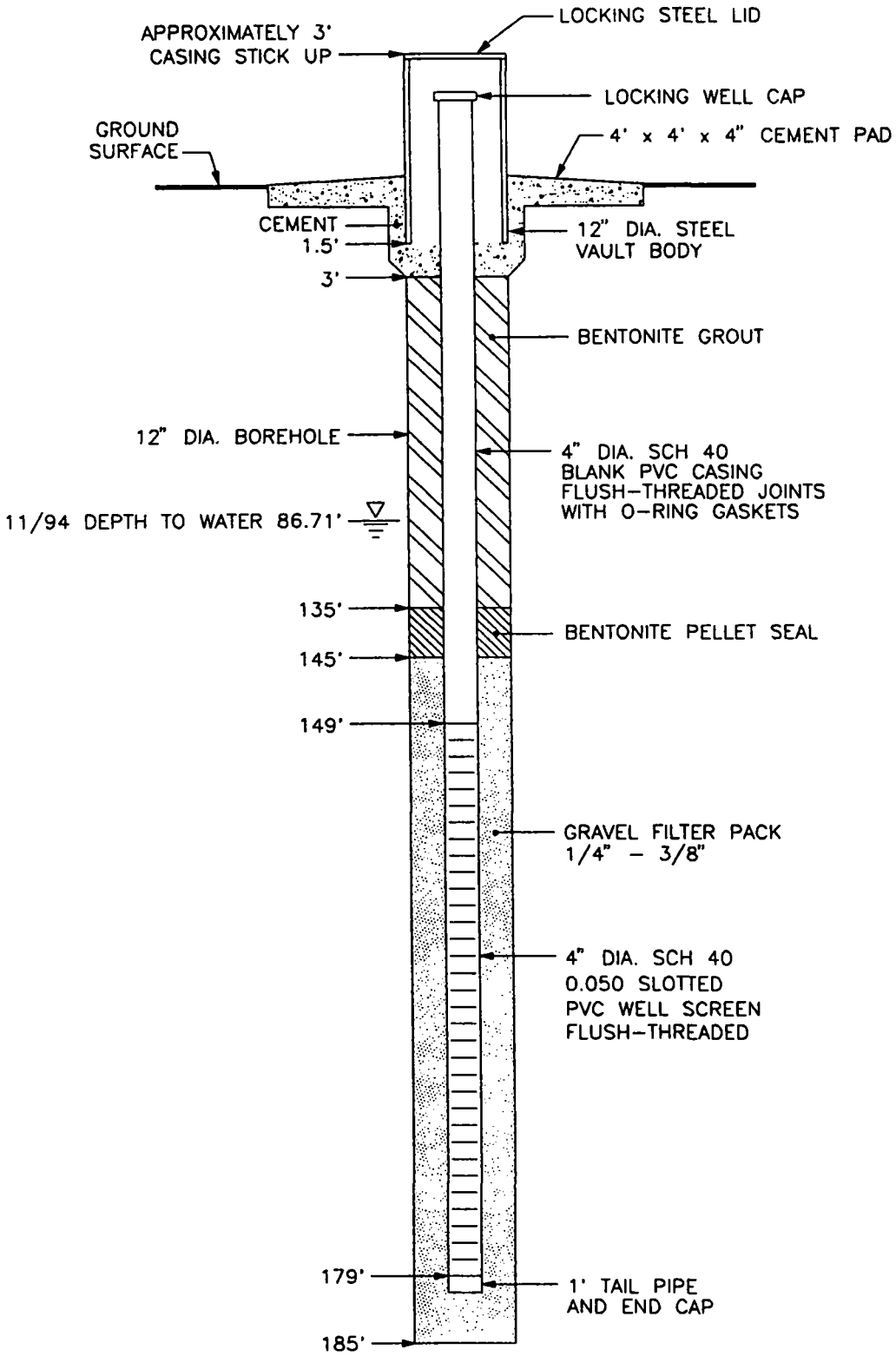
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-11




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL MMW-11<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C9 |
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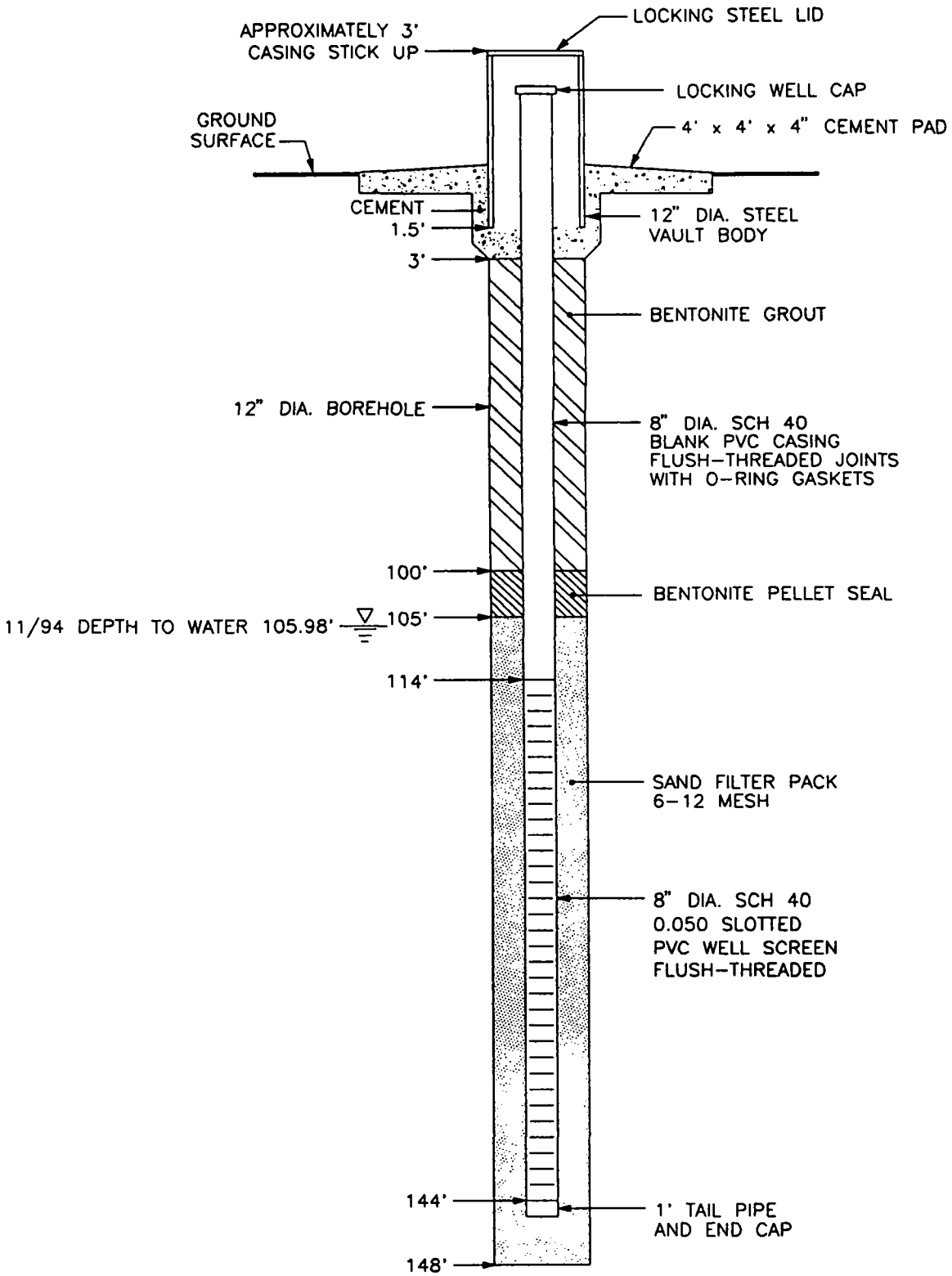
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-13




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

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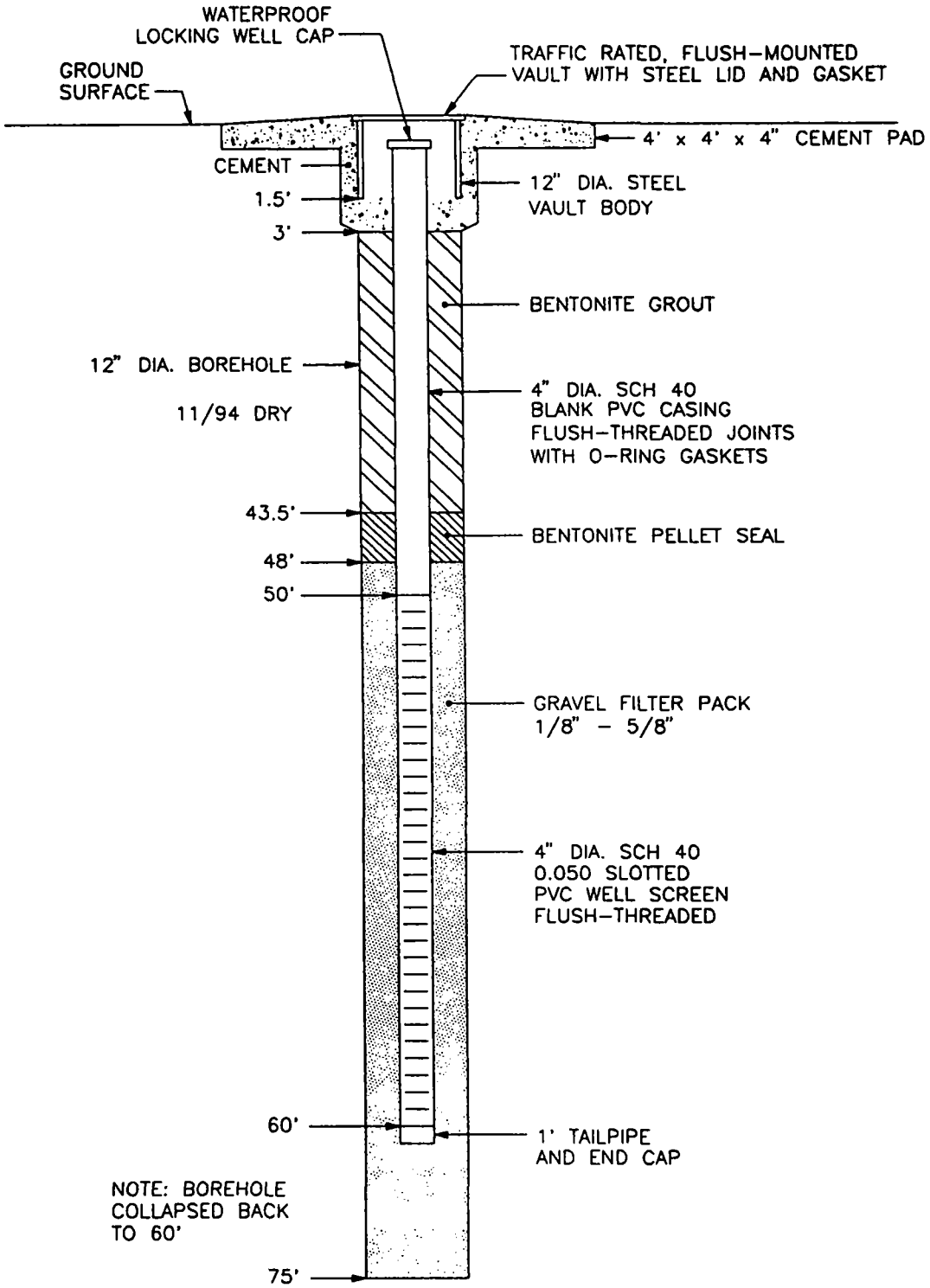
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-14




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

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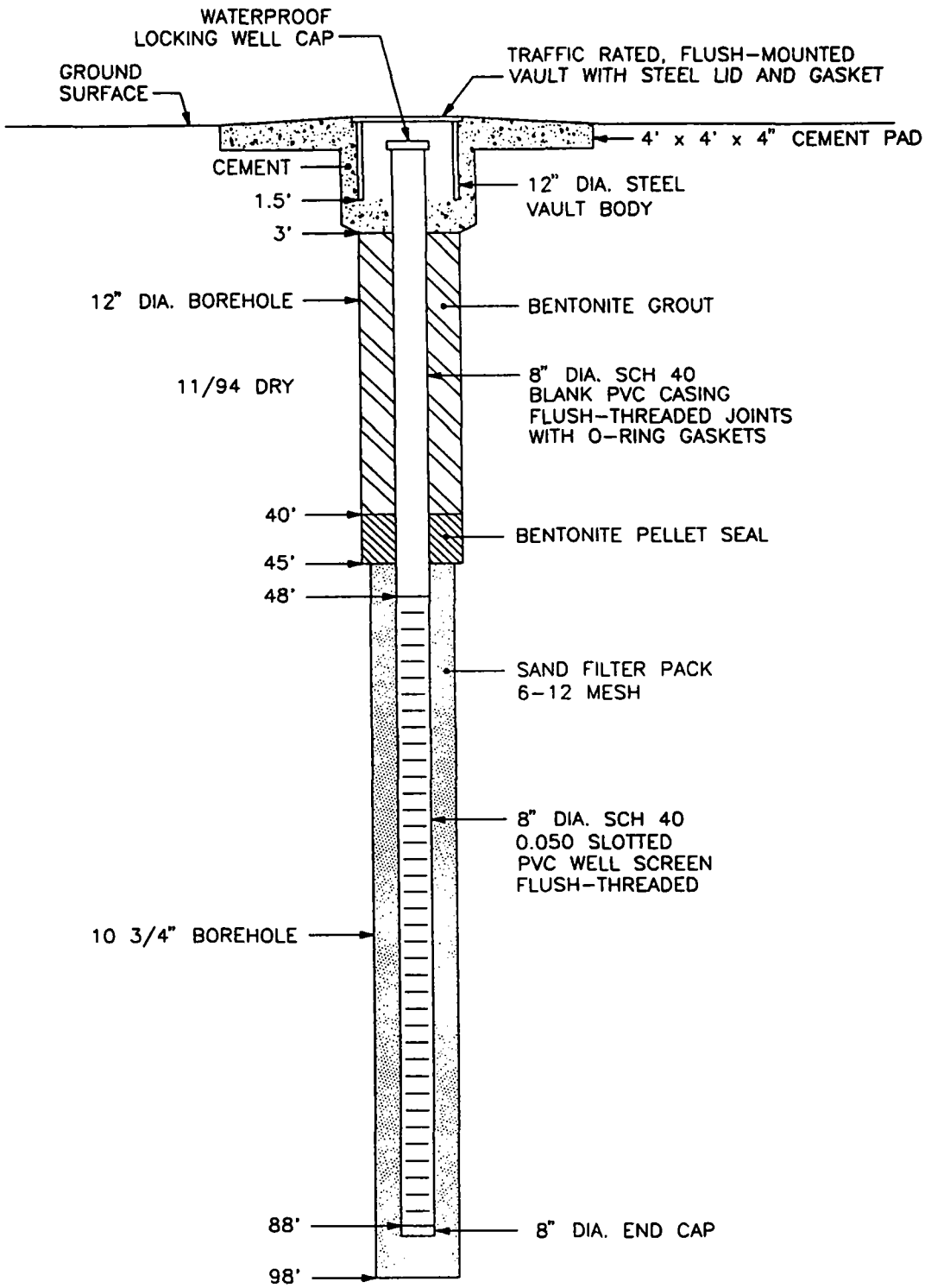
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

MMW-16




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

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|---|---|---|---|---|---|
| PROJECT No.:<br>001-05 | DATE:<br>2/15/95 | AUTHOR: | DRAWN BY:<br>M.O'M. | | |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | Fill | Fill<br>fragments of andesite and rhyolite. |
| | | | 5 | | | | |
| | | | 10 | | | GC | BROWN SANDY CLAYEY GRAVEL<br>clasts of andesite and rhyolite matrix. Matrix sandy clay to clayey sand. |
| | | | 15 | | | | |
| | | | 20 | | | | |
| | | | 25 | | | | |
| | | | 30 | | | | |
| | | | 35 | | | | |
| | | | 40 | | | | andesite boulder associated with coarse gravel |
| | | | 45 | | | | |
| | | | 50 | | | | |
| | | | 55 | | | | |
| | | | 60 | | | Rock | DARK GRAY ANDESITE<br>bedrock contact, some flow banding and tan to gray rhyolite. |
| | | | 65 | | | | |
| | | | 70 | | | | Boring terminated at 68.0 feet and monitor well installed. |
| | | | 75 | | | | |
| | | | 80 | | | | |

DRILL DATE
START: 8/27/94 FINISH: 8/28/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-2<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C13 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | Fill | Fill<br>fragments of andesite and phyrite. |
| | | | 10 | | | GC | BROWN SANDY CLAYEY GRAVEL<br>clasts of andesite and rhyolite matrix. Matrix sandy clay to clayey sand. |
| | | | 40 | | | | andesite boulder associated with coarse gravel |
| | | | 60 | | | Rock | DARK GRAY ANDESITE<br>bedrock contact, some flow banding and tan to gray rhyolite. |
| | | | 70 | | | | andesiste pyritic |
| | | | 80 | | | | |

DRILL DATE
START: 8/24/94 FINISH: 8/26/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-3<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C14 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| | | | 85 | | | | |
| | | | 90 | | | | |
| | | | 95 | | | | |
| | | | 100 | | | | |
| | | | 105 | | | | |
| | | | 110 | | | | |
| | | | 115 | | | | |
| | | | 120 | | | | |
| | | | 125 | | | | |
| | | | 130 | | | | |
| | | | 135 | | | | |
| | | | 140 | | | | |
| | | | 145 | | | | Boring terminated at 145.0 feet and monitor well installed. |
| | | | 150 | | | | |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 8/24/94 FINISH: 8/26/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-3<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C14a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | GM | Fill or Colluvium<br>angular fragments of yellow, gray and red rhyolite with minor amounts of dark glassy porphyritic volcanics. |
| | | | 25 | | | GM/GC | BROWN CLAYEY GRAVEL<br>clasts of andesite, rhyolite, welded tuff, and dark volcanics, subangular to subrounded. Matrix of silt, clay and sand. |
| | | | 45 | | | | larger chips, cobbles and boulders |
| Moisture content pick up at 50'-55', sticy clays | | | 50 | | | | clay content increasing in matrix, strong yellow color to clay |
| | | | 75 | | | | more andesite clasts |

DRILL DATE
START: 8/10/94 FINISH: 8/13/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-7<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C15 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| Borehole water is < 1 gpm | | | 85 | | | Rock | GRAY ANDESITE<br>bedrock contact, porphyritic andesite, pyrite and calcite vein fill. |
| | | | 90 | | | | |
| Borehole water 1–2 gpm, unaltered pyrite in fractures | | | 95 | | | | |
| | | | 100 | | | | |
| | | | 105 | | | | |
| | | | 110 | | | | |
| | | | 115 | | | | |
| | | | 120 | | | | |
| | | | 125 | | | | |
| | | | 130 | | | | |
| | | | 135 | | | | |
| | | | 140 | | | | |
| | | | 145 | | | | |
| | | | 150 | | | | |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 8/10/94 FINISH: 8/13/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-7<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C15a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 160 | | | | |
| | | | | | | | Boring terminated at 181.0 feet and monitor well installed. |
| | | | 165 | | | | |
| | | | 170 | | | | |
| | | | 175 | | | | |
| | | | 180 | | | | |
| | | | 185 | | | | |
| | | | 190 | | | | |
| | | | 195 | | | | |
| | | | 200 | | | | |
| | | | 205 | | | | |
| | | | 210 | | | | |
| | | | 215 | | | | |
| | | | 220 | | | | |
| | | | 225 | | | | |
| | | | 230 | | | | |
| | | | 235 | | | | |
| | | | 240 | | | | |

DRILL DATE
START: 8/10/94 FINISH: 8/13/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-7<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C15b |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | GC | SANDY CLAYEY GRAVEL<br>clasts of dark colored andesite, quartz monzonite in a yellow-tan clayey sand to sandy clay. |
| | | | 30 | | | | more cobbly material 26 to 36 feet |
| | | | 35 | | | | weld tuff clasts appear at 36 feet |
| | | | 60 | | | | matrix of sand and clay changes to brown color |
| | | | 75 | | | | matrix of sand and clay orange color |

DRILL DATE
START: 8/13/94 FINISH: 8/17/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-8A<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C16 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| | | | 85 | | | | |
| | | | 90 | | | SC | YELLOW/TAN CLAYEY SAND<br>clasts of andesite, rhyolite and quartz, subangular to subrounded. |
| | | | 95 | | | GC/SC | CLAYEY SANDY GRAVEL<br>coarse gravel, clasts of andesite and rhyolite, matrix of yellow to tan clayey sand.<br><br>gravel alternating with layers of clayey sand |
| | | | 100 | | | | |
| | | | 105 | | | GC | CLAYEY SANDY GRAVEL<br>as above. |
| | | | 110 | | | | |
| | | | 115 | | | | |
| | | | 120 | | | Rock | GRAY ANDESITE<br>bedrock contact, porphyritic andesite.<br><br>light brown to tan rhyolite and dark gray to tan andesite fragments |
| | | | 125 | | | | |
| | | | 130 | | | | |
| | | | 135 | | | | |
| | | | 140 | | | | predominately andesite below 141 feet |
| | | | 145 | | | | |
| | | | 150 | | | | |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 8/13/94 FINISH: 8/17/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-8A<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C16a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 160 | | | | Boring terminated at 161.0 feet and monitor well installed. |
| | | | 165 | | | | |
| | | | 170 | | | | |
| | | | 175 | | | | |
| | | | 180 | | | | |
| | | | 185 | | | | |
| | | | 190 | | | | |
| | | | 195 | | | | |
| | | | 200 | | | | |
| | | | 205 | | | | |
| | | | 210 | | | | |
| | | | 215 | | | | |
| | | | 220 | | | | |
| | | | 225 | | | | |
| | | | 230 | | | | |
| | | | 235 | | | | |
| | | | 240 | | | | |

DRILL DATE
START: 8/13/94 FINISH: 8/17/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-8A<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C16b |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | GC | SANDY CLAYEY GRAVEL<br>clasts of dark colored andesite, quartz monzonite matrix: yellow-tan clayey sand to sandy clay. |
| | | | 5 | | | | |
| | | | 10 | | | | |
| | | | 15 | | | | |
| | | | 20 | | | | |
| | | | 25 | | | | |
| | | | 30 | | | | more cobbly material 26 to 36 feet |
| | | | 35 | | | | weld tuff clasts appear at 36 feet |
| | | | 40 | | | | |
| | | | 45 | | | | |
| | | | 50 | | | | |
| | | | 55 | | | | matrix of sand and clay changes to brown color |
| | | | 60 | | | | |
| | | | 65 | | | | |
| | | | 70 | | | | |
| | | | 75 | | | | matrix of sand and clay orange color |
| | | | 80 | | | | |

DRILL DATE
START: 8/22/94 FINISH: 8/24/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-8B<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C17 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80–85–90 | | | | |
| | | | 90–95 | | | SC | YELLOW/TAN CLAYEY SAND<br>clasts of andesite, rhyolite and quartz, subangular to subrounded. |
| | | | 95–100–105 | | | GC/SC | CLAYEY SANDY GRAVEL<br>coarse gravel, clasts of andesite and rhyolite, matrix of yellow to tan clayey sand.<br><br>gravel alternating with layers of clayey sand |
| | | | 105–110–115 | | | GC | CLAYEY SANDY GRAVEL<br>as above. |
| | | | 115–120–125 | | | Rock | GRAY ANDESITE<br>bedrock contact, porphyritic andesite. |
| | | | 130–135–140–145–150–155–160 | | | | Boring terminated at 129.0 feet and monitor well installed. |

DRILL DATE
START: 8/22/94 FINISH: 8/24/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-8B<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C17a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | GW/GC | CLAYEY SAND GRAVEL<br>angular fragments of andesite dominate to 55 feet. Rocks are pyrite with iron oxide coatings. Dark brown matrix of clay and sand. |
| Free water <1 gpm | | | 25 | | | | clay more abundant below 45 feet |
| | | | 55 | | | | quartz monzonite, aplite and rhyolite more abundant than andesite 55'-75' |
| Borehole water 4-5 gpm | | | 75 | | | SP | BROWN GRAVELLY SAND<br>fine to coarse gravel, quartz monzonite, quartz, aplite and andsite. Clay less than 1%. |
| | | | 80 | | | | |

DRILL DATE
START: 7/17/94 FINISH: 7/20/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-10A<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C18 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| | | | 85 | | | | |
| | | | 90 | | | | |
| | | | 95 | | | GP/GW | BROWN SANDY GRAVEL<br>well rounded clasts of of quartz monzonite, granite, quartz and rhyolite.<br><br>105'-115' feet, thin interbedded clay layers (less than 0.5 foot) |
| Borehole water 70-100 gpm | | | 100 | | | | |
| | | | 105 | | | | |
| | | | 110 | | | | |
| | | | 115 | | | | |
| | | | 120 | | | | |
| | | | 125 | | | | |
| | | | 130 | | | Rock | LIGHT GRAY QUARTZ MONZONITE<br>bedrock contact, medium crystalline rock, dominantly white and gray feldspar with 10% quartz and less than 50% mafics. |
| | | | 135 | | | | |
| | | | 140 | | | | |
| | | | 145 | | | | Boring terminated at 144.0 feet and monitor well installed. |
| | | | 150 | | | | |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 7/17/94 FINISH: 7/20/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-10A<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C18a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | GW | SANDY GRAVEL<br>angular fragments of andesite with some rhyolite. Much iron staining on clasts. Brown matrix of sand. |
| Borehole water 2-3 gpm | | | 35 | | | GC/GW | DARK BROWN-BLACK CLAYEY GRAVEL |
| Borehole water 3-5 gpm | | | 45 | | | GW | SANDY GRAVEL<br>angular fragmnets of rhyolite and quartz monzonite. |
| Borehole water 2-3 gpm | | | 55 | | | CL | TAN TO YELLOW CLAY<br>gypsum present. |
| | | | 60 | | | GW | SANDY GRAVEL<br>angular fragments of quartz monzonite, rhyolite and pegmatite. Iron oxide coatings, pyrite present. Matrix of brown sand. |
| | | | 80 | | | | |

DRILL DATE
START: 7/11/94 FINISH: 7/14/94 LOGGED By: W. Opfel DRILL RIG: Casing Drive Air Rotary SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-10B<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. C19 |
|---|---|---|---|
| PROJECT No. 001-05 | DATE 1/16/95 | | |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| | | | 85 | | | | |
| | | | 90 | | | | buried log (laying horizontal) present |
| | | | 95 | | | | |
| | | | 100 | | | SP | BROWN-GRAY GRAVELLY SAND<br>medium-grained, well rounded, 90% quartz. Well rounded clasts of rhyolite, pegmatite, andesite, quartz. |
| | | | 105 | | | | |
| | | | 110 | | | | gravelly sand alternating with medium-grained sand |
| | | | 115 | | | | |
| | | | 120 | | | | black organic material at 121-122 feet |
| | | | 125 | | | | |
| | | | 130 | | | | |
| | | | 135 | | | Rock | QUARTZ MONZONITE<br>bedrock contact, pyritic, fractured. |
| | | | 140 | | | | |
| | | | 145 | | | | |
| | | | 150 | | | | |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 7/11/94 FINISH: 7/14/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-10B<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C19a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 180 | | | | |
| | | | 185 | | | | |
| | | | 170 | | | | |
| | | | 175 | | | | |
| | | | 180 | | | | |
| | | | 185 | | | | |
| | | | 190 | | | | Boring terminated at 189.0 feet and monitor well installed. |
| | | | 195 | | | | |
| | | | 200 | | | | |
| | | | 205 | | | | |
| | | | 210 | | | | |
| | | | 215 | | | | |
| | | | 220 | | | | |
| | | | 225 | | | | |
| | | | 230 | | | | |
| | | | 235 | | | | |
| | | | 240 | | | | |

DRILL DATE
START: 7/11/94 FINISH: 7/14/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-10B<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | C19b |
| 001-05 | 1/16/95 | | |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | GC/GM | CLAYEY SANDY GRAVEL<br>angular fragments of andesite dominate to 55 feet |
| | | | 50 | | | | Boring terminated at 50.0 feet and monitor well installed. |

DRILL DATE
START: 7/25/94 FINISH: 7/26/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-10C<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C20 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0–80 | | | Fill | Fill<br>angular fragments of andesite, quartz monzonite, aplite, and quartz. Iron oxide coatings, but pyrite on fresh surfaces, 15%–20% yellow clay matrix present. |

DRILL DATE
START: 7/15/94 FINISH: 7/17/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-11<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C21 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| increasing moisture content; no free water | | | 80 | | | | |
| | | | 85 | | | | |
| Borehole water 1-2 gpm | | | 90 | | | | |
| | | | 95 | | | SP | SANDY GRAVEL<br>clasts as above but rounded. |
| | | | 100 | | | | |
| | | | 105 | | | CL | GRAVELLY CLAY<br>clasts as above, clay content 75% |
| | | | 110 | | | | |
| Borehole water 1 gpm | | | 115 | | | GC | CLAYEY GRAVEL<br>clay content 10%-20%. |
| | | | 120 | | | | |
| Borehole water 2-3 gpm | | | 125 | | | | |
| | | | 130 | | | | |
| | | | 135 | | | | |
| Borehole water 2-4 gpm | | | 140 | | | | |
| Borehole water 2-4 gpm | | | 145 | | | Rock | QUARTZ MONZONITE<br>bedrock contact. |
| Borehole water 5-10 gpm | | | 150 | | | | |
| | | | 155 | | | | Cuttings to 185 feet, > 1/2 inch slight decrease in chip size below 185 feet. Fracture zone better developed above 185 feet. |
| | | | 160 | | | | |

DRILL DATE
START: 7/15/94 FINISH: 7/17/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-11<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C21a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 160 | | | | |
| | | | 165 | | | | |
| | | | 170 | | | | |
| | | | 175 | | | | |
| | | | 180 | | | | |
| | | | 185 | | | | Boring terminated at 185.0 feet and monitor well installed. |
| | | | 190 | | | | |
| | | | 195 | | | | |
| | | | 200 | | | | |
| | | | 205 | | | | |
| | | | 210 | | | | |
| | | | 215 | | | | |
| | | | 220 | | | | |
| | | | 225 | | | | |
| | | | 230 | | | | |
| | | | 235 | | | | |
| | | | 240 | | | | |

DRILL DATE
START: 7/15/94 FINISH: 7/17/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-11<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C21b |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | Fill | Fill<br>angular fragments of quartz monzonite, rhyolite diabase in a matrix of medium-brown silt to coarse-grained sand with wood fragments. |
| | | | 10 | | | GW | SANDY GRAVEL<br>coarse gravel, cobbles, angular to subangular; clasts consist of quartz monzonite, rhyolite, and red-purple volcanic, diabase. Medium to dark brown matrix of fine- to coarse-grained sand, subangular to subrounded, less than 5% silt. |
| | | | 20 | | | GW/GP | SANDY GRAVEL<br>fine and coarse gravel, fine gravel is subrounded; clasts consist of quartz monzonite, andesite, quartzite, and iron-stained rhyolite. Dark brown matrix of fine- to coarse-grained sand; subangular to subrounded quartz, feldspar and lithics. |
| | | | 35 | | | SP/GW | GRAVELLY SAND/SANDY GRAVEL<br>fine to coarse gravel and cobbles; subangular to subrounded; clasts consist of gray-green andesite, rhyolite tuff, red sandstone and quartz monzonite. Medium brown sand matrix, medium- to coarse-grained subangular to subrounded. |
| | | | 40 | | | | |

DRILL DATE
START: 8/1/94 FINISH: 8/9/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-13<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C22 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 40 | | | GW | SANDY GRAVEL<br>fine and coarse gravel, cobbles and boulders, subangular to subrounded; clasts consist of andesite, aplite, purple volcanics, limonite/silica rock. Medium brown matrix of medium- to coarse-grained sand, subangular to subrounded. |
| | | | 45 | | | GM | Similar to above, sand matrix is fine- to coarse-grained, 5%-10% silt and clay. |
| | | | 50 | | | | |
| | | | 55 | | | GP | SANDY GRAVEL<br>as above, cobbles and boulders more common, no silt or clay. |
| | | | 60 | | | GM | SANDY GRAVEL<br>as above, more iron-stained silica rock. |
| | | | 65 | | | GM/GC | SANDY GRAVEL<br>same as above, clay and silt increases to 20%-30% in matrix. |
| | | | 70 | | | | |
| | | | 75 | | | ML/SM | DARK BROWN SILTY SAND/SANDY SILT<br>fine- to coarse-grained; clasts consist of quartz and lithics, subangular to subrounded. |
| | | | 80 | | | | |

DRILL DATE
START: 8/1/94 FINISH: 8/9/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-13<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C22a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | GP | BROWN SANDY GRAVEL<br>fine to coarse gravel, cobbles and boulders, subangular to subrounded; clasts consist of quartz monzonite, purple and green volcanics, iron-stained silica rock. Medium to dark brown matrix of fine- to coarse-grained sand, subangular to subrounded. |
| | | | 85 | | | SM/GM | SILTY SAND AND SILTY SANDY GRAVEL<br>fine to coarse gravel, cobbles and boulders, subangular to subrounded; clasts consist of quartz monzonite, andesite, purple volcanics. Medium brown matrix of fine to coarse-grained sand; clasts of quartz and lithics, 5%-10% silt. |
| | | | 90 | | | | |
| | | | 95 | | | SP/GP | GRAVELLY SAND TO SANDY GRAVEL<br>fine and coarse gravel, cobbles and scattered boulders, subangular to subrounded; clasts consist of predominately quartz monzonite with minor amounts of volcanic rock and altered volcanic rock. Light gray matrix of medium- to coarse-grained sand, subrounded, 70% quartz and 30% feldspar and lithics. |
| | | | 100 | | | | |
| | | | 105 | | | | |
| | | | 110 | | | | |
| | | | 115 | | | | |
| | | | 120 | | | | |

DRILL DATE
START: 8/1/94 FINISH: 8/9/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-13<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | C22b |
| 001-05 | 1/16/95 | | |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 120 | | | Rock | QUARTZ MONZONITE<br>Bedrock Contact at 120 feet, 120-125 feet; large 1 to 1 1/2 inch fragments, unstained quartz monzonite, probably upper fracture zone. Chip size decreases with depth. |
| | | | 125 | | | | |
| | | | 130 | | | | light gray coarsely crystalized rock, predominately feldspar with minor quartz and mafic minerals. |
| | | | 135 | | | | |
| | | | 140 | | | | |
| | | | 145 | | | | |
| | | | 150 | | | | Boring terminated at 148 feet and ground-water monitor well installed. |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 8/1/94 FINISH: 8/9/94 LOGGED By: J.Kepper DRILL RIG: Casing Drive Air Rotary/ SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-13<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C22c |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | Fill | Waste Dump Material<br>angular fragments of quartz, aplite and andesite diabase mixed with metal, asphalt wrappings, wire and wood. |
| | | | 5 | | | | |
| | | | 10 | | | | |
| | | | 15 | | | | |
| | | | 20 | | | | |
| | | | 25 | | | | |
| | | | 30 | | | | 25 to 35 feet: 20%-30% clay probably waste rock used to fill depression behind berm. |
| | | | 35 | | | GW | SANDY GRAVEL<br>fine to coarse gravel, cobbles (1 1/2" chips), angular to rounded; clasts consist of granite, diabase and mafic rock. Medium brown matrix of very fine- to coarse-grained sand, subangular to subrounded. |
| | | | 40 | | | | |

DRILL DATE
START: 7/30/94 FINISH: 7/31/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-14<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C23 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 40 | | | | |
| | | | 45 | | | SW | DARK BROWN SILTY GRAVELLY SAND<br>fine- to coarse-grained, subangular to subrounded grains. Gravel is fine to coarse, rounded; clasts consist of granitic aplite and andesite, much iron-staining, 10%-15% silt. |
| | | | 50 | | | GW | SANDY GRAVEL<br>coarse gravel and cobbles; angular to subrounded; clasts consist of granite, andesite, mafic rock and quartzite. Light gray matrix of fine- to coarse-grained sand, angular to subrounded; clasts of quartz, lithics; large (3") wood fragments. |
| | | | 55 | | | | |
| | | | 60 | | | SP/GW | GRAVELLY SAND TO SANDY GRAVEL<br>fine gravel, subrounded; clasts consist of granite, red sandstone and andesite. Light gray matrix of coarse-grained sand, 70% quartz. |
| | | | 65 | | | | |
| | | | 70 | | | | 67 to 75 feet: no return rig action indicates boulders and gravel |
| | | | 75 | | | | Boring terminated at 75.0 feet and monitor well installed. |
| | | | 80 | | | | |

DRILL DATE
START: 7/30/94 FINISH: 7/31/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

**SOUTH PASS RESOURCES, Inc.**

PROJECT No. 001-05 | DATE 1/16/95

# LOG OF BORING No. MMW-14
Molycorp, Inc.
Questa, New Mexico

FIGURE No. **C23a**

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | Fill | Fill<br>angular fragments of aplite and andesite in a gray-brown sand matrix. |
| | | | 5 | | | GW | SANDY GRAVEL<br>fine to coarse gravel, subangular to subrounded; clasts consist of granite, minor andesite, diabase and mafic rock. Medium brown matrix of fine- to coarse-grained sand, subangular to subrounded; clasts consist of quartz, feldspar and lithics. |
| | | | 10 | | | | |
| | | | 15 | | | | as above, clay and limnoite altered clasts more common, rare wood fragments |
| | | | 20 | | | | |
| | | | 25 | | | | DARK BROWN SANDY SILT (ML) |
| | | | | | | GW | SANDY GRAVEL<br>fine to coarse gravel; subangular to subrounded; strongly cemented by black limonite; clasts consist of aplite, granite, altered rock. Clasts are pyritic. Dark brown matrix of fine- to medium-grained sand, subangular to subrounded; clasts of quartz feldspar and lithics. Similar to 6-16' interval but larger fragments indicate cobble/boulder zone. |
| | | | 30 | | | | |
| | | | 35 | | | | |
| | | | 40 | | | | |

DRILL DATE
START: 7/26/94 FINISH: 7/28/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-16<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C24 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 40 | | | | |
| | | | 45 | | | | |
| | | | 50 | | | GW | SANDY GRAVEL<br>fine to coarse gravel, cobbles and boulders (large 1"-2" fragments), subangular to subrounded; clasts consist of aplite, granite, porphyrite andesite, altered rock. Medium brown matrix of fine- to coarse-grained sand, subangular to subrounded. |
| | | | 55 | | | | injecting water at 56 feet |
| | | | 60 | | | | |
| | | | 65 | | | | |
| | | | 70 | | | SP | MEDIUM BROWN GRAVELLY SAND<br>fine- to coarse-grained, subangular to subrounded. Fine gravel is subangular to rounded; clasts consist of volcanic breccia, andesite, granite, quartzite, diabase, quartz, chloritized andesite. Clasts are pyritic. |
| | | | 75 | | | GW | SANDY GRAVEL<br>similar to above, but gravel less than 50%. |
| | | | 80 | | | | |

DRILL DATE
START: 7/26/94 FINISH: 7/28/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-16<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C24a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| | | | 85 | | | | 86 to 90 feet: granite clasts are 75% of gravel |
| | | | 90 | | | Rock | LIGHT GRAY GRANITE<br>angular chips 1/8" to 1/2", no significant fracturing. |
| | | | 95 | | | | Boring terminated at 98.0 feet and monitor well installed. |
| | | | 100 | | | | |
| | | | 105 | | | | |
| | | | 110 | | | | |
| | | | 115 | | | | |
| | | | 120 | | | | |

DRILL DATE
START: 7/26/94 FINISH: 7/28/94 LOGGED By: J.Kepper DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MMW-16<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/16/95 | | C24b |

# APPENDIX D

## Mine Area
## 1994 Water-Quality Results

# APPENDIX D

## Mine Area 1994 Water-Quality Results

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# APPENDIX D

## Mine Area 1994 Water-Quality Results

Following the Fall 1994 installation of the 12 new monitor wells in the Mine Area, water samples were collected to measure temperature, pH, and conductivity and to analyze for carbonate, bicarbonate, hydroxide, total alkalinity, chloride, fluoride, and sulfate. Monitor well locations are shown on Figures 2 and 10 (main text). Red River and seep sampling locations are shown on Figure D1. Water quality results are provided in Table D1 (Monitor Wells), Table D2 (Red River: May 1994), Table D3 (Red River: October 1994), Table D4 (Mine Water), and Table D5 (Production Wells). The monitor-well data were collected in November 1994, the surface-water data in May and November 1994, and the underground mine and production well samples were taken earlier in the spring of 1994. Temperature, conductivity, and pH were recorded in the field prior to collecting the samples. Because of the low yield (less than 1 gallon per minute) typical of many of the monitor wells, a bladder pump was used to collect the water samples. Temperature, conductivity, and pH were measured at each well until these parameters stabilized (succeeding measurements differed by less than 10%) before sampling.

A precipitation sample was collected in August 1994 near the mill in the Mine Area. The pH of this water was 4.78. Thus, the natural recharge related to precipitation in the mine drainage basin is acidic.

For purposes of comparing a selected set of water samples, the milligrams per liter (mg/L) values have been converted to milliequivalents per liter (meq/L) on the STIFF diagrams. The conversion accounts for differences in weights and electrical charges among the cations and anions. The meq/L values have been plotted on Figures D2, D3, D4, D5, D6 and D7 as STIFF Diagrams in order to facilitate comparisons between water from different sources. The pre-May 1994 water chemistry does not cover the full spectrum of ions included in the later studies and cannot be illustrated on the STIFF Diagrams. The STIFF Diagram has been used in a conventional mode to classify the water sample (such as calcium sulfate water, sodium bicarbonate water) and also as a device to illustrate differences between samples based on a selected set of metals and of anions (fluoride and sulfate). Each sample site has a conventional STIFF diagram for the purpose of characterizing the general chemistry of the water (Na+k, Ca, Mg, Fe, Cl, $HCO_3$, $SO_4$, and $CO_5$) and a second diagram based on selected metals and anions (Al, Mn, Fe, Zn, F, and $SO_4$).

## D.1 Seepage Water Quality

Mine Waste-Rock Dump Seeps: Seepage water from the mine waste-rock dumps is represented by samples CCS-1 (Table D2 and Figure D1) and GHS-1 (Table D2), which plot on the conventional diagram (Figure D2) as magnesium sulfate waters. Calcium and iron are fairly high in these samples. These are acidic waters with pH of 3.0 and 2.0 and total dissolved solids (TDS) of 24,950 mg/L and 23,390 mg/L, respectively. The major dissolved metal is aluminum followed by iron, manganese and zinc in lower concentrations.

Bedrock Seeps: Two samples were collected from natural seeps outside of the Mine Area (HTS-1 and HCS-1: Table D2) and two samples from seeps within the mined area (GHS-1 and CCS-3: Table D2). The natural seeps outside of the Mine Area are highly acidic and have moderate to high TDS values (No. 10: pH 2.86, TDS 2,610 mg/L; No. 22: pH 2.5, TDS 6,493 mg/L). On the conventional diagram (Figure D3), the Hot-N-Tot sample (HTS-1) plots as an iron sulfate water. The Hanson Creek sample (HCS-1) plots as a calcium magnesium sulfate water. Iron is the dominant metal followed by aluminum at Hot-N-Tot, while aluminum followed by iron dominates at Hanson Creek. The concentration of fluoride in the bedrock seeps is less than that in the waste-rock dump seeps. Zinc and manganese are evident in these samples but in much lower concentration than the dump samples.

The bedrock seep at the head of Goathill Gulch (GHS-3: Table D2) is similar to the waste seepage (highly acidic, pH 2.0, and high TDS, 11,980 mg/L). Aluminum (Figures D2b,c) is the dominant metal followed by iron and manganese. This seep is in a highly fractured and altered rhyolitic tuff (clay + quartz + pyrite + gypsum alteration). The outcrop extends beneath the Goathill dump, and its chemistry may reflect a mixture of natural and mine seepage. The second sample (CCS-3: Table D2) was collected from fractured and moderately altered rhyolite in the back of a small adit in lower Capulin Canyon. It is a calcium sulfate water (Figure D2) and has metal concentrations that are considerably lower than the bedrock seep at GHS-3. Aluminum followed by iron and manganese are the significant metal concentrations. It is a moderately acidic water with a moderate TDS of 2,686 mg/L and a fluoride concentration slightly less than sample GHS-3.

## D.2 Monitor Well Water Quality

The water quality of well water (Table D1) is best described in terms of specific areas where there may be linkages between sources (dumps, bedrock, valley-fill) and sinks (river seeps). These areas are:

- Middle Waste-Rock Dump (MMW-13)
- Sugar Shack South Waste-Rock Dump (MMW-10A,-10B,-10C, and -11)

- Sugar Shack West Waste-Rock Dump (MMW-7,-8A, and -8B)
- Capulin Canyon (MMW-2 and -3)

Middle Waste-Rock Dump (MMW-13):

The single water sample from the Middle Waste-Rock Dump area is from MMW-13 (valley-fill well) and is characterized as a calcium sulfate water (Figure D4) on the conventional diagrams. It has a high pH of 7.9 and a moderate to low TDS of 1,400 mg/L. Metal concentrations are low.

Sugar Shack South Waste-Rock Dump (MMW-10A, -10B, -10C, and -11):

Based on currently available information, the relationship between Sugar Shack South Waste-Rock Dump ground water (as sampled at MMW-10A, -10B, -10C, and MMW-11) and the Portal Springs seeps along the north side of the Red River is uncertain. Flow directions and hydraulic gradient for the two aquifers can not be evaluated because there are only two wells in each unit. As noted in Section 3.0, water levels for the two bedrock wells are tens of feet above the contact between the valley-fill and the bedrock indicative of an upward gradient as would be expected in a zone of discharge (i.e. the Red River valley).

All of the monitor well water samples would be classified as calcium sulfate (or calcium-magnesium sulfate in the case of MMW-11) (Figures D5a). The pHs are mostly acidic (4.7 to 5.8), except for MMW-10B (a bedrock well) which is alkaline (pH 7.9). The highest TDS for this group of wells occurs at MMW-11 (2,000 mg/L) with the MMW-10 samples in the 1,400 to 1,800 mg/L range. The Portal Springs seep has a higher TDS (2,017 mg/L) than the wells on Figure D5d. In this sample, alkalis (sodium + potassium) and chloride concentrations are elevated compared to the ground-water samples from the wells. Evaporation of these shallow seep waters is the likely cause of these higher concentrations.

The Portal Springs seeps begin about 100 feet west of the MMW-10 wells. These seeps were not noted until January 1993, despite numerous earlier river surveys (Molycorp 1994 communication). The immediate source of the springs is ground water seeping from the valley-fill aquifer exposed along the banks of the river. However, the source of the elevated TDS and sulfate along with fluorine and some metals is not clearly established. Based on the water chemistry and the post-1952 tritium results for MMW-11 (see Section D.2), a possible source is water from the waste-rock dumps infiltrating bedrock and/or valley-fill up-gradient from the wells. Considering that the waste-rock dumps were inplace in the 1970s, the apparent delay in the high TDS and high sulfate water arriving at the river is either the result of a slow travel time (i.e. distant source or low seepage velocity) or seepage was stored in the valley-fill aquifer (precipitation of sulfates, absorption of metals on limonite) later to be released by a change in water chemistry. The water quality from the Red River sewage

treatment plant production well may serve as an illustration of ground water impacted by water-rock interactions in a valley-fill. The valley-fill there contains mudflow deposits derived from adjacent hydrothermal scars.

An additional uncertainty is the location of the edge of the original cone of depression during the time the underground mine was in operation in the 1980s. If the cone had extended to the river, seepage from northern sources would have been captured. The succeeding rewatering period may have caused the edge of the cone to migrate northward allowing some seepage to move westward with the ground water. Continued monitoring of water levels and water quality may supply some answers.

**Sugar Shack West Waste-Rock Dump (MW-7, -8A, and -8B):**

The unnamed tributary canyon that lies just east of Shaft No. 1 could conceivably carry drainage from the Sugar Shack West Waste-Rock Dump and possibly from the east end of the Goathill Gulch Waste-Rock Dump. Monitor well MMW-7 is screened in a pyritic andesite. As indicated in the hydrogeology discussion (Section 2.2 and Appendix B), the andesite in this area is highly fractured along a series of stacked north-dipping low-angle faults. A perched ground-water zone that lies some 500 feet above the cone of depression may be present in the andesite fractures. The water is highly acidic (pH 4.4), has a very high TDS (16,000 mg/L), and is a magnesium-aluminum sulfate water (Figures D6a), similar in this respect to the waste-rock seepage at Capulin Canyon and Goathill Gulch. Again, like the waste seepage, the water has a very high aluminum concentration followed by elevated concentrations of iron, manganese, zinc, copper, and nickel. Seepage from Sugar Shack West or east Goathill Gulch Waste-Rock Dumps could contribute to the water chemistry, but such a linkage has not been established at this time. The perched zone may be close enough to the surface to be impacted by leachate from oxidizing vadose water.

Perched zones of this type may occur elsewhere in the Mine Area. Similar sites of low-angle north-dipping faults that are offset by north-trending high-angle faults occur in the bedrock exposure above Cabin Springs. A similar perched zone may be responsible for the moderate pH (5.1), moderate TDS (2,040 mg/L), high aluminum (32.7 mg/L) waters that issue from the bedrock seep at Cabin Springs (Figure D6c,d). Fluoride, manganese, and zinc occur in elevated concentrations at this seep.

Water samples from the two monitor wells close to the river and at the downstream end of the unnamed tributary canyon are also calcium sulfate waters (Figure D6) with moderate to high pH (8.2 at MMW-8A, and 6.4 at MMW-8B) and moderate TDS (2,200 and 1,100 mg/L, respectively). Metal concentrations are very low. A strong hydrogen sulfide odor was noted when both MW-8A and MW-8B were sampled in November 1994. This odor suggests the presence of localized reducing conditions related to breakdown of organic chemicals in drilling

foam that was not flushed out during development. However, organic matter in the fan delta deposit, or fine organic matter recharged from the river to the well, can not be ruled out. Until more water-level and water-quality data are collected from these wells, their relationship to the cone of depression is uncertain.

Capulin Canyon (MMW-2 and MMW-3):

The water from MMW-2 (valley-fill) is acidic (pH 4.9) with a TDS of 3,400 mg/L. Well MMW-3 (bedrock) water has a higher pH (7.5) but only a slightly lower TDS (2,900 mg/L). Both waters are classified as calcium sulfate waters (Figure D7). The metal concentrations result in different STIFF Diagrams. The aluminum and manganese concentrations are higher in MMW-2 water compared to MMW-3 water (Figure D7a).

The valley-fill well (MMW-2) may be more closely related to the surface flow in lower Capulin Canyon that infiltrates the fill about 1,000 feet up-canyon from the wells. This surface flow (CCS-4: Table D2) has a low pH (4.0), a TDS concentration of 1,192 mg/L, and aluminum concentration of 23.2 mg/L. However, there are some significant chemical differences between the surface seepage at the point where it infiltrates the valley-fill up-gradient from the monitor wells (CCS-4) and the monitor well (particularly MMW-2) chemistry. Manganese, iron, zinc, and copper concentrations are much higher at MMW-2 than at CCS-4. This metals concentration either represents an earlier slug of seepage water or reflects in-situ reactions between the valley-fill rock material and acidic water. The metals STIFF Diagram (Figure D7a) for the Capulin Canyon seep (which occurs along an abandoned river channel just east of Capulin; see CCS-6: Table D2) is similar to the valley-fill well water. On a conventional STIFF Diagram, this seep is a calcium sulfate (Figure D7) water but shows evidence of the effect of evaporation on the shallow surface water (elevated alkalis, chloride, and TDS).

Production well water chemistry: Table D5 illustrates the water chemistry for ground water from wells screened in valley-fill (sewage plant well and Columbine Well No. 2). The sewage plant well is screened in valley-fill near an area of hydrothermal scar material, which is a source of mudflow sediment and which may be interbedded in the valley-fill. This would account for the low pH, high TDS/sulfate, and high iron, manganese, and aluminum content. The Columbine well is screened in river alluvium and is of much higher quality than the tributary waters. The reason for its low pH relative to the river water is not clear.

## D.3 Mine Water Quality

Available water chemistry data from samples taken at the shafts and the decline is shown in Table D4. The underground mine waters are significantly more alkaline (higher pH) but lower in metals, sulfate, and TDS compared to seepage waters. Oxygen can reach the

underground workings above the rising water table through surface connections (e.g., caved area and decline) and create a thin zone of oxidizing vadose waters which react with the fractured, pyritic rock to produce the TDS and sulfate concentrations. Water levels are probably rising faster than downward infiltration is occurring; therefore, high TDS/sulfate water is incorporated and diluted in the ground water. Once the pyrite-bearing rock in the area of the underground mine is submerged beneath the water table, little oxidation may occur (Frost, 1979), and the ground-water chemistry should be a combination of ambient water quality plus leachate from surface connections. The deep water sample (taken at a depth of 400 feet below the water table) collected at Shaft No. 1 has a chemistry very similar to the shallow sample. This similar chemistry may not be related to vertical dispersion and mixing, but rather to the incorporation of vadose water at an earlier time when the water table was lower than present -- indicating that ground water may be nearly stagnant, enclosed by low hydraulic conductivity rocks.

Acidic, high TDS water enters the ground-water system in the underground mine area through several avenues:

- The vadose zone above the workings consists of fractured (partly mine-induced) and mineralized rock that is a source of such water. Once the workings are submerged, this is no longer a source.

- The caved area developed as the result of the block-caving mining method conducted at Molycorp's deeper mine. The upper part of the caved area consists, in part, of hydrothermally altered rock (pyrite, kaolinite, sericite, and quartz), which is typical of hydrothermal scar material and of unmineralized andestic volcanics (unpublished map, Molycorp). The elevation of the postulated water-table surface across the caved area after recovery from the rewatering of the mine is expected to be at least 7,840 feet (SPRI, 1993b). The elevation of the rim of the caved area is 8,100 feet, leaving 255 feet of fragmented unmineralized volcanic rock and hydrothermal scar material above the water table. It is this material, in the vadose (unsaturated) zone above the water table, that would be subject to more intense oxidation processes.

- Seepage barrier water from Capulin and Goathill Gulch mine waste-rock dumps is discharged to the caved area. Future plans are to pipe this water to the tailings pond area.

- Currently, the underground mine is being dewatered, creating a sink for water from all of the above sources.

## D.4 Tritium Isotope Analyses

Tritium is the heavy isotope of hydrogen ($^3H$) that disintegrates radioactively to helium ($^3He$) at a half-life of 12.3 years (Mazor, 1991). After 12.3 years, half of the initial amount of tritium has decayed to helium. The concentration of tritium in water is expressed in tritium units (TU), which is a ratio of tritium to hydrogen atoms. The T/H ratio of $10^{-18}$ is defined as one TU.

Tritium is produced naturally in the atmosphere by the radioactive decay of nitrogen ($^{15}N$). Tritium atoms are oxidized to water, become mixed with precipitation, and eventually enter the ground-water system. Natural production of tritium introduces about 5 TU to precipitation and surface water. In the saturated zone, water is isolated from the atmosphere and the tritium concentration drops due to radioactive decay.

Using a measured value for tritium and a half-life curve (tritium concentration as a function of time), however, does not lead to a precise age for the ground water. As a consequence of recharge, water accumulates and mixes over time in the aquifer such that the age obtained from tritium data is an average or effective age (Mazor, 1991). Smith and Wheatcraft (1993) refer to this "ground-water age" as an estimate of the subsurface residence time of ground water since it was isolated from the atmosphere and soil gas.

Hydrogen bomb tests which began in 1952 in the northern hemisphere added large amounts of tritium to the atmosphere, completely masking the natural tritium input. The peak of man-made tritium production was in 1963, which was the same year that atmospheric testing was halted by international treaty. Since this testing stopped, the tritium content of precipitation has been declining. The tritium content of precipitation has been measured at a worldwide network of stations since the end of testing. These data are normally presented as concentration curves of the annual weighted average of tritium since 1961. Concentration curves from the network show:

- values in the northern hemisphere that are much higher than those in the southern;
- summer peaks and winter lows related to the annual redistribution of tritium in the atmosphere; and
- significant variance from one station to another in terms of the tritium concentrations.

As noted earlier, due to mixing of recharge waters in the aquifer over time, the age of a ground-water sample is an effective age. Further estimates of an effective age are only valid if it is known that the water is derived from a single source/single aquifer system. If older

ground water from a bedrock aquifer were to mix with younger water from an adjacent shallow aquifer, the effective age would only reflect dilution. If the appropriate concentration curve is available (i.e. from a geographically nearby station), and if the sample was collected from a single source/aquifer unit, then an effective age can be assigned. According to Mazor (1991), water that has zero tritium (in practice, $<0.5$ TU) has a pre-1952 age. Water that has significant tritium concentrations (in practice, $>10$ TU) is of post-1952 age. Water that has concentrations between 0.5 and 10 TU seems to be a mixture of pre- and post-1952 water.

Water samples for tritium analyses were collected in 1-liter brown glass bottles. No head space was allowed in these samples. Six samples were collected in May 1994 and three in November 1994. All samples were sent to Chempet Research Corporation in Moorpark, California for analysis. The enriched tritium procedure allows for a precision of 0.8 TU. The results of the tritium analyses for the May 1994 sample are presented below. (The results of the November 1994 analyses are discussed in Section 4.0 of the main text of this report.)

**Results of Tritium Analyses**

| Sample No. | Site Description | TU ± 2σ |
|---|---|---|
| CCS-1 | seepage from the base of the Capulin Canyon mine waste-rock dump | 15.1 ± 2.2 |
| CCS-2 | fresh water spring, west side of Capulin Canyon | 12.3 ± 1.8 |
| CCS-3 | bedrock seep in an adit, west side of Capulin Canyon | 8.0 ± 1.4 |
| GHS-1 | seepage from the base of the Goathill Gulch waste-rock dump | 16.7 ± 2.4 |
| GHS-3 | bedrock seep on the divide near the head of Goathill Gulch | 8.5 ± 1.4 |
| Cabin Springs | seeps on the north bank of the river behind the Cabins | 17.5 ± 0.6 |
| MMW-11 | bedrock well near Sugar Shack South waste-rock dump | 16.9 ± 0.6 |
| MMW-3 | bedrock well in lower Capulin Canyon | 4.38 ± 0.14 |

Given that the open pit operation (which was the source of the dump material) began in the late 1960s, the tritium data, supported by water chemistry, indicates most, if not all, of the water collected from the dump seepage at the head of Capulin and Goathill Canyons is derived from the dumps. The values greater than 10 TU for the two waste dump samples indicate

post-1952 water. Without the appropriate tritium concentration curve, a more precise effective age cannot be made.

Water from the freshwater spring that flows at 12 gallons per minute (gpm) may also be post-1952, but considering the standard deviation, it could be a mixture of older perched water and post-1952 water. The two bedrock seeps appear to be a mixture of pre- and post-1952 water. In the case of the Goathill Gulch sample, the seep lies several hundred feet below the Capulin/Goathill mine waste-rock dumps and may include older perched water and dump leachate that has infiltrated the bedrock. Likewise, the adit sample may include water from pre- and post-adit fractures (caused by excavation of the adit). The tritium values for these bedrock samples reflect dilution rather than effective age.

The average tritium concentrations for precipitation per year have been collected at various world-wire weather stations since 1961. The weather station closest to the Red River area is Flagstaff, Arizona; however, telephone calls to the Flagstaff weather station and several hydrologists who use tritium data failed to locate such a database. Mazor (1991) illustrates plots of TU against years for several different stations. The nearest station in terms of similar latitude is Hatteras, North Carolina, on the east coast. Although the average tritium concentration curves from the northern hemisphere stations are similar (peaks and troughs roughly correspond and their slopes are similar), the absolute value for TU in any one year varies by an order of magnitude or less depending on station location. These absolute values are related to atmospheric circulation patterns. To obtain a reliable estimate of the significance of the TU values for the mine samples, a station about the same latitude but in the western United States would be preferable.

As an example of the application of tritium results, using the Hatteras data from Mazor (1991), precipitation infiltrating the ground in 1970 would have contained about 75 TU. In the intervening 24 years (1970 to 1994), the tritium would have radioactively decayed, leaving about 22 percent (Mazor, 1991, Figure 10.1) of the tritium retained in a 1994 water sample. Assuming no mixing of older and younger water, there should be about 16.5 TU left in the sample. This value is within the range of the "young" water samples collected in the Mine Area (e.g. CCS-1, GHS-1, Cabin Springs, and MMW-11). If the Hatteras data can be applied here, these results, combined with the water chemistry of these samples, indicate water stored in the waste-rock dumps (constructed in the 1970s) could be a source. However, with the limited amount of site-specific hydrogeological data available, a natural acidic seepage source following a short flow path (from recharge to discharge zone) or traveling parallel to a highly permeable zone (short travel time) can not be entirely ruled out. The relatively high TU value for the spring at CCS-2 may be an example of a short flow path.

Pre-1952 ground water contained about 5 TU. In the intervening 42 years (1952 to 1994), approximately 8 percent of the tritium would be retained which corresponds to 0.4 TU.

If ground water was recharged with pre-1952 water without any subsequent mixing, it should contain about 0.4 TU. Samples such as MMW-3, CCS-3, and GHS-3 or those with results in the 0.5 to 10 TU range are mixtures of young (post-1952) and older (pre-1952) water (e.g. an average value for a mixture of 16.5 TU and 0.4 TU water is 8.45 TU).

## D.5 Stable Isotope (Lead and Strontium) Study

Eight water samples from the Mine Area (four from Capulin Canyon, two from Goathill Gulch, one from the Red River, and one from Hot-N-Tot Canyon) were analyzed for lead and strontium isotopic composition (Chempet, 1994). The limited objective of this study was to evaluate if any isotopic differences between natural acidic ground water and acidic mine drainages could be detected. To demonstrate statistically significant differences, a much larger number of samples, taken at different times of the year to assess seasonal effects and from varied geologic settings, would need to be collected. Furthermore, isotopic analyses of bedrock, dump, and alluvial source materials would have to be made to evaluate water/rock interactions and causes for any detected differences.

Both strontium and lead consist of radiogenic and non-radiogenic isotopes. In general, as the result of radioactive decay of the parent element, the radiogenic component increases with time. However, the ratio of radiogenic to non-radiogenic isotopes in any given sample containing lead or strontium is not a fixed value. The value depends on the history of the sample: how much of the radioactive precursor was present in the sample originally and how much of the radioactive element of strontium or lead has been removed from or added to the sample at a later time.

Three stable isotopes of lead (Pb) -- 206 Pb, 207 Pb, and 208 Pb -- are radiogenic and are derived by radioactive decay of 238 uranium, 235 uranium, and 232 thorium, respectively. Another stable isotope, 204 Pb, is non-radiogenic and is used as a reference isotope in the lead system. Strontium (Sr) has four naturally occurring stable isotopes -- 88 Sr, 87 Sr, 86 Sr, and 84 Sr. Only one of these (87 Sr) is radiogenic. It is derived from the radioactive decay of 87 rubidium. The reference isotope is the non-radiogenic 86 Sr, and the ratio of 87 Sr to 86 Sr (87 Sr / 86 Sr) is used in evaluating biogeological processes. The purpose of both lead and strontium isotope studies, other than age of the sample, has been to identify probable source material(s), mixing of water from multiple sources, and, from this, flow paths in a ground-water system.

Isotopic studies which focus on a particular mineral (such as galena from an ore deposit) may result in a very narrow range of ratios (age) which are statistically indistinct. However, when ground water or surface water which has reacted with a greater variety of rock types of different ages and different histories is examined isotopically, the range of values widens and isotopic distinctions may be evident. At Questa, Oligocene to Miocene

sedimentary rocks ranging from rhyolite to basalt in composition are intruded by granitic bodies of similar but slightly younger ages. These Tertiary units are variably altered and mineralized. Precambrian metasedimentary rocks and granitic intrusions form a basement complex which is juxtaposed structurally, or in an intrusive relationship, to the Tertiary rocks. The rocks in the Mine Area have clearly had different histories, and isotopic ratios might be expected to vary.

Depending on the length of the flow path and the geology along that path, subsurface water (vadose and ground water) may react with a few or a wide variety of minerals that have different isotopic ratios. These differences may be very small, but the high resolution analyses conducted by Chempet can discriminate between water samples where the lead concentrations are in the parts per billion (at Questa, the lead in the water samples ranged from 0.233 to 6.9 parts per billion). Measurements are at the nanogram level (billionth of a gram). Details of the Chempet procedure, including precision and accuracy, are presented in their report (Chempet, 1994). A copy of the Chempet report is available in Molycorp files.

The results are illustrated in a series of isotope-isotope or isotope concentration covariance plots. Data points are plotted with the analytical error. As noted by Mazor (1991), analytical error (sum of all uncertainty in the measurements) is needed to ascertain which data differ from each other with analytical significance. Only data that differ by more than the analytical error should be regarded as different for purposes of data processing. Analytical difference is not the same as statistical difference. At this point, there are far too few data points to say that any cluster of analytically different samples is statistically different from another sample cluster. Given sufficient numbers of samples, data may form statistically distinct clusters suggesting common chemistry and/or Pb/Sr source. The data may form linear arrays related to mixing of ground water along a flow path (such as a flow path from mine waste-rock dump perched water through bedrock or valley-fill).

Prior to summarizing the results of the analyses, some comments and corrections regarding the nature of some of the samples need to be made. Samples GHS-3 and CCS-3 are referenced on the plots as natural seeps in the Chempet (1994) report. While both samples are bedrock seeps, CCS-3 was taken from fractured rock in an adit and GHS-3 was taken several hundred feet below the Goathill Waste Dump. Both may have a component of mine-related water. Sample CCS-4 is from a surface flow in lower Capulin Canyon and is a mixture of mine and natural sources. It is correctly referenced as a mixture on Figures 1 and 2 in the Chempet (1994) report, but is incorrectly labeled as a natural seep on Figures 3, 4, and 5. Also in this same set of figures, CCS-3 is from a natural seep, but is incorrectly labeled as a mixture. Figures D8 through D12 are corrected figures prepared by SPRI.

Figure D8 (207 Pb/204 Pb plotted against 208 Pb/204 Pb), Figure D9 (208 Pb/204 Pb plotted against 206 Pb/204 Pb), and Figure D10 (206 Pb/207 Pb plotted against Pb

concentration) all show the two mine waste-rock dump waters are isotopically distinct from the other samples. When strontium is plotted [Figure D11 (206 Pb/207 Pb plotted against 87 Sr/86 Sr) and Figure D12 (87 Sr/86 Sr against Sr concentration)], the separation of the waste-rock dump waters from other waters is not as clear (CCS-1 is closer to the natural spring CCS-3 than the other dump sample GHS-1). On Figure D11, GHS-1, CCS-1, and CCS-3 cluster together. The Chempet report suggests that the clustering may be due to short-term reactions between ground water and mine-impacted rock material (waste-rock fragments and mine-induced fractures in the adit).

The Hot-N-Tot Canyon sample (HTS-1) is from a highly altered but unmined area of volcanic rocks similar to those at Questa. It appears to be isotopically distinct from all of the other samples including the bedrock seeps at Questa. At this point, it is not known whether the difference is the result of a mixing of mine waters with natural acidic seeps at Questa or reflects a distinctively difference hydrothermal system in the Hot-N-Tot area. On the strontium plot (Figure D12), the Red River sample plots off the diagram because of the influence of the older Precambrian rocks in the Red River drainage basin (high ratio of 87 Sr/86 Sr reflects age).

## D.6 Summary of the Water-Quality Studies

Mine waste-rock dump seepage and most of the bedrock seeps (except CCS-2) are acidic waters (pH $<4.0$) with moderate to high TDS, and high levels of aluminum (Al), iron (Fe), manganese (Mn), and zinc (Zn). On STIFF Diagrams, these seeps are typically calcium and/or magnesium sulfate water, but aluminum or iron can exceed the calcium/magnesium in some samples. The major distinction between seepage water and bedrock seeps is the significantly higher concentrations of sulfate, fluoride, and metals [Al, Fe, Mn, Zn, Cu, and cadmium (Cd)]. Tritium results indicate the waste-rock dump seepage is post-1952 water. Preliminary lead and strontium isotopic results suggest the possibility that dump seepage may have a different isotope signature than natural acidic seeps.

The chemistry of the monitor well water and river seeps is more site-specific. The three river seeps of concern are the Portal Springs seeps, Cabin Springs seeps, and Capulin Canyon seeps. At both Portal Springs and Capulin Canyon, the seep water appears to be more closely aligned (based partly on pH) to ground water in the valley-fill than the underlying bedrock aquifer. At Capulin Canyon, elevated concentrations of iron, manganese, zinc, and copper in the valley-fill water (MMW-2) relative to recent nearby up-gradient sources (CCS-4) and down-gradient river seeps (CCS-5 and -6) suggest that either an earlier (pre-1994) slug of leachate is stored in the fill or acidic ground water is actively leaching minerals in the valley-fill deposit.

All of the monitor well water samples exceed State standards for total dissolved solids (TDS), $SO_4$, F, and Mn. Wells MMW-7 and MMW-2 exceed standards for Zn, Cd, and Fe. Cadmium is slightly elevated at MMW-10A, MMW-10B, MMW-10C, and MMW-11. The November 1994 sampling shows nickel (Ni) exceeds State standards at MMW-2, MMW-3, MMW-10A, MMW-10B, and MMW-7. Nickel was not included in the May sampling.

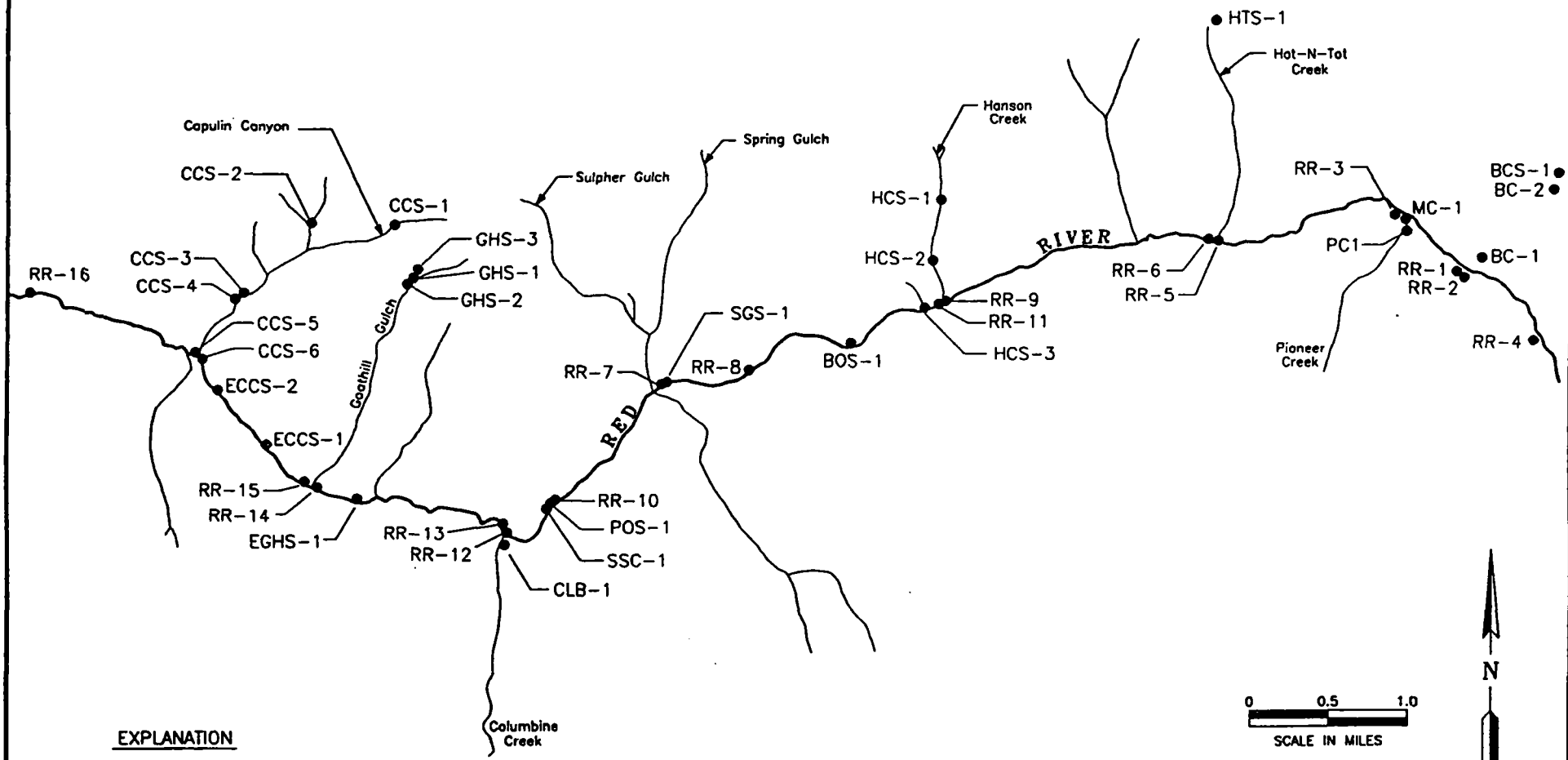
Seeps at Portal Springs and Capulin Canyon, like the adjacent valley-fill aquifer, exceed State standards for TDS, $SO_4$, F, Fe (one sample), Al, Mn, and Zn. Cadmium was not included in the May surface-water survey. Both sites are close enough to the surface that natural oxidizing vadose water could contribute to their chemistry.

The bedrock seepage at Cabin Springs exceeds State standards for TDS, $SO_4$, F, Al, Zn, Mn, and Cd. As in the case of MMW-7, it is not possible to clearly show that waste-rock dump seepage has contributed to the ground water at these sites. Both sites are close enough to the surface that natural oxidizing vadose water could contribute to their chemistry.

Mixing of river seeps with the Red River water (Vail, Surface Water Chemistry, October 1994; Table D3) indicates that, except for Mn, the seep chemical constituents are diluted well below State standards. From the Portal Springs area downstream to the Questa gauge, Mn concentrations slightly exceed State standards.

There is a limited data set for the underground mine waters. What is available indicates that TDS and $SO_4$ exceed State standards as does F and Mn. Iron and Al are in very low concentrations suggesting that shallow oxygenated and alkaline ground water may serve as a sink (precipitation) for these metals. Oxygenated vadose water, reacting with fractured and rubbilized pyritic rock on the emergent part of the underground mine and in the caved area, as well as dump seepage captured by the caved area are sources of leachate. The cone of depression prevents this ground water form impacting the river or regional ground water.

The production well at Columbine Creek meets all of the State standards, but the one at the Red River Sewage Treatment Plant does not. This well is screened in a mudflow deposit derived from a large hydrothermal scar area. Water from this well exceeds State standards for TDS, $SO_4$, F, Al, and Mn.

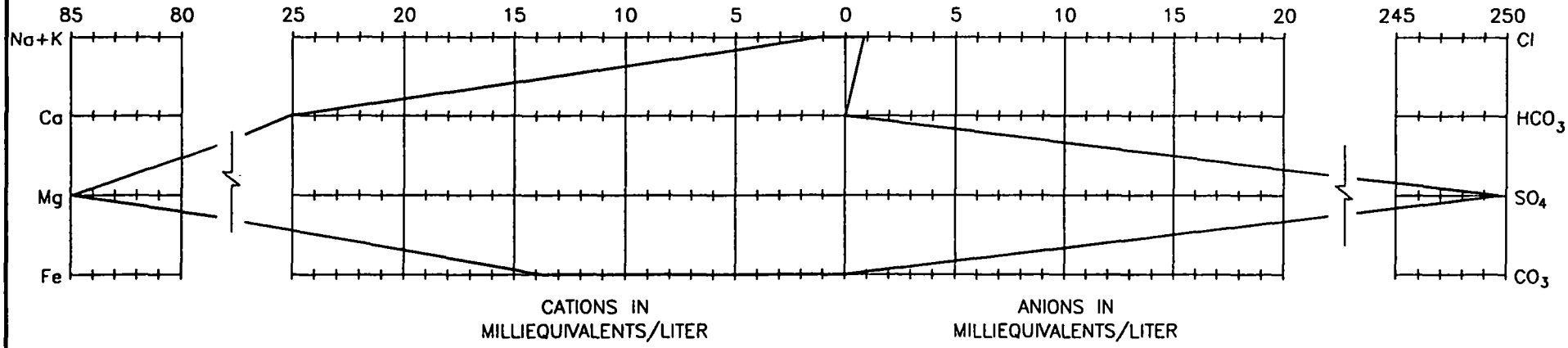



| FIGURE: D1 | SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. |

# RED RIVER & SEEP SAMPLE LOCATIONS MAY 1994

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 3.0 CCS-1 TDS = 24,950




pH = 4.0 CCS-3 TDS = 2686

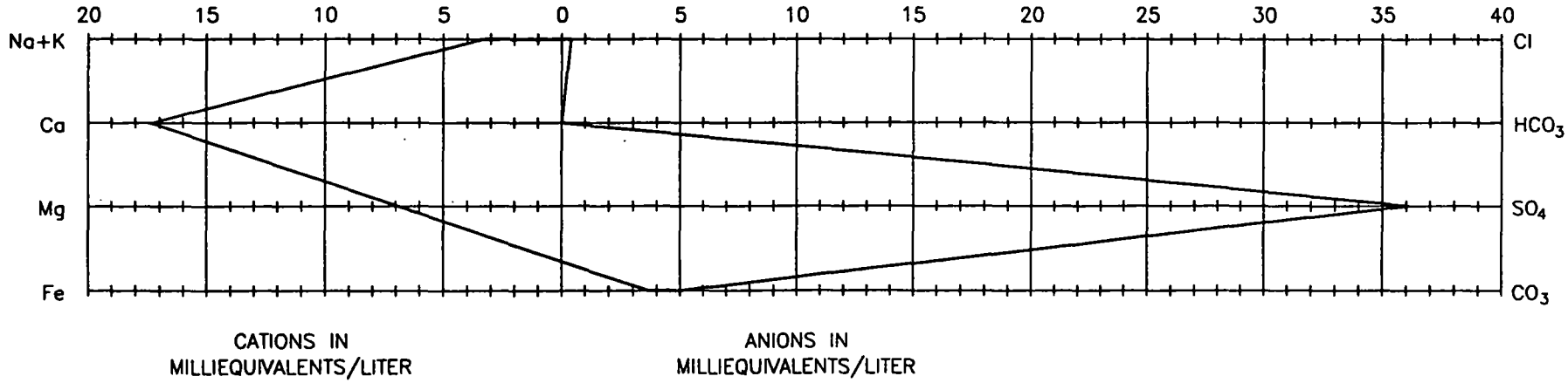



FIGURE: D2

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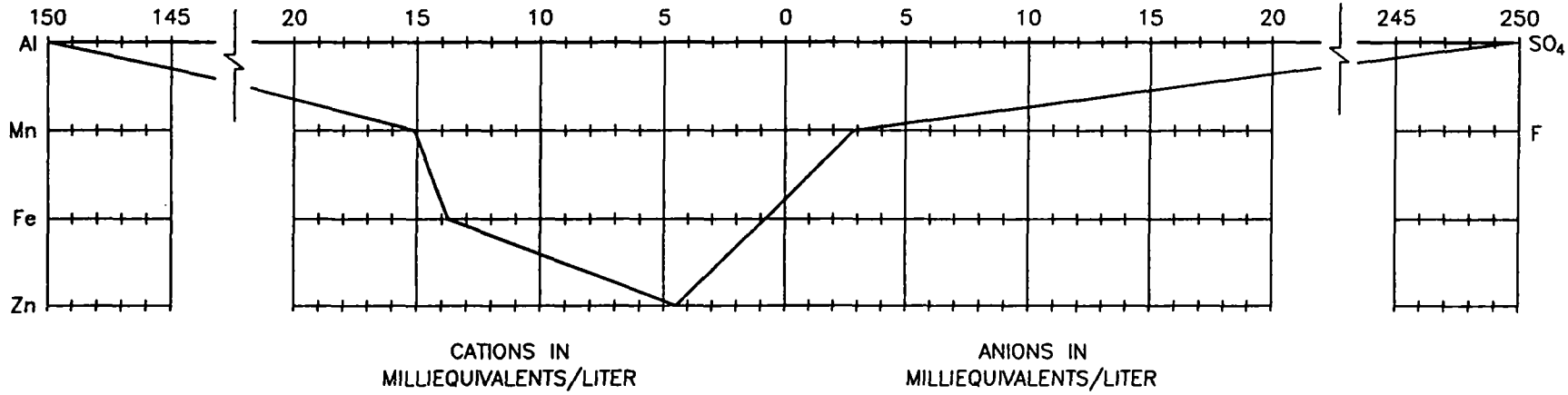
# STIFF DIAGRAMS-WASTE ROCK DUMPS AND BEDROCK SEEPS

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 3.0 CCS-1 TDS = 24,950




pH = 4.0 CCS-3 TDS = 2686

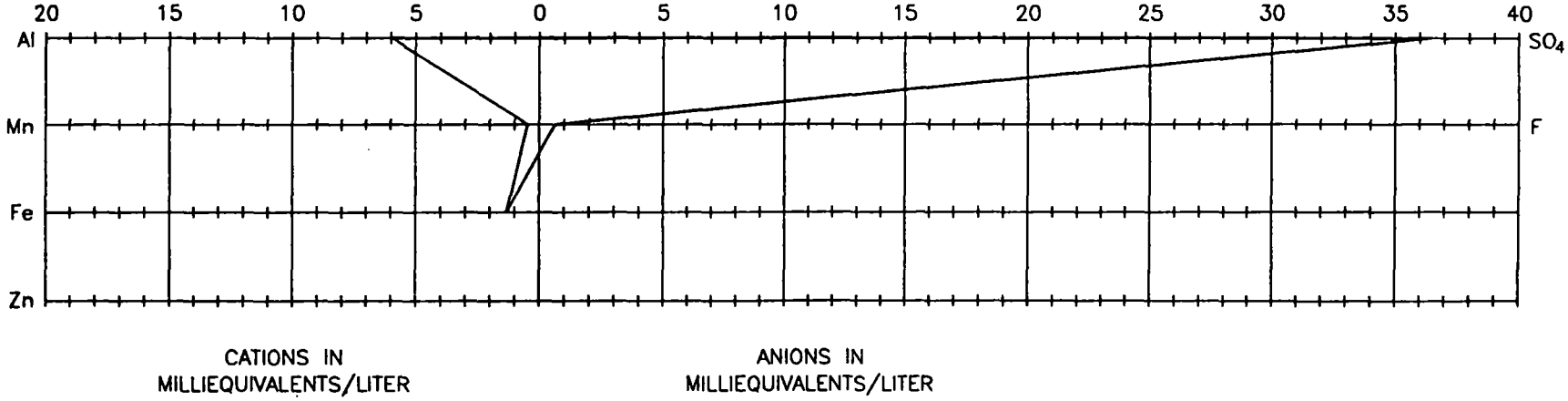



FIGURE: D 2a

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|---|---|---|---|
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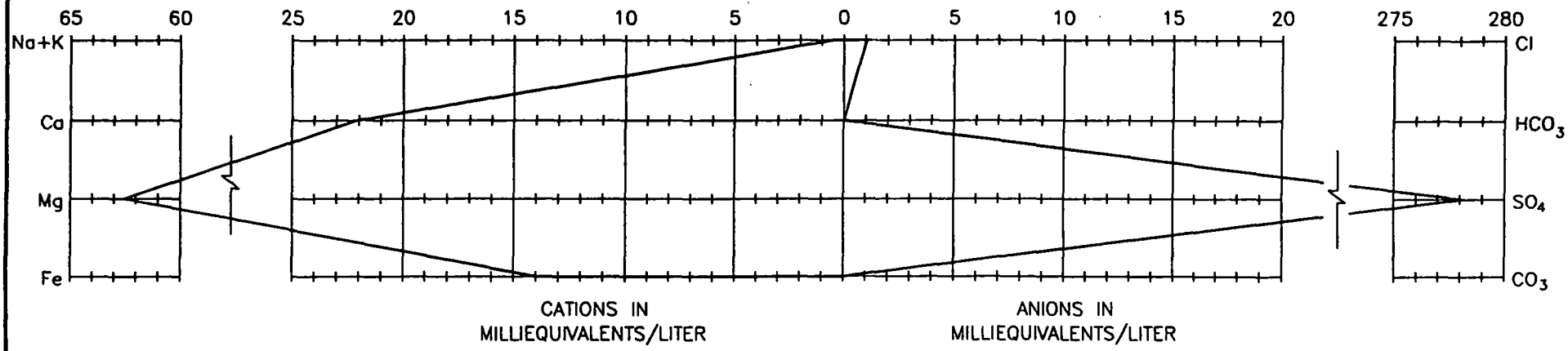
# STIFF DIAGRAMS-WASTE ROCK DUMPS AND BEDROCK SEEPS

Mine Area - Molycorp, Inc.
Questa, New Mexico

STIFF-7

pH = 2.0 GHS-1 TDS = 23,890




pH = 2.0 GHS-3 TDS = 11,980

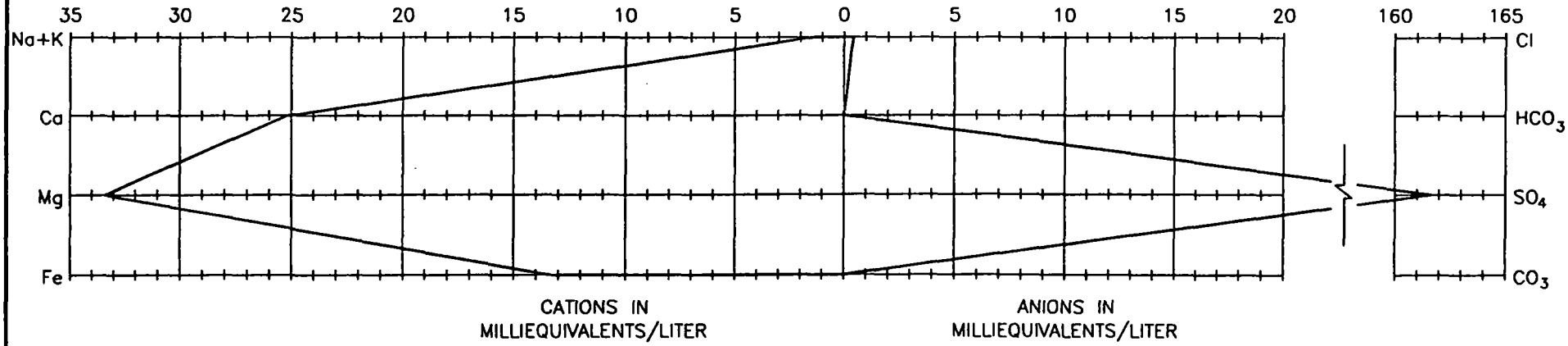



FIGURE: D 2b

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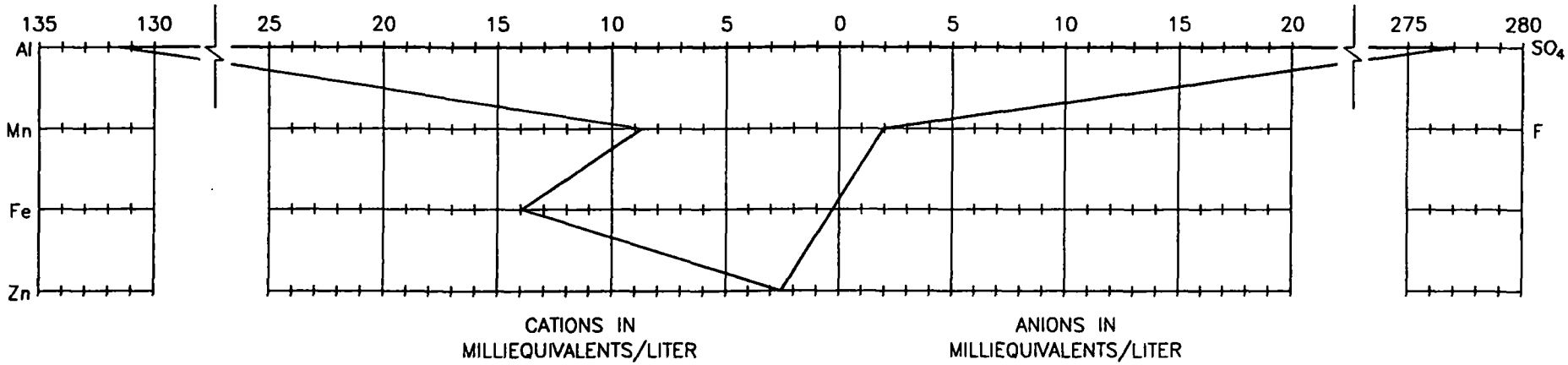
# STIFF DIAGRAMS-WASTE ROCK DUMPS AND BEDROCK SEEPS

Mine Area - Molycorp, Inc.
Questa, New Mexico

STIFF-7A

pH = 2.0 GHS-1 TDS = 23,890




pH = 2.0 GHS-3 TDS = 11,980

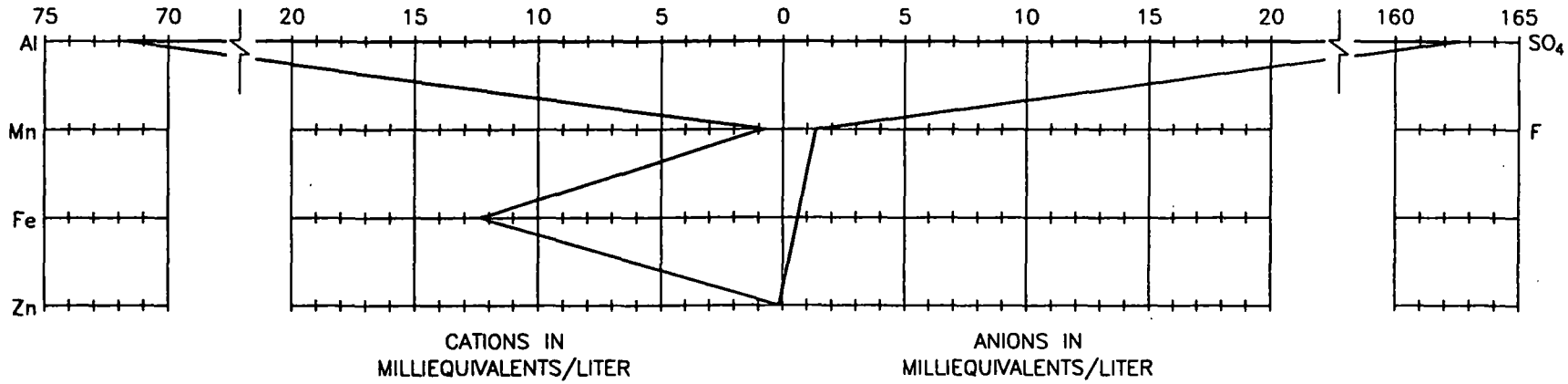



FIGURE: 2C D

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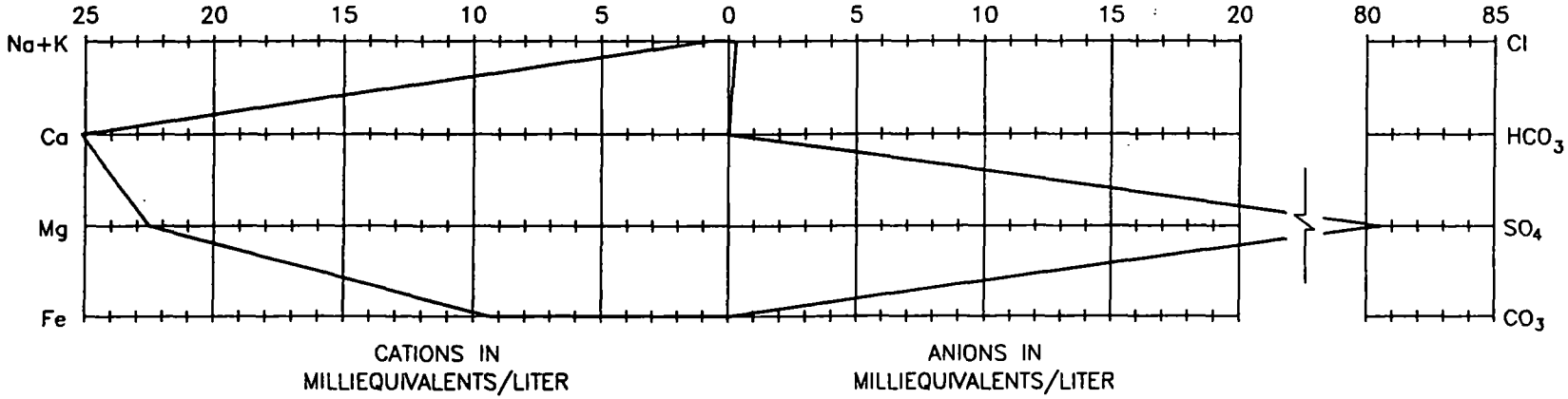
# STIFF DIAGRAMS-WASTE ROCK DUMPS AND BEDROCK SEEPS

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 2.5 HCS-1 TDS = 6493




pH = 2.3 HTS-1 TDS = 2610

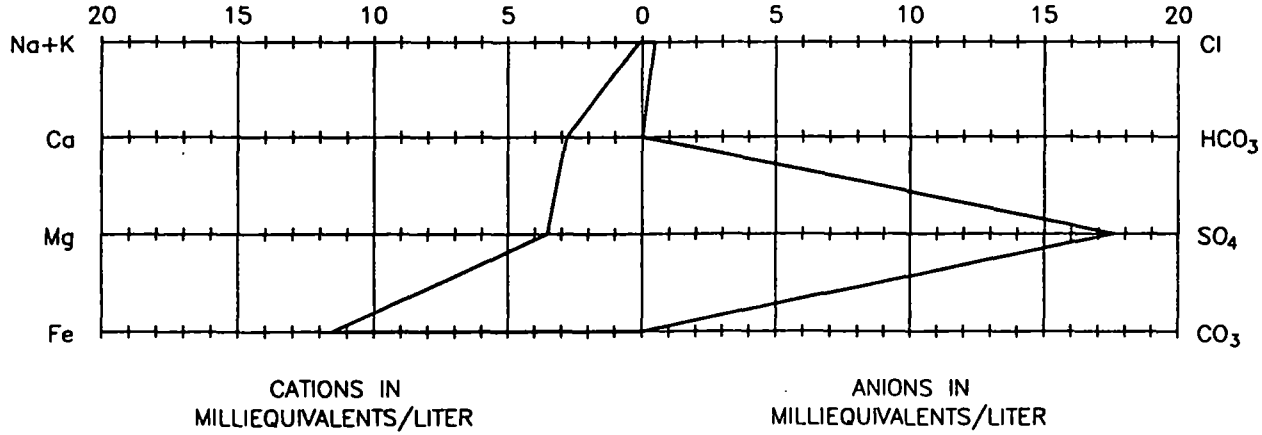



FIGURE: D3

SOUTH PASS RESOURCES, Inc.

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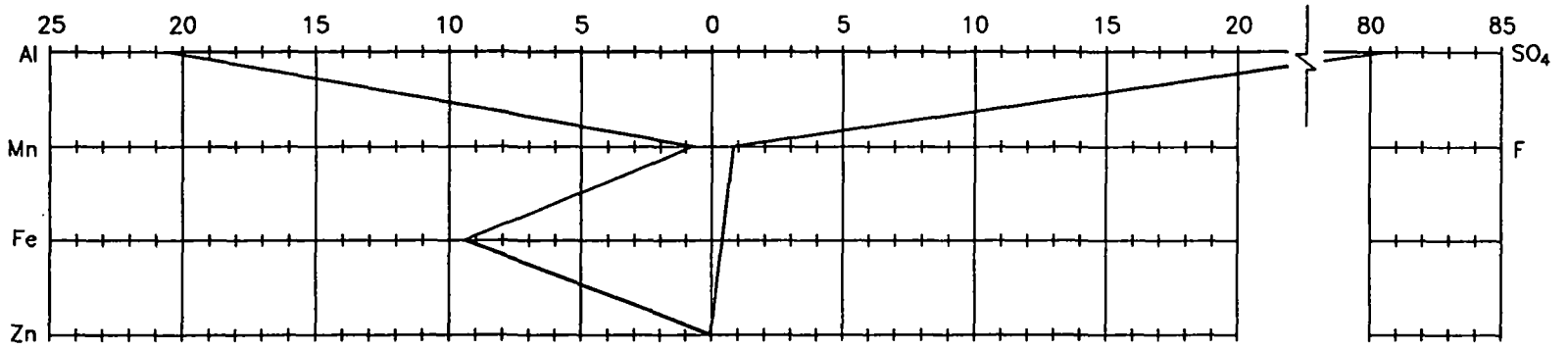
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

# STIFF DIAGRAMS-NATURAL SEEPS OUTSIDE MINE AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 2.5 HCS-1 TDS = 6493




pH = 2.3 HTS-1 TDS = 2610

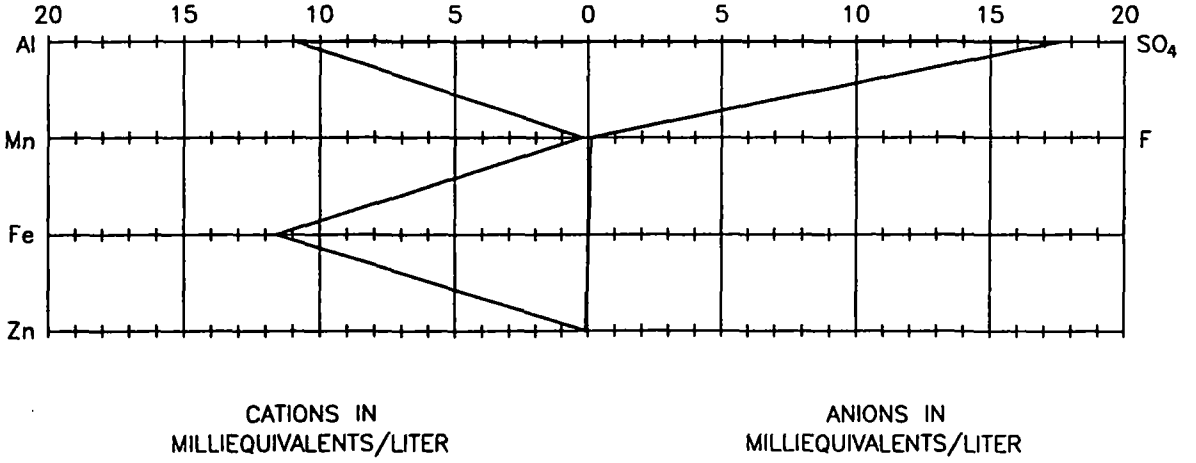



FIGURE: D 3a

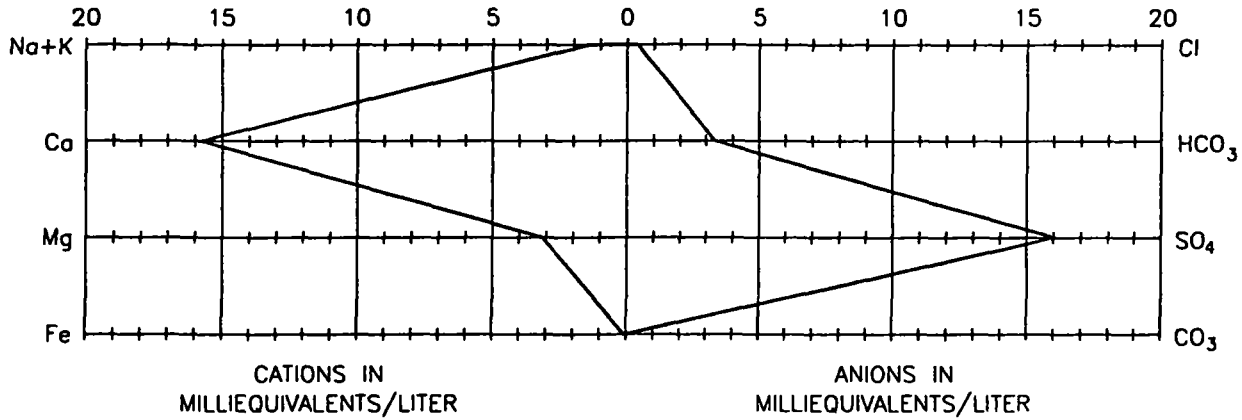
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

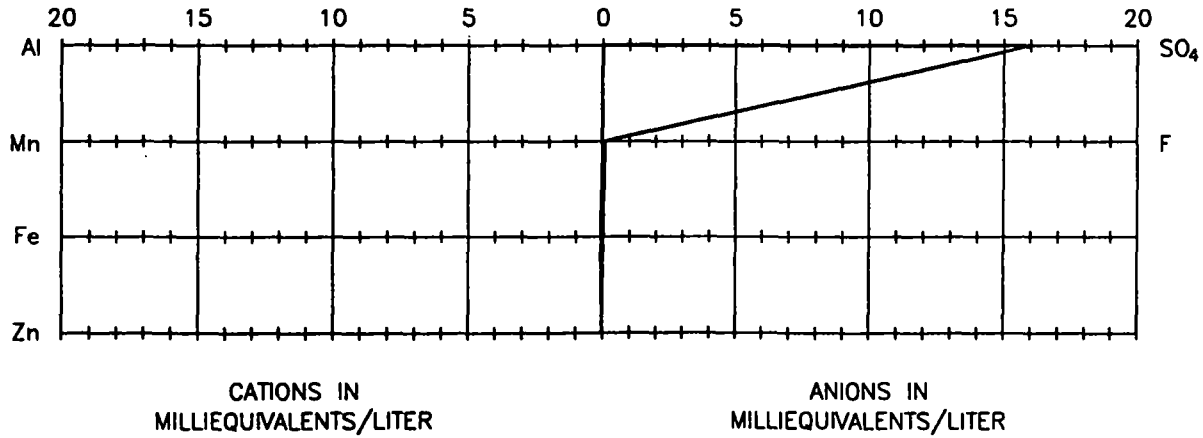
# STIFF DIAGRAMS-NATURAL SEEPS OUTSIDE MINE AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 7.9 MMW-13 TDS = 1400




pH = 7.9 MMW-13 TDS = 1400




| FIGURE: | SOUTH PASS RESOURCES, Inc. | | | | STIFF DIAGRAM – MIDDLE WASTE-ROCK DUMP<br>Mine Area – Molycorp, Inc.<br>Questa, New Mexico |
|---|---|---|---|---|---|
| D4 | PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | |

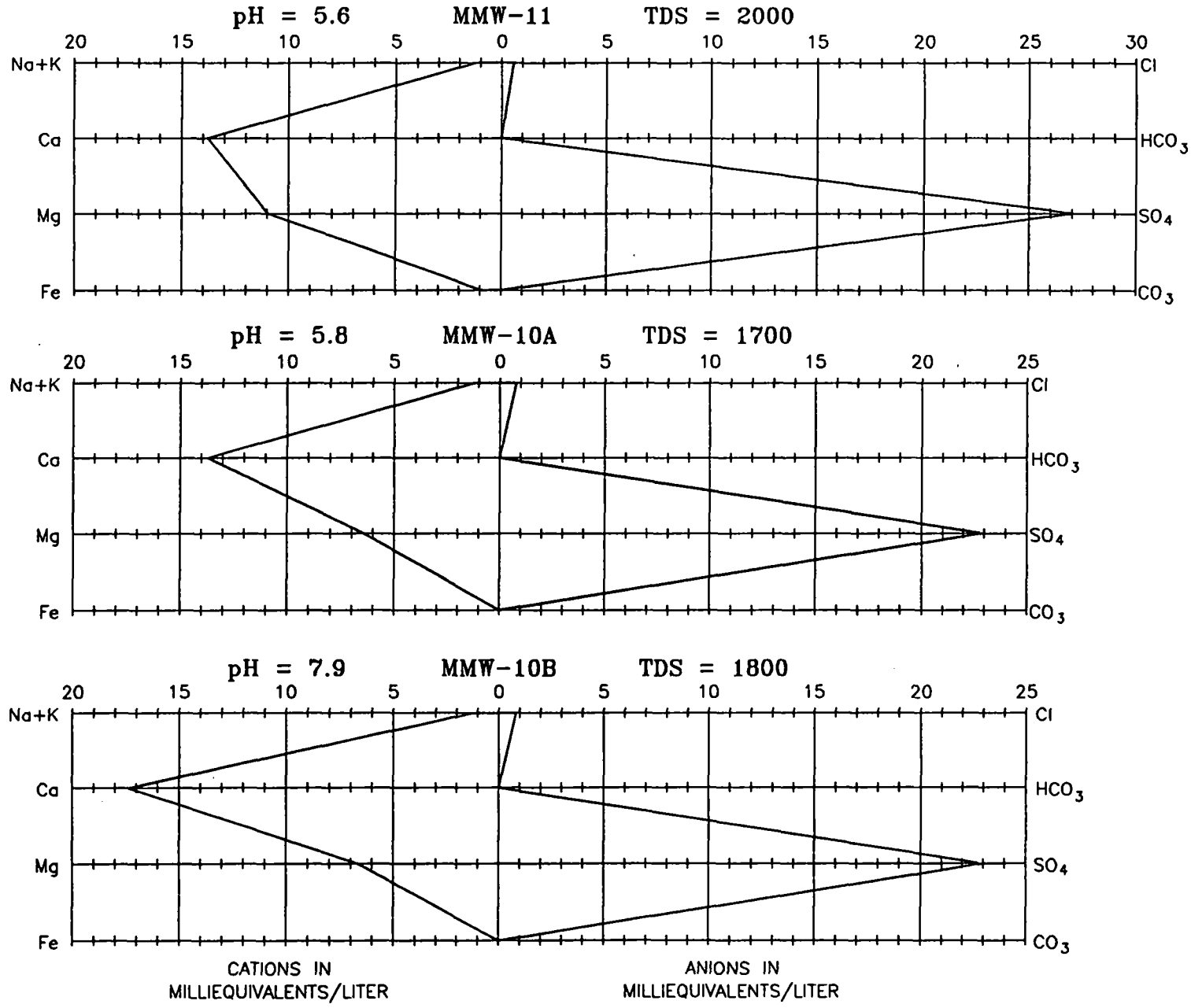



FIGURE: D5

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

# STIFF DIAGRAMS - SUGAR SHACK SOUTH AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

STIFF-8A

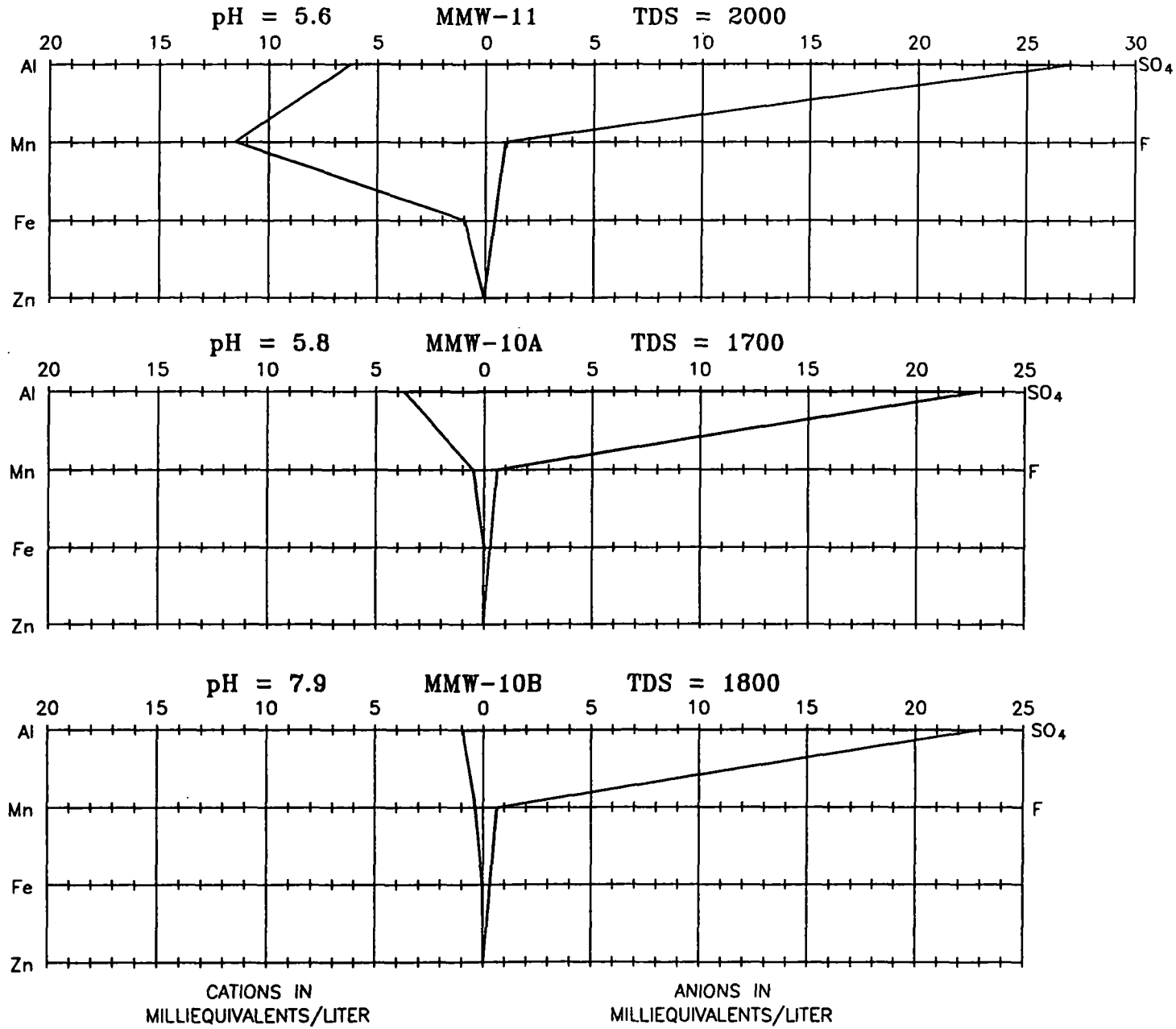



FIGURE: D 5a

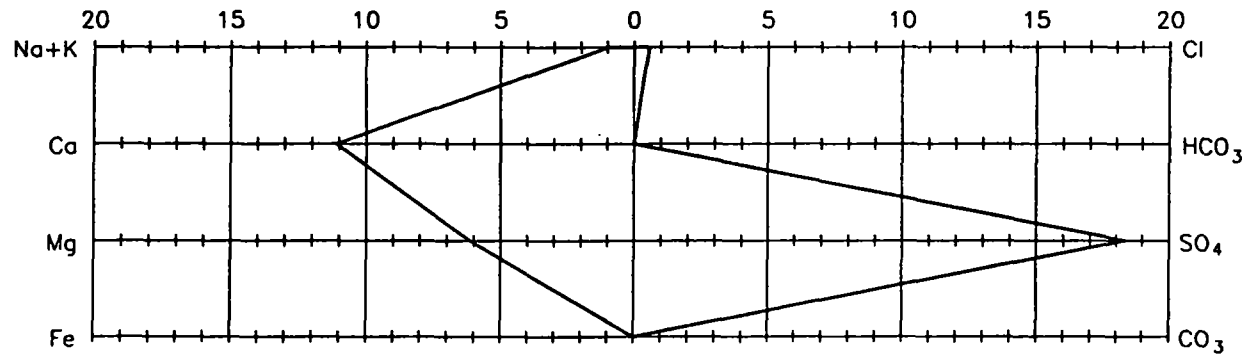
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

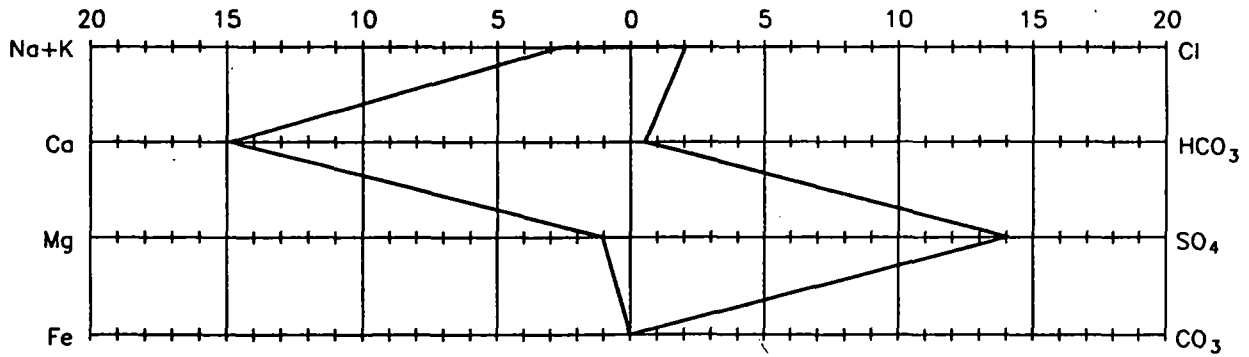
# STIFF DIAGRAMS - SUGAR SHACK SOUTH AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 4.7 MMW-10C TDS = 1400




pH = 5.0 PORTAL SPRINGS TDS = 2017
(SPRI 5/94, #20)




CATIONS IN MILLIEQUIVALENTS/LITER

ANIONS IN MILLIEQUIVALENTS/LITER

FIGURE: D 5b

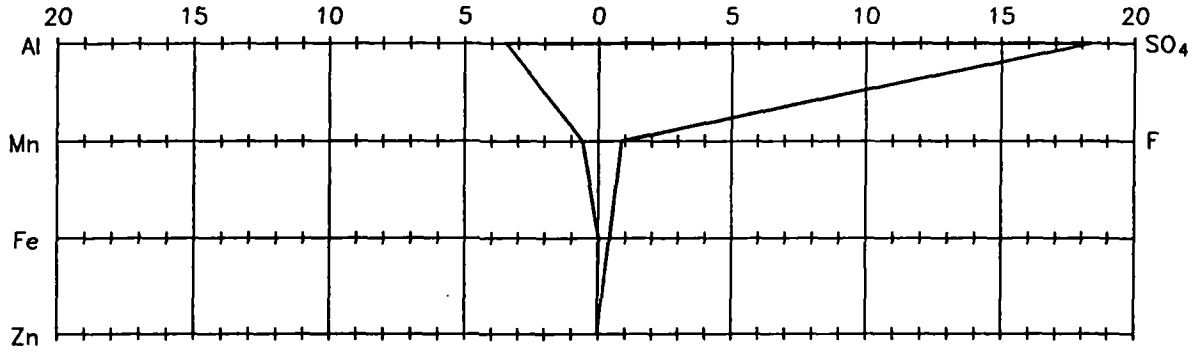
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

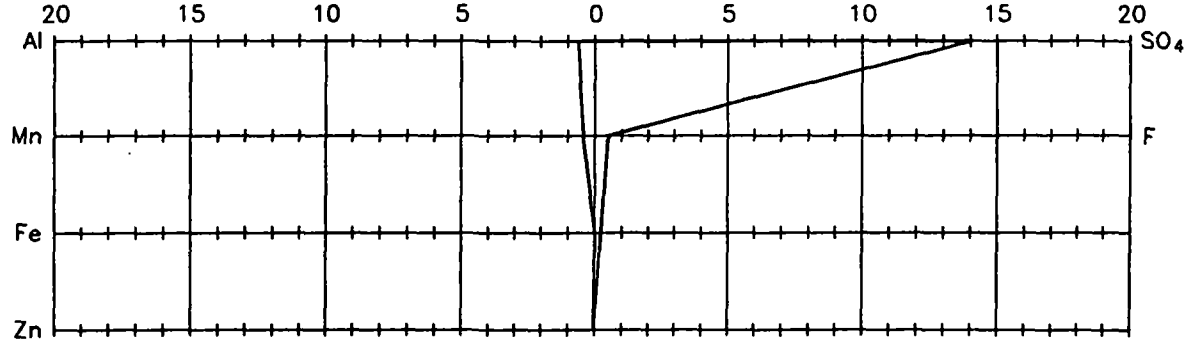
# STIFF DIAGRAMS - SUGAR SHACK SOUTH AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 4.7 MMW-10C TDS = 1400




pH = 5.0 PORTAL SPRINGS TDS = 2017
(SPRI 11/94, #20)




CATIONS IN
MILLIEQUIVALENTS/LITER

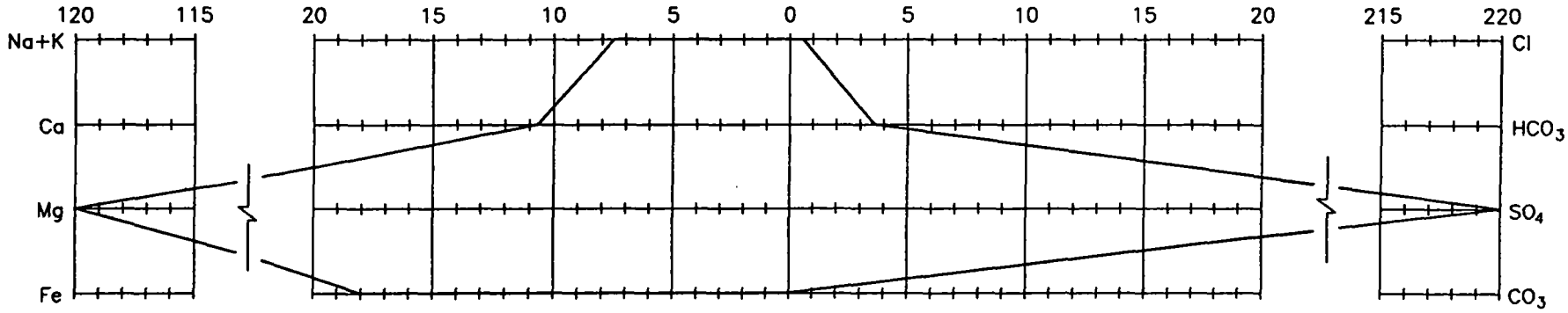
ANIONS IN
MILLIEQUIVALENTS/LITER

FIGURE: D 5C

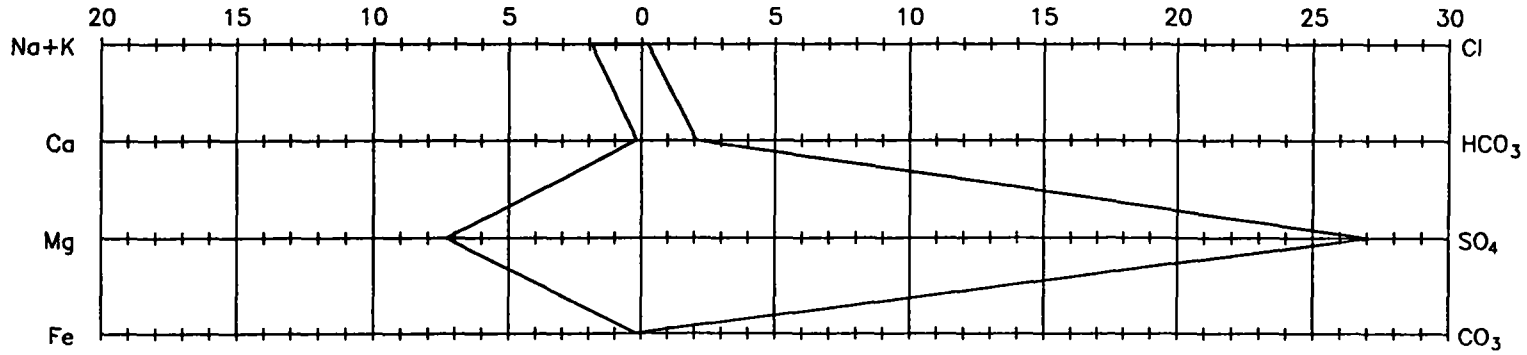
| SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. |

STIFF DIAGRAMS - SUGAR SHACK SOUTH AREA
Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 4.4 MMW-7 TDS = 16,000




pH = 7.0 MMW-8A TDS = 2200




CATIONS IN MILLIEQUIVALENTS/LITER

ANIONS IN MILLIEQUIVALENTS/LITER

FIGURE: D6

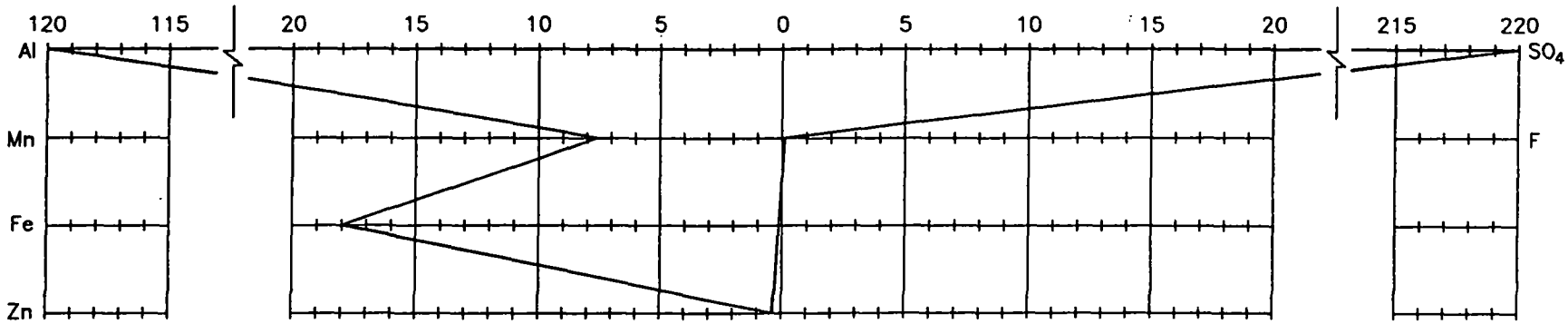
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

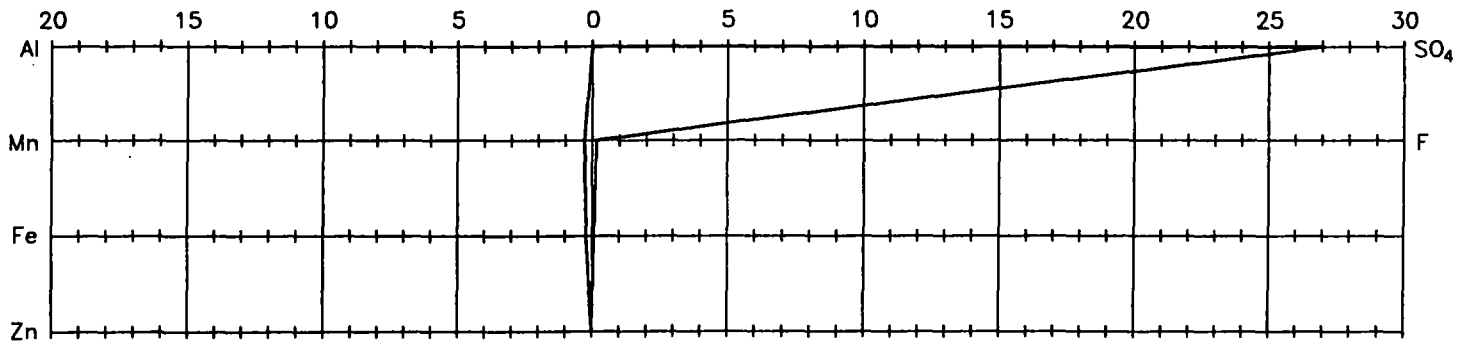
# STIFF DIAGRAMS - SUGAR SHACK WEST AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 4.4 MMW-7 TDS = 16,000




pH = 7.0 MMW-8A TDS = 2200




CATIONS IN MILLIEQUIVALENTS/LITER

ANIONS IN MILLIEQUIVALENTS/LITER

FIGURE: D 6a

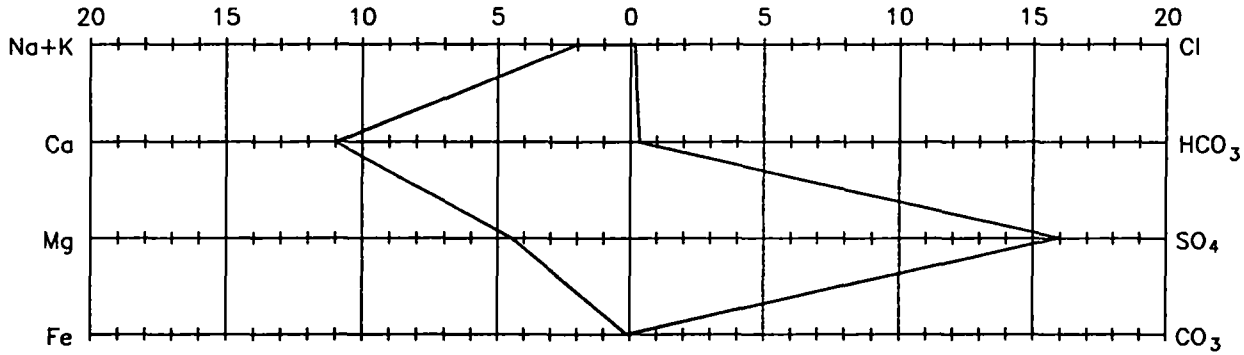
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

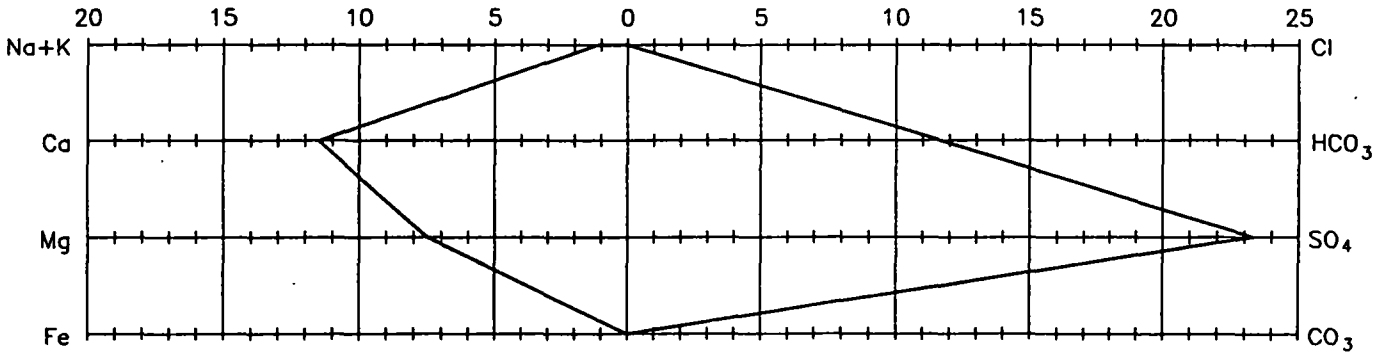
# STIFF DIAGRAMS – SUGAR SHACK WEST AREA

Mine Area – Molycorp, Inc.
Questa, New Mexico

pH = 6.4 MMW-8B TDS = 1100




pH = 5.1 CABIN SPRINGS TDS = 2040
(Vail, #10)




CATIONS IN MILLIEQUIVALENTS/LITER

ANIONS IN MILLIEQUIVALENTS/LITER

FIGURE: D 6b

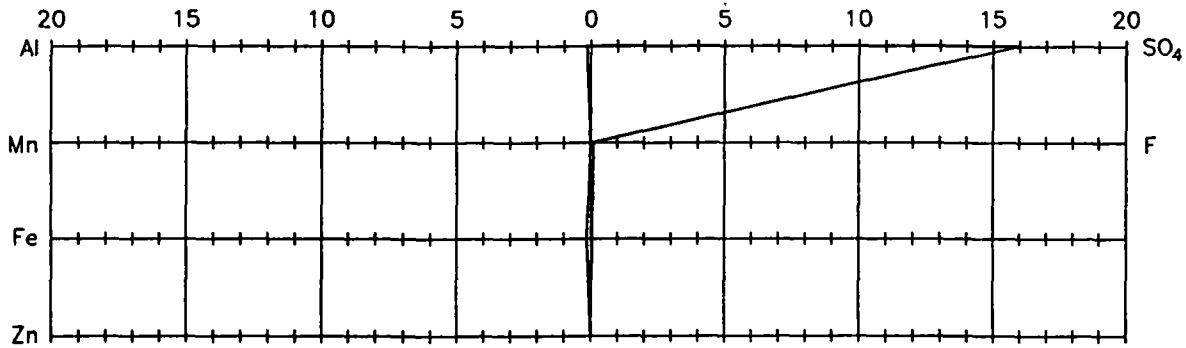
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

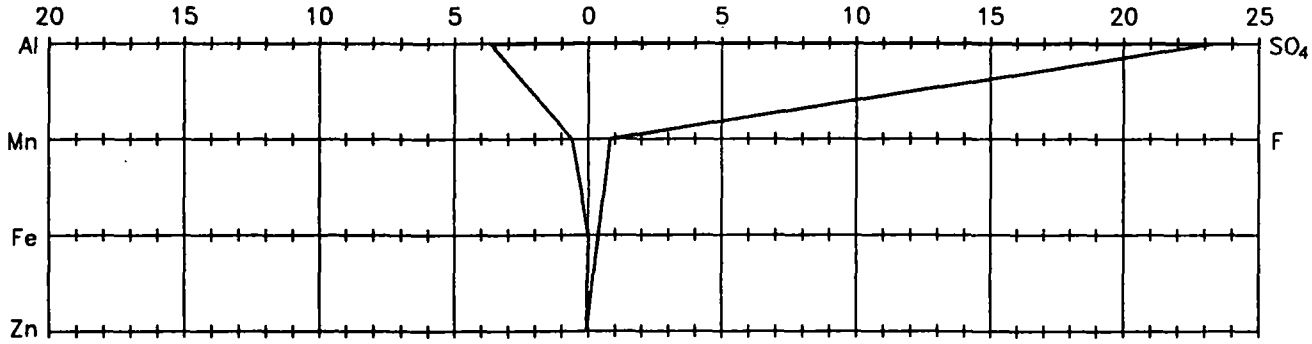
# STIFF DIAGRAMS - SUGAR SHACK WEST AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

pH = 6.4 MMW-8B TDS = 1100




pH = 5.1 CABIN SPRINGS (Vail, #10) TDS = 2040




CATIONS IN MILLIEQUIVALENTS/LITER

ANIONS IN MILLIEQUIVALENTS/LITER

FIGURE: 6c D

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

# STIFF DIAGRAMS - SUGAR SHACK WEST AREA

Mine Area - Molycorp, Inc.
Questa, New Mexico

STIFF-6

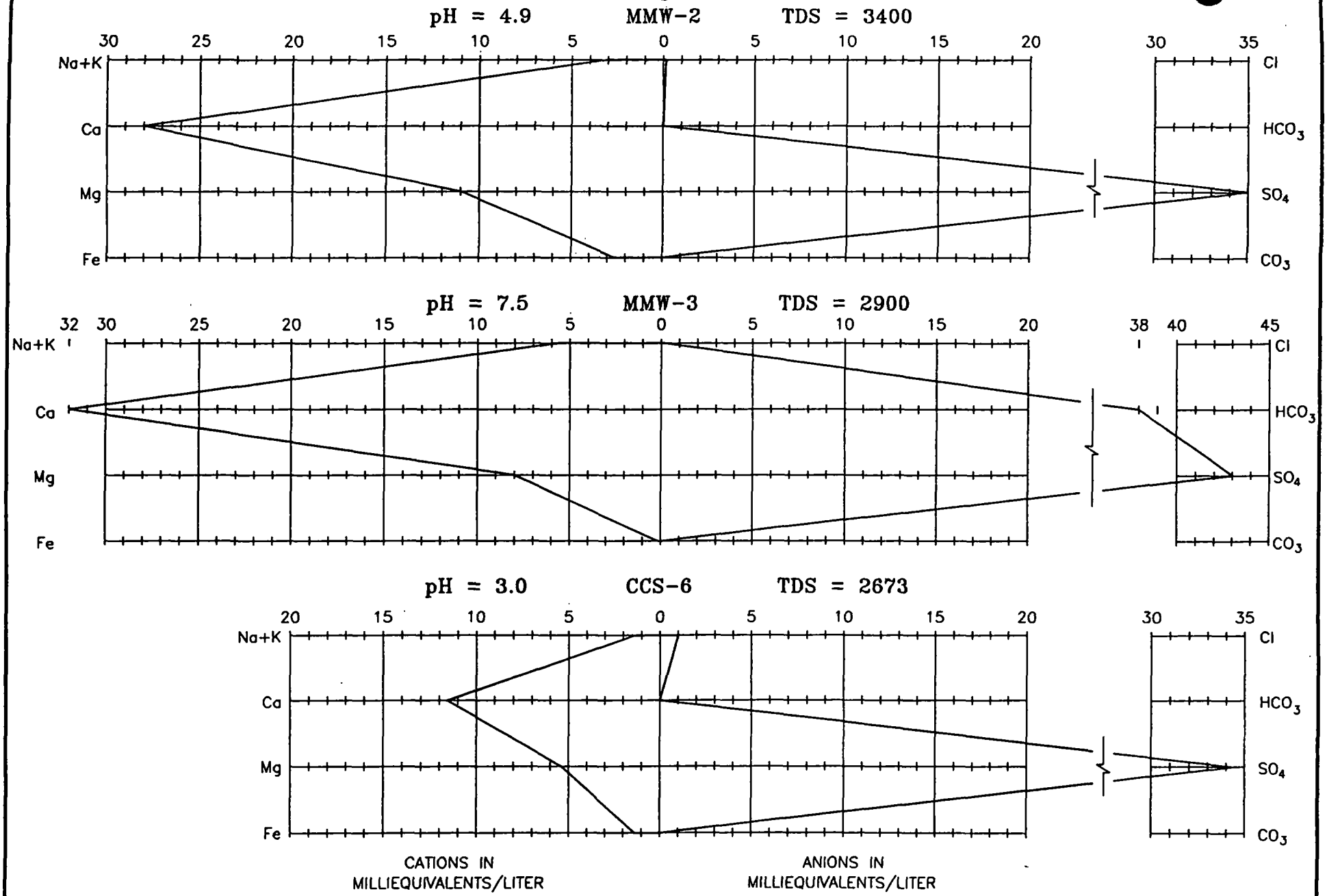



FIGURE: D7

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 4/13/95 | | M.O'M. |

# STIFF DIAGRAM – CAPULIN CANYON AREA

Mine Area – Molycorp, Inc.
Questa, New Mexico

STIFF-6A

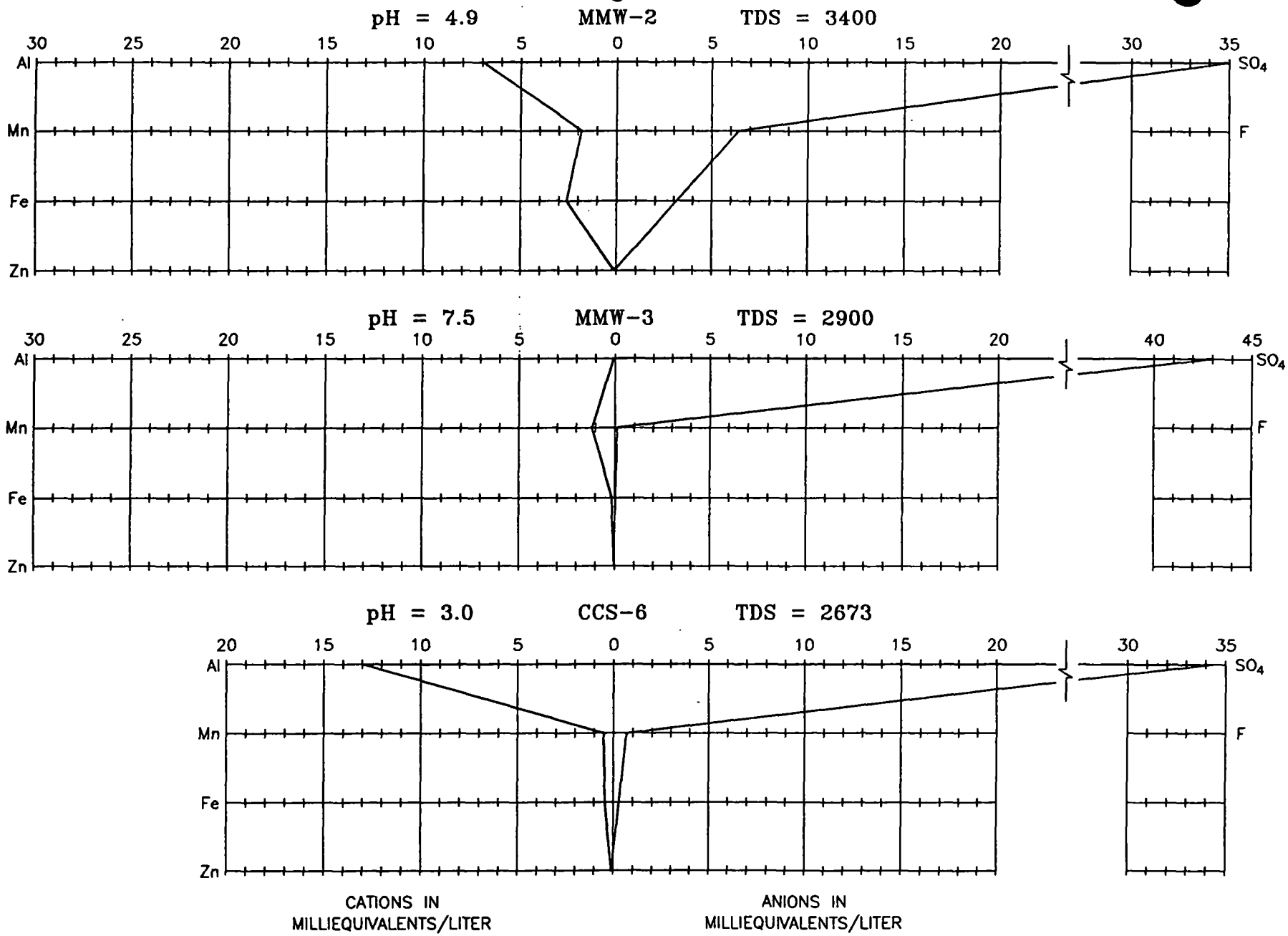



FIGURE: 7a

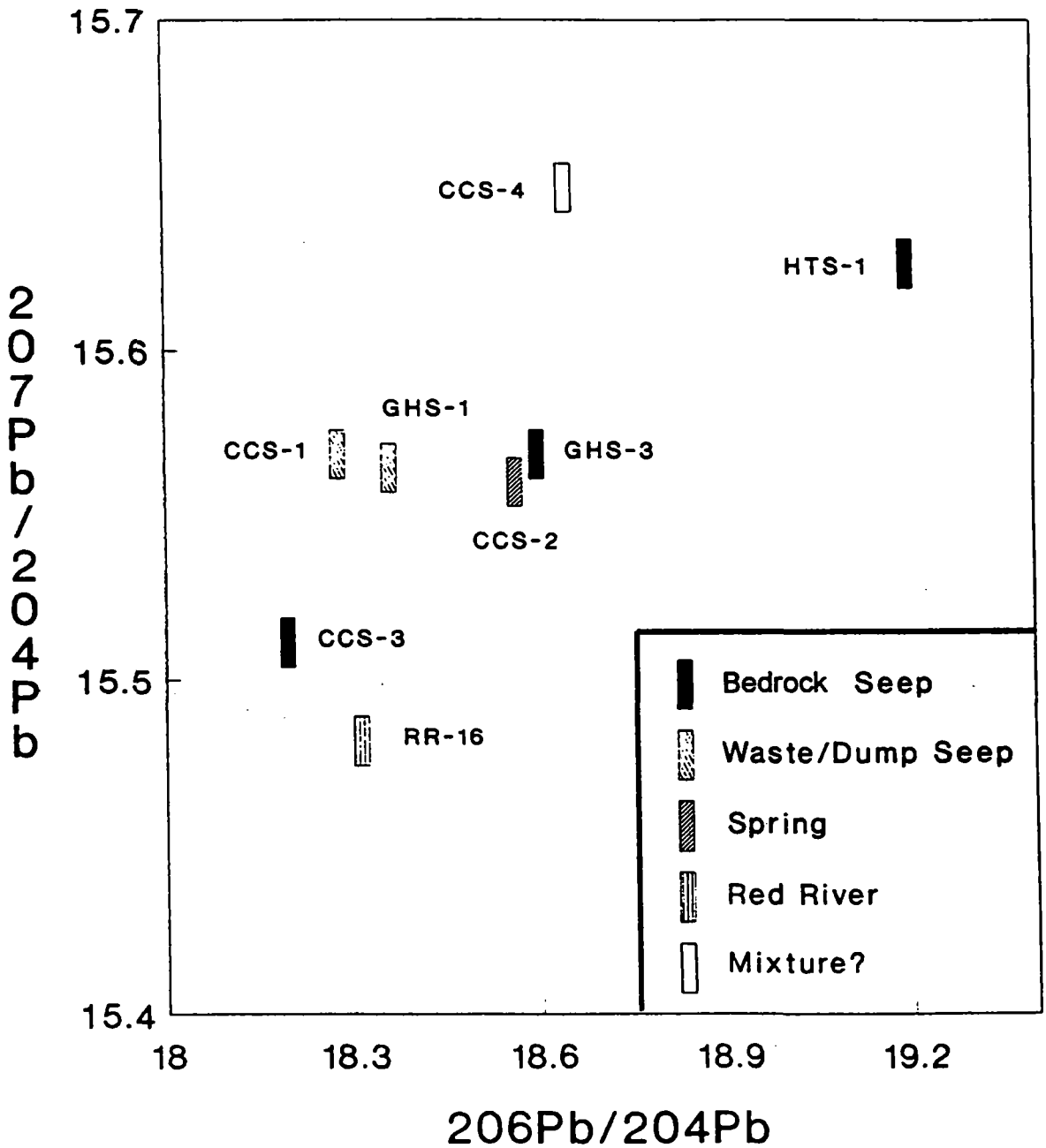
| SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. |

# STIFF DIAGRAM – CAPULIN CANYON AREA

Mine Area – Molycorp, Inc.
Questa, New Mexico

ISOTOPES

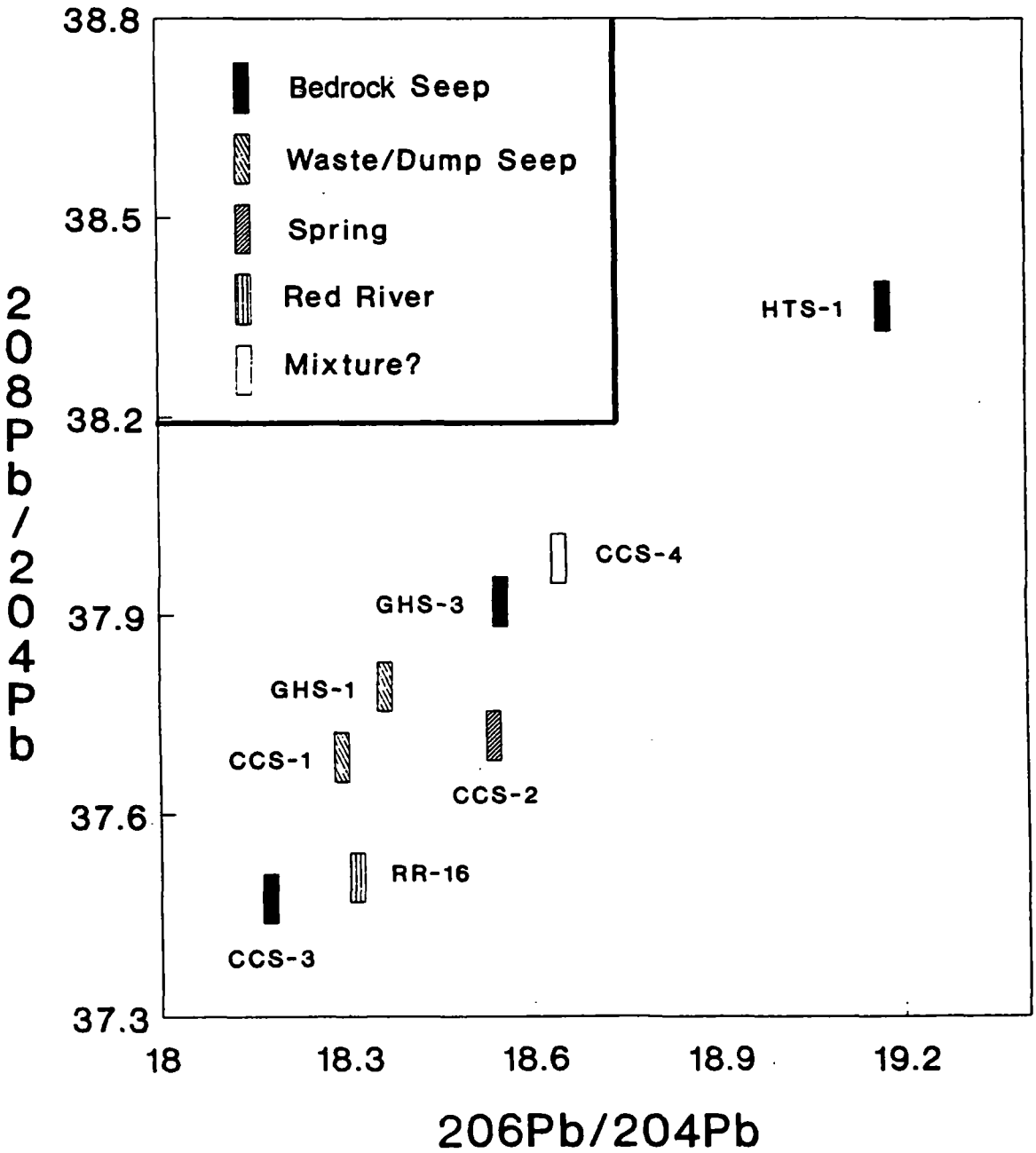
# UNOCAL MOLYCORP QUESTA MINE GROUNDWATER STUDY




*The waste/dump seep waters (CCS-1, GHS-1) form a cluster that is statistically different from other waters. Data points are shown with true analytical errors.*

| SOUTH PASS RESOURCES, Inc. | | | | 207Pb/204Pb vs 206Pb/204Pb<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D8 |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

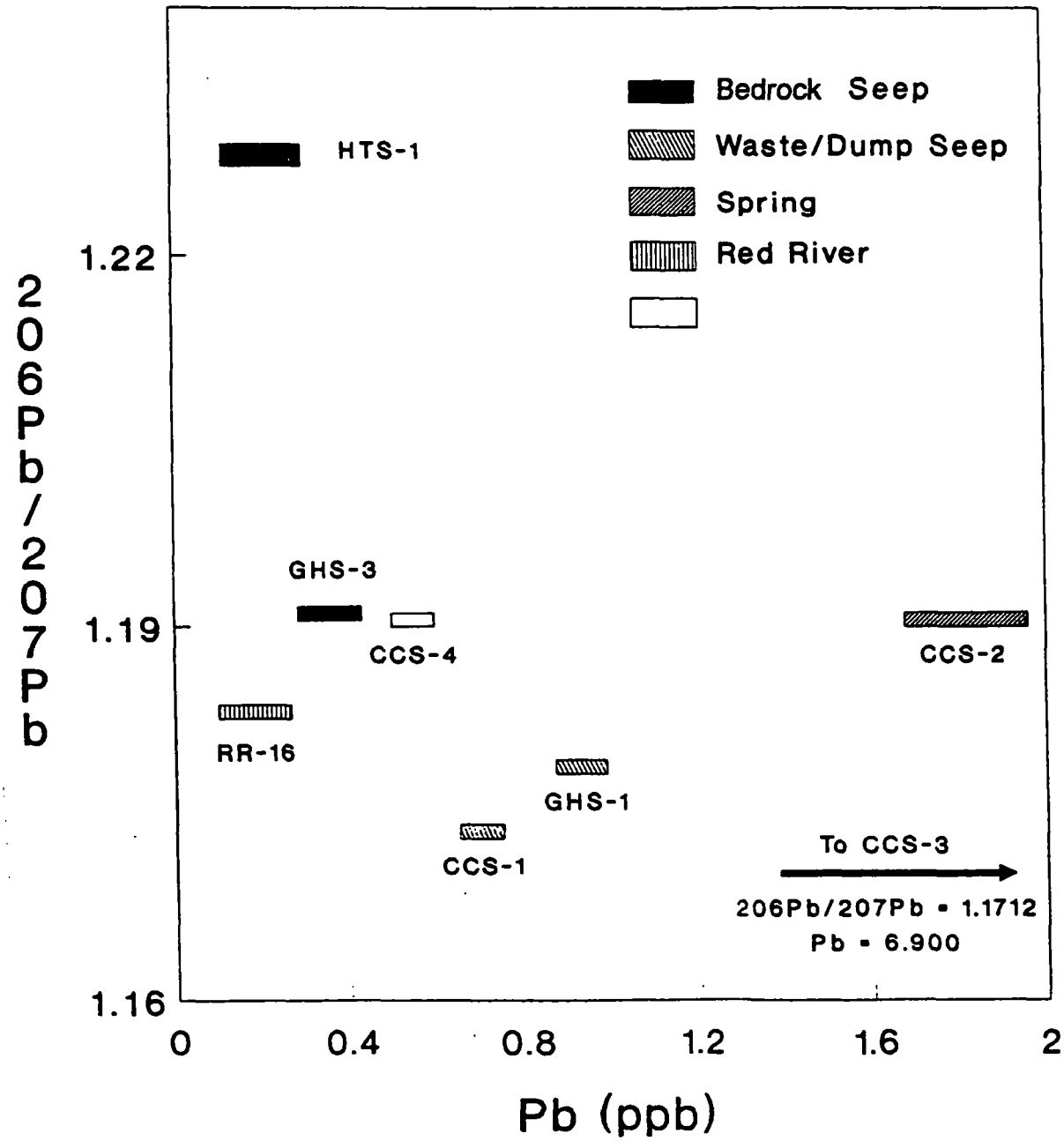
# UNOCAL MOLYCORP QUESTA MINE GROUNDWATER STUDY




*The two waste/dump seep waters (CCS-1, GHS-1) may either be a distinct cluster or part of a trend. Data points are shown with true analytical errors.*

| SOUTH PASS RESOURCES, Inc. | | | | 208Pb/204Pb vs 206Pb/204Pb<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D9 |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

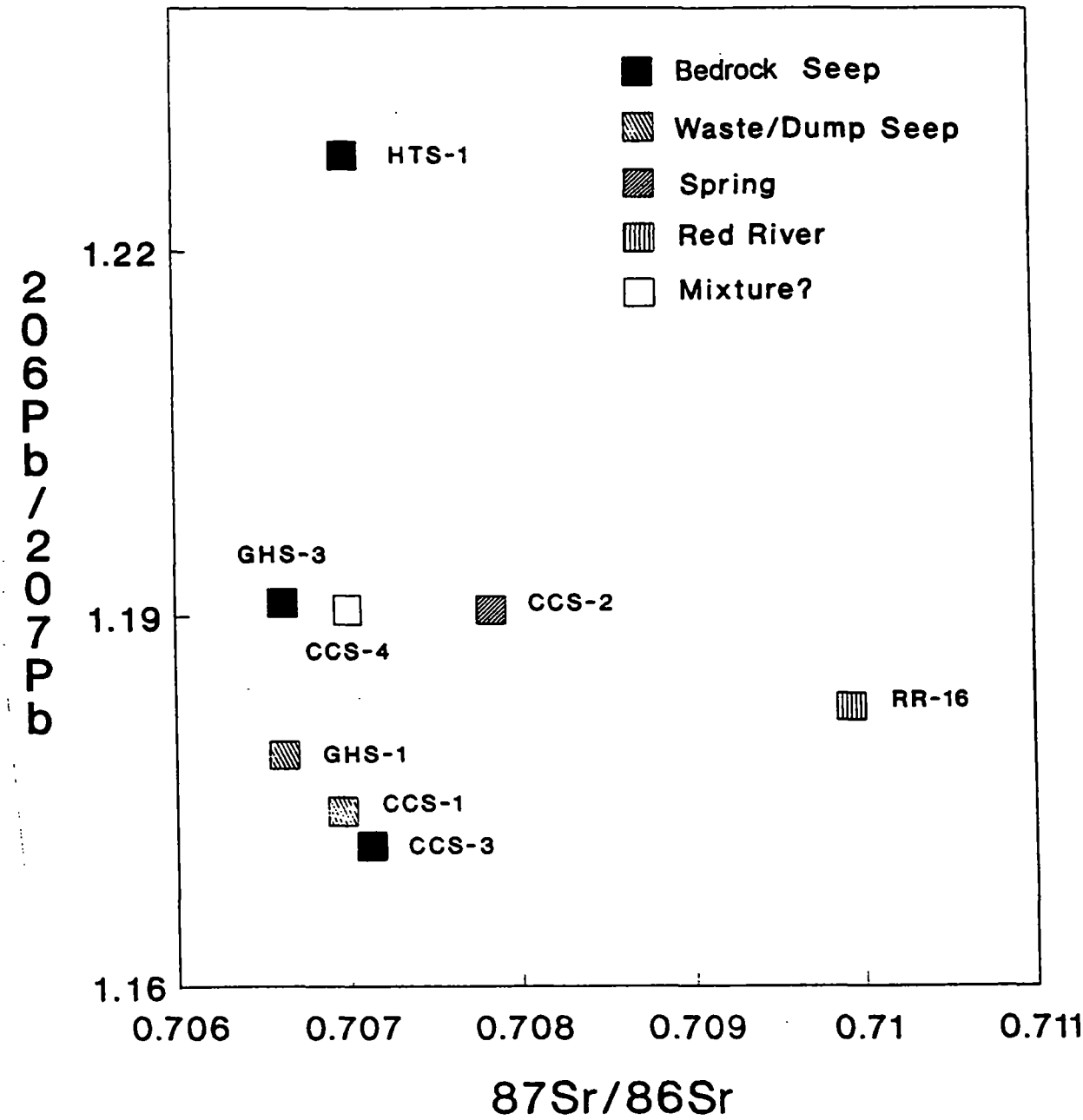
# UNOCAL MOLYCORP QUESTA MINE GROUNDWATER STUDY




*Waste/dump seep waters (CCS-1, GHS-1) are distinct from other water samples. Long-term water-rock equilibria may explain the clustering of 206Pb/207Pb ratios near 1.19. The error in 206Pb/207Pb is exaggerated 4X for clarity.*

| SOUTH PASS RESOURCES, Inc. | | | | 206Pb/207Pb vs Pb Concentration<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D10 |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

# UNOCAL MOLYCORP QUESTA MINE GROUNDWATER STUDY

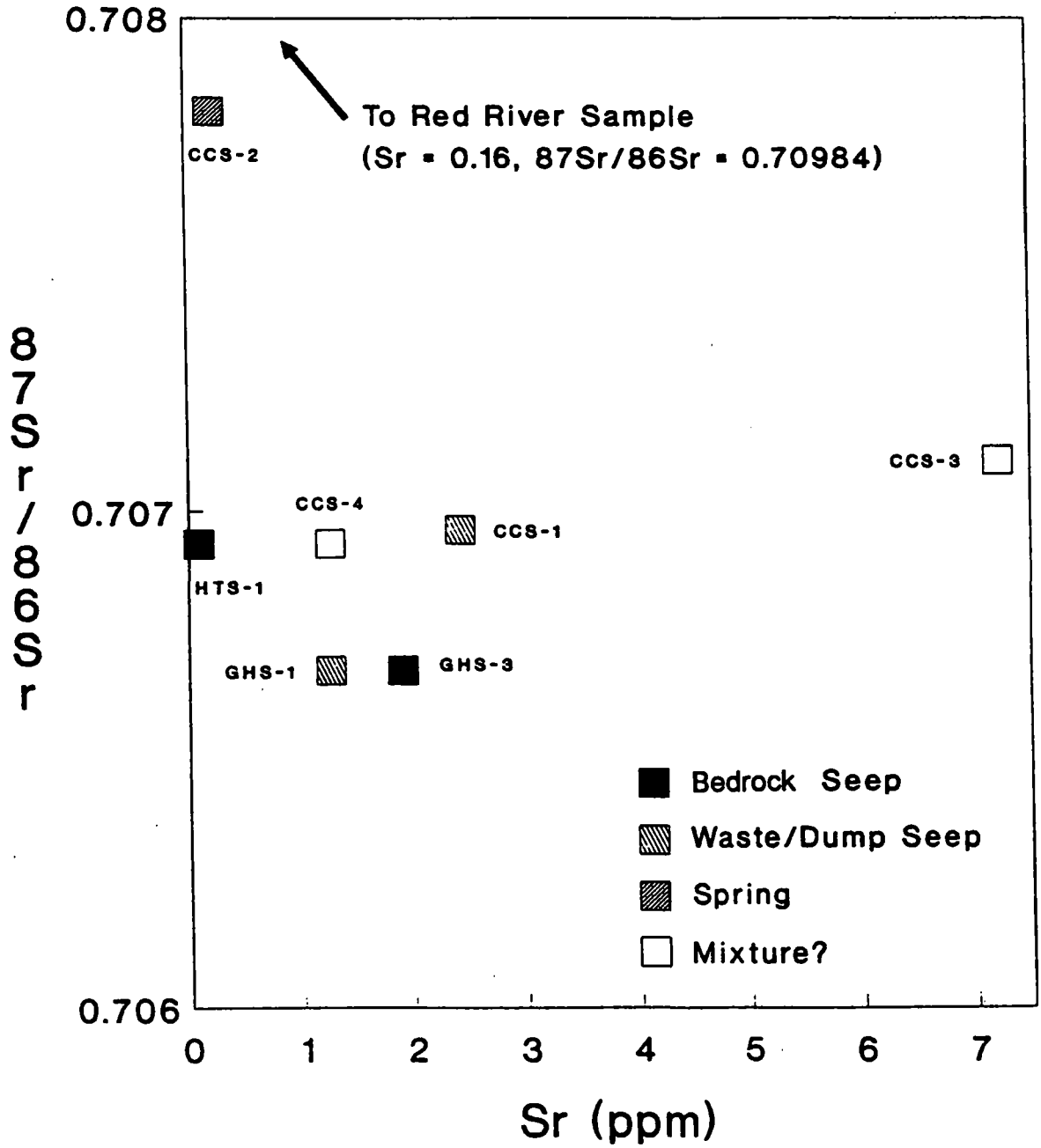



*The 87Sr/86Sr ratios of natural and waste/dump seep waters cluster. Waste/dump seep waters and CCS-3 cluster; this may be the result of short-term water-waste reactions. Analytical errors are exaggerated 10X to 20X for clarity.*

| SOUTH PASS RESOURCES, Inc. | | | | 206pB/207Pb vs 87Sr/86Sr<br>Tailings Area - Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D11 |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

ISOTOPES

# UNOCAL MOLYCORP QUESTA MINE GROUNDWATER STUDY




*Strontium isotopic/concentration data indicate similar hydrologic systems for natural and waste/dump seep waters. Goathill Gulch may be a distinct hydrologic system. Analytical errors are exaggerated 3X to 4X for clarity.*

| SOUTH PASS RESOURCES, Inc. | | | | 87Sr/86Sr vs Sr Concentration<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D12 |
|---|---|---|---|---|---|
| PROJECT No.: 001–06 | DATE: 4/13/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

# TABLE D1
## 1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | SAMPLE DATE 1994 | WELL TD (feet) | Corrected DEPTH TO WATER (feet) | DEPTH TO PUMP INTAKE (feet) | pH (1) | CONDUC-TIVITY(1) (uhmos) | TEMP.(1) (°C) | CARBO -NATE (mg/L) | BICARBO -NATE (mg/L) | HYDR-OXIDE (mg/L) | TOTAL ALK (mg/L) | CHLORIDE (mg/L) | FLUORIDE (mg/L) | SULFATE (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MMW-2 | 8-Nov | 68 | 31.69 | 50 | 4.90 | 3,680 | 7.9 | <1 | <1 | <1 | <1 | 6.8 | 24.0 | 2,100 |
| MMW-3 | 7-Nov | 140 | 27.76 | 80 | 7.50 | 3,970 | 10.9 | <1 | 222 | <1 | 222 | 5.8 | 2.59 | 1,700 |
| MMW-7 | 7-Nov | 161 | 61.11 | 120 | 4.40 | 9,490 | 17.2 | <1 | <1 | <1 | <1 | 21 | 1.12 | 10,400 |
| DUP-11A (2) | 7-Nov | NA | NA | NA | NA | NA | NA | <1 | <1 | <1 | <1 | 21 | 0.98 | 10,500 |
| MMW-8A | 8-Nov | 178 | 96.77 | 140 | 7.00 | 2,860 | 8.4 | <1 | 165 | <1 | 165 | 8.7 | 2.72 | 1,300 |
| MMW-8B | 8-Nov | 129 | 96.03 | 112 | 6.40 | 1,780 | 7.1 | <1 | 19 | <1 | 19 | 5.6 | 1.83 | 730 |
| MMW-10A | 8-Nov | 144 | 21.70 | 100 | 5.80 | 2,400 | 7.8 | <1 | <1 | <1 | <1 | 27 | 11.2 | 1,100 |
| DUP-12B (3) | 8-Nov | NA | NA | NA | NA | NA | NA | <1 | <1 | <1 | <1 | 26 | 7.96 | 1,100 |
| MMW-10A (4) | 19-Nov | NA | NA | NA | NA | NA | NA | <1 | <1 | <1 | <1 | 26 | 8.28 | 1,200 |
| MMW-10B | 7-Nov | 189 | 21.57 | 140 | 7.90 | 2,250 | 10.1 | 10 | <1 | 66 | 76 | 28 | 12.2 | 1,100 |
| MMW-10C | 8-Nov | 50 | 21.80 | 40 | 4.70 | 2,000 | 11.8 | <1 | <1 | <1 | <1 | 20 | 15.4 | 880 |
| MMW-11 | 7-Nov | 184 | 86.71 | 150 | 5.60 | 2,450 | 15.7 | <1 | <1 | <1 | <1 | 22 | 17.6 | 1,300 |
| MMW-13 | 8-Nov | 145 | 105.98 | 130 | 7.90 | 2,280 | 8.9 | <1 | 200 | <1 | 200 | 14 | 1.67 | 770 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER AQUIFER TEST

NA - Not Available

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

# TABLE D1
## 1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | TDS (mg/L) | SILVER (mg/L) | ALUMINUM (mg/L) | ARSENIC (mg/L) | BARIUM (mg/L) | BERYLLIUM (mg/L) | CALCIUM (mg/L) | CADMIUM (mg/L) | COBALT (mg/L) | CHROMIUM (mg/L) | COPPER (mg/L) | IRON (mg/L) | MERCURY (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MMW-2 | 3,400 | <0.10 | 63.5 | <0.005 | <0.010 | 0.015 | 501 | 0.024 | 0.280 | <0.010 | 0.088 | 50.8 | <0.0002 |
| MMW-3 | 2,900 | <0.10 | 0.75 | <0.005 | 0.047 | <0.004 | 567 | 0.0024 | 0.089 | <0.010 | <0.010 | 0.076 | <0.0002 |
| MMW-7 | 16,000 | <0.50 | 943 | <0.05 | 0.108 | 0.104 | 544 | 0.096 | 4.91 | 0.193 | 4.84 | 384 | <0.0002 |
| DUP-11A (2) | 16,000 | <0.50 | 961 | <0.05 | 0.074 | 0.122 | 534 | 0.092 | 4.99 | 0.17 | 5.04 | 375 | <0.0002 |
| MMW-8A | 2,200 | <0.10 | <0.05 | <0.005 | 0.103 | <0.004 | 466 | 0.002 | <0.010 | <0.010 | <0.010 | 2.84 | <0.0002 |
| MMW-8B | 1,100 | <0.10 | 0.44 | <0.005 | 0.016 | <0.004 | 206 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MMW-10A | 1,700 | <0.10 | 33.4 | <0.005 | <0.010 | 0.008 | 275 | 0.028 | 0.148 | <0.010 | 0.558 | <0.050 | <0.0002 |
| DUP-12B (3) | 1,700 | <0.10 | 34.2 | <0.005 | <0.010 | 0.008 | 270 | 0.024 | 0.137 | <0.010 | 0.58 | <0.050 | <0.0002 |
| MMW-10A (4) | 1,700 | <0.010 | 31.6 | <0.005 | <0.010 | 0.006 | 245 | 0.0224 | 0.141 | <0.010 | 0.534 | 0.086 | <0.0002 |
| MMW-10B | 1,800 | <0.10 | 8.74 | <0.005 | 0.034 | 0.007 | 347 | 0.025 | 0.074 | <0.010 | 0.179 | 0.101 | <0.0002 |
| MMW-10C | 1,400 | <0.10 | 31.1 | <0.005 | 0.014 | 0.007 | 204 | 0.026 | 0.106 | <0.010 | 0.38 | <0.050 | <0.0002 |
| MMW-11 | 2,000 | <0.10 | 56.3 | <0.005 | 0.016 | 0.013 | 276 | 0.036 | 0.266 | 0.036 | 0.919 | 0.129 | <0.0002 |
| MMW-13 | 1,400 | <0.10 | <0.05 | <0.005 | 0.036 | <0.004 | 316 | <0.0005 | 0.013 | <0.010 | <0.010 | 0.198 | <0.0002 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER PUMP TEST

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

# TABLE D1
## 1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | POTASSIUM (mg/L) | MAGNESIUM (mg/L) | MANGANESE (mg/L) | MOLYBDENUM (mg/L) | SODIUM (mg/L) | NICKEL (mg/L) | LEAD (mg/L) | ANTIMONY (mg/L) | SELENIUM (mg/L) | SILICON (mg/L) | THALLIUM (mg/L) | VANADIUM (mg/L) | ZINC (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MMW-2 | 10.8 | 137 | 52.1 | <0.02 | 64.6 | 0.61 | <0.002 | <0.05 | <0.05 | 20.3 | <0.005 | <0.010 | 9.48 |
| MMW-3 | 7.5 | 96.2 | 34.5 | <0.02 | 103 | 0.236 | <0.002 | <0.05 | <0.005 | 7.6 | <0.005 | <0.010 | 1.36 |
| MMW-7 | 12.0 | 1250 | 72.1 | <0.10 | 175 | 10.5 | 0.10 | <0.25 | <0.025 | 22.7 | <0.005 | 0.104 | 11.7 |
| DUP-11A (2) | 12.1 | 1230 | 73.3 | <0.10 | 178 | 10.7 | 0.06 | <0.25 | <0.025 | 22.6 | <0.005 | 0.106 | 11.9 |
| MMW-8A | 3.8 | 85.6 | 7.15 | <0.02 | 41.5 | <0.020 | <0.002 | <0.05 | <0.005 | 11.1 | <0.005 | <0.010 | <0.050 |
| MMW-8B | 2.9 | 55.5 | 0.202 | <0.02 | 33.9 | 0.059 | <0.002 | <0.05 | <0.005 | 17.3 | <0.005 | <0.010 | 0.211 |
| MMW-10A | 2.8 | 77.9 | 13.8 | <0.02 | 26.5 | 0.325 | <0.002 | <0.05 | <0.005 | 14.3 | <0.005 | <0.010 | 2.29 |
| DUP-12B (3) | 2.5 | 76.7 | 12.8 | <0.02 | 26.4 | 0.293 | <0.002 | <0.05 | <0.005 | 14.0 | <0.005 | <0.010 | 2.07 |
| MMW-10A (4) | 3.7 | 69.7 | 13.1 | <0.02 | 25.6 | 0.279 | 0.004 | <0.05 | <0.005 | 14.1 | <0.005 | <0.010 | 2.68 |
| MMW-10B | 3.5 | 80.3 | 8.55 | <0.02 | 25.8 | 0.201 | 0.021 | <0.05 | <0.05 | 12.8 | <0.005 | <0.010 | 1.5 |
| MMW-10C | 2.8 | 75.2 | 16.3 | <0.02 | 20.2 | 0.0347 | <0.002 | <0.05 | <0.005 | 9.9 | <0.005 | <0.010 | 3.2 |
| MMW-11 | 3.4 | 133 | 31.7 | <0.02 | 25.5 | 0.593 | 0.086 | <0.05 | <0.005 | 14.2 | <0.005 | <0.010 | 5.0 |
| MMW-13 | 5.4 | 38.7 | 1.02 | 0.05 | 30 | <0.020 | <0.002 | <0.05 | <0.005 | 8.8 | <0.005 | <0.010 | 0.222 |

NOTES:

(1) Ph, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER PUMP TEST

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

# TABLE D2

## WATER QUALITY DATA FOR THE RED RIVER - (SPRI, MAY 1994)

MINE AREA - MOLYCORP, INC. - QUESTA, NEW MEXICO



| Sample ID | Sample Description | pH Meter | pH Strip | Temp (F°) | Conduc-tivity (uhmos) | Total Alkalinity (mg/L) | TDS (mg/L) | TSS (mg/L) | Aluminum Susp. (mg/L) | Aluminum Dis. (mg/L) | Fluoride (mg/L) | Iron (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BC-1 | BC 75' N of High St. bridge | 6.40 | 5.0 | 44.9 | 49.8 | 20 | 82 | 26 | 0.75 | 0.60 | 0.15 | 2.70 |
| BC-2 | BC 500' S of Spring flow from BCS-1 | 6.55 | 5.5 | 43.6 | 66.2 | 18 | 78 | 10 | <.5 | 0.60 | 0.12 | 1.00 |
| BCS-1 | Spring, 1.2 mi. N High St. | 4.42 | 5.0 | 44.7 | 478.0 | 0 | 530 | <1 | <.5 | 5.20 | 0.30 | <.01 |
| BOS-1 | Spring, W side of Bobita Campground | | 6.0 | 61.0 | 605.0 | 44 | 737 | 8 | <.5 | <.5 | 0.32 | 0.16 |
| CCS-1 | Middle sump Capulin Canyon | | 3.0 | 50.9 | 13,440 | 0 | 24,950 | 8 | 1.00 | 1,310 | 53.30 | 258.30 |
| CCS-2 | Spring drainage W side Capulin Canyon | | 7.0 | 56.9 | 260.0 | 54 | 416 | 107 | 2.80 | 2.2 | 0.62 | 11.72 |
| CCS-3 | Adit W side Capulin Canyon | | 4.0 | 45.1 | 2,960 | 0 | 2,686 | 295 | 1.60 | 53.6 | 12.00 | 25.20 |
| CCS-4 | Seep, Capulin Canyon S of adit | | 4.0 | 48.2 | 1,775 | 0 | 1,193 | 12.7 | <.5 | 23.2 | 5.70 | 2.35 |
| CCS-5 | Culvert drain W side of Capulin Canyon | | 4.0 | 66.7 | 1,700 | 0 | 1,896 | 3.7 | <.5 | 74.8 | 9.80 | 0.21 |
| CCS-6 | Seep, 200' E Capulin Canyon | | 3.0 | 73.7 | 2,430 | 0 | 2,673 | 6.4 | <.5 | 116.2 | 13.00 | 7.68 |
| CLB-1 | Columbine Creek-200' up from confluence | | 6.5 | 57.7 | 134.0 | 49 | 70 | 3 | <.5 | <.5 | 0.18 | 0.34 |
| ECCS-1 | Seep near river, E of Capulin Canyon | | 6.5 | 60.5 | 580.0 | 26 | 413 | 8 | <.5 | <.5 | 1.50 | 0.32 |
| ECCS-2 | Seep S of Hwy 38, E of Capulin Canyon | | 4.0 | 62.0 | 1,752 | 0 | 913 | 1 | <.5 | 73 | 5.20 | 0.79 |
| EGHS-1 | Seep, S of Hwy 38, E of Goathill | | 7.0 | 55.6 | 810.0 | 47 | 843 | 1.2 | <.5 | <.5 | 0.47 | 0.15 |
| GHS-1 | Seepage Goat Hill dump | | 2.0 | 69.1 | 11,140 | 0 | 23,890 | 39 | 0.97 | 1,183 | 36.70 | 257.00 |
| GHS-2 | Seep from bore hole +GHS1 | | 2.0 | 73.0 | 11,350 | 0 | 17,623 | 29 | 1.70 | 1,125 | 43.30 | 252.00 |
| GHS-3 | Natural seep from volcanic rock | | | | | 0 | 11,980 | 94 | 1.30 | 645 | 26.00 | 250.00 |
| HCS-1 | seeps, Upper Hanson Creek Canyon | | 2.5 | 44.2 | 5,520 | 0 | 6,493 | 13.6 | <.5 | 185.4 | 15.00 | 177.90 |
| HCS-2 | seep, downgradient from HCS-1 | | 2.5 | 50.6 | 5,390 | 0 | 6,230 | 7.6 | <.5 | 154 | 15.60 | 164.80 |
| HCS-3 | Seep S of Hwy 38, W Hanson Creek | | 4.0 | 77.0 | 1,232 | 0 | 1,773 | <1 | <.5 | 2.6 | 1.40 | 0.43 |
| HTS-1 | Upper Hot-N-Tot Canyon | 2.86 | 2.3 | 48.2 | 2,670 | 0 | 2,610 | 43 | <.5 | 97.8 | 2.30 | 212.80 |
| MC-1 | Mallette Creek-Alpine Lodge | 6.86 | 6.0 | 52.2 | 80.4 | 22 | 96 | 16 | 0.65 | 0.60 | 0.25 | 1.20 |
| PC-1 | Pioneer Creek, Arrowhead Lodge | 7.34 | 7.0 | 45.1 | 107.0 | 43 | 94 | 15 | <.5 | 0.50 | 0.10 | 0.70 |
| POS-1 | seep, Portal Springs W of mine portal | | 4.5 | 54.4 | 1,900 | 10 | 1,800 | 34 | <.5 | 21.3 | 153.00 | 8.24 |
| RR-1 | RR W of confluence w/BitCrk | 7.40 | 6.0 | 43.8 | 99.3 | 43 | 82 | 4 | <.5 | 0.50 | 0.86 | 1.10 |
| RR-2 | RR 50' E of BC Confluence | 7.58 | 6.5 | 45.9 | 108.0 | 70 | 88 | 18 | <.5 | 0.50 | 0.08 | 0.80 |
| RR-3 | RR behind Alpine Lodge | 7.53 | 6.0 | 48.2 | 93.7 | 51 | 92 | 22 | 0.5 | 0.50 | 0.10 | 2.10 |
| RR-4 | RR, Goose Lake Rd/East RR | 7.73 | 7.0 | 43.5 | 130.0 | 47 | 98 | 13 | <.5 | <.5 | 0.10 | 0.70 |
| RR-5 | RR, Hot-N-Tot Creek/upstream | 7.45 | 7.0 | 47.0 | 144.0 | 59 | 100 | 32 | 0.75 | 0.50 | 0.11 | 2.20 |

# TABLE D2

## WATER QUALITY DATA FOR THE RED RIVER - (SPRI, MAY 1994)

MINE AREA - MOLYCORP, INC. - QUESTA, NEW MEXICO



| Sample ID | Sample Description | pH Meter | pH Strip | Temp (F°) | Conduc-tivity (uhmos) | Total Alkalinity (mg/L) | TDS (mg/L) | TSS (mg/L) | Aluminum Susp. (mg/L) | Aluminum Dis. (mg/L) | Fluoride (mg/L) | Iron (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RR-6 | RR, Hot-N-Tot Creek/dwnstream | 7.52 | 6.5 | 48.0 | 145.0 | 43 | 92 | 34 | 0.60 | <.5 | 0.11 | 1.90 |
| RR-7 | RR down from Sulpher Gulch | 7.48 | 7.0 | 62.0 | 122.0 | 48 | 108 | 49 | 0.75 | <.5 | 0.16 | 2.10 |
| RR-8 | RR upstream from mill gate | 7.53 | 6.5 | 57.0 | 129.0 | 56 | 106 | 57 | 0.50 | 0.60 | 0.12 | 2.14 |
| RR-9 | RR, 200' up from Hanson Creek confluence | 7.46 | 7.0 | 54.5 | 144.0 | 53 | 104 | 31.2 | <.5 | <.5 | 0.13 | 1.70 |
| RR-10 | RR, downstream of Portal Springs | 7.46 | 7.0 | 54.5 | 196.0 | 48 | 112 | 61.2 | 1.60 | <.5 | 0.20 | 2.41 |
| RR-11 | RR, Down from Hanson Creek confluence | 7.51 | 6.5 | 51.5 | 177.0 | 61 | 104 | 17.6 | <.5 | <.5 | 0.11 | 1.29 |
| RR-12 | RR 100' E of Columbine Creek Confluence | | 6.5 | 55.5 | 196.0 | 48 | 213 | 58 | 0.54 | 0.6 | 0.30 | 2.35 |
| RR-13 | RR, highway bridge W of Columbine Creek | | 6.5 | 55.5 | 196.0 | 50 | 163 | 54 | 0.54 | <.5 | 0.20 | 1.80 |
| RR-14 | RR up from Goathill Gulch | | 6.5 | 58.1 | 241.0 | 42 | 123 | 52 | 0.72 | <.5 | 0.32 | 2.05 |
| RR-15 | RR down from Goathill Gulch | | 7.0 | 57.0 | 224.0 | 52 | 130 | 62 | 0.83 | <.5 | 0.32 | 2.24 |
| RR-16 | RR Questa Ranger Station | | 6.5 | 54.0 | 171.0 | 41 | 150 | 106 | 0.83 | <.5 | 0.35 | 2.72 |
| SGS-1 | Sulpher Gulch-spring pond | 6.65 | 7.0 | 75.5 | 753.0 | 83 | 620 | 6.5 | <.5 | <.5 | 1.30 | 0.75 |
| SSC-1 | seep, S of west end Sugar Shack South | | 5.0 | 55.0 | 2,350 | 33 | 2,017 | 214 | 2.20 | 5.3 | 92.00 | <.01 |

NOTES:

Sampling by SPRI; analytical results from Molycorp. Inc.

(1) - pH Strip, Temperature and Conductivity were measured field measurements.

All samples are total metals except Alum. Suspended and Alum. Dissolved

< symbols are detection limits.

# TABLE D2
## WATER QUALITY DATA FOR THE RED RIVER - (SPRI, MAY 1994)
MINE AREA - MOLYCORP, INC. - QUESTA, NEW MEXICO


| Sample ID | Ferrous Iron (mg/L) | Lead (mg/L) | Manganese (mg/L) | Zinc (mg/L) | Copper (mg/L) | Molybdenum (mg/L) | Sodium (mg/L) | Potassium (mg/L) | Calcium (mg/L) | Magnesium (mg/L) | Silica (mg/L) | Chlorine (mg/L) | Cadmium (mg/L) | Sulfate (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BC-1 | | 0.003 | 0.041 | 0.025 | 0.03 | <.02 | 2.5 | <1.0 | 6 | 1.6 | 20 | 2.5 | <.005 | 12 |
| BC-2 | | 0.002 | 0.034 | 0.025 | 0.02 | <.02 | 2.7 | <1.0 | 12.5 | 3.5 | 22 | 3 | <.005 | 13.7 |
| BCS-1 | | <.002 | 1.360 | 0.491 | 0.18 | <.02 | 9.4 | 1.5 | 48.9 | 27.2 | 46 | 5 | 0.005 | 171 |
| BOS-1 | | <.002 | <.01 | 0.060 | 0.01 | <.02 | 13.1 | 1.2 | 85.2 | 21.5 | 20 | 20 | <.005 | 217 |
| CCS-1 | 7.0 | <.002 | 416.20 | 146.00 | 15.3 | <.02 | 23.7 | <1.0 | 504 | 1,032 | 92.4 | 30 | 0.75 | 11,996 |
| CCS-2 | | 0.036 | 0.213 | 0.149 | 0.024 | <.02 | 9.5 | 2.6 | 20.2 | 4.2 | 46.6 | 7.5 | <.005 | 56.8 |
| CCS-3 | <1.0 | 0.078 | 12.600 | 6.960 | 0.162 | <.02 | 70.3 | 9.6 | 348 | 84 | 76 | 14.5 | 0.021 | 1,736 |
| CCS-4 | | <.002 | 10.300 | 2.620 | 0.21 | <.02 | 30.9 | 2 | 145 | 38.5 | 52 | 9.5 | 0.007 | 541.7 |
| CCS-5 | | 0.004 | 28.900 | 7.600 | 1.21 | <.02 | 19.1 | 1.7 | 118 | 76.9 | 112 | 9.5 | 0.036 | 1,152 |
| CCS-6 | | 0.003 | 13.600 | 4.470 | 0.998 | <.02 | 30 | 3.5 | 233 | 65 | 62 | 35 | 0.017 | 1,649 |
| CLB-1 | | <.002 | <.01 | 0.022 | 0.008 | <.02 | 1.5 | <1.0 | 17 | 1.8 | 14 | 2.5 | <.005 | 1.7 |
| ECCS-1 | | <.002 | <.01 | 0.115 | 0.01 | <.02 | 9.8 | 1.2 | 52.8 | 12.7 | 28 | 18.5 | <.005 | 128.3 |
| ECCS-2 | | 0.003 | 8.740 | 2.820 | 0.921 | <.02 | 55.7 | 3.5 | 138 | 41 | 28 | 95 | 0.015 | 669 |
| EGHS-1 | | <.002 | <.01 | 0.042 | 0.009 | <.02 | 9.5 | 1.7 | 104.4 | 23.1 | 18 | 10.5 | <.005 | 190 |
| GHS-1 | 8.0 | <.010 | 239.50 | 82.70 | 8.6 | <.02 | 11.7 | <1.0 | 444 | 760 | 104 | 37 | 0.381 | 13,312 |
| GHS-2 | 10.0 | <.010 | 263.80 | 86.40 | 8.5 | <.02 | 18.4 | <1.0 | 432 | 704 | 96.7 | 40 | 0.409 | 11,667 |
| GHS-3 | 1.0 | 0.017 | 22.00 | 4.22 | 1.58 | <.02 | 32.6 | <1.0 | 504 | 405 | 102 | 15 | <.005 | 7,763 |
| HCS-1 | 2.0 | 0.004 | 20.300 | 3.740 | 0.512 | <.02 | 17.8 | <1.0 | 504 | 274 | 63.5 | 10 | 0.012 | 3,876 |
| HCS-2 | | <.002 | 17.100 | 3.880 | 0.629 | <.02 | 17.2 | <1.0 | 454 | 199 | 75.9 | 16 | 0.013 | 3,436 |
| HCS-3 | | 0.004 | 0.445 | 0.183 | 0.025 | <.02 | 48 | 2.6 | 156 | 18 | 22 | 90 | <.005 | 377 |
| HTS-1 | 7.0 | 0.009 | 6.250 | 2.960 | 1.14 | <.02 | 2.1 | <1.0 | 55.9 | 43.5 | 100 | 16 | 0.012 | 848 |
| MC-1 | | <.002 | 0.054 | 0.043 | 0.02 | <.02 | 3.9 | 1.4 | 8.2 | 3.1 | 32 | 4.5 | <.005 | 16.4 |
| PC-1 | | <.002 | 0.036 | 0.014 | 0.02 | <.02 | 2 | <1.0 | 19.8 | 2.4 | 15 | 5 | <.005 | 20 |
| POS-1 | | <.002 | 6.830 | 2.490 | 0.05 | <.02 | 26.2 | 3.4 | 206 | 16.6 | 32 | 27 | 0.01 | 622 |
| RR-1 | | <.002 | 0.033 | 0.048 | 0.02 | <.02 | 2.2 | <1.0 | 15 | 2.5 | 14 | 4 | <.005 | 7 |
| RR-2 | | <.002 | 0.039 | 0.012 | 0.01 | <.02 | 2 | <1.0 | 17.7 | 2.4 | 14 | 2.5 | <.005 | 3 |
| RR-3 | | 0.004 | 0.086 | 0.018 | 0.02 | 0.03 | 2.3 | <1.0 | 15.7 | 2.5 | 17 | 4 | <.005 | 13.8 |
| RR-4 | | <.002 | 0.030 | 0.006 | 0.01 | <.02 | 1.9 | <1.0 | 17 | 2.2 | 12 | 5 | <.005 | 2.2 |
| RR-5 | | 0.003 | 0.065 | 0.022 | 0.02 | <.02 | 2.3 | <1.0 | 17 | 2.5 | 14 | 5 | <.005 | 17.4 |

# TABLE D2
## WATER QUALITY DATA FOR THE RED RIVER - (SPRI, MAY 1994)
MINE AREA - MOLYCORP, INC. - QUESTA, NEW MEXICO


| Sample ID | Ferrous Iron (mg/L) | Lead (mg/L) | Manganese (mg/L) | Zinc (mg/L) | Copper (mg/L) | Molybdenum (mg/L) | Sodium (mg/L) | Potassium (mg/L) | Calcium (mg/L) | Magnesium (mg/L) | Silica (mg/L) | Chlorine (mg/L) | Cadmium (mg/L) | Sulfate (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RR-6 | | 0.003 | 0.080 | 0.034 | 0.02 | <.02 | 2.3 | <1.0 | 16.6 | 2.4 | 14 | 5 | <.005 | 17.7 |
| RR-7 | | 0.004 | 0.080 | 0.030 | 0.02 | <.02 | 2.8 | <1.0 | 20 | 3.1 | 16 | 5 | <.005 | 15.9 |
| RR-8 | | 0.004 | 0.082 | 0.027 | 0.02 | <.02 | 2.8 | <1.0 | 19.1 | 3 | 24 | 4.5 | <.005 | 19.5 |
| RR-9 | | 0.003 | 0.064 | 0.202 | 0.01 | <.02 | 2.6 | <1.0 | 18.6 | 3.4 | 14 | 5 | <.005 | 14.5 |
| RR-10 | | 0.004 | 0.109 | 0.018 | 0.02 | <.02 | 2.9 | <1.0 | 20.4 | 3.9 | 17 | 5 | <.005 | 17.4 |
| RR-11 | | 0.004 | 0.048 | <.005 | 0.02 | <.02 | 2.6 | <1.0 | 18.5 | 3.3 | 20 | 4 | <.005 | 11.4 |
| RR-12 | | 0.004 | 0.126 | 0.042 | 0.018 | <.02 | 3 | <1.0 | 21.4 | 4.6 | 64 | 2.5 | <.005 | 33.6 |
| RR-13 | | 0.004 | 0.078 | 0.031 | 0.016 | <.02 | 2.9 | <1.0 | 21 | 4.4 | 18 | 3 | <.005 | 23.5 |
| RR-14 | | 0.006 | 0.242 | 0.067 | 0.02 | <.02 | 3 | 1 | 23 | 5 | 18 | 3 | 0.007 | 29.7 |
| RR-15 | | 0.004 | 0.213 | 0.062 | 0.018 | <.02 | 3 | <1.0 | 22.8 | 4.9 | 20 | 3.5 | <.005 | 34.7 |
| RR-16 | | 0.014 | 0.290 | 0.073 | 0.024 | <.02 | 2.7 | <1.0 | 22.1 | 4.5 | 14 | 6.5 | <.005 | 28.9 |
| SGS-1 | | <.002 | 0.252 | 0.099 | 0.01 | 0.19 | 17.6 | 4 | 119 | 17.7 | 24 | 22.5 | <.005 | 160 |
| SSC-1 | | 0.026 | 12.300 | 2.920 | 0.213 | 0.88 | 58.7 | 5.3 | 298 | 13.5 | 30 | 72.5 | 0.02 | 679.8 |

# TABLE D4
## WATER QUALITY OF MINE WATER
MOLYCORP, INC. - QUESTA, NEW MEXICO

| Sample Location | Shaft No. 1 Shallow | Shaft No. 1 Deep (mg/L) | Shaft No. 1 Top (mg/L) | Shaft No. 1 1000 ft (mg/L) | Shaft No.2 (mg/L) | Decline (mg/L) | Decline (mg/L) | Open Pit (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Date | NA | NA | 10/94 | 10/94 | NA | NA | 10/94 | 10/94 |
| pH | 6.9 | 7.7 | 6.96 | 6.96 | 7.2 | 7.5 | 6.7 | 3.1 |
| Aluminum | NA | NA | 0.5 | 0.5 | <0.5 | 1.2 | 1.0 | 303.0 |
| Sulfate | 1,455 | 1,480 | 1,665 | 1,720 | 1,345 | 1,004 | 1,720 | 11,561 |
| TDS | 3,072 | 3,386 | 3,276 | 3,584 | 3,164 | 2,468 | 3,507 | 24,420 |
| Fluoride | NA | 13.1 | NA | NA | 5.0 | 7.10 | NA | NA |
| Cadmium | <0.005 | 0.01 | <0.01 | <0.01 | <0.005 | <0.005 | <0.01 | 0.304 |
| Lead | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.1 | <0.10 | <0.10 |
| Iron | 0.30 | <0.05 | 50.0* | 46.2* | <0.05 | <0.05 | 39 | 164.0 |
| Manganese | 8.6 | 15.5 | 11.5 | 12.0 | 5.10 | 1.20 | 13.30 | 408.0 |
| Zinc | 1.3 | 0.30 | 0.283 | 1.54 | 2.70 | 2.80 | 1.52 | 70.1 |
| Copper | <0.01 | 0.02 | 0.03 | 0.03 | <0.01 | <0.01 | 0 | 6.7 |
| Molybdenum | 2.70 | 2.20 | 2.22 | 2.22 | 1.80 | 1.20 | 2.44 | 0.41 |
| Arsenic | <0.01 | <0.01 | NA | NA | <0.01 | <0.01 | NA | NA |
| Mercury | <0.20 | <0.20 | NA | NA | <0.20 | <0.20 | NA | NA |

* Total Iron

# APPENDIX E

# APPENDIX E

## Data from Mine Area Aquifer Drawdown and Recovery Tests

# MMW-10A PUMP TEST

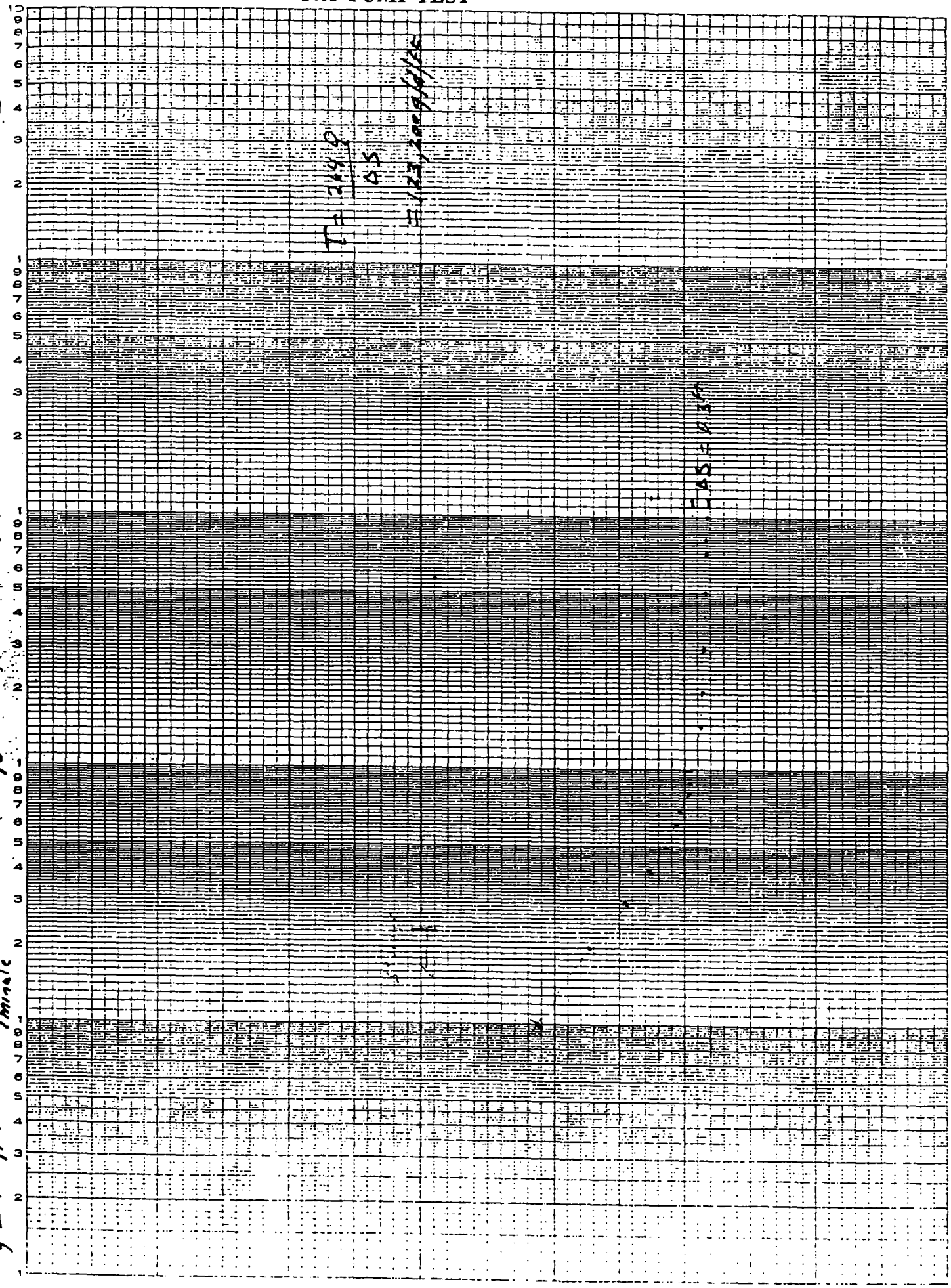



FIGURE E1

# MMW-10A RECOVERY TEST

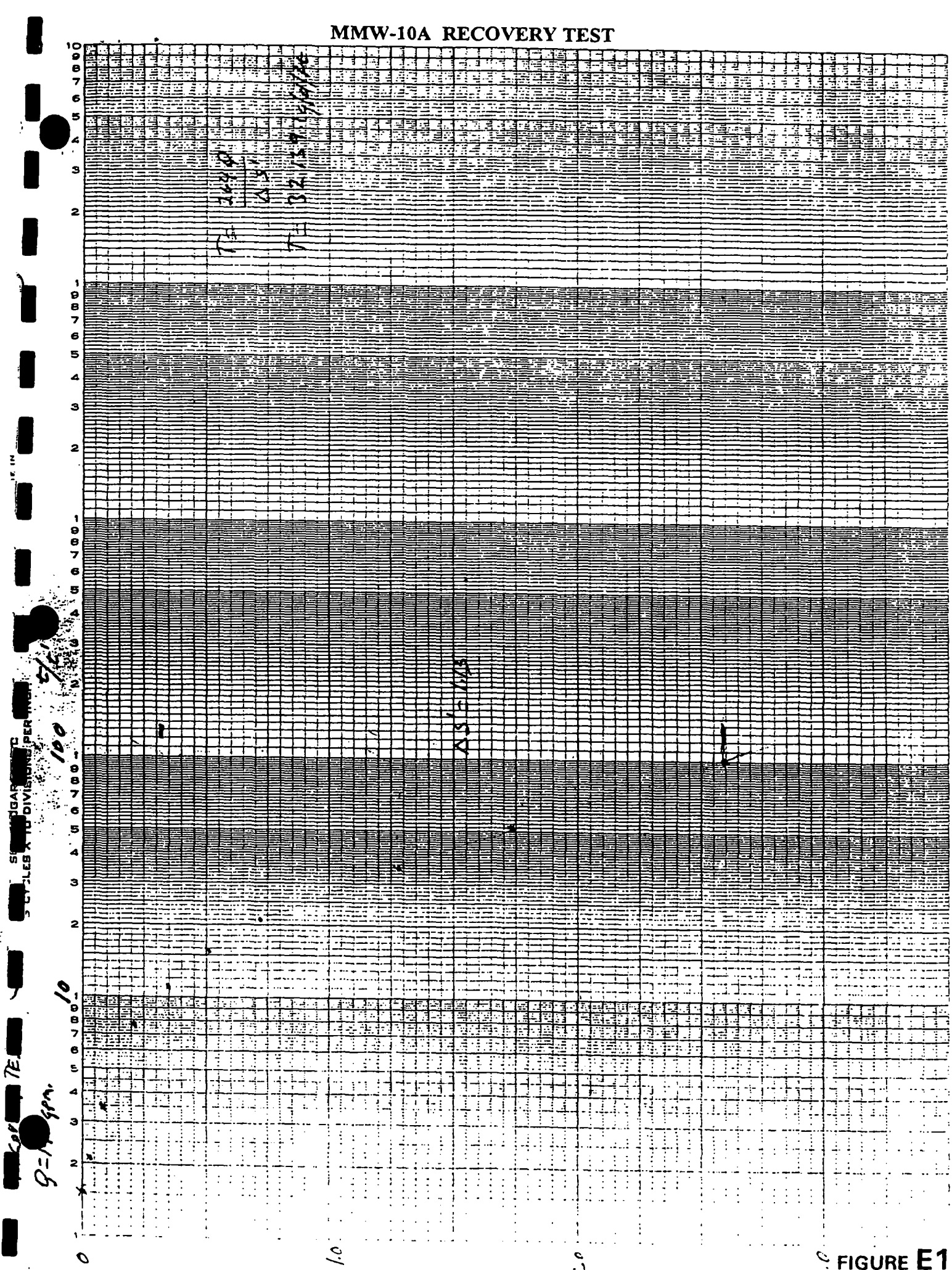


FIGURE E1a

DEWATERING CURVE FOR ROCK BETWEEN A LEVEL OF 7686'
(POINT ON DEWATERING) LEVEL AND TOP OF UNDERGROUND MINE, SEPT. 19, 1994

$Q = 450gpm$

$\Delta S = 49$ ft

$$T = \frac{264Q}{\Delta S}$$

2424 g/day/ft

$$\frac{2424}{476} = 5.09 \text{ g/day/ft}$$

$$\begin{array}{rl} 7686 & \text{Top} \\ -\,7210 & \text{Undercut} \\ \hline 476 & \end{array}$$

Thick Rock Below 7686'
To Top of Mine 476
9/19/94 – 11/14/94

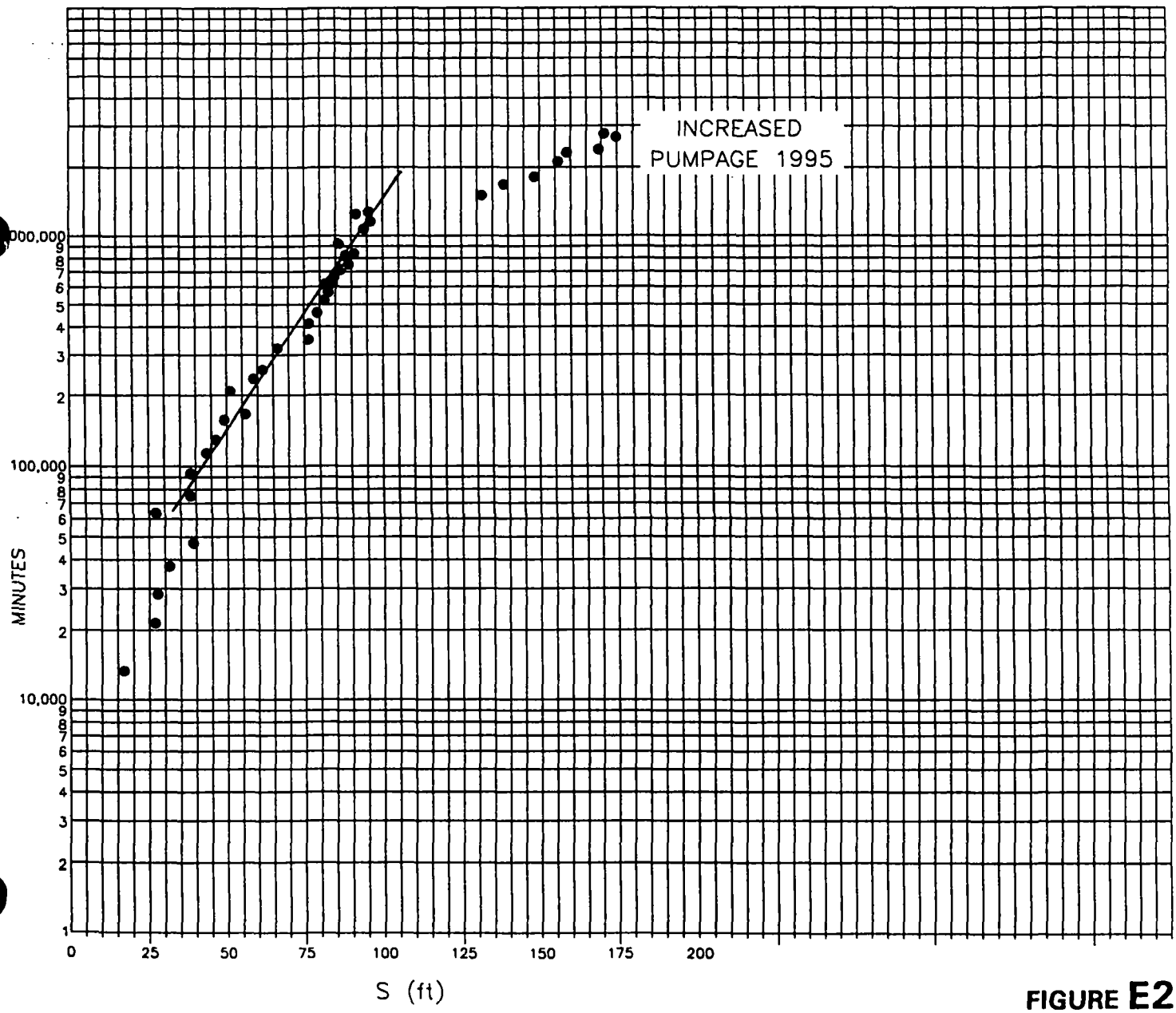



FIGURE E2

#15

SOUTH PASS RESOURCES, Inc.
8669 East San Alberto Drive, Suite 101
Scottsdale, Arizona 85258
Telephone: 602-948-7171
Fax: 602-948-7205

NM 22306

FOLDER # 001-06

COPY

# REMEDIATION PLAN
# for the
# TAILINGS AREA
## Molycorp Facility
## Taos County, New Mexico

*prepared for*
**Molycorp, Inc.**
Questa Division
P.O. Box 469
Questa, NM 87556

*prepared by*
**South Pass Resources, Inc./SPRI**

April 13, 1995

6WQ-SG
SEP 16 1997

# TAILINGS AREA

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6WQ-SG
SEP 16 1997

# 1.0 INTRODUCTION

The Molycorp molybdenum mine is located on the western slope of the Taos Range of the Sangre de Cristo Mountains, Taos County in north-central New Mexico (Figure 1). State Highway 38 runs along the north side of the Red River and connects the mine area with the Town of Red River (6 miles to the east) and the Town of Questa (6 miles to the west). For the purposes of this report, the area that consists of tailings embankments, tailings ponds, seepage controls, and outfall facilities is referred to as the ***Tailings Area***. The Tailings Area is located about 1 mile west of the town of Questa and 0.5 mile north of the Red River (Figure 2). The significant features associated with the area are shown on Figure 3.

In 1989, Molycorp retained the services of South Pass Resources, Inc. (SPRI) to evaluate impacts of past and present Molycorp mining operations on ground-water and surface-water quality. SPRI's most recent (Fall 1994) activities have involved the design, installation, and testing of five (5) new monitor/extraction wells in the Tailings Area. This report presents the findings of the Fall 1994 investigation and of previous investigations. The geologic, hydrogeologic and water-quality aspects of the Molycorp mining activities in the study area (Section 2.0 of this report) form the basis for the proposed Remediation Plan presented in Section 3.0.

## SUMMARY OF SPRI FALL 1994 INVESTIGATION

Between August 28 and September 27, 1994, SPRI overviewed the installation and testing of one monitor and four extraction wells in the Tailings Area. The purpose of this field effort was to:

- further delineate ground-water flow patterns between the tailings ponds and the Red River;
- further identify the geologic controls on ground-water flow;
- further characterize perched-water conditions in the Tailings Area;
- continue the investigation of contaminant flow paths from the tailings ponds; and
- emplace extraction wells for potential remediation efforts.

The wells that were installed during the Fall 1994 field effort, and the details of their installation and testing, are summarized below. The locations of these wells are shown on Figure 3. [All of the wells (except MMW-12 which has 4-inch PVC casing) were constructed with 8-inch PVC casing and screen to allow for pumping and extraction, if desired.]

| Tailings Area Monitor/Exploration Wells Installed in August/September 1994 | | | |
|---|---|---|---|
| **Well No.** | **Total Depth (feet)** | **Screened Interval (feet)** | **Well Completed In** |
| EW-1 | 157 | 83 - 157 | basalt/basalt gravel |
| EW-2 | 214 | 104 - 114<br>120 - 132<br>151 - 185 | sandy gravel<br>sandy gravel, gravelly sand, clay<br>basalt gravel in clay |
| EW-3 | 104 | 62 - 77 | sandy clay/clayey gravel |
| EW-4 | 58 | 42 - 58 | clayey gravel |
| MW-12 | 234 | 203 - 234 | basalt and basalt gravel |

These new monitor and exploration wells in the Tailings Area supplement monitor wells previously installed under SPRI direction (see SPRI, 1993; 1994). These wells are summarized below:

| Tailings Area Monitor Wells Previously Installed by SPRI (1993) | |
|---|---|
| **Well No.** | **Total Depth (feet)** |
| MW-11 | 249 |
| MW-7A, -7B, -7C | 146 |
| MW-9A, -9B | 147 |
| MW-8 | 225 |
| MW-10A | 136 |

A partial listing of other monitor and extraction wells in the Tailings Area that pre-date SPRI field activities are summarized below. (Note: A complete list of all wells located in the study area is unknown at this time.)

**Other Wells Located in the Tailings Area (Partial Listing)**

| Well No. | Total Depth (feet) | Year Installed |
|---|---|---|
| Change House (CH) | 250 | 1967 |
| MW-1 | 117 | 1979 |
| MW-2 | 80 | 1979 |
| MW-3 | 52 | 1979 |
| MW-4 | 102 | 1979 |
| MW-A | 38 | NA |
| MW-B | 18 | NA |
| MW-C | 15 | NA |
| MW-6 | 101 | NA |

Figure 3 shows the locations of all SPRI and other wells installed in the Tailings Area.

# 2.0 GEOLOGY, HYDROGEOLOGY, AND WATER QUALITY OF THE TAILINGS AREA

The ground-water flow patterns -- and the contaminant flow paths -- within the Tailings Area are controlled by the site geology. The geologic and hydrogeologic factors involved are summarized below. The current water quality issues of the Tailings Area are also presented. A more detailed discussion of the geology, hydrogeology, and water quality of the Tailings Area is presented in SPRI's report, *Discussion of Geology, Hydrogeology, and Water Quality of the Tailings Area, Molycorp Facility, Taos County, New Mexico*, dated March 31, 1995 (see Appendix A for Table of Contents).

## OVERVIEW OF GEOLOGY AND HYDROGEOLOGY OF THE TAILINGS AREA

1. Five new wells were emplaced in 1994, which added to an existing system composed of nine monitor wells, the Change House production well, and MW-6 (east of Dam No. 1). A limited amount of data is available for private wells south of the Molycorp property. The description of the hydrogeologic character of the area has been based on data from all of these wells.

2. The major hydrogeologic units in the Tailings Area are the Santa Fe Group and the underlying volcanic sequence. The Santa Fe Group consists of:

    - An Upper Aquifer Unit (UAU) composed of brown sandy gravels and gravelly sands with some pale red brown silty, sandy clay;
    - a Middle Aquitard Unit (MAU) composed of pale red brown clay and gravelly clay;
    - a Lower Aquifer Unit (LAU) composed of sandy or clayey gravel, with some thin, cemented sand units; and
    - a Basal Aquitard Unit (BAU) composed of bouldery clay.

    In addition to the above units, a thin sequence of volcanic silty sands, and gravelly clayey sands recognized in the Dam No. 4 area are probably part of the Santa Fe Group, but their stratigraphic position is not clear.

    The volcanic aquifer consists of a basalt unit that extends beneath both tailings ponds and a sequence of ash flow tuffs and lava flows in fault-contact with the basalt and the Santa Fe Group along the west side of Dam No. 4.

3. Structural relationships in the Tailings Area are dominated by northeast-trending high-angle fault lines, probably resulting from a combination of mid-Tertiary rifting, erosion, and sedimentation. These structural zones influence the ground-water flow paths.

4. The key ground-water relationships are:

   - Multiple perched zones in the Santa Fe Group with a main perched zone south of Dam No. 1 involving the lower UAU and upper MAU.

   - The main perched zone may extend to the Red River (based on logging and slug test data in monitor wells south of Dam No. 1 and on private well and field springs data farther south). It may also merge with the deeper LAU aquifer; however, upward hydraulic gradients in the LAU prevent leachate from impacting deeper zones.

   - From the fault zone along the west side of Dam No. 1 westward, the piezometric surface may be a composite which includes heads related to semi-confined conditions for the basalt gravel unit (MW-1 and EW-1) and unconfined conditions elsewhere (MW-11). The upper part of the basalt unit beneath Dam No. 4 may be unsaturated.

   - East of the fault zone, saturated conditions may be continuous from the lower LAU and the BAU across the basalt unit.

5. The leachate-contaminated shallow private wells appear to be screened in the main perched zone while deeper wells in the LAU and in basalt unit contain water that meets drinking-water quality standards.

6. Ground-water flow directions in the basalt aquifer, based on three-point calculations and potentiometric maps, range between S20°W and S75°W. Hydraulic gradients vary from 0.1 ft/ft to as low as 0.003 ft/ft. Steeper gradients result from localized discharge conditions such as occur along permeable fracture zones (such as in the MW-11 area). Estimates for a flow rate based on a mixing equation calculation for the volcanic aquifer at Dam No. 4 resulted in a value of 5.9 cubic feet per second (cfs) and a high degree of dilution for any leachate that might reach the water table. Analyses of water samples from MW-11, the Red River, and springs along the north side of the Red River down-gradient from Dam No. 4 support the results of the mixing equation.

7. Aquifer tests conducted at EW-2, -3, and -4 in 1994 gave the following results:

   - EW-3 (sand and gravel unit at base of UAU): hydraulic conductivity of 87 gallons per day per square foot (gpd/ft$^2$). The aquifer test (pump rate of 7 to 8 gallons per minute) created drawdown at the up-gradient well MW-7A located 210 feet north of EW-3. An aquifer test conducted at MW-11 in 1993 resulted in a hydraulic conductivity ranging between 6,833 and 14,102 gpd/ft$^2$ for the basalt.

   - EW-2 (basalt gravel within BAU): hydraulic conductivity of 913 gpd/ft$^2$.

   - EW-4: broke suction before one well volume was discharged.

## OVERVIEW OF WATER QUALITY OF THE TAILINGS AREA

8. Results of water-quality analyses from sampling of the monitor-well system in August 1993 and November 1994 are augmented by smaller data sets from the pre-1993 monitor-well samples. A limited amount of water-quality data is also available from the private wells.

9. STIFF Diagrams indicate that the water in the main perched zone (and shallower perched zones) is a calcium sulfate water. The Change House well water (sodium and potassium bicarbonate water) and the sample from the BAU at MW-12 (calcium bicarbonate) may be more representative of regional water quality (Winograd, 1959).

10. The basalt aquifer typically contains a bicarbonate water with either calcium or sodium plus potassium as the dominant cation phase. Locally, at MW-1 and EW-1, the ground water is classified as a calcium sulfate water (STIFF Diagram). Leakage of leachate from the main perched zone westward across the fault zone on the west side of Dam No. 1 is the probable source of the sulfate.

11. Total dissolved solids (TDS) and sulfate are the chief chemical parameters and exceed State standards in the main perched zone and, locally, in the basalt aquifer (MW-1 and EW-1).

12. Comparison of 1993 and 1994 water-quality data for wells in the main perched zone shows decreases in sulfate at MW-2, -3, and -4 and an increase at MW-7A. Water samples from the two new wells in the main perched zone showed lower concentrations for sulfate and calcium. The LAU well MW-7C shows an increase in sulfate while MW-10 shows a decrease.

13. Causes for these changes in sulfate concentrations result from a combination of factors including:

    - Precipitation of gypsum after the sample was collected and before analysis (EW-3 and EW-4).
    - Dilution from natural recharge combined with no new slurry additions to the Dam No. 1 ponds.
    - Slugs of older higher concentration leachate reaching a down-gradient well.
    - Shallow southeastward flow from beneath the Dam No. 4 pond area reaching MW-7A.
    - Changes in natural recharge rates.
    - Older (pre-1994) main perched zone wells are screened in sandy gravels of the lower UAU and clays of the upper MAU while the 1994 wells are in the sandy gravel above the clays only. Screens may intercept ground water following different flow paths (i.e. through different lithologies) that may have different chemical histories (e.g., dissolution and precipitation cycles for gypsum associated with clay-rich zones).
    - Bacterial activity in wells with steel casing (MW-1, -2, -3, and -4) which can influence iron concentrations.
    - Analytical errors.

14. The basalt aquifer at EW-1 and MW-1 shows an increase in sulfate which may result from the down-gradient position of these wells with respect to the main perched zone. At MW-11, south of Dam No. 4, there was a decrease in sulfate concentrations.

15. Mixing equations indicate that the Red River dilutes sulfate and TDS concentrations in inflow from the perched zones, including the main perched zone, to well below State standards.

# 3.0 REMEDIATION PLAN

Based on the geologic, hydrogeologic, and water-quality studies presented in the previous sections and in the supplement to this report (*Discussion of Geology, Hydrogeology, and Water Quality of the Tailings Area*: see Appendix A), a staged approach to controlling leachate from the Dam No. 1 area is recommended. Water-quality results show that the LAU and the volcanic aquifer (except at MW-1 and EW-1) are at the water-quality standards of the regional aquifer and, at this time, require only continual monitoring. Leachate contamination is located in the shallow perched zones (UAU) or within the main perched zone (lower UAU and upper MAU) south of Dam No. 1.

Proposed remediation for each of these areas is discussed below.

## 3.1 SHALLOW PERCHED ZONES (UAU)

Shallow perched zones are located in the upper 40 feet of the UAU. Water-level contour maps of two shallow perched zones (Figure 4) show southward-sloping mound structures related to seepage from the underdrain system at Dam No. 1. Seepage Barriers 002 and 003 have a practical depth limit of approximately 15 to 20 feet. To effectively extract leachate between the depth of the barriers and the depth of the main perched zone and, therefore, to reduce leakage to the main zone, a series of small-diameter extraction wells are proposed (Figure 5). This array of four to eight 4-inch diameter wells would be constructed between the toe of the dam and monitor wells MW-7, MW-A, MW-B, and MW-C.

These small-diameter wells would be screened in several thin sand and gravel zones above clay aquitards over the 40-foot section. Based on the hydraulic conductivity calculated from the aquifer test at EW-3 and on laboratory estimates of the hydraulic conductivity of beds within the MAU, an average and conservative hydraulic conductivity value of 150 gpd/ft$^2$ was used in preliminary modeling with the THWELLS program. These wells are anticipated to be low yield, discharging on the order of a few gallons per minute (gpm). A single well that has 10 feet of screen, hydraulic conductivity equal to 150 gpd/ft$^2$, and a storage coefficient of 0.05, and that pumps 2 gpm (2,880 gpd) for 30 days with an aquifer thickness of 40 feet would result in a cone of depression having a 100-foot radius. The drawdown would range from 0.03 to 2.12 feet at the well. The same well with 20 feet of screen results in a similar sized cone of depression; however, the drawdown would range from 0.04 to 1.14 feet at the well. Pumping at 5 gpm, a well with a 20-foot screen would result in a cone of depression having a 200-foot radius and a drawdown ranging from 0.1 to 2.73 feet at the well.

Because the wells will be pumping from discreet, thin perched zones separated by unsaturated intervals, and because the 40-foot interval is not fully saturated, the expected drawdown at the well would be greater than the model shows and the radius of the cone of depression would be smaller. Aquifer tests will be necessary to evaluate actual field conditions.

Recharge to these shallow zones will vary seasonally and that, periodically, one of more of the zones may be dry (if screened over multiple zones, the yields could range from less than 1 gpm to more than 5 gpm). Hydrographs prepared from water-level data collected at MW-A, -B, and -C will be used to evaluate seasonal fluctuations in the depth-to-water and the appropriate location of the pump intakes.

To evaluate the appropriate spacing among the wells and the number of wells needed to effectively drain some of the shallow perched water, the first well will be constructed 50 feet north of the MW-A, -B, -C alignment. The new well will be pumped while MW-A, -B, and -C serve as observation wells. The planned alignment of the small-diameter extraction wells (Figure 4) is across the hydraulic gradient that should enhance their capture zone. (For example, pumping at 7.5 gpm in EW-3 resulted in a shallow cone of depression which extended 200 feet to MW-7.) The small-diameter extraction wells will be joined by a header and connected to the 002 Outfall system.

## 3.2 MAIN PERCHED ZONE (LOWER UAU/UPPER MAU)

During SPRI's 1994 field investigation, two extraction wells (EW-3 and EW-4) were constructed in the main perched zone. These wells were screened in the sand-and-gravel zone at the base of the UAU. During an aquifer test, EW-4 broke suction at 5 gpm before one well volume was discharged and was not tested further. This well should be a better producer and it is recommended that an attempt be made to use a jetting system to clean up any drilling mud or clay clogging the aquifer that may have survived the initial development. The well should be retested at the same time that testing is performed on the small-diameter extraction wells for the shallow perched zones (see Section 3.1).

The aquifer test was successful at EW-3 where pumping at 7.5 gpm resulted in a cone of depression having a 200-foot radius. This well, like EW-4, is screened only in the basalt sand and gravel of the UAU (not across the entire main perched zone) between approximately 65 and 110 feet below ground surface in the EW-3 area.

A proposed new extraction well (EW-5) will be constructed southeast of EW-3 near the old survey shack and south of EW-2 (Figure 5). Based on the water-level contour map for the main perched zone (Figure 6), a well in this position when combined with EW-3 should capture a significant amount of the leachate seeping through the underdrain system at Dam

No. 1. This well should be constructed of 6- to 8-inch diameter casing, should reach a total depth (TD) of 110 feet, and should be screened opposite sand-and-gravel beds throughout the main perched zone. Geophysical logs will be used to define the productive zones, and a 24-hour aquifer test will be conducted at EW-5. EW-3 and EW-5 will be joined by a header and connected to the 002 Outfall system.

The transverse (cross-gradient) dimension of the main perched zone leachate plume is fairly wide based on the distribution of TDS and sulfate in MW-2, MW-3, and private wells just south of Molycorp property. EW-4 will probably not capture much of the plume south of MW-2. Using the phased approach to remediation, EW-3 and EW-5 (together with the small-diameter extraction wells north of MW-7) will be pumped for a period of four months. During that time period, down-gradient monitor wells MW-2, MW-1, and EW-1 will be sampled for TDS and sulfate concentrations. Depending on the response by these monitor wells to the extraction of leachate, a third extraction well (EW-6) may be constructed near MW-2 and screened across the main perched zone.

## 3.3 ADDITIONAL TESTING

Well EW-1 (southwest of Dam No. 1) is screened across the upper basalt and the underlying basalt gravel unit. Concentrations of TDS (1,200 mg/L) and sulfate (620 mg/L) in a water sample collected in November 1994 from this well indicated that some leachate has moved from the main perched zone westward across the fault zone and into the basalt. The hydrogeologic cross-section (Figure 7), along with geophysical logs from MW-12, indicate that the lower part of the main perched zone is in fault contact with the volcanic unit. Given the flow rates within the basalt aquifer, contributions of leachate from the perched zone would be rapidly diluted. Because EW-1 was not accessible due to impassable road conditions in Fall 1994, no aquifer test was performed. This well may be tested to estimate hydraulic conductivity for the volcanic unit and to evaluate the influence of the fault (which should function as a recharge barrier) on pumping conditions at the well. (Well MW-1 would be an observation well during the test.) Both TDS and sulfate concentrations will be measured before and after the aquifer test to evaluate whether there is a hydrologic connection between the main perched zone and the volcanic unit and whether EW-1 could be used for extraction purposes.

## 3.4 PUMPS

Because the proposed extraction wells are anticipated to be fairly low yield and subject to seasonal fluctuations in recharge and yield, we recommend evaluating the use of pneumatic pumps in lieu of submersible (electrical) pumps. Pneumatic pumps can operate at very low yields (less than 1 gpm if necessary) and are not damaged if, as in the case of the shallow

perched zone, a well drys up. (A submersible pump would burn out.) Pneumatic pumps are simpler in design and require less maintenance than submersibles. However, the performance of pneumatic pumps in the cold climate of the Questa area needs to be reviewed before a commitment to pneumatic extraction can be made.

### 3.5 SEEPAGE CUTOFF

Molycorp plans to construct a shallow cutoff drain in the arroyo east of Outfall 002 to intercept near-surface seepage moving to the south. Seepage will be piped to the Outfall 002 system.

### 3.6 MONITORING PROGRAM

Monitoring of water levels should continue on a monthly basis to develop a database on seasonal fluctuations in recharge. Water-quality data should be collected on a quarterly basis to evaluate seasonal and long term changes resulting from natural recharge and from the extraction well system.

The following water-quality parameters should be measured: temperature, pH, conductivity, TDS, alkalinity, aluminum, iron, manganese, zinc, copper, molybdenum, fluoride, sulfate, chloride, nitrate, and the EPA toxicity metals (cadmium, lead, arsenic, mercury, chromium, barium, selenium, and silver). Protocols developed for SPRI's sampling program in November 1994, including field and laboratory documentation of the sampling and analytical procedures, will be continued.

Based on the current understanding of the flow conditions in the basalt aquifer and dilution effects resulting from a high flow rate [see mixing equation results for MW-11 (SPRI, 1994)], no extraction wells are proposed for the Dam No. 4 area. However, monitoring of wells (e.g., MW-11) and of springs or seeps along the Red River Gorge will continue.

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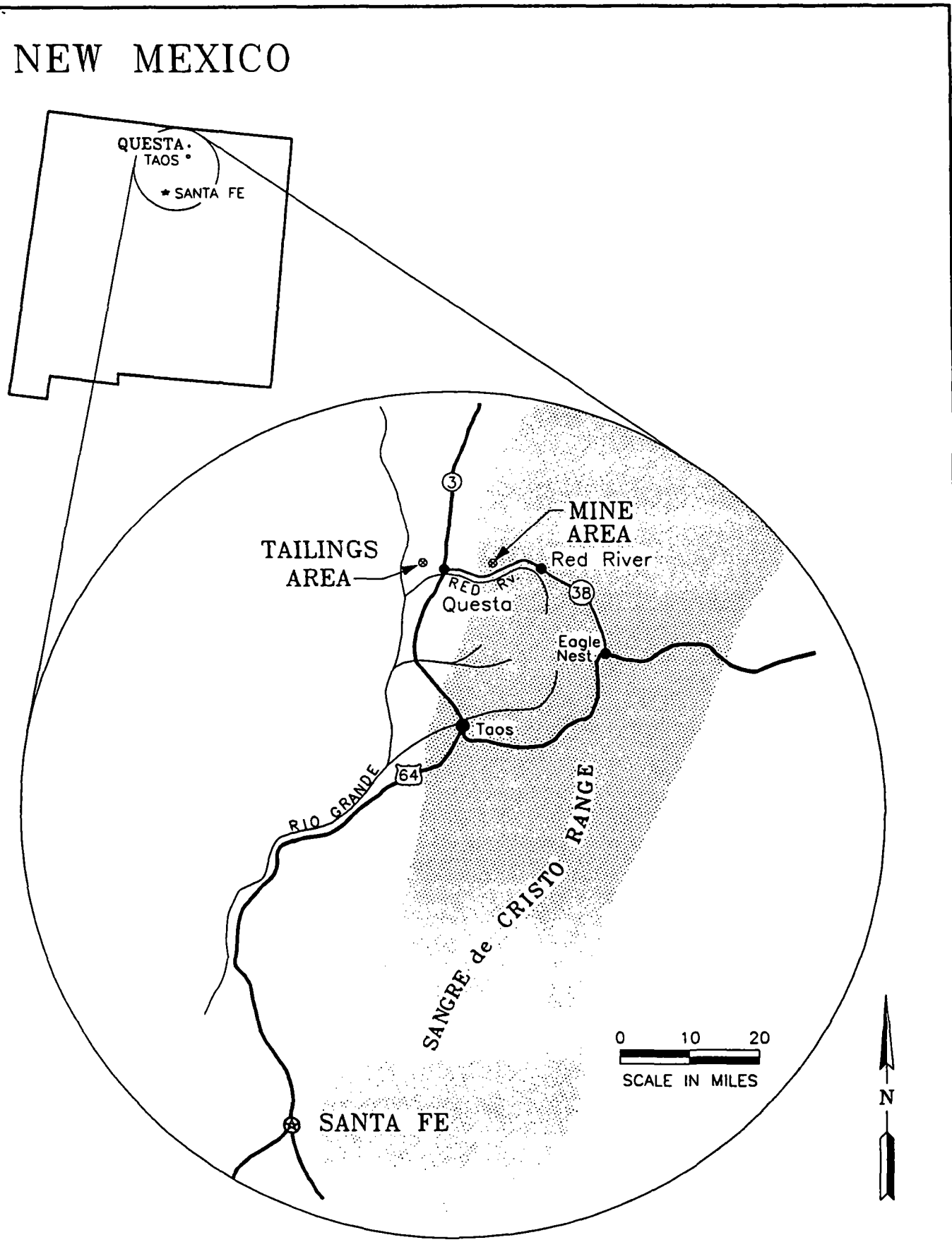
## FIGURES




| SOUTH PASS RESOURCES, INC. | | | | REGIONAL LOCATION MAP | FIGURE: |
|---|---|---|---|---|---|
| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: | Molycorp, Inc. | 1 |
| 001-06 | 3/31/95 | | M.O'M. | Questa, New Mexico | |

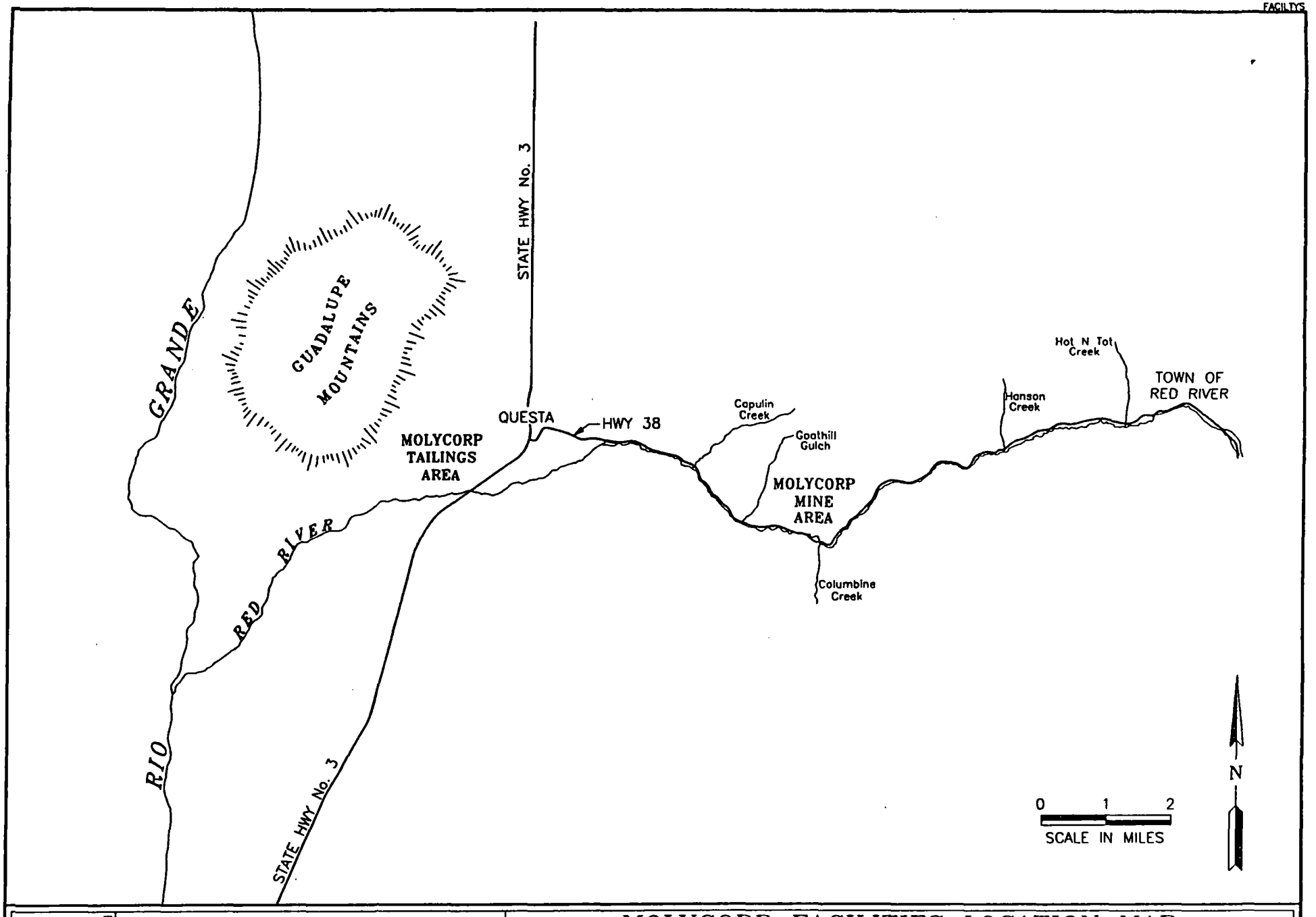



FIGURE: 2

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# MOLYCORP FACILITIES LOCATION MAP

Molycorp, Inc.
Questa, New Mexico

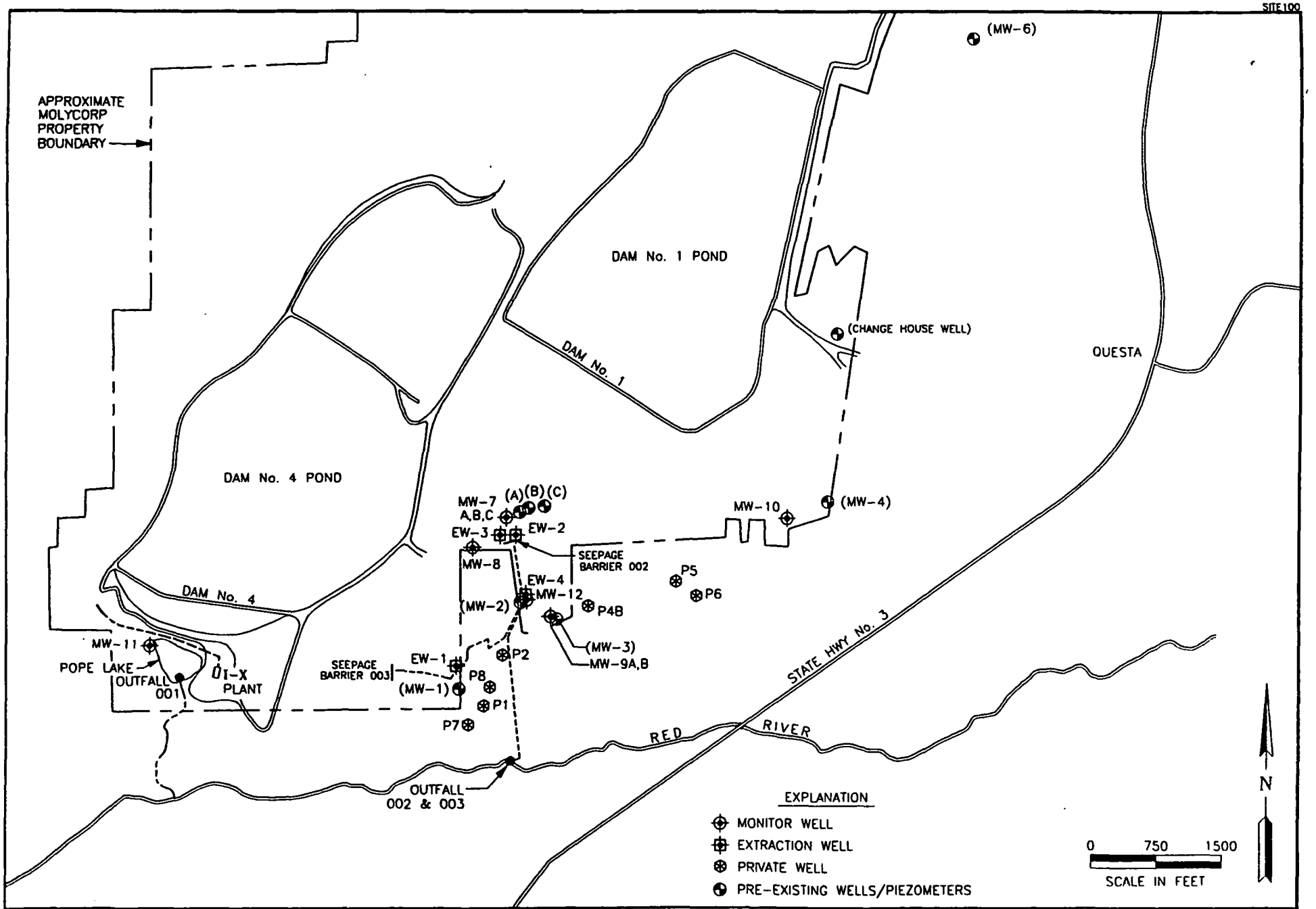


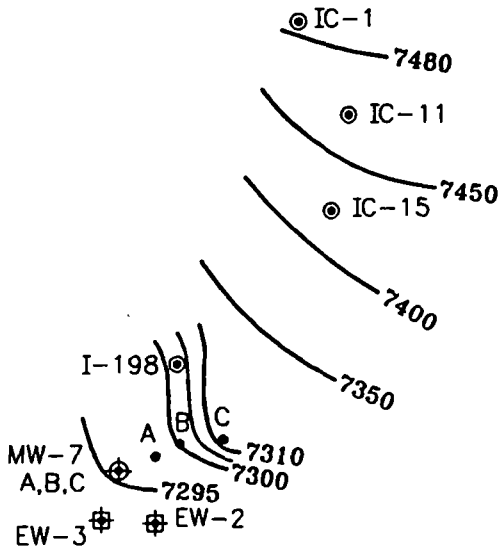

FIGURE 3

SOUTH PASS RESOURCES, INC.

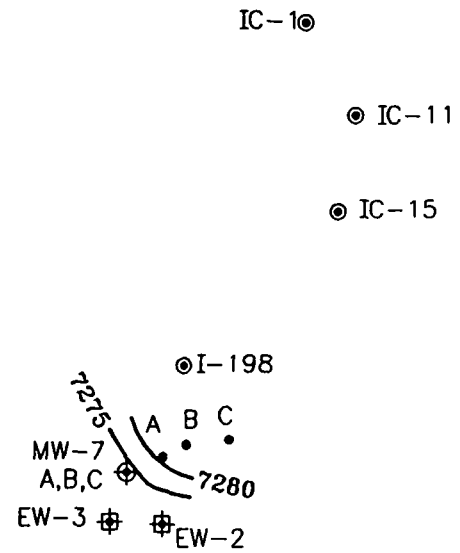
| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# TAILINGS AREA SITE MAP

Molycorp, Inc.
Questa, New Mexico




SHALLOWEST
PERCHED ZONE




INTERMEDIATE
PERCHED ZONE

EXPLANATION

| | |
|---|---|
| —7300— | Water-Level Elevation |
| EW-1 | Extraction Well Location |
| MW-1 | Monitor Well Location |
| • A | Shallow Piezometer |

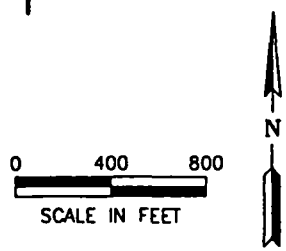



FIGURE: 4

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

WATER-LEVEL CONTOURS OF THE
UAU SHALLOW AND INTERMEDIATE PERCHED ZONES
Tailings Area - Molycorp, Inc., Questa, New Mexico

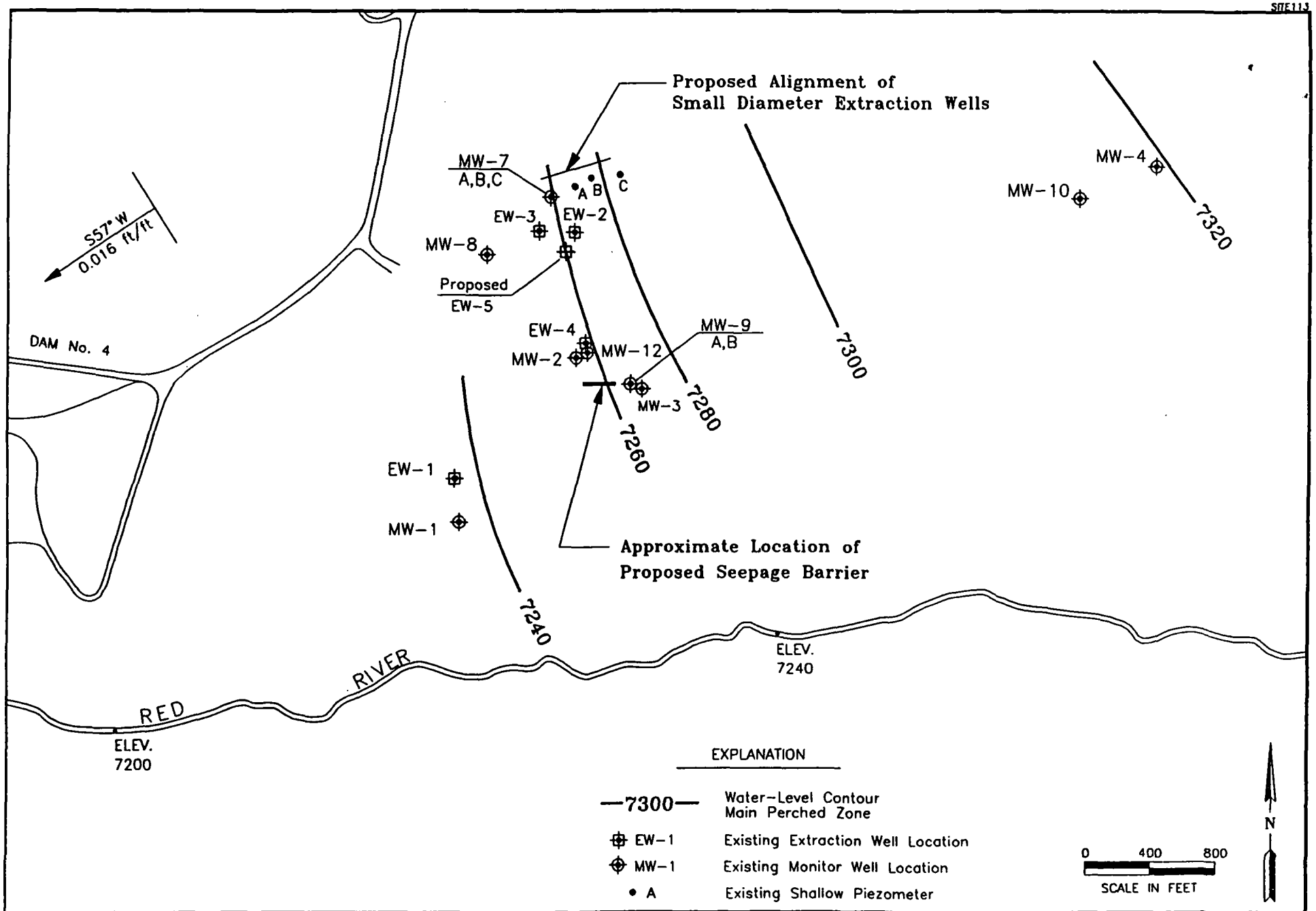


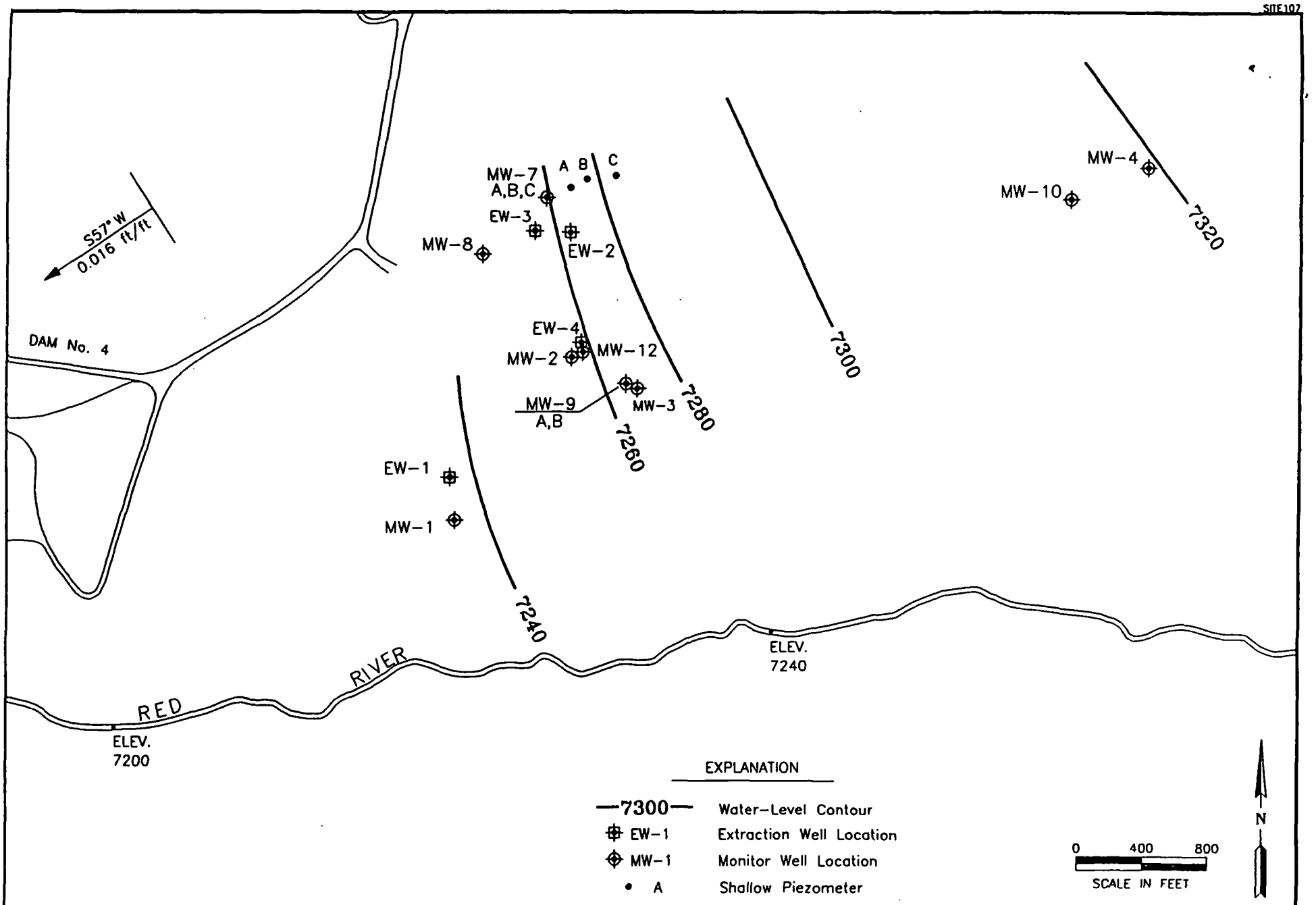

FIGURE: 5

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

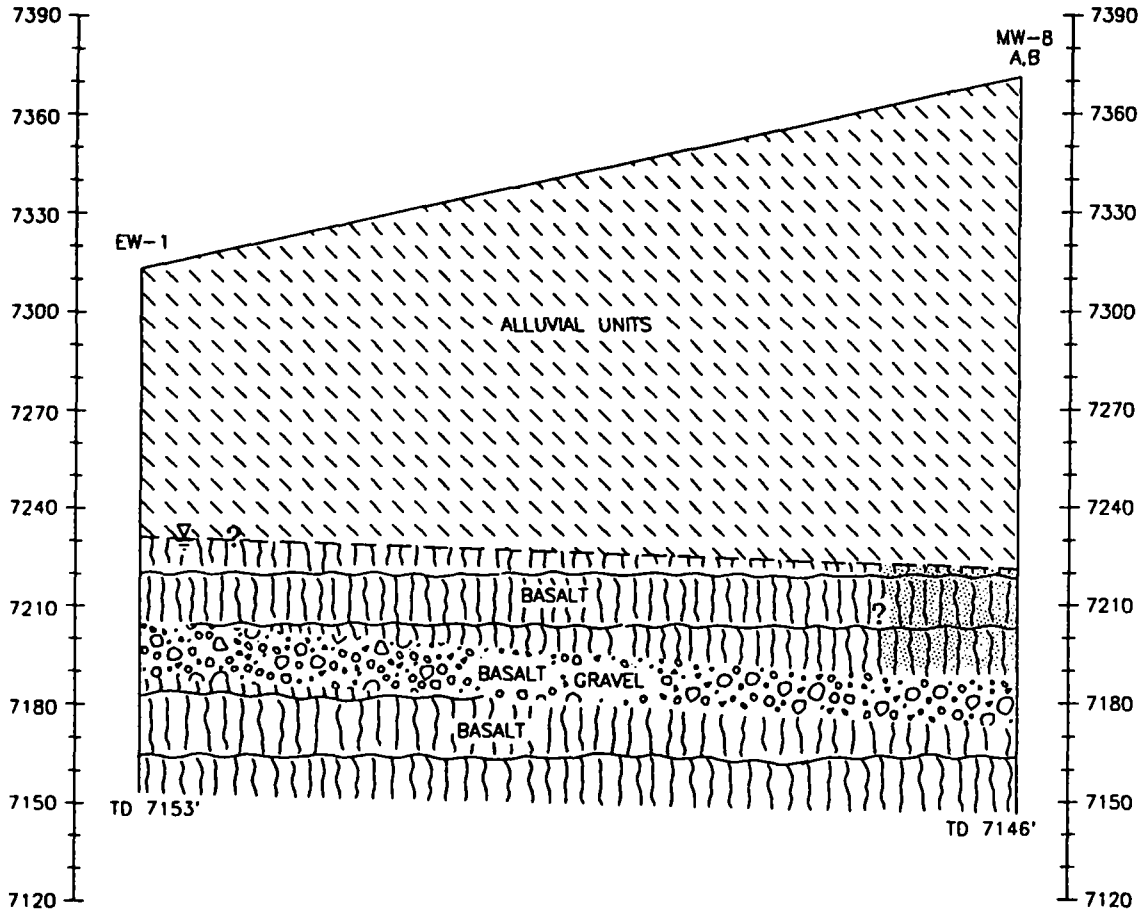
# EXISTING AND PROPOSED EXTRACTION WELL LOCATIONS

Tailings Area - Molycorp, Inc.
Questa, New Mexico




| FIGURE: 6 | SOUTH PASS RESOURCES, Inc. | | | | WATER-LEVEL CONTOURS OF THE UAU PERCHED ZONE<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico |
|---|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | |

XSEC-10




EXPLANATION

Alluvial units include the upper and lower aquifers and the Middle Aquitard.

MW-8A,B:
A is the original borehole drilled to 225 feet. B is the replacement borehole drilled to 185 feet.

— ▽ — Potentiometric surface for the volcanic unit where screened intervals include basalt gravel at EW-1 and MW-1.

Unsaturated Zone in the upper part of the volcanic unit above the basalt gravel at MW-8B. May include basalt above gravel at EW-1 and MW-1.

0 30 60
VERTICAL SCALE IN FEET

0 150 300
HORIZONTAL SCALE IN FEET

FIGURE: 7

SOUTH PASS RESOURCES, Inc.

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|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# HYDROGEOLOGIC CROSS-SECTION WEST OF DAM No. 1

Tailings Area – Molycorp, Inc.
Questa, New Mexico

APPENDIX A

# APPENDIX A

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**for**
***Discussion of Geology, Hydrogeology, and Water Quality of the Tailings Area***

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COPY

# DISCUSSION OF GEOLOGY, HYDROGEOLOGY, AND WATER QUALITY OF THE TAILINGS AREA
## Molycorp Facility
## Taos County, New Mexico

*prepared for*
**Molycorp, Inc.**
Questa Division
P.O. Box 469
Questa, NM 87556

*prepared by*
**South Pass Resources, Inc./SPRI**

April 13, 1995

6WQ-SG
SEP 16 1997

# Discussion of Geology, Hydrogeology, and Water Quality of the Tailings Area

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6WQ-SG
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# TAILINGS AREA

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# 1.0 INTRODUCTION

## 1.1 INTRODUCTION

The Molycorp molybdenum mine is located on the western slope of the Taos Range of the Sangre de Cristo Mountains, Taos County in north-central New Mexico (Figure 1). State Highway 38 runs along the north side of the Red River and connects the mine area with the Town of Red River (6 miles to the east) and the Town of Questa (6 miles to the west). For the purposes of this report, the area consisting of tailings embankments, tailings ponds, seepage controls, and outfall facilities is defined as the ***Tailings Area***. The Tailings Area is located about 1 mile west of the town of Questa and 0.5 mile north of the Red River (Figure 2).

In 1989, Molycorp retained the services of South Pass Resources, Inc. (*SPRI*) to evaluate impacts of past and present Molycorp mining operations on ground-water and surface-water quality. SPRI's most recent (Fall 1994) activities have involved the design, installation, and testing of five (5) new monitor/extraction wells in the Tailings Area. This report presents a discussion of the Fall 1994 investigation and of previous investigations, of the geologic, hydrogeologic, and water-quality aspects of the Molycorp mining activities.

### HISTORY OF INVESTIGATIONS

Molybdenum ore was discovered in the Questa area in 1916. Original underground mining was replaced in 1964-1965 with open-pit excavations and increased milling activities. Starting in 1979, mining was once again diverted to underground operations. Coincident to increasing mining activities, tailings-disposal operations were initiated by 1965 with completion of Dam No. 1 and the Dam No. 1 tailings pond.

A number of studies have investigated the geology and hydrogeology of the area (see Section 4.0, References). Regional studies were conducted by I. Winograd (1959); the U.S. Army Corps of Engineers from 1936-46 in conjunction with a dam-siting study at Chiflo; and others. Beginning in the early 1980s, more site-specific investigations were commissioned by Molycorp. These studies were designed to focus on ground-water flow patterns, surface-water and ground-water quality, and relationships between tailings disposal activities and any down-gradient water quality. The site-specific studies have been conducted predominately in two locations:

- Guadalupe Mountain and south (to the Red River) and west (to the Rio Grande); and

- The area between Red River and tailings Dams Nos. 1 and 4 (the Tailings Area of this report).

Geoscience and engineering consulting firms that have conducted most of the studies since the early 1980s include: Dames & Moore, Harding-Lawson, South Pass Resources, Inc. (SPRI: formerly the GeoWest Group), Vail Engineering, and Water Resources Associates.

Considerable information has now been generated on the geology, hydrogeology, and water quality within the Tailings Area, as well as the interrelationships between these three parameters. In March 1993, a Ground-Water Discharge Plan Permit Application for the Tailings Area was submitted to the New Mexico Environmental Improvement Division (NMEID). This report presents the findings from SPRI's recent (Fall 1994) field investigation and other investigations in support of the Discharge Plan Permit Application.

## 1.2 SUMMARY OF FALL 1994 AND PREVIOUS INVESTIGATIONS

Between August 28 and September 27, 1994, SPRI overviewed the installation and testing of one monitor and four extraction wells in the Tailings Area. The purpose of this field effort was to:

- further delineate ground-water flow patterns between the tailings ponds and the Red River;
- further identify the geologic controls on ground-water flow;
- further characterize perched-water conditions in the Tailings Area;
- continue the investigation of contaminant flow paths from the tailings ponds; and
- emplace extraction wells for potential remediation efforts.

The wells that were installed during the Fall 1994 field effort, and the details of their installation and testing, are summarized below. The locations of these wells are shown on Figure 2. [All of the wells (except MW-12 which has 4-inch PVC casing) were constructed with 8-inch PVC casing and screen to allow for future pumping and extraction, if desired.]

| Tailings Area Monitor/Extraction Wells Installed in August/September 1994 | | | |
|---|---|---|---|
| **Well No.** | **Total Depth (feet)** | **Screened Interval (feet)** | **Well Completed In** |
| EW-1 | 157 | 83 - 157 | basalt/basalt gravel |
| EW-2 | 214 | 104 - 114<br>120 - 132<br>151 - 185 | sandy gravel<br>sandy gravel, gravelly sand, clay<br>basalt gravel in clay |
| EW-3 | 104 | 62 - 77 | sandy clay/clayey gravel |
| EW-4 | 58 | 42 - 58 | clayey gravel |
| MW-12 | 234 | 203 - 234 | basalt gravel/basalt |

These new monitor and exploration wells in the Tailings Area supplement monitor wells previously installed under SPRI direction (see SPRI, 1993; 1994). These wells are summarized below:

| Tailings Area Monitor Wells Previously Installed by SPRI (1993) | |
|---|---|
| **Well No.** | **Total Depth (feet)** |
| MW-11 | 249 |
| MW-7A, -7B, -7C | 146 |
| MW-9A, -9B | 147 |
| MW-8 | 225 |
| MW-10A | 136 |

A partial listing of other monitor and extraction wells in the Tailings Area that pre-date SPRI field activities are summarized below. (Note: A complete list of all wells located in the study area is unknown at this time.)

| Other Wells Located in the Tailings Area (Partial Listing) | | |
|---|---|---|
| **Well No.** | **Total Depth (feet)** | **Year Installed** |
| Change House (CH) | 250 | 1967 |
| MW-1 | 117 | 1979 |
| MW-2 | 80 | 1979 |
| MW-3 | 52 | 1979 |
| MW-4 | 102 | 1979 |
| MW-A | 38 | NA |
| MW-B | 18 | NA |
| MW-C | 15 | NA |
| MW-6 | 101 | NA |

Figure 2 shows the locations of SPRI and other wells installed in the Tailings Area.

# 2.0 GEOLOGY AND HYDROGEOLOGY

The Molycorp study area is located on a broad, westward-sloping alluvial plain that is bound on the east by the Sangre de Cristo Mountains (elevations in the 12,000-foot range) and on the west by the Guadalupe Mountains (elevations in the 8,700-foot range). In the study area, this alluvial plain is the southern extension of Sunshine Valley but is topographically separated from the Valley by a low divide near the town of Cerro, about 3 miles north of Questa.

The Red River lies immediately south of Questa and is a perennial stream that flows from the Sangre de Cristo Mountains to the Rio Grande (5 miles west of Questa). From approximately 2 miles west of Questa to the Rio Grande, the Red River channel is entrenched in a deep gorge developed across the volcanic rocks on the south flank of the Guadalupe Mountains.

## 2.1 REGIONAL GEOLOGY

The Molycorp site is located within the Rio Grande rift zone, a northeast-/southwest-trending fault-bound structural depression that is Mid- to Late-Tertiary in age and that extends across New Mexico into southern Colorado. The rift zone is composed of a number of structural subbasins including the San Luis Basin. The San Luis Basin is located at the northern end of the rift zone and is bounded on the east by the Sangre de Cristo Mountains. The San Luis Basin contains coarser alluvial sediments along the range front. Farther to the west, the basin fill consists of finer clays and silts (deposited in lakes) and finer alluvial material along the distal edge of alluvial fans. To the east, volcanism and intrusion associated with the Questa caldera occurred.

Numerous volcanic fields developed as the result of the rifting and basin formation in Mid- to Late-Tertiary time. The volcanic units that underlie the Guadalupe Mountains along the west side of the site consist of lava flows and ash flow tuffs that range in composition from rhyolite to basalt. The volcanics erupted onto older basin-fill sediments from central vent and fissure eruptions (Winograd, 1959; unpublished reports in the Molycorp files). Eastward toward the uplifted Sangre de Cristo Mountains, the volcanics intertongue with contemporaneous alluvial sediments. Figure 3 (modified from Winograd, 1959) illustrates these stratigraphic relationships. A younger (Pliocene) basalt unit, the Servilleta Basalt, overlies these older volcanic units and intertongues with correlative basin-fill sediments. Winograd (1959) referred to the interlayered sedimentary and volcanic units filling the San Luis Basin in the Sunshine Valley areas as the Santa Fe Group.

## 2.2 TAILINGS AREA GEOLOGY AND HYDROGEOLOGY

### Geology

The Tailings Area is characterized by both volcanic rocks (rhyolites to basalts) intertongueing with or overlain by alluvial sediments and lacustrine deposits (the Santa Fe Group). Stratigraphic interpretations in the Tailings Area are based on 14 borehole logs and 3 geophysical logs, supplemented by field observations and unpublished maps (Vail, 1987; Molycorp files). Figure 4 illustrates the stratigraphy of the Tailings Area. The Santa Fe Group stratigraphy consists of :

- An Upper Aquifer Unit (UAU) composed of brown sandy gravels and gravelly sands with some pale red brown silty, sandy clay;
- a Middle Aquitard Unit (MAU) composed of pale red brown clay and gravelly clay;
- a Lower Aquifer Unit (LAU) composed of sandy or clayey gravel, with some thin, cemented sand units; and
- a Basal Aquitard Unit (BAU) composed of bouldery clay.

There are five recognized northeast-trending faults (see Appendix A for detailed discussion) in the Tailings Area that, in areas, bring volcanic rocks into lateral contact with the Santa Fe Group alluvial materials.

### Hydrogeology

The major regional aquifer is in the basalt and older volcanics beneath the Santa Fe Group. Within the Santa Fe Group alluvium, lateral hydraulic conductivities are considered higher than vertical hydraulic conductivities. Field investigations demonstrate that perched zones in the UAU and a main perched zone involving the lower UAU and upper MAU overlie a regional water table in the LAU and basalt aquifer (see Figure 5).

A limited number of aquifer tests were conducted in the Tailings Area. Horizontal hydraulic conductivities for these tests ranged from approximately 87 gallons per day per square foot ($gpd/ft^2$) to 913 $gpd/ft^2$. These values are compatible with average hydraulic conductivities for sands and gravels. Vertical hydraulic conductivities from laboratory tests were about 0.01 to 73 $gpd/ft^2$. The finer-grained beds would significantly reduce the vertical migration of leachate.

Hydraulic conductivity values calculated from an aquifer test at MW-11 for the basalt aquifer ranged from 6,833 gpd/ft$^2$ (specific capacity calculation) to 14,103 gpd/ft$^2$ (recovery test). These values are within the range of published values for permeable basalt.

The ground-water gradient is to the south at 0.07 ft/ft in the shallow perched zones and to the southwest at 0.016 ft/ft in the underlying main perched zone. There are not enough data points to evaluate flow direction and gradients for the LAU and BAU.

Ground-water flow directions in the basalt aquifer range from S20°W to S75°W. These are based on three-point calculations from water-level data measured at Guadalupe Mountain (Dames and Moore, 1986), by SPRI in the Dam No. 4 area, and from a potentiometric map for the volcanic aquifer (Winograd, 1959). Hydraulic gradients range from 0.003 ft/ft to 0.1 ft/ft. Steeper gradients are related to localized discharge conditions such as occur along permeable fault zones (e.g., MW-11 area).

With some exceptions, near-surface ground water in the Tailings Area can now be categorized as a calcium sulfate water. The regional ground water is a sodium potassium or a calcium bicarbonate water. Most perched ground water has high total dissolved solids (TDS) and high sulfate.

Appendix A contains a detailed discussion of the Tailings Area site geology. Appendix B contains detailed discussions of the hydrology of the tailings dams plus the hydrogeology of the areas between Dam Nos. 1 and 4 and the Red River. Appendix C contains well construction diagrams and geologic and geophysical logs for wells emplaced during SPRI's Fall 1994 investigation. Appendix D contains detailed discussions of ground-water quality. Appendix E contains data from three aquifer drawdown and recovery tests.

# 3.0 RESULTS AND DISCUSSION OF FALL 1994 FIELD ACTIVITIES IN THE TAILINGS AREA

## 3.1 WELL EMPLACEMENTS AND WATER LEVELS

During SPRI's Fall 1994 investigation, five wells were installed. (Aquifer tests were conducted on three of these wells.)

- EW-1: 157 feet total depth (TD)
- EW-2: 214 feet TD
- EW-3: 104 feet TD
- EW-4: 58 feet TD
- MW-12: 234 feet TD

Well EW-1 is screened in the basalt aquifer and, like the nearby MW-1, has a water level close to the basalt/LAU contact. EW-1 was located between MW-1 (also screened in basalt) and a potential source of leachate from the Dam No. 4 tailings pond. The purpose for EW-1 was to evaluate water chemistry and to position an extraction well for remediation of Dam No. 1 and Dam No. 4 leachate, if necessary.

Wells EW-3 and EW-4 are both screened in a gravelly zone within the main perched zone to evaluate their capacity for extracting Dam No. 1 leachate. Water-level elevations at both of these wells are related to the water table for the main perched zone. These wells were also designed for leachate extraction, if practicable.

Wells EW-2 and MW-12 are deep wells located south of Dam No. 1. The purpose of these wells was to evaluate the LAU and the basalt aquifer, respectively. EW-2 was designed to also function as a leachate extraction well in the LAU, if necessary. With the discovery of the previously unknown bouldery clay beneath the LAU aquifer, this well was extended to evaluate water quality in the deeper sedimentary unit. The EW-2 water level is related to a zone of confined gravel within the bouldery clay unit below the LAU. Well MW-12 was drilled to evaluate the perched zone first noted at the nearby MW-9 well and to test the water quality in the basalt aquifer on the east side of the Dam No. 1 arroyo. The water level in the well is above the sediment/basalt contact as the result of confined conditions related to the overlying clay unit.

Results of the most recent water quality sampling (Fall 1994) for wells located in the Tailings Area are presented on Table 1.

## 3.2 HYDROGEOLOGIC CONDITIONS AND WATER-QUALITY ASPECTS SOUTH OF THE DAM NO. 1 ARROYO

The deeper private wells (P-4B and P-5) south of the tailings ponds have good quality water in terms of TDS and sulfate (Table 2). Well P-4B is a deep well (175 feet TD), is partly screened in the volcanic unit, and is partly in the overlying sedimentary material. Well P-5 is 131 feet deep, which is enough to be into the LAU (perforated interval unknown). Well P-5 may be east of an LAU flow path from the Tailings Area.

South of the Molycorp boundary, hydrogeologic data on the Santa Fe Group alluvial section is incomplete. The main perched zone may extend to the river. The shallower private wells between the Molycorp property line and the river (P-1: 90 feet TD; and P-8: 67 feet TD) have high concentrations of TDS and sulfate and are probably screened in portions of the lower UAU and MAU (equivalent to the main perched zone to the north). Some of the springs near the river have elevated sulfate concentrations (Vail, 1993). It is also possible that the main perched zone merges with the LAU toward the river; however, because of upward head conditions leachate-impact of the LAU would be prevented. The water-level elevation contours drawn on the top of the main perched zone in the area just south of Dam No. 1 would, if extended to the south, curve eastward because the Red River is probably a gaining stream along the segment of its course opposite the dams and upstream from the Pope Lake wash.

Vail (1993) recorded a sulfate concentration of 504 mg/L from a field spring in the vicinity of Big Springs (Table 2). In Vail's report, the cold spring water piped to the Fish Hatchery came from Questa Spring (part of the Big Spring Complex). However (Vail, personal communication, 1994), indicates that the source of the Hatchery cold water is a spring in the fields just east of the Questa Spring. This spring water has a sulfate content of 80 mg/L. It appears that the shallower alluvial units (UAU/MAU) are the probable sources of the poorer quality water and that some of the spring water comes from deeper sources in the Santa Fe Group (LAU) or the basalt. All of these springs are located within the postulated fault zone south of Dam No. 1 identified in the Tailings Area. Water may migrate upward along fractures from different levels in the Santa Fe Group or the basalt aquifer.

As indicated earlier in this report, seepage from shallow perched zones in the UAU along the east side of the pond at Dam No. 4 is partially captured by Seepage Barrier 002. No perched zones were identified in the Santa Fe sediments when EW-1 was drilled. The sulfate and TDS concentrations in EW-1 and MW-1, however, may be related to westerly flow of the shallow ground water south of Dam No. 1. Leachate may leak westward across the fault zone on the west side of Dam No. 1.

## 3.3 HYDROGEOLOGIC CONDITIONS AND WATER-QUALITY ASPECTS SOUTH OF THE DAM NO. 4 ARROYO

Ground-water flow directions range from S20°W to S75°W in the basalt (volcanic) aquifer. These are based on three-point calculations from water-level data at Guadalupe Mountain (Dames and Moore, 1986), south of Dam No. 4 (SPRI 1993, 1994) , and from a potentiometric map for the volcanic aquifer (Winograd, 1959).

Hydraulic gradients range from 0.003 ft/ft to 0.1 ft/ft. Steeper gradients are related to discharge conditions such as occur along permeable fault zones (e.g., MW-11 area). The water-level elevation at MW-11 (7,153 feet) corresponds to a stream bed elevation on the Red River approximately 1,500 feet west of the confluence of Pope Lake Wash (MW-11 area) and the river. Allowing for a water table below the stream bed, it still appears that the Red River may be, for a short segment in the upper Red River Gorge, a losing stream. Discharge from the river may occur along a permeable northeast-trending fault zone located west of Dam No. 4. The steepening of the hydraulic gradient (Winograd, 1959) across this area may be related to discharge along the fault zone. Stream gauge data indicate overall gaining conditions between Questa Ranger Station and the Fish Hatchery in the Red River Gorge. If there is flow loss at the fault zone, it is not enough to be noticed in the stream gauge data.

SPRI (1994), on the assumption of a southwesterly flow direction, estimated an underflow rate in the basalt aquifer to account for the low sulfate concentration at MW-11. A mixing formula (Hem, 1970) was used to calculate a flow rate:

$$Cm = \frac{\sum_{1}^{n} CnQn}{\sum_{1}^{n} Qn}$$

where $C_m$ = sulfate concentration of the river, in mg/L
$C_n$ = sulfate concentration of tributary sources, in mg/L
Q = flow rate, in cubic feet per second (cfs)
n = number of sample points

A major element in this calculation is the pond seepage rate which ranges from 0.5 to 1.5 cfs (Geocon, 1983). The higher seepage rate resulted in an underflow on the order of 19.7 cfs, roughly double the flow rate estimated from studies along the Rio Grande. The lower seepage rate resulted in a more reasonable underflow on the order of 6 cfs. The actual rate may be even lower because:

- A vadose zone (partly alluvial, partly basalt) of approximately 190-foot thickness beneath the pond would attenuate the sulfate concentration entering the ground water.

- The sulfate concentration for the pond water below Dam No. 4 may be less than the combined 002/003 Outfall water at the Red River used in the calculations.

Monitoring of water quality at MW-11 and along the Red River indicates that the rate of ground-water flow in the basalt aquifer causes significant dilution of any pond leachate that may migrate through the thick vadose zone to the water table.

## 3.4 IMPACT ON THE RED RIVER

Data from two U.S. Geological Survey stream gauges have been used to evaluate the impacts of tailings water on the Red River: one at the Ranger Station (1.5 miles east of Questa), and the other at the confluence of the Red River with the Rio Grande River (a distance of 8.1 miles). The section of the Red River that may be impacted by the tailings ponds is 1.84 miles in length (roughly from the 002/003 Outfall west to the area of the Fish Hatchery). Water levels for wells near the river are close to, but above, river level which indicates that the Red River is a gaining stream for the segment opposite Dam No. 1.

Accretions from tributary sources to segments of the Red River between the gauges have been studied by Wilson and Associates (1978), Water Resources Associates (1984), Dames and Moore (1987), and Vail (1993). These different studies generally conclude that the net gain between Questa and the confluence is roughly 30 cfs. Vail (1993) provides the most recent and detailed estimates for tributary source discharges and their sulfate concentrations to the Red River. Water-quality data from sampling along the Red River are provided on Table 3, and sampling locations (and corresponding sulfate concentrations) are shown on Figure 6. Accretion estimates for the area from the Big Springs Complex (which includes Questa Springs) eastward to the highway bridge over the Red River (the alluvial segment) are given below.

| | Flow Rate (Q) (cfs) | Sulfate Concentration (C) (mg/L) |
|---|---|---|
| Cold springs from alluvium east of Red River Gorge | | |
| piped to Fish Hatchery | 2.7 | 80 |
| directly to Red River | 0.4 | 80 |
| Field drainage (probably includes seepage from springs east of Big Springs) | 2.76 | 240 |
| 002 Outfall (seepage from 001 and 002 barriers) | 0.6 | 840 |

The estimated rate of flow for the Red River just upstream of the alluvial segment at the highway bridge is 46 cfs and the sulfate concentration is 119 mg/L. Using the values above, the calculation for mixing is:

$$C_m = \frac{\sum_1^n C_n Q_n}{\sum_1^n Q_n}$$

$$\frac{(46)(119)+2.7(80)+0.4(80)+2.76(240)+0.6(840)}{46+2.7+0.4+2.76+0.6} = 131.3$$

Based on this calculation, the tributary sulfate input to the Red River directly from the alluvial segment would be diluted to 131.3 mg/L sulfate. A Red River water sample taken 500 feet west of Big Springs Complex has a sulfate concentration of 138 mg/L.

Estimates for tributary sources along the north side of the Red River Gorge (from Big Springs Complex to the Fish Hatchery) are based on estimates of warm spring flow (the assumption, as noted earlier, is that warm water is derived from ground water moving through the volcanic pile).

| | Flow Rate (Q) (cfs) | Sulfate Concentration (C) (mg/L) |
|---|---|---|
| Warm springs from volcanics directly to the river: | | |
| Warm springs potentially influenced by seepage | 1.65 | 120 |
| Warm springs not influenced by seepage | 2.18 | 20 |

Adding the inflows from the alluvial segment between the highway bridge and the head of the gorge results in a flow to the upper portion of the gorge on the order of 52 cfs (assuming 138 mg/L sulfate for the Red River below Big Springs). Using the mixing equation and spring flows directly to the river:

$$C_m = \frac{\sum_1^n C_n Q_n}{\sum_1^n Q_n} = \frac{(138)(52)+(120)(1.65)+(2.18)(20)}{52+1.65+2.18} = 132.86$$

The sulfate is diluted to 132.86 mg/L. The two Red River samples measured in this segment of the river have sulfate concentrations of 126 and 129 mg/L.

The sulfate concentrations in water samples collected from springs in the upper Red River Gorge are (see Table 3 and Figure 6):

- 115 mg/L for Sample Location 12;
- 126 mg/L for Sample Location 14; and
- 20 mg/L for Sample Location 15.

The water temperatures for these springs were 15.3°C, 14.5°C, and 16.4°C, respectively. Red River water in the same area has a temperature of 10.3 to 11.2°C. The spring temperatures seem to indicate that the springs' source is ground water that is derived from the volcanic aquifer, not river water recharged to the volcanic aquifer along the fault zone near Pope Lake. If the river is discharging to the volcanic aquifer at the fault zone (as

suggested by the MW-11 water level), it is not losing much water to the aquifer and temperature effects are not evident.

An issue raised in the SPRI (1994) report regarding the assumption that MW-11 was down-gradient from the pond (southwesterly flow): why would the well have a substantially lower sulfate concentration than the springs farther down-gradient along the Red River? Two possible answers to this question are:

1) There was an earlier pulse of seepage water that had higher sulfate than presently measured (such that the spring samples represent older water than MW-11).

2) There is some iron-sulfide in the basalt that oxidizes in the vadose zone and releases some sulfate to the ground water. The spring at Sampling Location 14 is located on the south side of the Red River and it has a sulfate concentration of 126 mg/L. Localized iron sulfide mineralization in the fracture volcanics on both sides of the river could be supplying the sulfate.

The spring at Sampling Location 15 has a very low sulfate concentration (20 mg/L). It is possible that the higher sulfate springs are discharging water that lies close to the water table and that the water at Sampling Location 15 comes from a deeper source.

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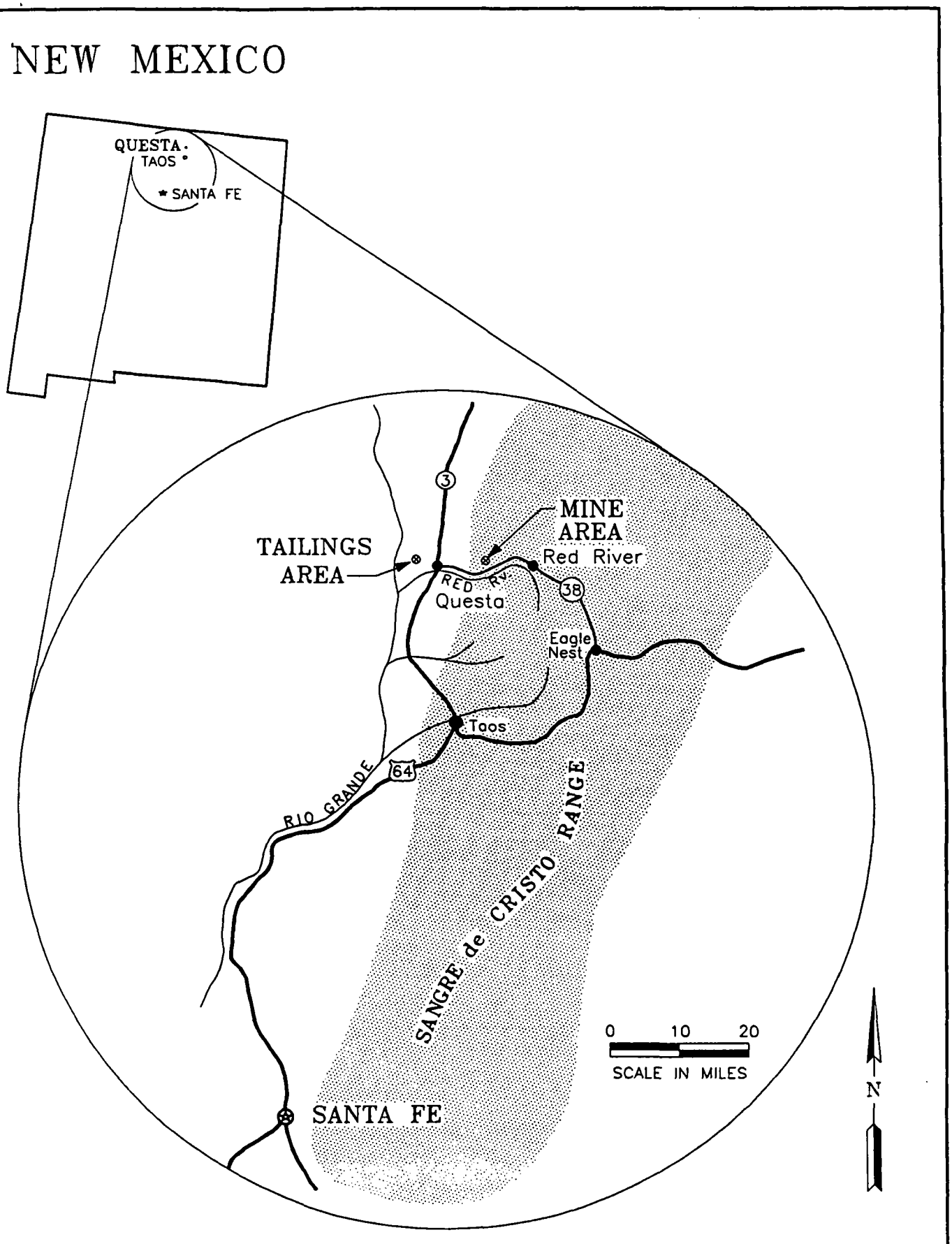
FIGURES

V-MAP




| SOUTH PASS RESOURCES, INC. | | | | REGIONAL LOCATION MAP<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: 1 |
|---|---|---|---|---|---|
| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: | | |
| 001-06 | 3/31/95 | | M.O'M. | | |

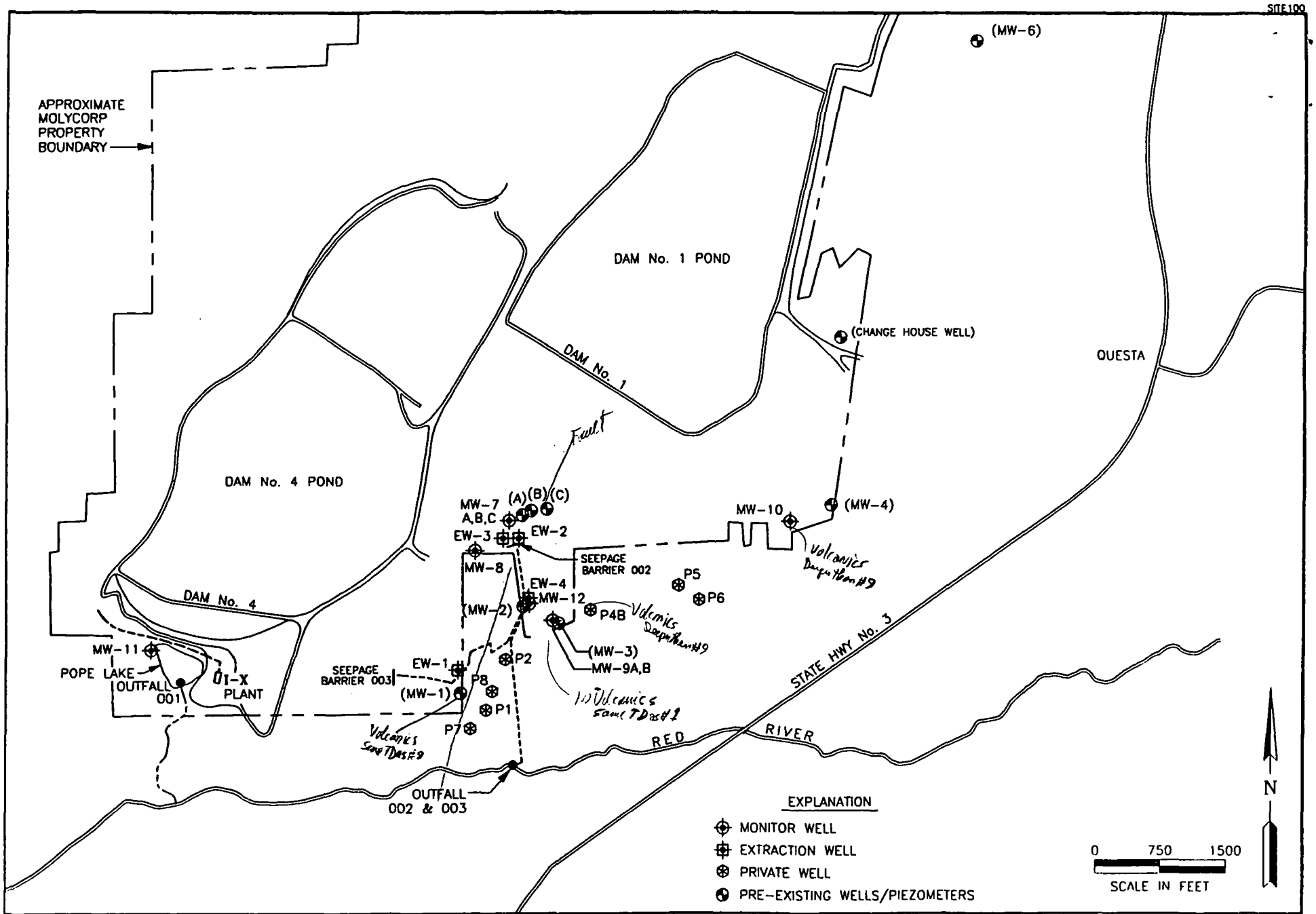



FIGURE: 2

SOUTH PASS RESOURCES, INC.

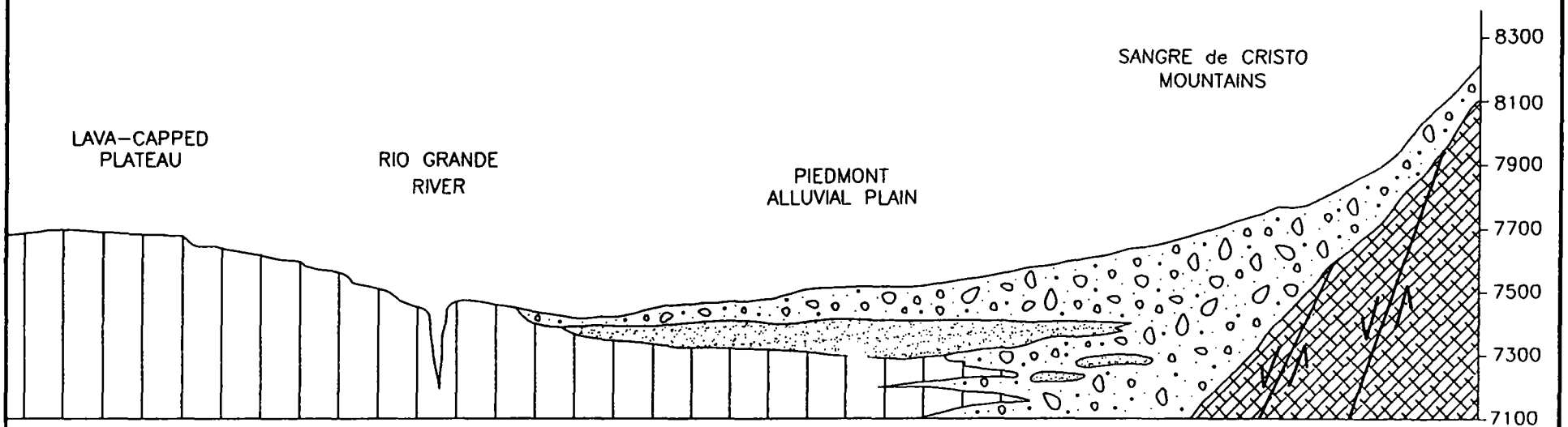
| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# TAILINGS AREA SITE MAP

Molycorp, Inc.
Questa, New Mexico

XSEC-8

# SUNSHINE VALLEY, TAOS COUNTY NEW MEXICO




EXPLANATION

ALLUVIAL SEDIMENTS

BASALT/ANDESITIC ASH FLOW TUFFS

LAKE SEDIMENTS

GRANITIC/GNEISS METAVOLCANIC

FAULTS

0 3000 6000

HORIZONTAL SCALE IN FEET

N

REFERENCE: MODIFIED FROM WINOGRAD, 1959.

FIGURE: 3

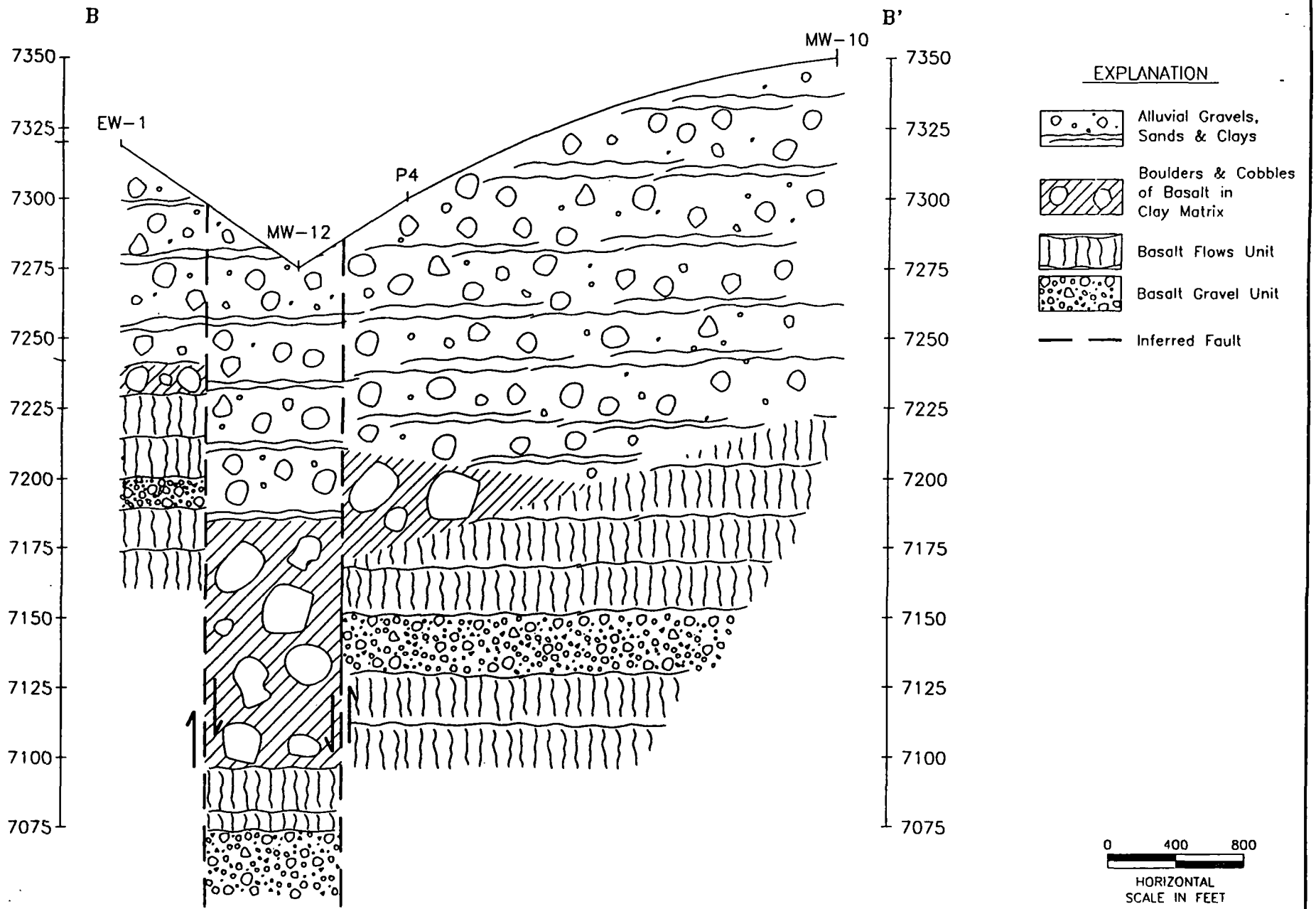
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

## GENERALIZED GEOLOGIC CROSS-SECTION

Molycorp , Inc.
Questa, New Mexico

XSEC-9

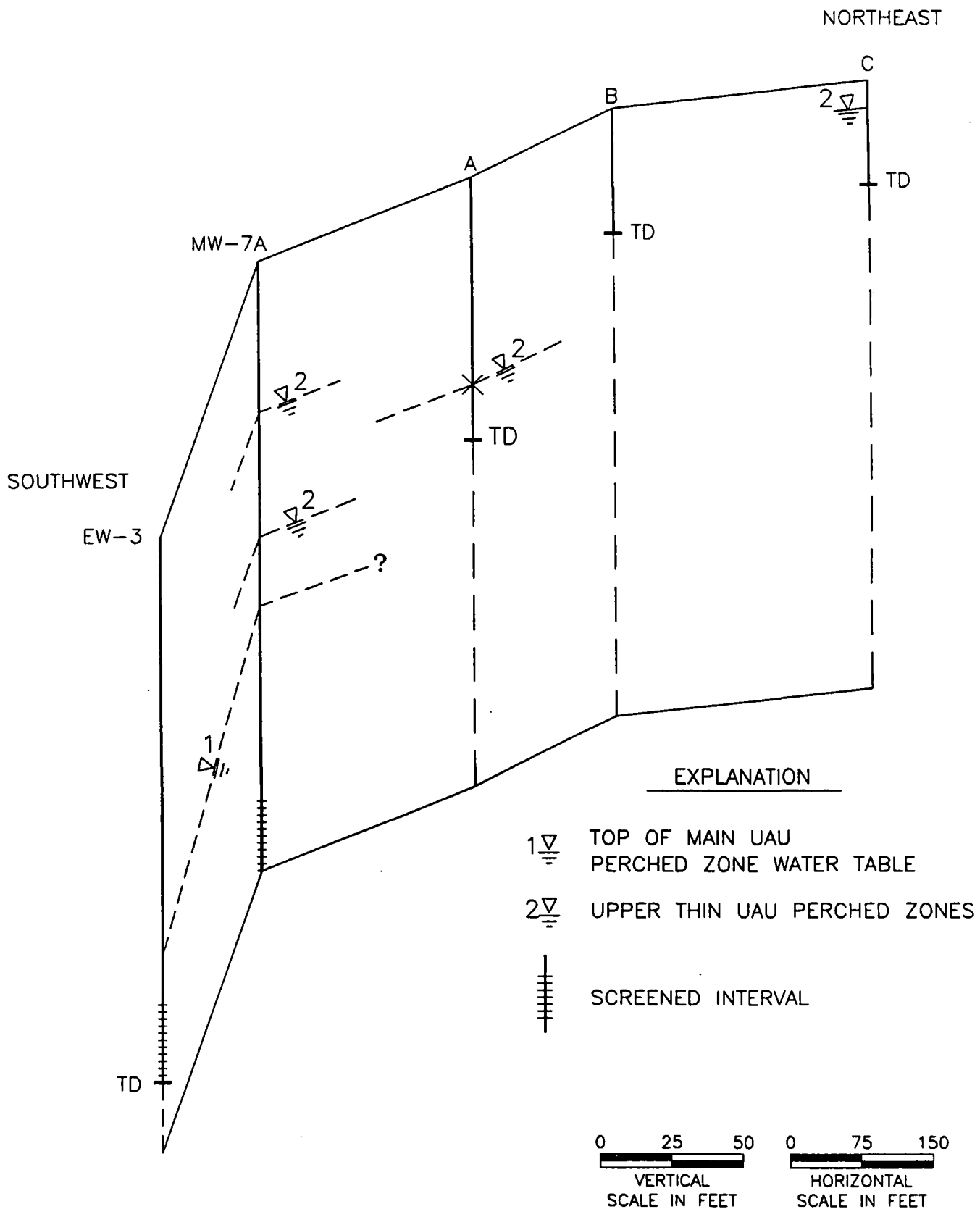



| FIGURE: 4 | SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. |

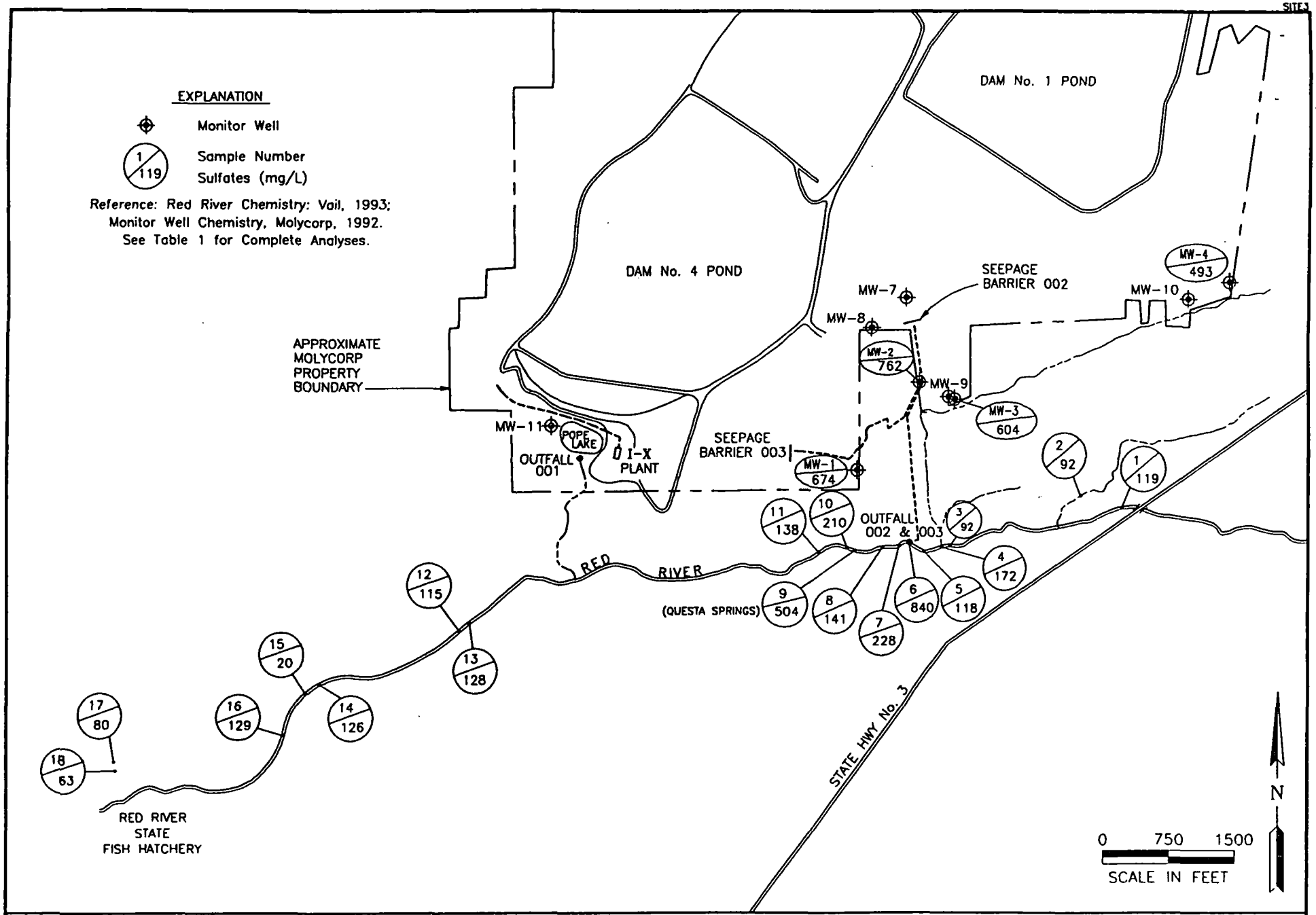
# GEOLOGIC CROSS-SECTION SOUTH OF DAM No. 1

Tailings Area - Molycorp, Inc.
Questa, New Mexico

XSEC-12A




| SOUTH PASS RESOURCES, Inc. | | | | HYDROGEOLOGIC CROSS-SECTION | FIGURE: |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | SOUTH OF DAM No 1 - Tailings Area<br>Molycorp, Inc., Questa, New Mexico | 5 |




| FIGURE: 6 | SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. |

# WATER QUALITY SURVEY: MONITOR WELLS & RED RIVER

Tailings Area – Molycorp, Inc.
Questa, New Mexico

TABLES

# TABLE 1
## 1994 MONITOR WELL WATER QUALITY DATA FOR TAILINGS AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | SAMPLE DATE 1994 | WELL TD (feet) | Corrected DEPTH TO WATER (feet) | DEPTH TO PUMP INTAKE (feet) | pH (1) | CONDUC-TIVITY (1) (uhmos) | TEMP (1) (°C) | CARBO -NATE (mg/L) | BICARBO -NATE (mg/L) | HYDR-OXIDE (mg/L) | TOTAL ALK (mg/L) | CHLORIDE (mg/L) | FLUORIDE (mg/L) | NITRATE (mg/L) | SUFATE (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW-1 | 7-Nov | 157 | 83.00 | 102 | 7.50 | 1,460 | NA | <1 | 156 | <1 | 156 | 23 | 0.25 | 0.72 | 620 |
| EW-2 | 8-Nov | 204 | 147.91 | 170 | 7.48 | 850 | 12.9 | <1 | 122 | <1 | 122 | 4.8 | 0.49 | 0.2 | 96 |
| EW-2 | 17-Nov | NA | NA | NA | NA | NA | NA | <1 | 118 | <1 | 118 | 4.6 | 0.5 | 0.38 | 90 |
| EW-3 | 8-Nov | 78 | 57.74 | 70 | 7.48 | 1,135 | 11.4 | <1 | 110 | <1 | 110 | 17 | 0.16 | 0.6 | 440 |
| EW-3 | 19-Nov | NA | NA | NA | NA | NA | NA | <1 | 136 | <1 | 136 | 18 | 0.19 | 0.49 | 410 |
| EW-4 | 7-Nov | 58 | 18.49 | 50 | 7.78 | 650 | 11.6 | <1 | 152 | <1 | 152 | 26 | 0.21 | 0.35 | 150 |
| EW-4 | 16-Nov | NA | NA | NA | NA | NA | NA | <1 | 156 | <1 | 156 | 26 | 0.2 | 0.36 | 160 |
| MW-1 | 7-Nov | 100 | 53.17 | 80 | 7.28 | 1,322 | NA | <1 | 136 | <1 | 136 | 14 | 0.27 | 0.45 | 610 |
| MW-2 | 7-Nov | 80 | 22.07 | 60 | 7.96 | 1,701 | NA | <1 | 80 | <1 | 80 | 15 | 0.96 | <0.06 | 860 |
| MW-3 | 8-Nov | 60 | 19.97 | 55 | 7.38 | 1,679 | 12.4 | <1 | 183 | <1 | 183 | 18 | 0.44 | 0.31 | 780 |
| MW-4 | 8-Nov | 96 | 40.77 | 65 | 7.61 | 1,157 | 12.3 | <1 | 184 | <1 | 184 | 7.3 | 0.73 | 0.24 | 460 |
| MW-7A | 7-Nov | 90 | 58.84 | 80 | 7.50 | 1,565 | 11.9 | <1 | 126 | <1 | 126 | 16 | 0.18 | 0.72 | 730 |
| MW-7C | 9-Nov | 146 | 111.79 | 135 | 7.10 | 2,160 | 12.4 | <1 | 124 | <1 | 124 | 16 | 0.17 | 0.32 | 790 |
| MW-9A | 8-Nov | 44 | 26.30 | 35 | 7.32 | 1,021 | 13.1 | <1 | 174 | <1 | 174 | 20 | 0.44 | 0.33 | 680 |
| MW-10 | 8-Nov | 129 | 26.23 | 100 | 8.16 | 236 | 12.3 | <1 | 77 | <1 | 77 | 1.6 | 0.36 | 0.27 | 35 |
| MW-11 | 9-Nov | 249 | 191.93 | 210 | 7.00 | 440 | 19.8 | <1 | 82 | <1 | 82 | 10.3 | 1.28 | 0.39 | 58 |
| MW-11AB | 9-Nov | NA | NA | NA | NA | NA | NA | <1 | 79 | <1 | 79 | 10.1 | 1.29 | NA | 58 |
| MW-12 | 7-Nov | 234 | 128.11 | 210 | NA | NA | NA | <1 | 120 | <1 | 120 | 5.1 | 0.46 | NA | 66 |
| MW-A | 7-Nov | 38 | 30.58 | NA | 7.28 | 1,332 | NA | <1 | 154 | <1 | 154 | 14 | 0.35 | 0.37 | 560 |
| MW-C | 7-Nov | 14.5 | 1.80 | NA | 7.24 | 1,902 | NA | <1 | 185 | <1 | 185 | 19 | 1.16 | <0.06 | 970 |
| CH | 8-Nov | NA | NA | NA | 7.97 | 539 | 13.5 | <1 | 206 | <1 | 206 | 2.3 | 0.71 | 0.44 | 75 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.
SOURCE: SAMPLES TAKEN BY SPRI. ANALYTICAL RESULTS FROM MOLYCORP.

NA - NOT AVAILABLE

# TABLE 1
## 1994 MONITOR WELL WATER QUALITY DATA FOR TAILINGS AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | TDS (mg/L) | SILVER (mg/L) | ALUMINUM (mg/L) | ARSENIC (mg/L) | BARIUM (mg/L) | BERYLLIUM (mg/L) | CALCIUM (mg/L) | CADMIUM (mg/L) | COBALT (mg/L) | CHROMIUM (mg/L) | COPPER (mg/L) | IRON (mg/L) | MERCURY (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW-1 | 1,200 | <0.10 | <0.05 | <0.005 | 0.053 | <0.004 | 240 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-2 | 240 | <0.10 | <0.05 | <0.005 | 0.068 | <0.004 | 59.4 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-2 | 290 | <0.010 | <0.05 | <0.005 | 0.065 | <0.004 | 57.8 | 0.0036 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-3 | 830 | <0.10 | <0.05 | <0.005 | 0.074 | <0.004 | 179 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-3 | 750 | <0.010 | <0.05 | <0.005 | 0.054 | <0.004 | 158 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-4 | 440 | <0.10 | <0.05 | <0.005 | 0.065 | <0.004 | 101 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-4 | 450 | <0.010 | <0.05 | <0.005 | 0.068 | <0.004 | 104 | <0.0005 | <0.010 | <0.010 | 0.012 | <0.050 | <0.0002 |
| MW-1 | 1,100 | <0.10 | <0.05 | <0.005 | 0.025 | <0.004 | 207 | <0.0005 | <0.010 | <0.010 | <0.010 | 0.068 | <0.0002 |
| MW-2 | 1,400 | <0.10 | <0.05 | <0.005 | 0.022 | <0.004 | 241 | <0.0005 | <0.010 | <0.010 | <0.010 | 4.6 | <0.0002 |
| MW-3 | 1,400 | <0.10 | <0.05 | <0.005 | 0.032 | <0.004 | 264 | <0.0005 | <0.010 | <0.010 | <0.010 | 0.07 | <0.0002 |
| MW-4 | 890 | <0.10 | <0.05 | <0.005 | 0.084 | <0.004 | 166 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-7A | 1,300 | <0.10 | <0.05 | <0.005 | 0.028 | <0.004 | 273 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-7C | 1,300 | <0.10 | <0.05 | <0.005 | 0.028 | <0.004 | 279 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-9A | 1,200 | <0.10 | <0.05 | <0.005 | 0.061 | <0.004 | 247 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-10 | 150 | <0.10 | <0.05 | <0.005 | 0.038 | <0.004 | 28.2 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-11 | 200 | <0.10 | <0.05 | <0.005 | 0.014 | <0.004 | 28.6 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-11AB | 220 | <0.10 | <0.05 | <0.005 | 0.015 | <0.004 | 28.5 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-12 | 260 | <0.10 | <0.05 | <0.005 | 0.096 | <0.004 | 47.1 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-A | 1,000 | <0.10 | <0.05 | <0.005 | 0.03 | <0.004 | 214 | <0.0005 | <0.010 | <0.010 | <0.010 | 0.066 | <0.0002 |
| MW-C | 1,700 | <0.10 | <0.05 | <0.005 | 0.04 | <0.004 | 334 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| CH | 340 | <0.10 | <0.05 | <0.005 | 0.059 | <0.004 | 48.5 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.
SOURCE: SAMPLES TAKEN BY SPRI. ANALYTICAL RESULTS FROM MOLYCORP.

NA - NOT AVAILABLE

# TABLE 1
## 1994 MONITOR WELL WATER QUALITY DATA FOR TAILINGS AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | POTASSIUM (mg/L) | MAGNESIUM (mg/L) | MANGANESE (mg/L) | MOLYBDENUM (mg/L) | SODIUM (mg/L) | NICKEL (mg/L) | LEAD (mg/L) | ANTIMONY (mg/L) | SELENIUM (mg/L) | SILICON (mg/L) | THALLIUM (mg/L) | VANADIUM (mg/L) | ZINC (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW-1 | 3.7 | 47.9 | 0.017 | <0.02 | 41.7 | <0.020 | <0.002 | <0.05 | <0.005 | 13.8 | <0.005 | <0.010 | <0.050 |
| EW-2 | 3.3 | 10.4 | 0.169 | <0.02 | 20.0 | <0.020 | <0.002 | <0.05 | <0.005 | 15.7 | <0.005 | <0.010 | <0.050 |
| EW-2 | 3.6 | 10 | 0.138 | <0.02 | 19.6 | <0.020 | <0.002 | <0.05 | <0.005 | 17.3 | <0.005 | <0.010 | 0.091 |
| EW-3 | 2.6 | 31.8 | 0.056 | <0.02 | 28.6 | <0.020 | <0.002 | <0.05 | <0.005 | 12.4 | <0.005 | <0.010 | <0.050 |
| EW-3 | 2.2 | 27.8 | 0.036 | <0.02 | 28.9 | <0.020 | <0.002 | <0.05 | <0.005 | 11.9 | <0.005 | <0.010 | 0.364 |
| EW-4 | 1.5 | 17.8 | <0.010 | <0.02 | 15.5 | <0.020 | <0.002 | <0.05 | <0.005 | 12.4 | <0.005 | <0.010 | <0.050 |
| EW-4 | 2.1 | 18.1 | 0.019 | <0.02 | 16 | <0.020 | <0.002 | <0.05 | <0.005 | 12.7 | <0.005 | <0.010 | 0.364 |
| MW-1 | 3.0 | 41.2 | 0.035 | 0.04 | 55.4 | <0.020 | <0.002 | <0.05 | <0.005 | 11.9 | <0.005 | <0.010 | <0.050 |
| MW-2 | 3.1 | 52.2 | 0.37 | 1.7 | 95.6 | <0.020 | <0.002 | <0.05 | <0.005 | 1.8 | <0.005 | <0.010 | <0.050 |
| MW-3 | 1.5 | 48.6 | 0.032 | <0.02 | 71.6 | <0.020 | <0.002 | <0.05 | <0.005 | 10.3 | <0.005 | <0.010 | <0.050 |
| MW-4 | 1.1 | 32.7 | <0.010 | 0.21 | 64.2 | <0.020 | <0.002 | <0.05 | <0.005 | 10.3 | <0.005 | <0.010 | <0.050 |
| MW-7A | 2.6 | 47.1 | <0.010 | <0.02 | 39.5 | <0.020 | <0.002 | <0.05 | <0.005 | 12.3 | <0.005 | <0.010 | <0.050 |
| MW-7C | 3.9 | 48.4 | <0.010 | <0.02 | 45.1 | <0.020 | <0.002 | <0.05 | <0.005 | 12.1 | <0.005 | <0.010 | <0.050 |
| MW-9A | 1.7 | 45.5 | 0.111 | <0.02 | 66.0 | <0.020 | <0.002 | <0.05 | <0.005 | 10.5 | <0.005 | <0.010 | <0.050 |
| MW-10 | 1.3 | 4.4 | <0.010 | <0.02 | 14.7 | <0.020 | <0.002 | <0.05 | <0.010 | 10.8 | <0.005 | <0.010 | <0.050 |
| MW-11 | 2.8 | 8.6 | <0.010 | 0.06 | 25.8 | <0.020 | <0.002 | <0.05 | <0.005 | 15.5 | <0.005 | <0.010 | <0.050 |
| MW-11AB | 2.6 | 8.6 | <0.010 | 0.06 | 25.7 | <0.020 | <0.002 | <0.05 | <0.005 | 15.5 | <0.005 | 0.01 | <0.050 |
| MW-12 | 2.9 | 8.5 | <0.010 | 0.02 | 24.5 | <0.020 | <0.002 | <0.05 | <0.005 | 13.6 | <0.005 | <0.010 | <0.050 |
| MW-A | 2.8 | 35.7 | 0.04 | 0.63 | 50.6 | <0.020 | <0.002 | <0.05 | <0.005 | 10.9 | <0.005 | <0.010 | <0.050 |
| MW-C | 2.1 | 56.1 | 0.774 | 1.12 | 82.2 | <0.020 | <0.002 | <0.05 | <0.005 | 11.6 | <0.005 | <0.010 | <0.050 |
| CH | 1.2 | 9.4 | <0.010 | <0.02 | 57.8 | <0.020 | <0.002 | <0.05 | <0.005 | 9.8 | <0.005 | <0.010 | 0.946 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.
SOURCE: SAMPLES TAKEN BY SPRI. ANALYTICAL RESULTS FROM MOLYCORP.

NA - NOT AVAILABLE

# TABLE 2
## HISTORICAL WATER QUALITY DATA FOR PRIVATE WELLS
TAILINGS AREA - MOLYCORP, INC. - QUESTA, NEW MEXICO

| Well # | P-1 | P-2 | P-3 | P-4A | P-4B | P-5 | P-6 | P-7 | P-8 | P-9 |
|---|---|---|---|---|---|---|---|---|---|---|
| DATE | 1988 | 1979 | 1979 | 1987 | 1993 | 1993 | 1987 | 1975 | 1987 | 1993 |
| Bicarbonate Alkalinity (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Carbonate Alkalinity (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Hydroxide Alkalinity (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Aluminum (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Arsenic (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Cadmium (mg/L) | <0.01 | NA | NA | <0.01 | <0.005 | <0.005 | <0.1 | NA | <0.001 | <0.005 |
| Calcium (mg/L) | 246 | NA | NA | 128 | NA | NA | 37 | NA | 212 | NA |
| Chlorine (mg/L) | 21 | NA | NA | NA | NA | NA | <5.0 | NA | 18 | NA |
| Chromium (mg/L) | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Copper (mg/L) | <0.01 | NA | NA | 0.005 | 0.01 | <0.01 | NA | NA | <0.1 | 0.01 |
| Fluoride (mg/L) | 0.40 | 0.50 | 0.50 | NA | 0.45 | 0.42 | NA | NA | NA | 0.7 |
| Iron (mg/L) | <0.05 | 0.39 | 0.13 | 0.1 | <0.05 | 0.08 | <0.1 | 0.07 | <0.1 | 0.12 |
| Lead (mg/L) | <0.05 | NA | NA | <0.05 | <0.1 | <0.10 | <0.1 | NA | <0.01 | <0.1 |
| Magnesium (mg/L) | 39 | NA | NA | 17 | NA | NA | 3.0 | NA | 22 | NA |
| Manganese (mg/L) | 0.01 | 0.03 | 0.02 | NA | <0.01 | <0.01 | <0.05 | NA | <0.05 | 0.143 |
| Molybdenum (mg/L | 0.07 | 0.02 | NA | 0.01 | <0.005 | <0.005 | <0.1 | 2.27 | <0.1 | <0.005 |
| Potassium (mg/L) | 3.0 | NA | NA | 1.0 | NA | NA | 4.0 | NA | 2.0 | NA |
| Redox Pot. (mg/L) | NA | NA | NA | 27 | NA | NA | NA | NA | NA | NA |
| Sodium (mg/L) | 58 | NA | NA | 79 | NA | NA | 9.0 | NA | 41 | NA |
| Sulfate (mg/L) | 763 | 228 | 44 | 358 | 97 | 112 | 32 | NA | 504 | 94 |
| TDS (mg/L) | 1376 | 619 | 345 | 772 | 398 | 276 | 186 | NA | 982 | 270 |
| Zinc (mg/L) | 0.08 | 2.45 | 0.01 | 0.64 | 0.89 | 0.21 | <0.1 | NA | <0.1 | 0.08 |
| pH | 7.8 | 7.4 | 7.7 | 7.0 | 7.5 | 7.7 | 7.7 | NA | 7.1 | 7.3 |

## KEY TO TABLE 3
## LOCATIONS OF WATER SAMPLES
TAILINGS AREA - MOLYCORP, INC. - QUESTA NEW MEXICO

| | |
|---|---|
| #1 | Red River below Highway 38 bridge. |
| #2 | Spring on north side of Red River |
| #3 | Field Drainage to Red River, 500 feet east of Outfall 002 |
| #4 | Field Drainage to Red River, 450 feet east of Outfall 002 |
| #5 | Red River 300 feet east of Outfall 002 |
| #6 | Outfall No. 002 |
| #7 | Field Drainage 75 feet west of Outfall 002 |
| #8 | Red River above Questa Springs |
| #9 | Near Questa Springs, southeast of concrete box |
| #10 | Near Questa Springs, end of old pipe |
| #11 | Red River 500 feet west of Questa Springs |
| #12 | Spring, north side of Red River Station 47+20 |
| #13 | Red River Station 47+70, above Hatchery |
| #14 | Spring south side of Red River Station 36+80 |
| #15 | Spring north side of Red River Station 36+40 |
| #16 | Red River |
| #17 | Hatchery; cold water inlet |
| #18 | Hatchery; warm water inlet |

# TABLE 3
## WATER QUALITY DATA FOR THE RED RIVER (VAIL ENG., 1993)
TAILINGS AREA - MOLYCORP, INC. - QUESTA, NEW MEXICO


| Sample Location Number | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 |
|---|---|---|---|---|---|---|---|---|---|
| Total Alkalinity (mg/L) | 38 | 90 | 99 | 94 | 43 | 152 | 165 | 50 | 158 |
| Dissolved Aluminum (mg/L) | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 |
| Suspended Aluminum (mg/L) | 7.8 | 0.50 | <0.50 | <0.50 | 8.0 | <0.5 | 2.7 | 6.2 | 8.5 |
| Cadmium (mg/L) | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Copper (mg/L) | 0.036 | 0.007 | <0.005 | 0.008 | 0.028 | <0.005 | 0.009 | 0.029 | 0.016 |
| Fluoride (mg/L) | 0.84 | 0.55 | 0.60 | 0.46 | 0.90 | 1.90 | 0.80 | 0.88 | 0.38 |
| Iron (mg/L) | 0.594 | 0.543 | 0.405 | 0.115 | 0.569 | 0.102 | 1.09 | 0.573 | 2.94 |
| Lead (mg/L) | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Manganese (mg/L) | 0.92 | 0.02 | 0.05 | 0.05 | 0.88 | 1.40 | 0.03 | 0.88 | 0.07 |
| Molybdenum (mg/L) | <0.03 | <0.03 | 0.20 | <0.03 | <0.03 | 1.80 | 0.20 | <0.03 | <0.03 |
| Total Dissolved Solids (mg/L) | 255 | 247 | 246 | 648 | 240 | 1764 | 727 | 268 | 1094 |
| Total Suspended Solids (mg/L) | 31 | 20 | 7.0 | 6.0 | 22 | 2.0 | 39 | 21 | 88 |
| Sulfate (mg/L) | 119 | 92 | 92 | 172 | 118 | 840 | 228 | 141 | 504 |
| Zinc (mg/L) | 0.250 | 0.021 | 0.047 | 0.012 | 0.222 | 0.010 | 0.017 | 0.207 | 0.047 |
| Temprature (°C) | 8.3 | 10.5 | 11.2 | 17.8 | 9.1 | 9.7 | 10.1 | 9.8 | 7.8 |
| pH | 7.23 | 6.76 | 7.44 | 8.22 | 7.60 | 7.26 | 7.20 | 7.14 | 7.02 |

SOURCE: Vail Engineering (Ralph Vail).
NA - Not Available

# TABLE 3
## WATER QUALITY DATA FOR THE RED RIVER (VAIL ENG., 1993)
TAILINGS AREA - MOLYCORP, INC. - QUESTA, NEW MEXICO


| Sample Location Number | #10 | #11 | #12 | #13 | #14 | #15 | #16 | #17 | #18 |
|---|---|---|---|---|---|---|---|---|---|
| Total Alkalinity (mg/L) | 177 | 54 | 82 | 51 | 82 | 80 | 49 | 43 | 77 |
| Dissolved Aluminum (mg/L) | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 |
| Suspended Aluminum (mg/L) | <0.5 | 3.1 | 1.7 | 3.0 | <0.50 | <0.50 | 3.1 | <0.50 | <0.50 |
| Cadmium (mg/L) | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Copper (mg/L) | 0.005 | 0.033 | 0.011 | 0.026 | <0.005 | <0.005 | 0.024 | <0.005 | <0.005 |
| Fluoride (mg/L) | 0.60 | 0.90 | 0.80 | 0.90 | 0.80 | 1.10 | 0.90 | 0.64 | 0.54 |
| Iron (mg/L) | <0.05 | 0.618 | 2.36 | 0.590 | <0.05 | <0.05 | 0.527 | 0.138 | 0.181 |
| Lead (mg/L) | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Manganese (mg/L) | 0.01 | 0.88 | 0.13 | 0.83 | 0.01 | NA | 0.781 | NA | NA |
| Molybdenum (mg/L) | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| Total Dissolved Solids (mg/L) | 576 | 269 | 271 | 259 | 304 | 145 | 247 | 176 | 284 |
| Total Suspended Solids (mg/L) | 7.0 | 22 | 47 | 22 | <1.0 | <1.0 | 24 | NA | NA |
| Sulfate (mg/L) | 210 | 138 | 115 | 128 | 126 | 20 | 129 | 80 | 63 |
| Zinc (mg/L) | 0.010 | 0.215 | 0.046 | 0.206 | 0.005 | <0.005 | 0.191 | <0.005 | 0.010 |
| Temprature (°C) | 7.1 | 10.3 | 15.3 | 10.5 | 16.9 | 16.4 | 11 | 8.3 | 15.8 |
| pH | 7.50 | 7.45 | 6.94 | 7.45 | 8.14 | 7.26 | 7.8 | 7.14 | 7.87 |

SOURCE: Vail Engineering (Ralph Vail).
NA - Not Available

# APPENDIX A

# APPENDIX A

## Detail Of Tailings Area Site Geology

# APPENDIX A

## Detail Of Tailings Area Site Geology

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# APPENDIX A

## Detail of Tailings Area Site Geology

### A.1 STRATIGRAPHY

The stratigraphic sequence in the vicinity of the tailings ponds was identified based on 14 borehole lithologic logs, 3 geophysical logs, field reconnaissance, and unpublished geologic maps (Vail, 1987; Molycorp files) of the area. Much of the Tailings Area is immediately underlain by gravel, sand, and clay [assigned by Winograd (1959) to the Santa Fe Group]. Recent alluvial sediments appear to be confined to the bottom of the arroyos and are on the order of 20 feet or less in thickness (Dames and Moore, 1965, cross-section). A thin, distinctive sequence of coarse volcanic sand and volcanic conglomerate crops out along the southwest side of Dam No. 4 and appears in the top 29 feet of monitor well MW-11 in the same area. The stratigraphic relationship of this unit to the sedimentary beds elsewhere on the site is unresolved.

Borehole data show that a basalt/andesite unit (hereafter referred to as *basalt*) underlies the alluvial deposits of the Santa Fe Group from west to east across the site. A thin basalt gravel is interlayered with the basalt and is a distinct marker horizon in the wells that penetrate deeply enough in the volcanic unit. Volcanics along the eastern edge of the Guadalupe Mountains consist in part of ash flow tuffs and appear to be in fault contact with the basalts and the alluvial deposits of the Santa Fe Group. It is not known at this time whether these basalt flows are equivalent to the Servilleta Basalt or one of the older Miocene flow units. Ash flow tuffs are more typical of the Late-Oligocene to Mid-Miocene volcanics (Molycorp, unpublished data) and may be older than the basalt/alluvial units in the tailings area.

### A.2 SANTA FE GROUP

Based on the SPRI geophysical and borehole logs [Fall 1994 investigation (Appendix C) and previous field work], the alluvial deposits of the Santa Fe Group in the Tailings Area consists of:

- an Upper Aquifer Unit (UAU) composed of brown sandy gravels and gravelly sands with a subordinate component of pale red brown silty, sandy clay.
- a Middle Aquitard Unit (MAU) in which pale red brown clay and gravelly clay are the dominant sediments.

- a Lower Aquifer Unit (LAU) composed of sandy or clayey gravel. Thin beds of tightly cemented sandstone were noted in MW-7 and MW-10.

- a Basal Aquitard Unit (BAU) is a bouldery clay that is restricted to a few deep boreholes south of Dam No. 1.

[NOTE: These four lithologic divisions are based on dominant textural characteristics, but each unit contains subordinate amounts of the other lithologies (for example: clay beds occur within the UAU and LAU). There are no marker beds to establish lateral equivalence between borehole sections, such that parts of the MAU may be temporally equivalent to the lower part of the UAU, or the upper part of the LAU. In general, the internal structure of a sequence of alluvial or alluvial/lacustrine (lake) sediments is expected to be lensoid in character and to have sand and gravel lenses intertongueing with clay-rich units (Galloway and Hobday, 1983).]

East of Dam No. 1 (in the direction of the Sangre de Cristo Mountains), the Santa Fe Group coarsens and thickens. As evidence, the Change House Well (located east of Dam No. 1) bottoms at a depth of 250 feet in gravel, and the Questa Well No. 2 (north of the Town of Questa) bottoms at 500 feet in gravel.

In surface outcrops in the Tailings Area, gravels range from very fine gravel (0.08 to 0.16 inch) to cobble sizes (2.4 to 10.24 inches), but most of the material appears to be below cobble size. Geotechnical drilling for Dam No. 1 (Molycorp files: pre-dam cross-section along the proposed axis of Dam No. 1) and the borehole log for the Change House Well (east of Dam No. 1) indicate that boulder-size material is present in the UAU and LAU. Drilling conditions in the lower LAU at EW-2 and MW-12 also were indicative of boulder layers within the alluvial unit. Clast composition in the gravels (with the exception of the LAU in some boreholes) seems to largely reflect sources in the Sangre de Cristo Mountains to the east. A variety of volcanic rock types (flows, ash flow tuffs), intrusive igneous rocks (pegmatite, granite, quartz monzonite), and metamorphic rocks (gneisses) occur in the gravels.

The bouldery clay deposit is a basalt boulder/cobble unit below the LAU that contains an abundance of clay/silt in the matrix (20 to 40 percent clay matrix). Thin intervals of basaltic sandy gravels and gravelly sands occur within this unit. The unit appears to be thickest in EW-2 and MW-12 (which were drilled south of Dam No. 1), but thins abruptly to the west (less than 10 feet thick at EW-1) and appears to thin more gradually to the east (log for P-4B suggests 30 to 40 feet). Farther east, at MW-10, this unit is not present. The boulder clay unit is interpreted to be a mudflow deposit containing scattered channel gravels. The deposit is analogous to basalt mud flow deposits exposed along the current Rio Grande Gorge south of Taos. The bouldery clay unit functions as an aquitard.

A thin sequence of brown, silty, highly burrowed sands, black coarsely grained volcanic sands, and gravelly clayey volcanic sands crop out in the vicinity of MW-11. The gravels in this unit are entirely composed of volcanic clasts. Similar sediments were penetrated in the upper 29 feet of MW-11 and in several borings near the toe of Dam No. 4. This unit is shown separately (as $T_{svs}$) on the geologic map (Figure A1). It may be equivalent to the basaltic mudflow deposit below the LAU.

## A.3 VOLCANIC UNITS

Lithologic information for the volcanic rocks penetrated by the monitor wells in the Tailings Area comes primarily from descriptions of borehole cuttings (Appendix C). The flow rock is a finely crystalline olivine basalt or andesite containing brown millimeter-size phenocrysts of altered olivine and of pyroxene. White phenocrysts of feldspar were also noted. A few cuttings showed glassy textures which probably indicate the tops or bases of individual flows. Both vesicular, and to a greater extent, non-vesicular basalt are present. Flow banding was observed in some cuttings. White and pale blue quartz/chalcedony fills some vesicules and occurs along a few fractures. For the purpose of this report, this unit will be referred to as basalt. Thin volcanic breccias consisting of black to gray angular volcanic fragments in a red volcanic matrix are interlayered with the flows. Exposures of the basalt along the walls of Pope Wash, south of MW-11, show that the basalt is highly fractured with sets of vertical fractures coupled with units showing a distinct horizontal parting. (Volcanics observed along the east side of the Guadalupe Mountains were examined during a half-day reconnaissance of the area. These are dominantly medium gray ash flow tuffs characterized by flattened brown to tan pumice fragments and by the presence of black basal vitrophyres.)

## A.4 GEOLOGIC STRUCTURE

Reconnaissance mapping, combined with a description of the subsurface geology based on borehole data, indicate the presence of five northeast-trending faults that displace the Santa Fe Group alluvial sediments relative to various volcanic units in the tailings area (see Figures A1, A2, and A3). The apparent sense of movement along all of the faults is based on stratigraphic displacements. Because this Mid-Tertiary faulting was associated with rifting of the Rio Grande Basin, vertical displacements would be expected. However, lateral (including oblique) displacements also occur within the rift system.

Vail (unpublished geologic map, 1987) mapped a northeast-trending high-angle fault along the east flank of the Guadalupe Mountains. This fault appears to follow the west side of a linear, northeast-trending wash, now largely covered by the tailings behind Dam No. 4. The ash flow tuffs along the east flank of the mountain are moderately tilted along the fault line and, in places, unconformably overlain by Santa Fe Group or younger gravels. The Santa Fe volcanic sediments and the basalt unit south of Dam No. 4 lie east of the fault and appear to be

truncated by the structure. The ash flow tuffs may correlate with volcanics that are either the same age as the lower Santa Fe or older than the Santa Fe. This condition suggests that the fault block to the east has moved relatively downward.

In the Work Plan for the tailings pond facility study (SPRI, 1993), the linear, northeast-trending pattern of the ridge between Dam No. 1 and Dam No. 4 and of the wash to the east of the ridge was identified. The wash between MW-1 and MW-2 was postulated to follow a high-angle fault because of the apparent displacement of the volcanic unit in MW-1 relative to the sediments (at the same elevation) in MW-2 (Figure A2) and because of the linearity of the wash. Wells MW-8 and MW-7, drilled 1,500 feet to the north of MW-1 and MW-2, show a similar structural relationship confirming a linear structure extending northeast along the wash. The volcanics were not encountered in MW-9, drilled to elevations that are well below the level of the volcanics in MW-1. However, the volcanic unit does appear at deeper levels farther east in the lower part of private well P-4B and MW-10.

Cross-sections (Figure A2) indicate that a postulated northeast-trending fault may also extend beneath the ridge that divides Dam No. 1 and Dam No. 4. This structure is based on the difference in elevation between the basalt outcrop immediately east of the I-X building and the top of the volcanic unit in MW-1 (a difference of 157 feet), and the linearity of the ridge. However, at the I-X outcrop, Santa Fe gravels unconformably overlie the basalt, and the basalt ridge could be an erosional feature.

The volcanic sediments outcropping below Dam No. 4 and noted in several boreholes appear to be truncated by the basalt unit unconformably overlain by the Santa Fe Group immediately east of the I-X building. The volcanic sediments ($T_{svs}$ on Figure A1) were not observed in the exposures of the Santa Fe Group east of the I-X building. The apparent truncation of the stratigraphic units and the absence of the volcanic sediments are the basis for the fault shown east of the I-X building on the geologic map.

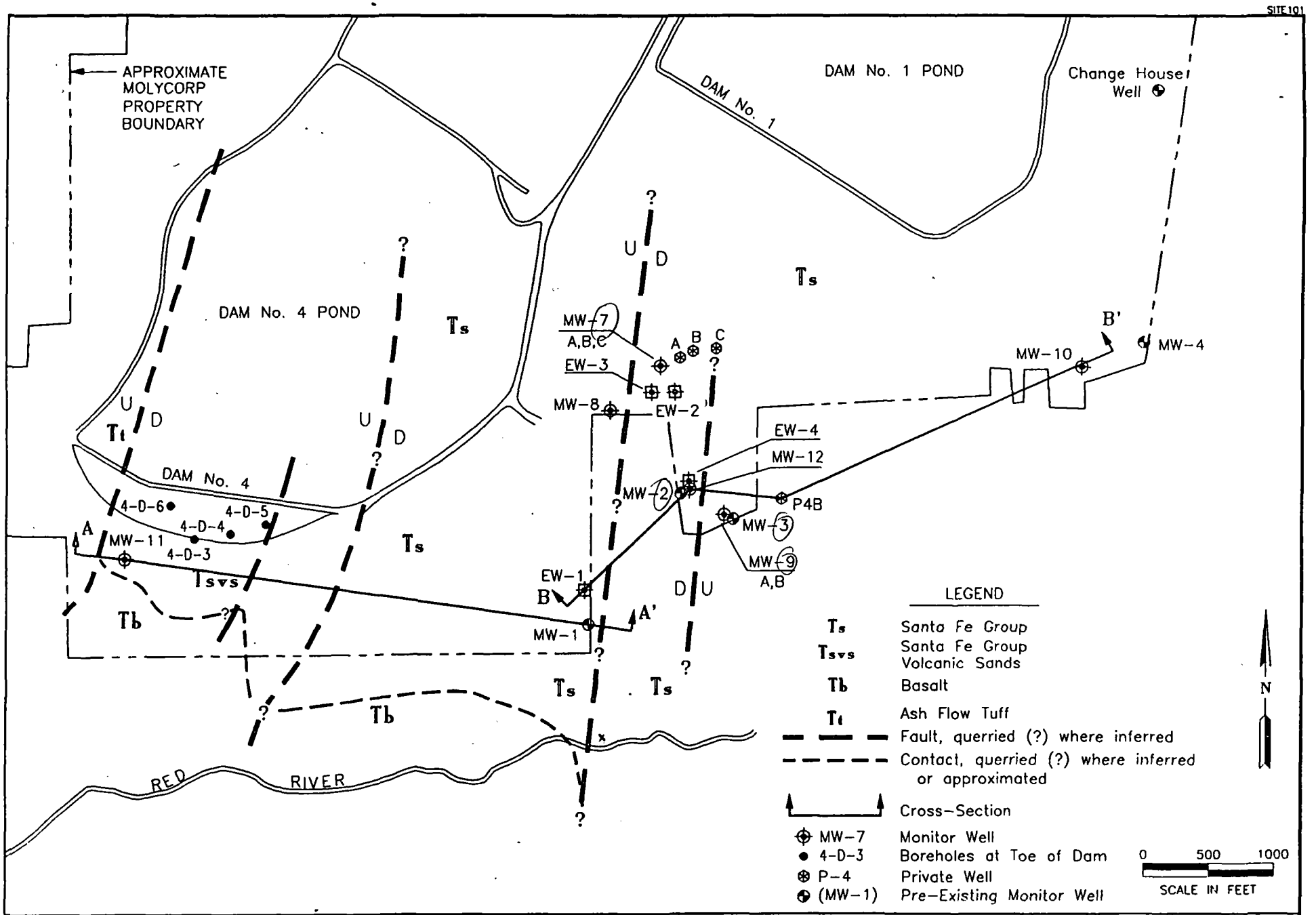
Given that both the outpouring of basalt flows and the deposition of the basin sediments occurred during the Rio Grande rifting, it is probable that the present stratigraphic and structural relationships are the result of a combination of faulting and contemporaneous erosional/sedimentation. The localized occurrence of the basaltic boulder clay south of Dam No. 1 suggests the possibility of mudflows contemporaneous with the development of fault topography. The maximum apparent displacement of the top of the basalt gravel between EW-1 and MW-12 is 125 feet. At this point, it is not known how much of this apparent displacement is tectonic and how much is erosional.

Both the borehole locations and the field exposures are in a narrow band along the front of Dam No. 1 and Dam No. 4. The geologic structure and the lithologic units, particularly the basalt unit, are believed to extend northward beneath the tailings ponds and southward at least to the Red River. Of geologic significance are:

1) the extension of the basalt unit in an east-west direction entirely beneath the tailings ponds is at fairly shallow depths;

2) a mudflow aquitard is present immediately above the regional volcanic aquifer south of Dam No. 1; and

3) the northeast-trending fault structures resulted in juxtaposed stratigraphic units that have different hydrogeological properties (for example: clay in fault contact with fractured basalt). These relationships can result in barriers to the regional flow systems.

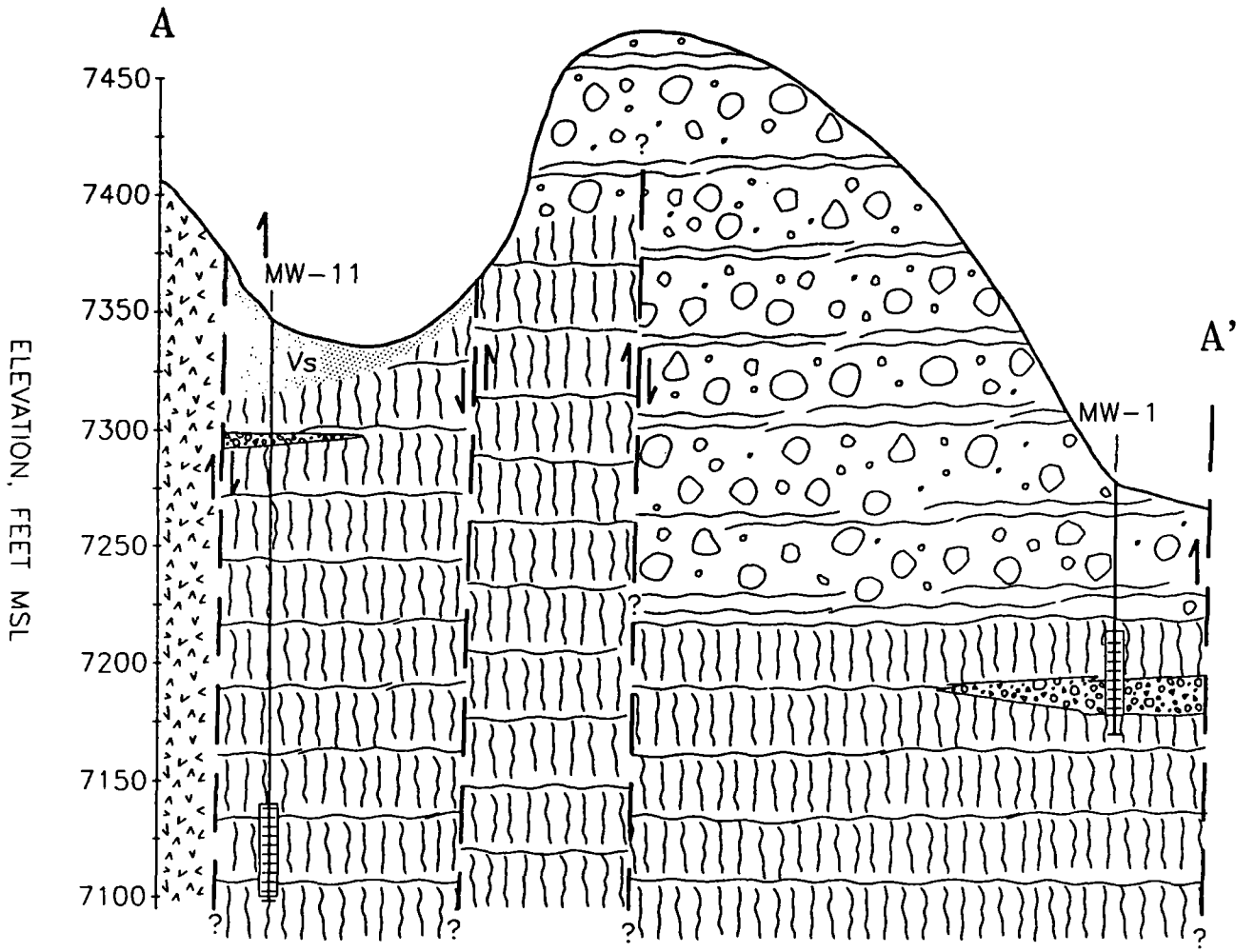



| FIGURE: A1 | SOUTH PASS RESOURCES, Inc. | | | |
|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. |

# GEOLOGIC MAP – TAILINGS AREA

Molycorp, Inc.
Questa, New Mexico

XSEC-6




EXPLANATION

- Santa Fe Group Undivided Alluvial Gravels, Sands & Clay
- Vs — Volcanic Sands
- Volcanic Tuff Unit
- Basalt Flows Volcanic Unit
- Gravels within Basalt Unit
- — — — Fault
- MW-1 — Monitor Well
- Screened Interval

HORIZONTAL SCALE IN FEET: 0 400 800

VERTICAL SCALE IN FEET: 0 50 100

FIGURE: A2

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# GEOLOGIC CROSS-SECTION A - A'

Tailings Area - Molycorp, Inc.
Questa, New Mexico

XSEC-9

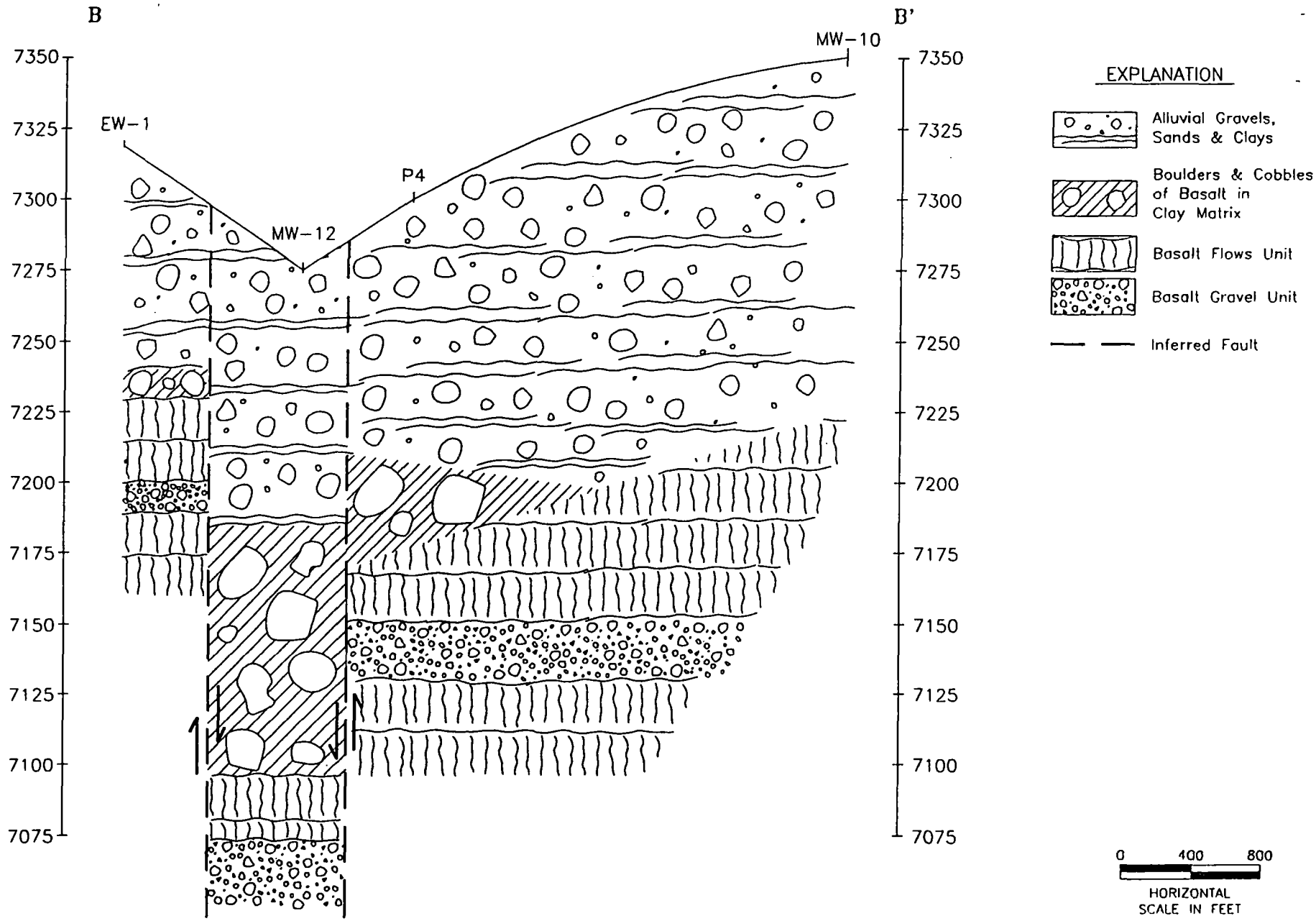



FIGURE: A3

SOUTH PASS RESOURCES, Inc.

GEOLOGIC CROSS-SECTION B-B' SOUTH OF DAM No. 1
Tailings Area - Molycorp, Inc.
Questa, New Mexico

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

APPENDIX B

# APPENDIX B

## Detail Of Tailings Area Hydrology And Hydrogeology

# APPENDIX B

## Detail Of Tailings Area Hydrology And Hydrogeology

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# APPENDIX B

## Detail Of Tailings Area Hydrology And Hydrogeology

## B.1 TAILINGS AREA HYDROLOGY

Molycorp currently has two earthfill tailings dams constructed across two arroyos: Dam No. 1 in the Section 36 arroyo, and Dam No. 4 in the Section 35 arroyo. The UAU of the Santa Fe Group (approximately 80 to 100 feet thick) underlies both dams. Below the UAU of Dam No. 1 are clays of the MAU. Beneath at least the toe area of Dam No. 4 are volcanic sandstone and conglomerate beds that are very thin (approximately 50 feet thick) and rest on the fractured basalt unit. The pre-dam arroyo beneath Dam No. 4 is broader, and the channel line is approximately 80 feet higher, than the pre-arroyo channel beneath Dam No. 1 (Questa and Guadalupe Mountain 7.5 Minute Quadrangle Maps, 1963). This condition is either the consequence of more erosionally resistant materiel beneath Dam No. 4 (volcanic sandstone and/or basalt) or a reflection of a longer and/or higher volume of discharge through the Dam No. 1 arroyo.

**Drainage of Decant Water**

The initial drainage of decant water at Dam No. 1 was carried by internal culverts directed to a still pond at the toe of the dam (elevation 7,290 feet) from which it flowed through a ditch southward to the Red River. Subsequently, the decant ponds were clarified upstream of the dam, and decant water was directed through a weir system to the west diversion ditch, to Pope Lake located just south of Dam No. 4, and eventually to the Red River. Since 1983, the decant at Pope Lake was processed at an ion exchange facility next to the lake prior to discharging to the Red River. Diversion ditches were constructed around both sides of the tailings ponds to divert all natural run-off away from the impounded tailings.

The drain system beneath both dams has evolved with time, but basically consists of chimney drains that connect at the base of the dam with blanket and finger drain underdrains (Molycorp engineering drawings). The lowest elevation for the underdrain at Dam No. 1 is about 7,320 feet and at Dam No. 4 is about 7,344 feet. These drains would rest on the UAU beneath Dam No. 1 and probably on the volcanic sandstone unit (based on pre-dam boring logs) at Dam No. 4.

Tailings material was delivered to the pond as a slurry (38 percent solids and 62 percent liquid). Sieve analyses of tailings material (Molycorp files) indicate a range of grain size distributions with median values in the medium to fine sand classes and a $<200$ mesh

fraction (silt and/or clay) that is less than 10 percent to as much as 50 percent of the sample. Slurry water that was not decanted or lost by evaporation infiltrated and was stored in the tailings material. The phreatic surface (top of saturated material) is monitored through a series of piezometers in the dam area and on the tailings surface. A comparison of the 1983 to the 1993 phreatic surface between Dam No. 1 and Dam No. 1C indicates a decline in head of about 19 feet (1.95 feet per year based on 9.75 years, or a rate of decline of 0.005 foot per day).

To monitor the fluid movement through the dams, Geocon (1983), the design engineers for the tailings dams, installed piezometers to measure the phreatic surface. Geocon used finite element code and water-level data from the piezometer in the vicinity of Dam No. 1 to model a flow net consisting of equipotential (equal head) lines and flow lines. On Geocon's flow net cross-section, the phreatic surface slopes south toward the upstream face of Dam No. 1 at a gradient of 0.07 foot/foot (ft/ft). [Note: the 1983 gradient and the SPRI (1993) reported gradient of 0.22 ft/ft are not comparable because the 1983 phreatic surface only extended to the upstream face of Dam No. 1 while the 1993 gradient includes both a piezometer point near the toe of the dam and the steeper gradient at the underdrain.]

The slope of the phreatic surface and the flow lines clearly show discharge to the underdrain system beneath Dam No. 1. The flow-line pattern also shows that flow is toward the bedrock base of the dam and that seepage is moving into the underlying UAU. In their modeling effort, Geocon used an "interpreted" rate of outflow (shown as vertical seepage on their drawing along the base of the tailings area) of 0.003 cubic feet per day per square foot ($ft^3/day/ft^2$) or 0.023 gallons per day per square foot ($gpd/ft^2$). If the rate of decline in head (based on the change in the elevation of the phreatic surface between 1983 and 1993 is converted from 0.005 ft/day to a vertical seepage, the result is 0.037 $gpd/ft^2$, in fairly good agreement with the modeling. This is an over simplification of the dewatering of the tailings material because there is a component of horizontal flow toward the underdrain system at Dam No. 1. In other words, the head decline behind Dam No. 1 is a function of seepage through the underdrain system (some of which seeps out along the surface) and seepage through the UAU along the base of the tailings material.

## B.2 DAM AREA HYDROGEOLOGY

As presented in Appendix A, the alluvial unit of the Santa Fe Group is a heterogeneous lithologic unit. Logs from borings drilled along the axis of Dam No. 1 prior to its construction (Dames and Moore, 1964) and from monitor wells (SPRI, 1993) indicate that the UAU contains silty clayey gravels with lenses of clay and of relatively clean sand and gravel. The driller's log for the Change House Well (located just east of Dam No. 1) indicates some bouldery material is present in the UAU. Since the source of most of the alluvial material is

from the Sangre de Cristo Mountains, the alluvial section would be coarser near the mountains and the clays would pinch out (Winograd, 1959).

The MAU is dominated by clay, but subordinate units of gravel and sand occur. The downward change to the LAU seems to be gradational with increasing amounts of gravel and sand over clay. The log for the Change House well shows some bouldery material at the top of the LAU. The three part division of the alluvial unit (UAU, MAU, and LAU) is modified with the addition of the bouldery clay (i.e. mudflow deposit) beneath the LAU.

Within the Santa Fe Group, lateral hydraulic conductivity is probably significantly higher than the vertical conductivity because of the relative low permeability clay beds. Seepage water (under an hydraulic head driven by mounding within the saturated tailings material) has preferentially migrated laterally along the tops of the clay beds to form shallow perched zones. Monitor wells A, B, and C near the toe of Dam No. 1 and monitor wells MW-7 and MW-9A record shallow water levels related to perched zones. MW-B is periodically dry, indicating the ephemeral nature of some of these perched zones. Seepage Barrier 003 along the east side of Dam No. 4 collects seepage from a perched zone in the UAU. At Seepage Barrier 002, much of the seepage is perched water related to the underdrain system beneath Dam No. 1. Head relationships, at least between the UAU and MAU, indicate a downward flow path. Seepage eventually reaches the water table, which currently is located in the UAU.

Prior to the construction of the tailings dam (pre-1965), some information is available on the subsurface units and depth-to-water for the private wells south of the Molycorp property and north of the Red River (well locations are at the ¼ and $^{1}/_{16}$ section level in the northwest and northeast quadrant of Section 1). The wells do not have measuring point elevations so they can not be used to calculate flow directions and gradients. Topographic contour data for well elevations and the approximate location on the Questa 7.5 minute map probably indicate that the shallow wells (less than 100 feet deep) are screened in the UAU/MAU units. The water-level elevations for these wells are very close to elevations along the channel of the Red River.

Geocon (1989), in their response to the New Mexico Environment Improvement Department's comments on the Guadalupe Mountain study, indicated that the original arroyo surface in the area of Dam No. 1 was typically wet with local springs and ponds. Whether this condition was related to perched water or the static water table is unknown. Winograd's (1959) water-level contour map indicates that the water table is close to the surface in this area, but acknowledges that the water levels used are a composite of water table, semi-perched, and artesian conditions. Long-time residents of the area recall cottonwood trees in the arroyo near the present dam and seepage water in one of the tributary arroyos. There are numerous springs in the fields along the north bank of the Red River. The pre-tailings dam

ground-water information indicates that saturated zones (perched?) were fairly close to the surface.

Two of the monitor wells constructed in 1993, MW-8 (replacement well screened in the basalt flow above the basalt gravel) and MW-9B (screened in the lower MAU or upper LAU) gave water-levels within a few feet of the bottom of the well. Subsequent water-level measurements (as recently as November 1994) have shown these two wells to be dry. In 1993, when MW-7 was drilled, several thin perched water zones were logged followed by a narrow interval described as dry clay in the MAU. At this point, the possibility of an unsaturated zone beneath a thick perched water zone involving the lower UAU and upper MAU became a possibility.

In September 1994, the results of a test performed at MW-9B confirmed that the formation opposite the MW-9B screen was unsaturated. Calculation of borehole volume, including an estimated 20 percent porosity for the gravel pack, indicated that 145 gallons of water would saturate the borehole below the seal at MW-9B. To test for the level of saturation, 250 gallons of water was added through the 2-inch piezometer at MW-9B. The 250 gallons was taken by the formation indicating a lack of saturation.

Resistivity logs for EW-2 and MW-12 (constructed in 1994), coupled with subsequent water-level measurements, also support the presence of an unsaturated interval in the MAU. At EW-2, the resistivity logs show two gravel zones (at 112 and 128 feet) in the lower MAU, both of which appeared to be water bearing (see Appendix C). The top of the main gravel zone (LAU) is at 148 feet. The open borehole gave a depth-to-water of 98 feet and that information, combined with the logs, led to the setting of screens for the two upper gravel zones and the main lower zone. When depth-to-water was measured at the time of well development, it had dropped to 150 feet and has stayed at that level. This occurrence suggests that although there was some perched water in the upper gravel, the water table is much deeper and is associated with the main gravel zone below 148 feet. Resistivity logs at MW-12 (Appendix C) show a sharp increase in resistivity in a gravel and clay interval between a depth of 89 to 114 feet, suggesting a thin unsaturated zone. This interval corresponds to part of the screened interval at MW-9B described above.

Figures B1, B2, and B3 are hydrogeological cross-sections illustrating the location of a perched zone involving the UAU and MAU and an underlying unsaturated zone, principally in the lower MAU. The cross-section along the west side of the Dam No. 1 arroyo (Figure B3) shows the unsaturated zone to be in the upper part of the basalt unit (above the basalt gravel). This is based on a limited amount of information taken from the drilling of the two wells at the MW-8 site. The original well was drilled across the basalt gravel which appeared to be saturated (open borehole data). Subsequent collapse of the casing resulted in the drilling of a replacement well which was screened in the basalt above the basalt gravel (to establish head

relationships between the two units). However, subsequent to an initial water-level reading in the lower part of the screened interval, MW-8B has been a dry well. (An open borehole depth-to-water of 132 feet below ground surface measured after 12 hours at MW-8A for the lower Santa Fe sediments probably reflects drilling fluid plus some shallow perched zone water and very slow leakage of the borehole fluids out into a clayey formations.) It does not appear that a permanent perched zone equivalent to the main perched zone occurs in the Santa Fe west of the fault zone.

The water levels at MW-1 and EW-1 are near the contact between the basalt and the overlying sediments. At MW-12, the water-level elevation is well above the contact. All three wells are screened in the basalt and the underlying basalt gravel unit. It is possible that the water level at these wells reflects a semi-confined condition for the basalt gravel and that some portion of the basalt above the gravel (as at MW-8B) is unsaturated. The upper 140 feet of the basalt unit at MW-11 is above the regional water table indicating that the regional piezometric surface lies below the contact between the Santa Fe and the basalt.

To summarize, there appears to be sufficient evidence drawn from lithologic and resistivity logs, water-level measurements, and one saturation test to demonstrate a thick perched ground-water zone in the lower UAU/upper MAU south of Dam No. 1. Borehole information from monitor wells west of the fault zone that extends along the west side of Dam No. 1 suggests that the main perched zone does not extend beyond the fault. Only shallow perched zones (e.g., Seepage Barrier 002) are known to occur in the Dam No. 4 area. The eastern extent of the main perched zone is not defined. The east-west extent of the zone is unknown. What happens to the perched zone south of the Molycorp property is also unknown. It may extend to the Red River or it may merge with the saturated LAU. With an upward gradient between the LAU and MAU (as shown by the MW-4 and MW-10 relationship), there would be no chemical impact on the deeper zone. Water-quality data for private wells (P-1 and P-8) and from field springs (Vail, 1993) suggest the perched zone may extend to the river.

Figures B1 and B2 illustrate the existence of several smaller perched zones above the main zone. These smaller zones were recognized when MW-7 was drilled in 1993 and by water-level measurements at piezometers MW-A, -B, and -C. Similar thin perched zones in the upper UAU are being tapped by Seepage Barrier 003 along the east side of Dam No. 4 and Seepage Barrier 002 south of EW-2 and -3. Figure B4 is a cross-section extending from the crest of Dam No. 1 southward to MW-7. It shows the April 1993 water-level surface across the dam and relates this surface to the shallow perched zone in front of the dam. The shallowest zone is probably related directly to the blanket/finger drain system beneath the dam. Water-level contours for these shallow perched zones are illustrated in Figure B5. The configuration of the perched water table for the shallowest zone reflect mounding beneath the dam and a steep gradient to the south (on the order 0.07 ft/ft). Just south of Dam No. 1,

depth-to-water increases from the shallowest perched zone to the main perched zone and across this zone to the deeper LAU. The vertical gradient across the alluvial unit is downward.

The water-level contour map for the main perched zone (Figure B6) is based on six water-level measurements. Three of the wells (MW-7A, EW-3, and EW-4) are screened in the basal sand/gravel unit of the UAU, and three of the wells are screened across the lower UAU and upper MAU. Although all of these wells are screened in the upper perched zone, they are not screened in the same interval within the zone and the depth-to-water may vary slightly as a function of screen location. The flow direction and hydraulic gradient are S57°W at 0.016 ft/ft, based on a three-point solution for EW-3, EW-4, and MW-7A. This gradient reflects the steepening of the hydraulic gradient south of Dam No. 1 and is probably related either to the lateral change in hydraulic conductivity or to a westward thinning of the perched zone.

Water-level contour maps were not drawn for the MAU or LAU because a sufficient number of wells have not been screened exclusively in these units. In the case of the LAU, both MW-7C and MW-10 are screened in sands and gravels just below the MAU. The relationship between the saturated LAU in these two wells and the underlying volcanic aquifer is not clearly defined. The third "LAU" well (EW-2) is in fact screened at a deeper level in a gravel unit now recognized as occurring with the bouldery clay unit beneath the LAU. The depth-to-water at EW-2 is significantly deeper and is more closely related to the underlying volcanic aquifer. Figure B7 illustrates this hydrologic relationship. The bouldery clay (mud flow deposit) fills a low area in the top of the basalt aquifer and, in that configuration, functions as a lense of low hydraulic conductivity material bounded laterally by higher conductivity rock. The gravel lense screened at EW-2 is confined within the clay lense, and its potentiometric level approximately corresponds to the potentiometric level associated with the adjacent volcanic aquifer. The relationship between saturated parts of the LAU and BAU and the underlying basalt east of MW-1 and EW-1 is not clear. It is possible that there is a continuous zone of saturation from the lower Santa Fe across the volcanic unit.

## B.3 AQUIFER TESTS

### B.3.1 Aquifer Test: Dam No. 1 Area

Aquifer tests were conducted in November 1994 in wells EW-2 and EW-3, and attempted in EW-4. The pumping rate at EW-4 was 5 gallons per minute (gpm) (at the lowest range of the pump), but suction was broken at or slightly before one borehole volume of water was discharged, and the testing at this well was terminated. However, successful tests were conducted at EW-2 and EW-3. Pump and Recovery test curves are included in Appendix E.

Well EW-2: This well is screened in a gravel unit enclosed within the bouldery clay deposit below the LAU. In the completed well, the depth-to-water was 151.05 feet. The pump intake was at 177 feet. The test was conducted over an 18-hour period at an average rate of 41.5 gpm. Earlier step tests at 35, 55, and 90 gpm drew water levels below (90 gpm) and close to (55 gpm) the pump intake. The thickness of the saturated interval screened at EW-2 is 30 feet (153 to 183 feet). The aquifer test results gave a transmissivity of 2,608.6 gpd/ft, which corresponds to a conductivity of 86.95 gpd/ft$^2$. The test was conducted over a period of 10 hours. However, after 15 minutes the drawdown curve flattened out and water levels actually rose slightly during a period of 50 to 90 minutes (Appendix E) indicating that recharge was occurring. The results for transmissivity and conductivity from the aquifer test are probably too low because of the recharge and are much lower than the recovery values. The recovery test for EW-2 lasted for 14 hours. The transmissivity value is 27,390 gpd/ft, which corresponds to a hydraulic conductivity of 913 gpd/ft$^2$. Recovery was very rapid for the first four minutes, but then settled down to a more gradual rate for the balance of the recovery period (Appendix E).

Water-level changes at MW-7C were monitored during the aquifer test at EW-2. At the time of the aquifer tests, several storm fronts passed through the area. Water levels in MW-7C fluctuated over a range of 3.2 inches. Because EW-2 was screened in a confined gravel lense below the LAU and because MW-7C was screened at the top of the LAU, these measured water-level fluctuations were likely the result of barometric changes.

Well EW-3: The aquifer test at EW-3 was the most successful of the three wells tested. EW-3 is screened in a sandy gravel at the base of the UAU (screened from 67 to 77 feet). The pump intake was at 75 feet. A step test at 15 gpm pulled water levels below the pump intake, but 12 gpm kept the water level above the intake and drawdown leveled at 72 feet. However, at these low yields, the pump rate could not be set precisely, and the test was conducted at 7 to 8 gpm (average of 7.5 gpm). The pump test was conducted for 100 minutes and resulted in a calculated transmissivity value of 4,400 gpd/ft which is a conductivity value of 440.0 gpd/ft$^2$. The recovery test, conducted over a 16-hour period, resulted in a transmissivity value of 2,200 gpd/ft (a conductivity value of 220 gpd/ft$^2$).

During the aquifer test of EW-3, water-level changes in MW-7A were monitored. Well MW-7A is located 210 feet north of EW-3 and is screened in the same lower sandy gravel of the UAU. Drawdown at MW-7A was 1.21 feet during the aquifer test of EW-3. The recovery curve for MW-7A resulted in a transmissivity value of 2,475 gpd/ft (a conductivity value of 247.5 gpd/ft$^2$), which is in very close agreement with results at EW-3.

The recovery results at EW-2 and EW-3 are probably more representative of aquifer transmissivity than the aquifer tests. A combination of well storage followed shortly by recharge effects strongly impacted the curves.

The hydraulic conductivity values from the EW-2 and EW-3 tests are compatible with standard textbook values for clean sands and gravels. Estimates of hydraulic conductivity were made from laboratory measurements on samples taken from the MAU during the drilling of MW-9 (SPRI, 1993). These measurements are for saturated vertical hydraulic conductivity (kv), which is lower than the horizontal kv measured from pump tests by a factor of 10 or more. The laboratory values for conductivity range from 0.01056 gpd/ft$^2$ to 73.3 gpd/ft$^2$. Using a factor of 10, the upper kv values would be in the range of the aquifer test results.

### B.3.2 Aquifer Test: Dam No. 4 Area

Monitor well MW-11 is located just east of the fault zone that runs along the western edge of Dam No. 4 and south of the toe of the dam. The well is screened in the basalt unit (from 207 to 247 feet). Aquifer tests conducted at the well resulted in hydraulic conductivities in the range of 6,833 gpd/ft$^2$ (specific capacity calculation) to 14,103 gpd/ft$^2$ (recovery test ). Dames and Moore (1986) calculated a hydraulic conductivity of 2,400 ft/day (17,952 gpd/ft$^2$) from an aquifer test conducted in volcanics at test well GM-5. These values are all well within the published values for permeable basalts (Freeze and Cherry, 1969).

The flow direction ranges from S20°W to S75°W, based on three-point solutions for water-level elevations in the volcanic aquifer [Dames and Moore (1986), SPRI (1993, 1994)] and on a potentiometric map for this aquifer (Winograd, 1959). Differences probably result from combining water levels from different flow paths or localized controls on flowage; nevertheless, a southwesterly flow direction seems to be well established. Three-point solutions for hydraulic gradients range from 0.003 ft/ft to 0.1 ft/ft. Steeper gradients result from localized discharge conditions (such as along a permeable fault zone) or lateral changes in hydraulic conductivity (K) caused by juxtaposing a low K unit down-gradient from a higher K unit. The deep water level at MW-11 may be related to discharge along a fault zone on the west side of Dam No. 4.

The elevation of the Red River at a point 180 feet south of MW-11 lies between the 7,160- and 7,200-foot contours (Guadalupe Mountain 7.5 minute Quadrangle map). The static water level at MW-11 is at 7,152.73 feet, slightly lower than the river. MW-1, also screened in the volcanic unit, has a water-level elevation of 7,228 feet—slightly higher than river level. For the segment of the Red River between Big Springs and Pope Lake, the water table in the volcanic unit appears to be just above river level. In the vicinity of Pope Lake, across the fault zone, there may be some ground-water discharge into the fractured volcanics. The water table gradients probably steepen slightly, bringing the static water level below river level.

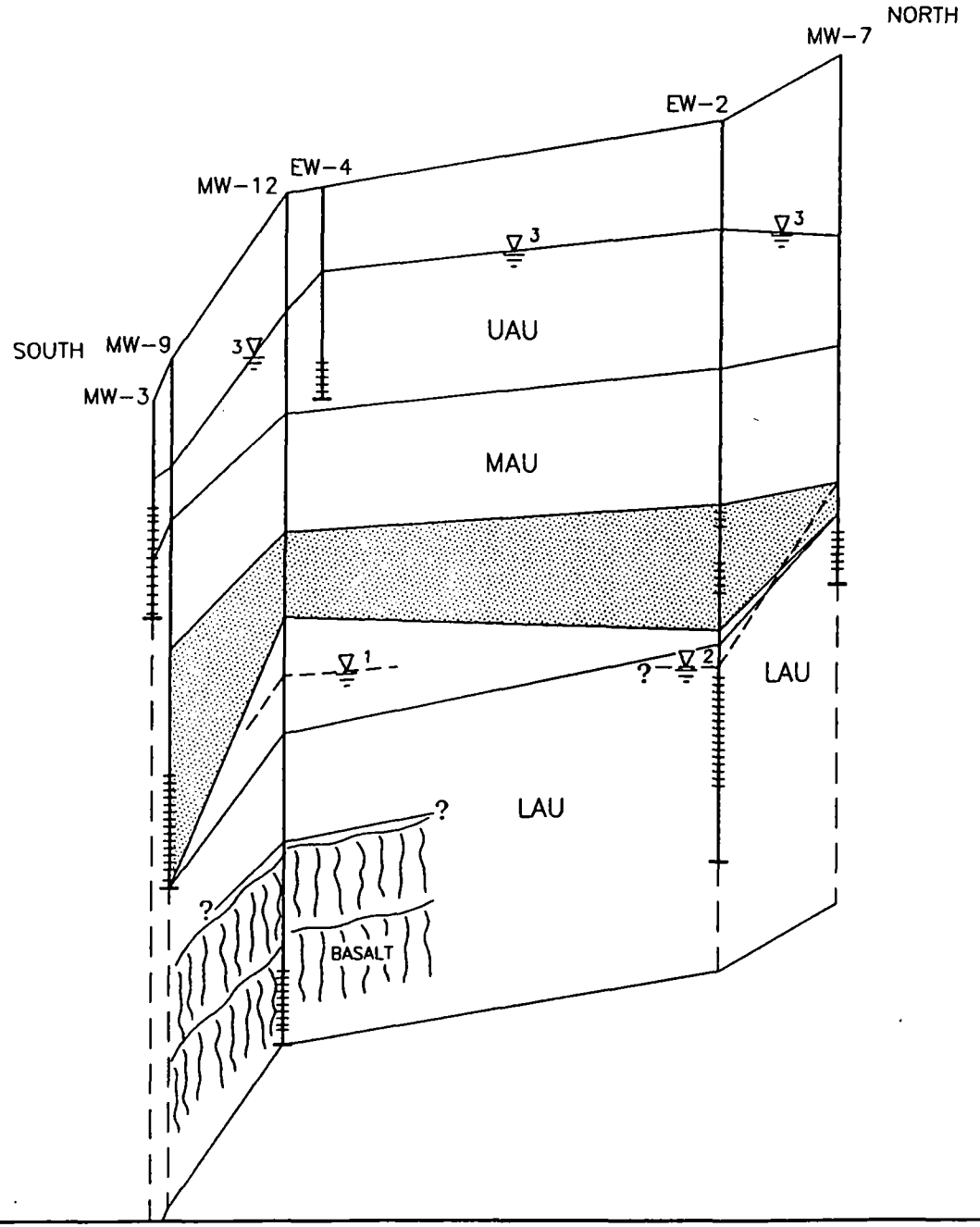
Since the river elevation is higher than the water table, there probably is some recharge or loss of flow from the river (but not enough to impact the overall gain recorded by stream gauges). Note that Winograd's (1959) water-level contour map shows a steepening as the gradient across the same area. In the Red River Gorge, the river has steepened its gradient and, at some point, river elevations are below the water table. The point when the water table in the volcanic unit rises above river level probably lies between the Pope Lake area and the Fish Hatchery.

Figure B8 is a water-level contour map for the volcanic aquifer across the front of Dam No. 1 and Dam No. 4. The contour pattern in the vicinity of the Dam No. 1 arroyo shows a ground-water high related to the top of the fault block (on terrace surface) defined by MW-1, EW-1, and MW-8. The structural depression shows a ground-water low (MW-12). The water-level elevation contours mimic the changes in elevation of the top of the basalt. The more southerly flow direction and the steeper gradient (as compared to regional flow) calculated with a three-point solution probably is influenced by the discharge effect at the fault zone near Pope Lake. With the exception of MW-11, there are no subsurface data points for the basalt west of EW-1/ MW-1.

The depth-to-water at MW-11 is 191.93 feet resulting in a water-level elevation of 7,152.73 feet. Well MW-11 is about 200 feet south of the toe of Dam No. 4. It appears that the unsaturated zone below the dam is on the order of 190 feet in thickness (50 feet of Santa Fe Group alluvial material and 140 feet of variable permeable basalt). Drilling history at MW-8A and -8B, combined with the fact that MW-8B (screened in the top of the basalt above the basalt gravel) is dry, indicates that the top of the basalt is unsaturated below Dam No. 4. The water levels at the contact between the basalt and Santa Fe Group at MW-1 and EW-1 probably result from confining conditions for the basalt gravel unit (screened by both wells), and the top of the basalt may be unsaturated here as well. Perched zones above the basalt were not detected in the alluvial sediments above the basalt at MW-11 or EW-1. Seepage from stratigraphic levels above EW-1 is collected at Seepage Barrier 002 along the southeast side of Dam No. 4.

Winograd (1959) indicated downward (vertical) gradient between the overlying alluvial material and the basalt aquifer. Water-levels for the basalt aquifer are considerably below the top of the basalt (MW-11), at or slightly above the basalt/alluvial contact (MW-1 and EW-1), or significantly above that contact (50 feet higher at MW-12). The latter may reflect semi-confined conditions associated with the basalt gravel unit within the volcanic aquifer or, more likely, semi-confined conditions created by the boulder clay unit overlying saturated basalt (i.e., saturation may be continuous across the lower Santa Fe and the basalt unit east of the fault zone that extends along the west side of Dam No. 1).

XSEC-1




EXPLANATION

1 WATER-LEVEL, BASALT UNIT

2 LAU WATER TABLE

3 TOP OF MAIN UAU PERCHED ZONE WATER TABLE

UNSATURATED INTERVAL

SCREENED INTERVAL

0 150 300
HORIZONTAL SCALE IN FEET

0 25 50
VERTICAL SCALE IN FEET

See Figure 2 (Main text) for Location of Wells

FIGURE: B1

SOUTH PASS RESOURCES, Inc.

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|---|---|---|---|
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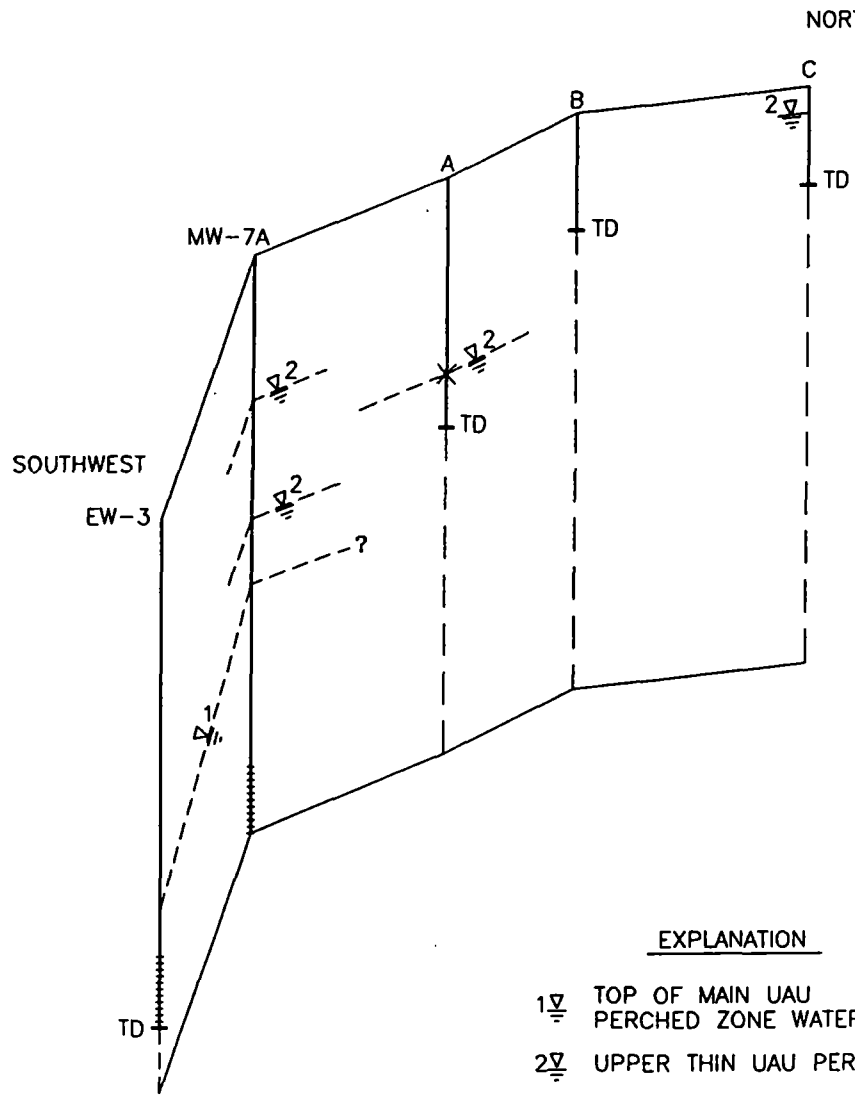
# SOUTH TO NORTH HYDROGEOLOGIC CROSS-SECTION

Tailings Area - Molycorp, Inc.
Questa, New Mexico

XSEC-12




EXPLANATION

1 TOP OF MAIN UAU PERCHED ZONE WATER TABLE

2 UPPER THIN UAU PERCHED ZONES

SCREENED INTERVAL

0 25 50
VERTICAL SCALE IN FEET

0 75 150
HORIZONTAL SCALE IN FEET

FIGURE: B2

SOUTH PASS RESOURCES, Inc.

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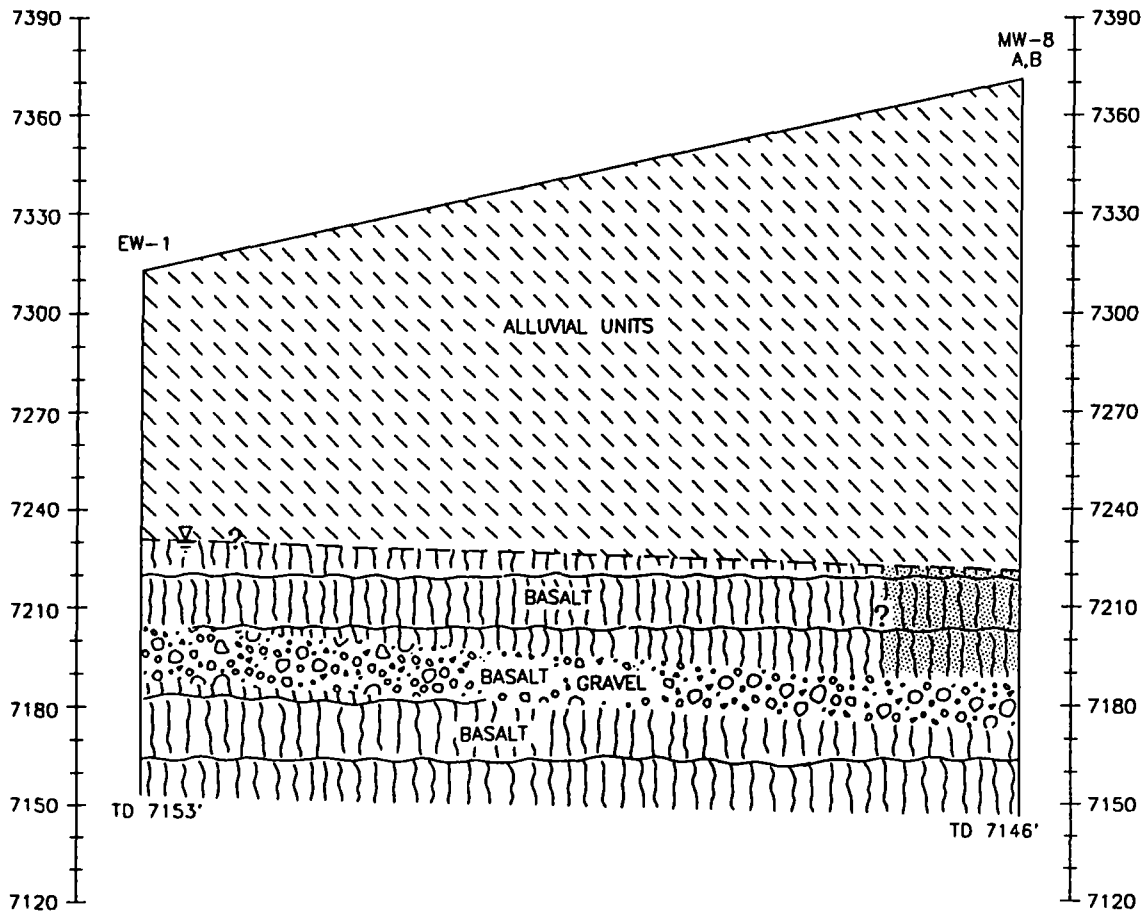
# SOUTHWEST TO NORTHEAST HYDROGEOLOGIC CROSS-SECTION

Tailings Area – Molycorp, Inc., Questa, New Mexico




EXPLANATION

Alluvial units include the upper and lower aquifers and the Middle Aquitard.

MW-8A,B:
A is the original borehole drilled to 225 feet. B is the replacement borehole drilled to 185 feet.

— ▽ — Potentiometric surface for the volcanic unit where screened intervals include basalt gravel at EW-1 and MW-1.

Unsaturated Zone in the upper part of the volcanic unit above the basalt gravel at MW-8B. May include basalt above gravel at EW-1 and MW-1.

0 30 60
VERTICAL SCALE IN FEET

0 150 300
HORIZONTAL SCALE IN FEET

FIGURE: B3

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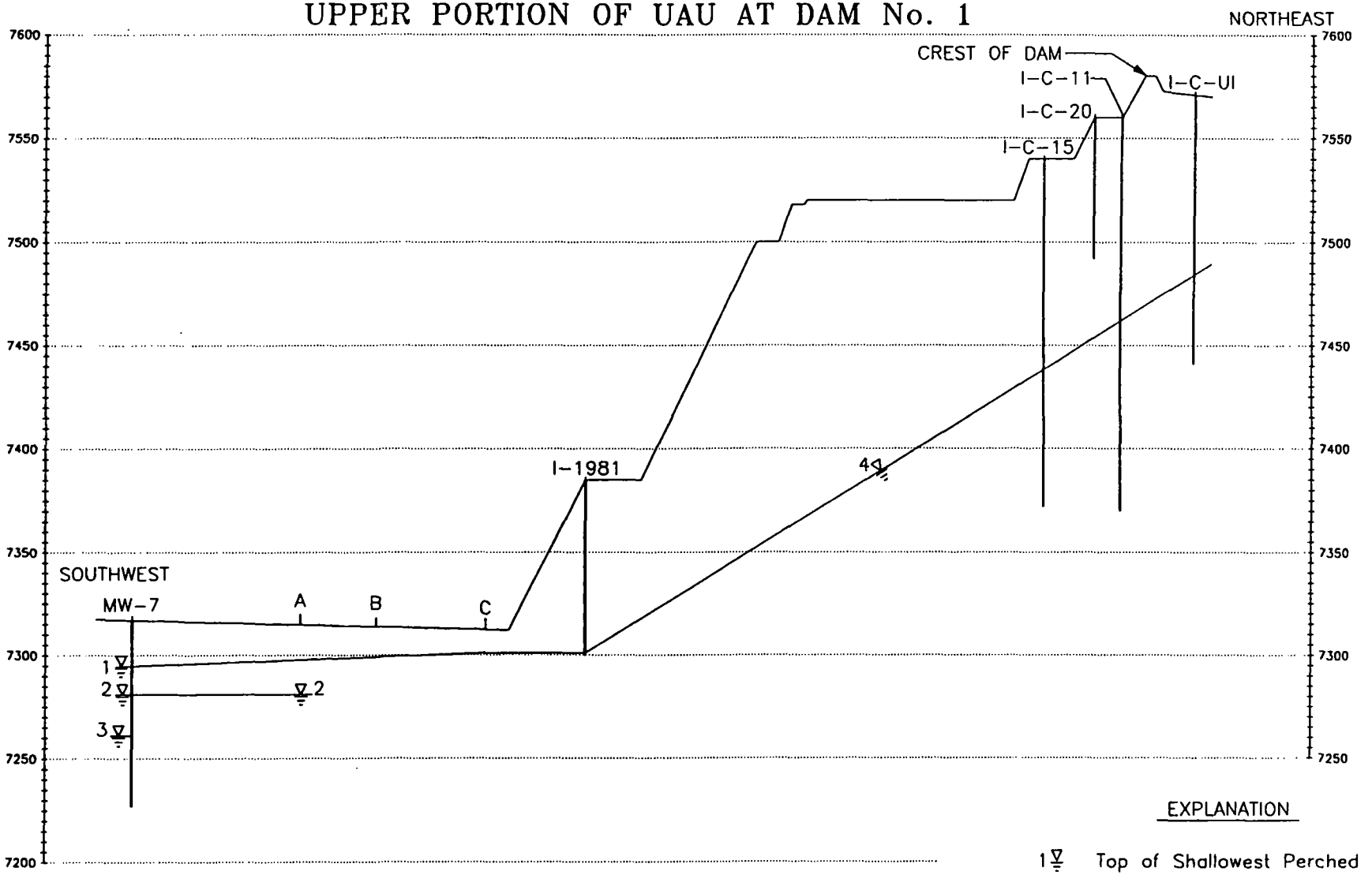
# HYDROGEOLOGIC CROSS-SECTION WEST OF DAM No. 1

Tailings Area - Molycorp, Inc.
Questa, New Mexico

XSEC-15

# UPPER PORTION OF UAU AT DAM No. 1




0 37.5 75
VERTICAL SCALE IN FEET

0 150 300
HORIZONTAL SCALE IN FEET

EXPLANATION

| | |
|---|---|
| 1 ▽ | Top of Shallowest Perched Zone |
| 2 ▽ | Top of Intermediate Perched Zone |
| 3 ▽ | Top of Main Perched Zone |
| 4 ▽ | Water Level in Tailings Dam |
| A,B,C | Piezometers projected into line of section |

FIGURE: **B4**

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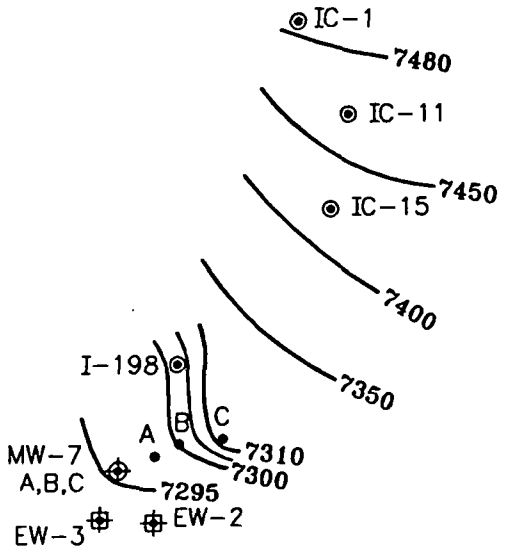
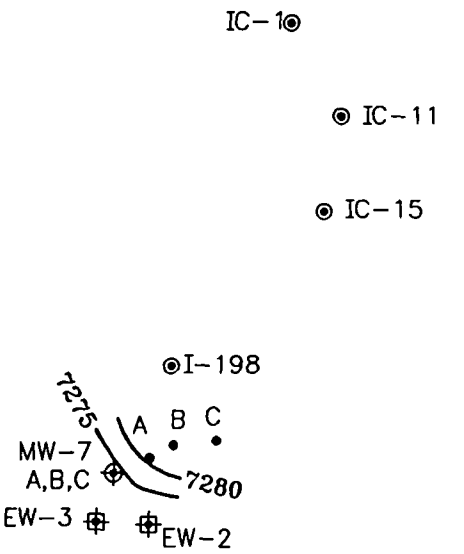
## WATER LEVELS FOR PERCHED ZONES (APRIL 1993)

Tailings Area - Molycorp, Inc.
Questa, New Mexico




SHALLOWEST
PERCHED ZONE




INTERMEDIATE
PERCHED ZONE

EXPLANATION

| | |
|---|---|
| —7300— | Water-Level Elevation |
| EW-1 | Extraction Well Location |
| MW-1 | Monitor Well Location |
| • A | Shallow Piezometer |

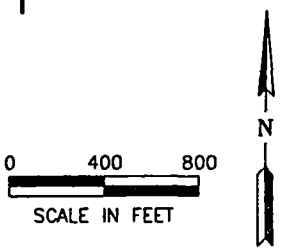



FIGURE: B5

SOUTH PASS RESOURCES, Inc.

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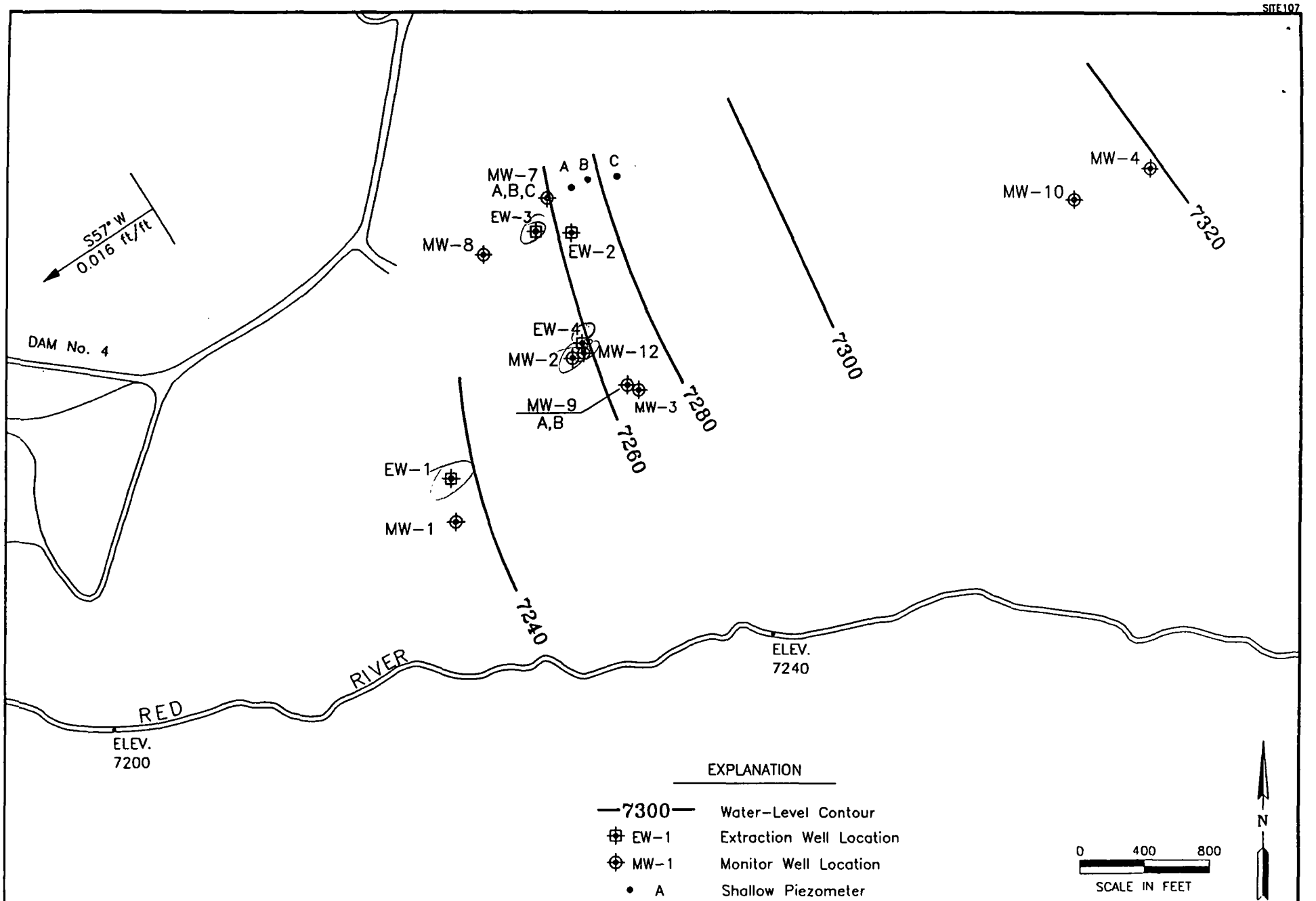
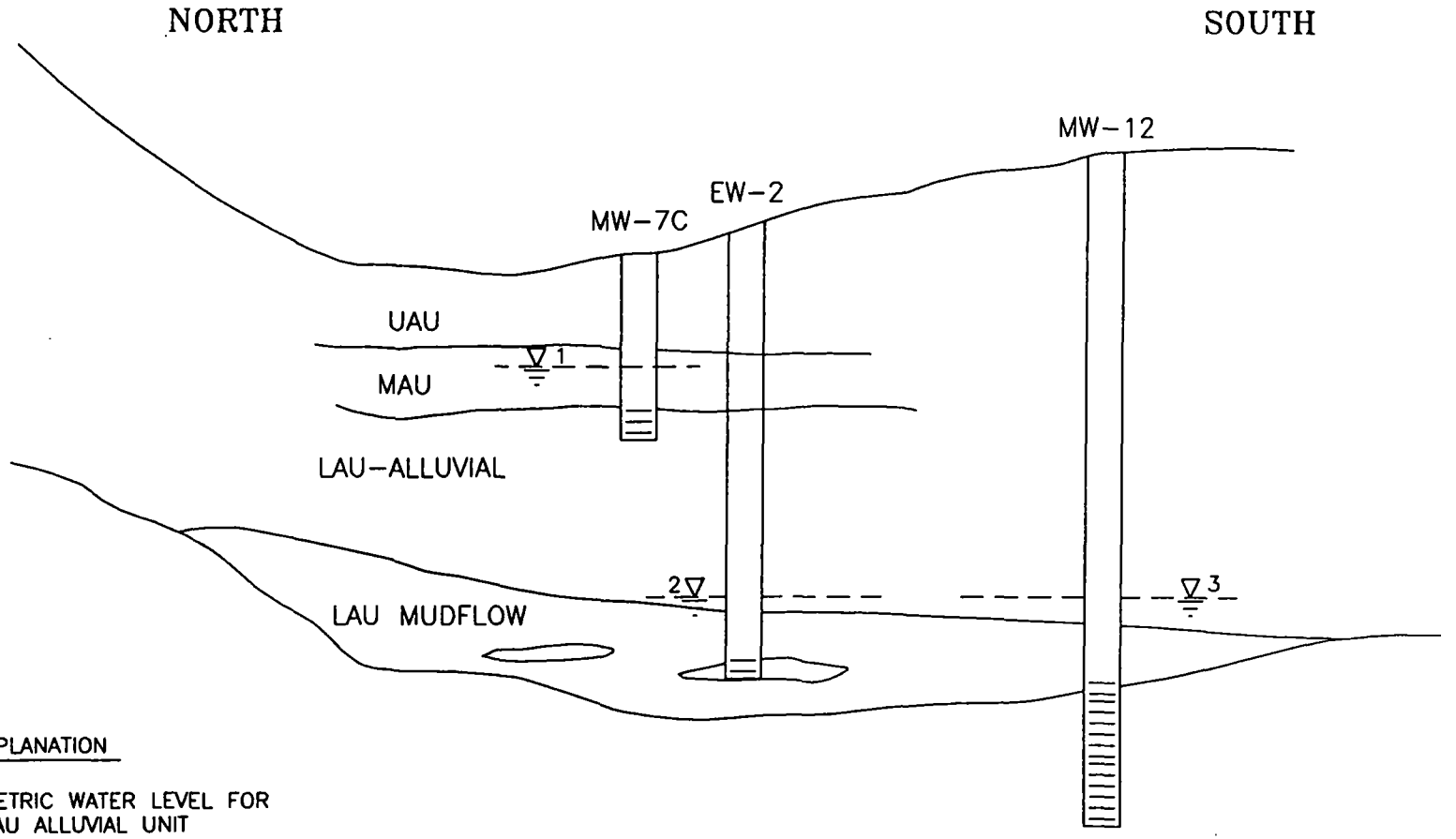
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

WATER-LEVEL CONTOURS OF THE
UAU SHALLOW AND INTERMEDIATE PERCHED ZONES
Tailings Area – Molycorp, Inc., Questa, New Mexico




| FIGURE: B6 | SOUTH PASS RESOURCES, Inc. | | | | WATER-LEVEL CONTOURS OF THE UAU PERCHED ZONE<br>Tailings Area - Molycorp, Inc.<br>Questa, New Mexico |
|---|---|---|---|---|---|
| | PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | |

XSEC-14




EXPLANATION

- 1 POTENTIOMETRIC WATER LEVEL FOR UPPER LAU ALLUVIAL UNIT
- 2 POTENTIOMETRIC WATER LEVEL FOR GRAVEL IN LAU MUDFLOW UNIT
- 3 POTENTIOMETRIC WATER LEVEL FOR VOLCANIC UNIT

# POTENTIOMETRIC WATER-LEVELS FOR THE LAU AND VOLCANIC UNITS

NOT TO SCALE

| FIGURE: | | | | | |
|---|---|---|---|---|---|
| B7 | SOUTH PASS RESOURCES, Inc. | | | | POTENTIOMETRIC WATER-LEVEL RELATIONSHIPS<br>Tailings Area - Molycorp, Inc.<br>Questa, New Mexico |
| | PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | |

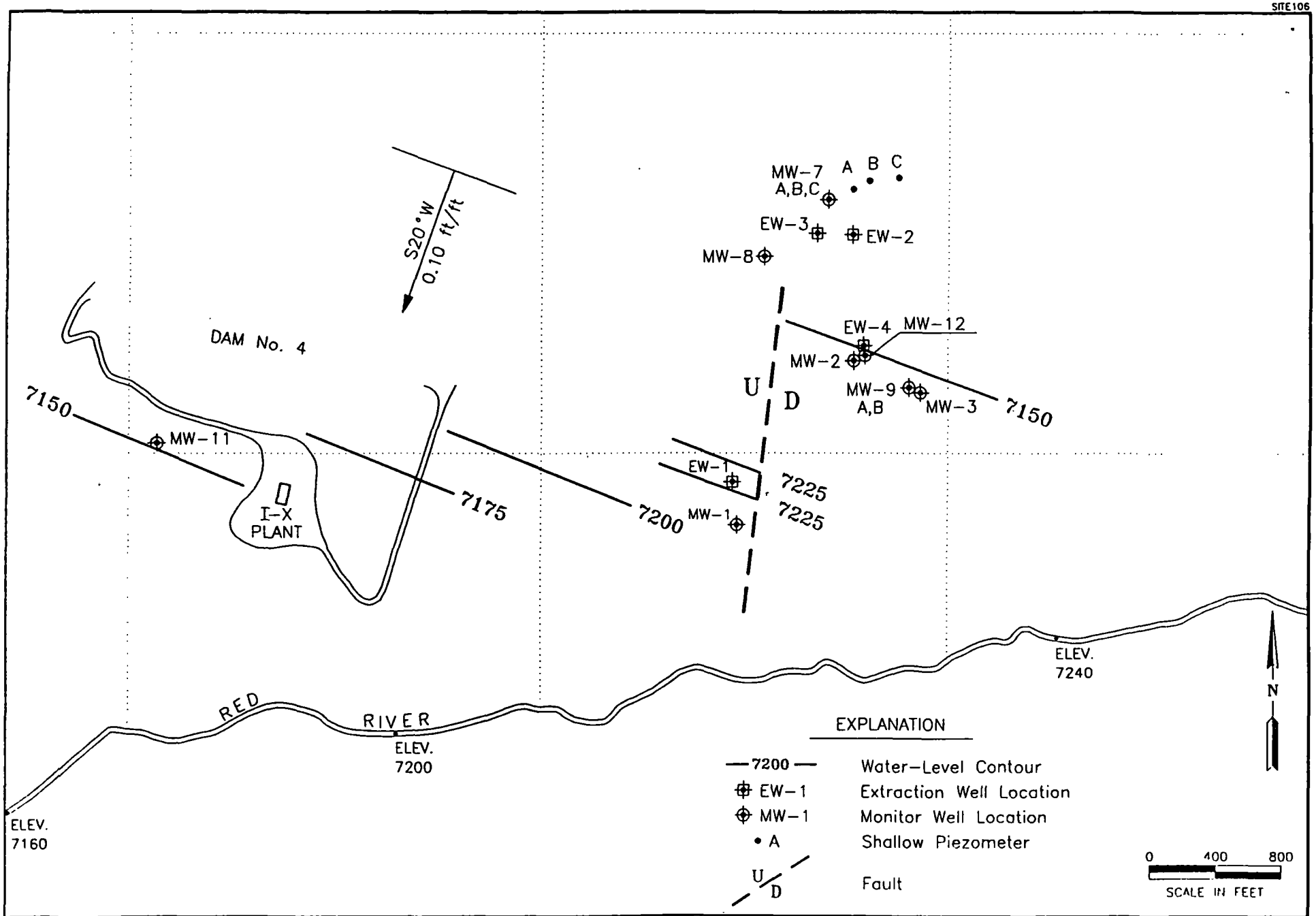



FIGURE: B8

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

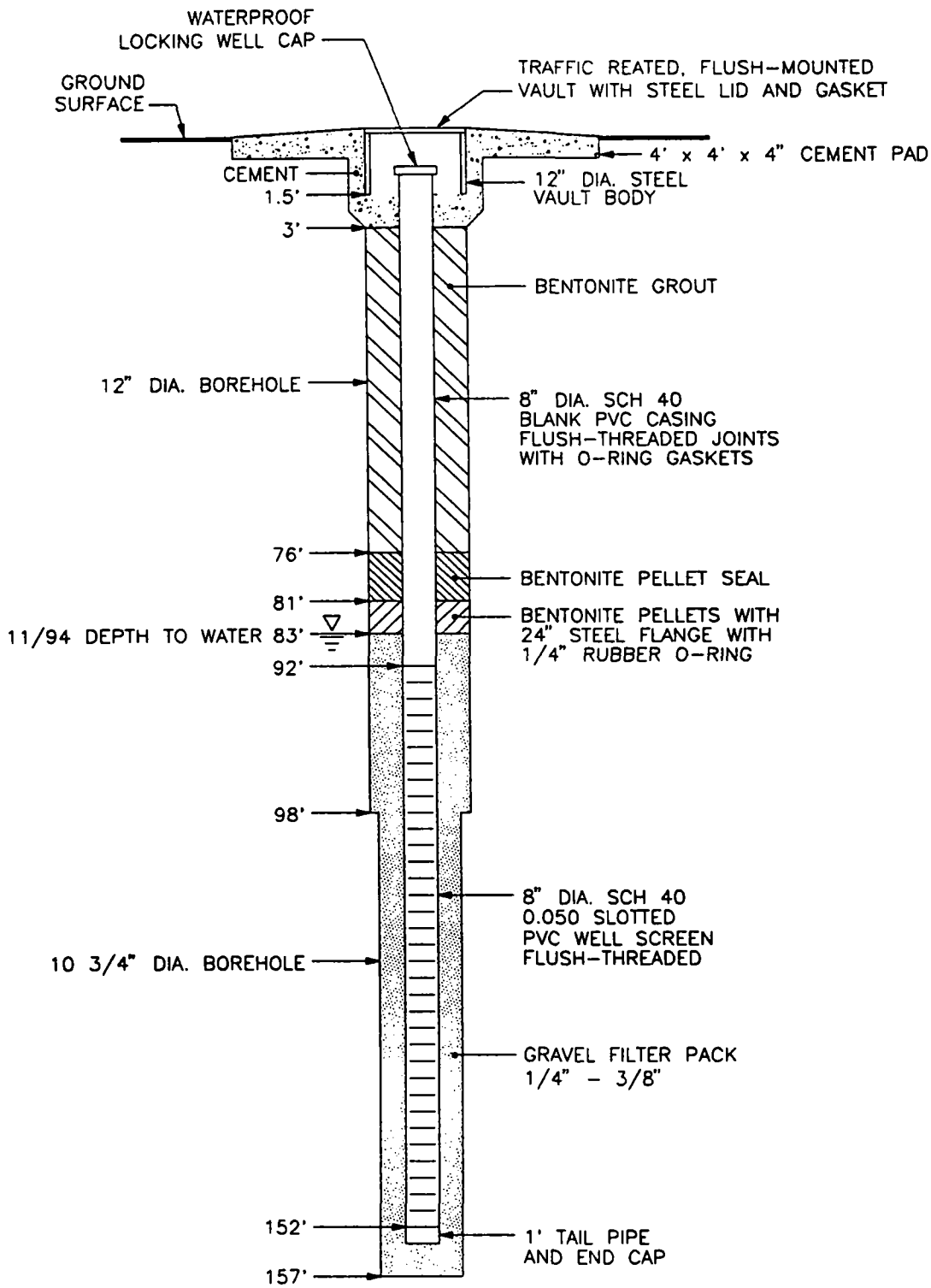
# WATER-TABLE CONTOURS OF BASALT AQUIFER (11/94)

Tailings Area - Molycorp, Inc.
Questa, New Mexico

APPENDIX C

# APPENDIX C

## Tailings Area Borehole and Geophysical Logs (from Fall 1994 Field Investigation)

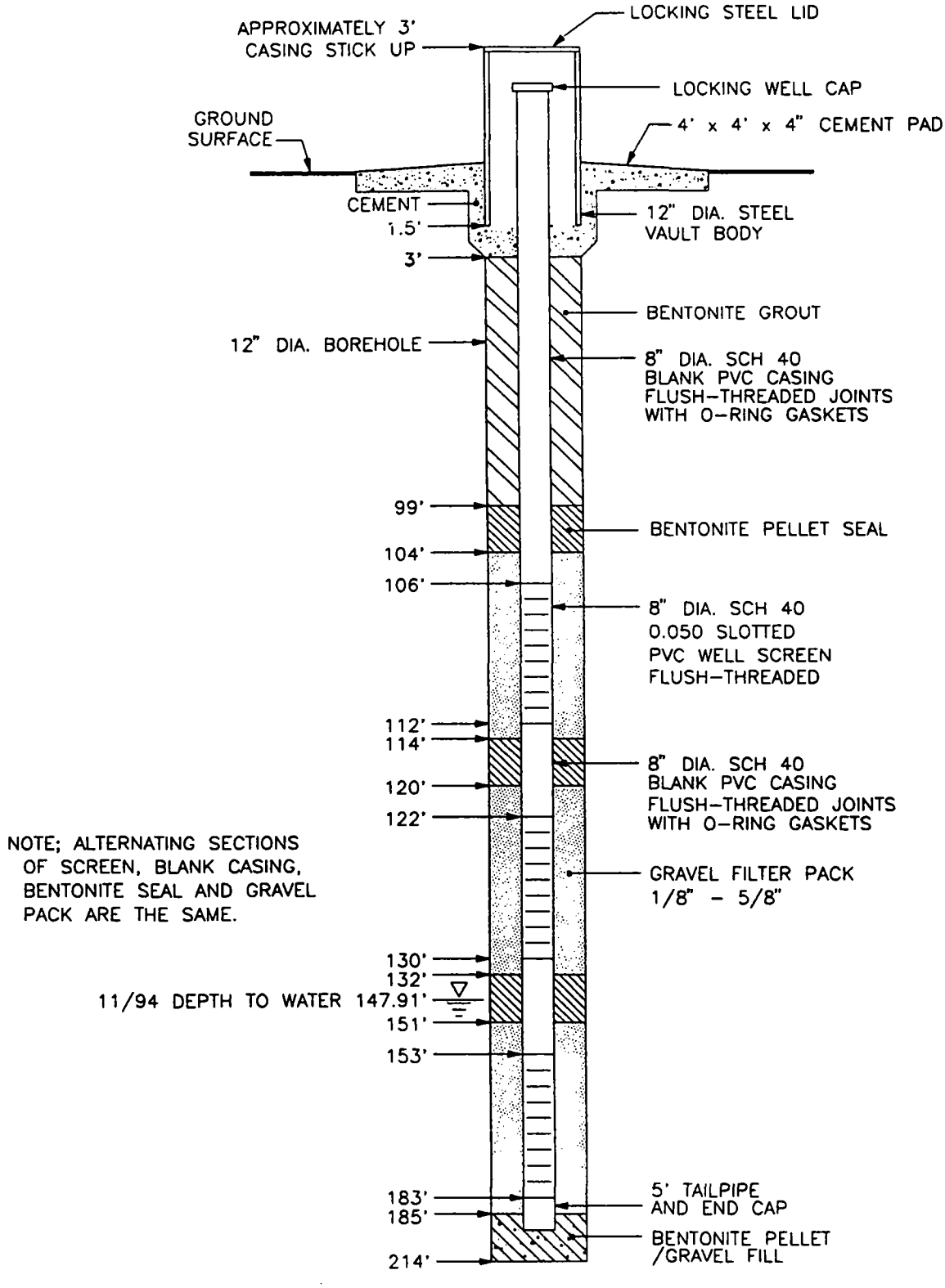



NOT TO SCALE

SCHEMATIC OF WELL CONSTRUCTION

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL EW-1<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C1 |
|---|---|---|---|---|---|
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

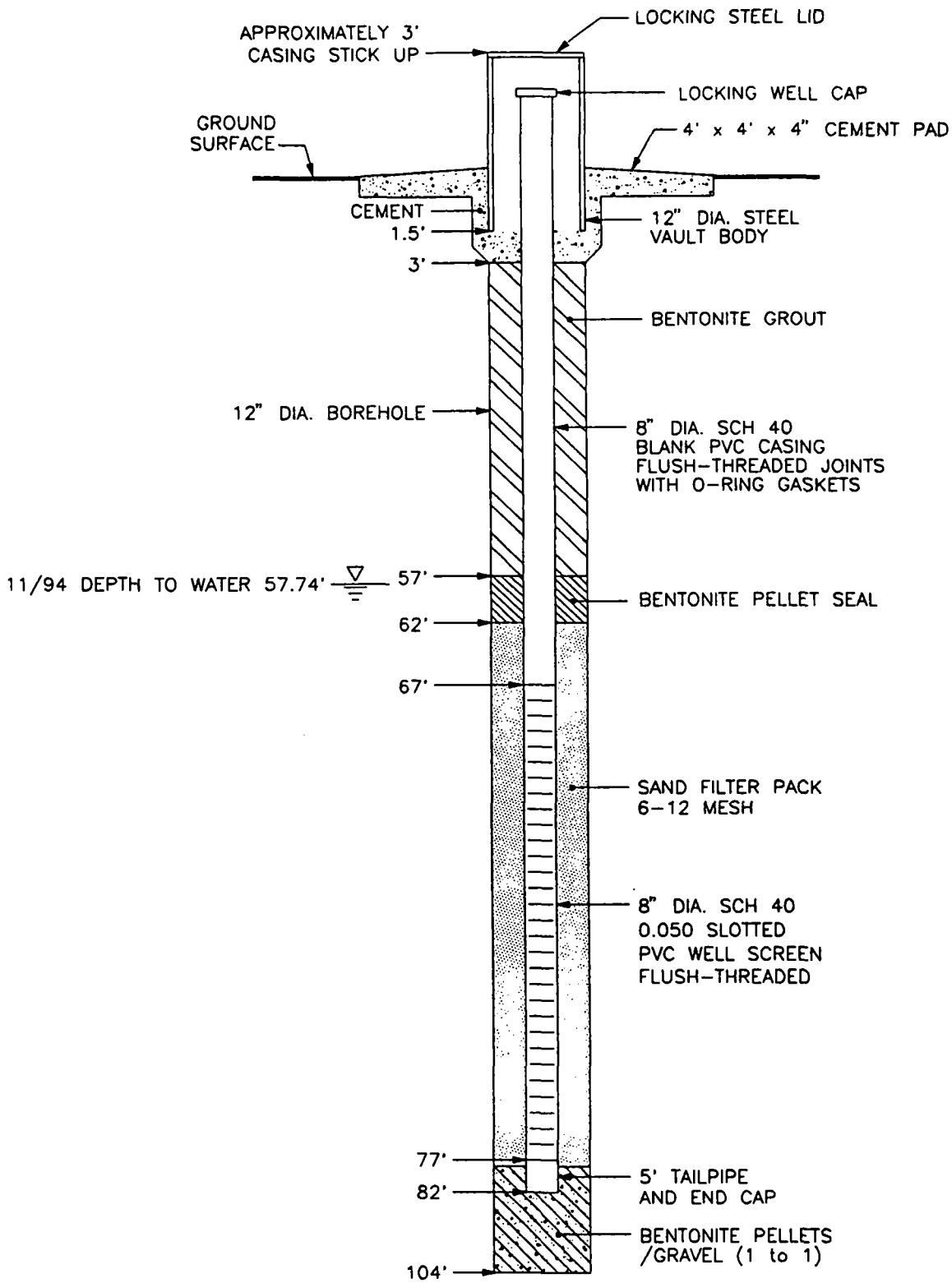
EW-2




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL EW-2<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE:<br>C2 |
|---|---|---|---|---|---|
| PROJECT No.:<br>001-05 | DATE:<br>2/15/95 | AUTHOR: | DRAWN BY:<br>M.O'M. | | |

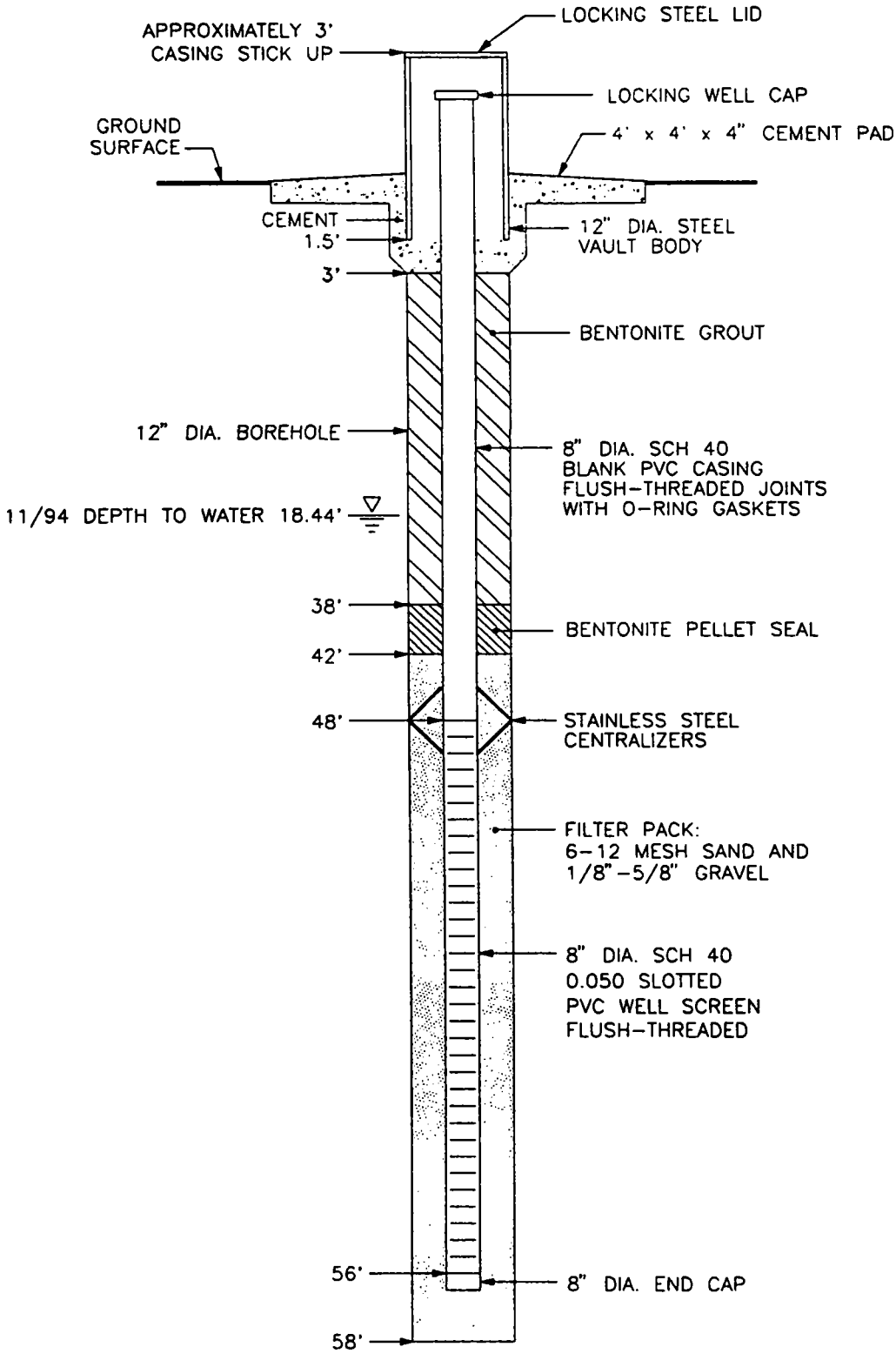



SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL EW-3<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C3 |
|---|---|---|---|---|---|
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

EW-4

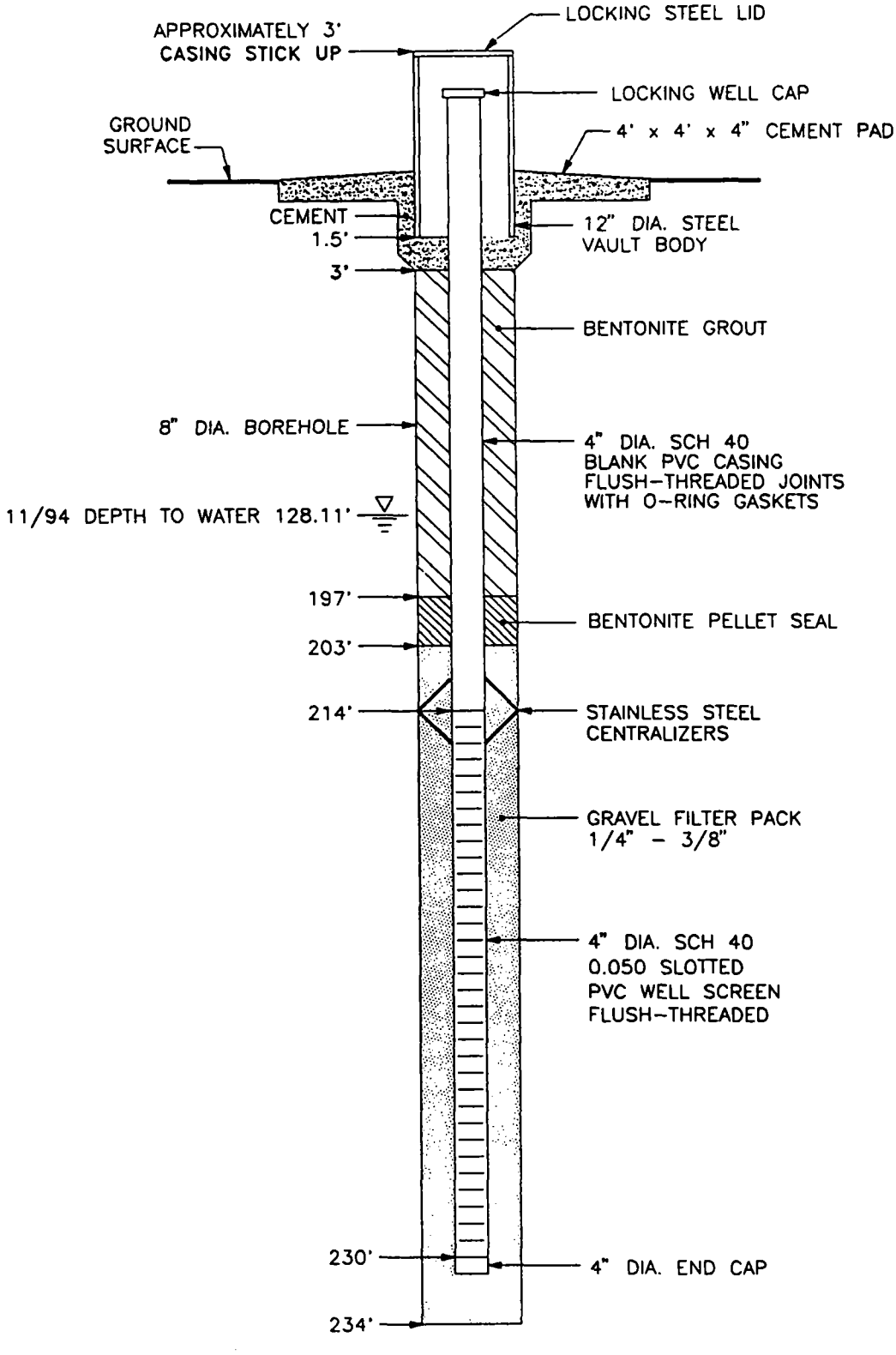



SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL EW-4<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C4 |
|---|---|---|---|---|---|
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR | DRAWN BY: M.O'M. | | |

MW-12




SCHEMATIC OF WELL CONSTRUCTION

NOT TO SCALE

| SOUTH PASS RESOURCES, Inc. | | | | MONITOR WELL MW-12<br>Molycorp, Inc.<br>Questa, New Mexico | FIGURE: C5 |
|---|---|---|---|---|---|
| PROJECT No.: 001-05 | DATE: 2/15/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0 | | | CL | BROWN GRAVELLY SILTY CLAY<br>10% fine to coarse gravel, clasts of andesite, light-colored volcanic. |
| | | | 5 | | | | |
| | | | 10 | | | | |
| | | | 15 | | | | silty sandy gravelly clay |
| | | | 20 | | | | |
| | | | 25 | | | | |
| | | | 30 | | | | |
| | | | 35 | | | | |
| | | | 40 | | | | |
| | | | 45 | | | | |
| | | | 50 | | | | |
| | | | 55 | | | | |
| | | | 60 | | | | |
| | | | 65 | | | | |
| | | | 70 | | | | |
| | | | | | | SP | SAND<br>fine-grained, calcium carbonate (?) cement. |
| | | | 75 | | | GC | BROWN CLAYEY GRAVEL<br>clasts of vesicular black basalt. |
| | | | 80 | | | | |

DRILL DATE
START: 8/28/94 FINISH: 9/6/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. EW-1<br>Molycorp<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/13/95 | | C6 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| | | | 85 | | | Rock | BASALT<br>bedrock contact, black vesicular basalt, opal in some vesicules cuttings up to 1 inch. |
| | | | 90 | | | | |
| | | | 95 | | | | |
| | | | 100 | | | | |
| | | | 105 | | | | |
| | | | 110 | | | Rock | GRAVEL<br>well rounded to subangular black and red vesicular basalt. |
| | | | 115 | | | | |
| | | | 120 | | | | |
| | | | 125 | | | Rock | BASALT<br>mixture of basalt gravel and angular basalt chips, angular fragments more common. |
| | | | 130 | | | | |
| | | | 135 | | | | yellow-brown, red and black vesicular basalt |
| | | | 140 | | | | |
| | | | 145 | | | | |
| | | | 150 | | | | |
| | | | 155 | | | | |
| | | | 160 | | | | Boring terminated at 160.0 feet and monitor well installed. |

DRILL DATE
START: 8/28/94 FINISH: 9/6/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

**SOUTH PASS RESOURCES, Inc.**

PROJECT No. 001-05 DATE 1/13/95

# LOG OF BORING No. EW-1
Molycorp
Questa, New Mexico

FIGURE No. **C6a**

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0–10 | | | Fill | GRAVELLY CLAY<br>fill and tailings fines. |
| | | | 10–30 | | | CL/GC | TAN GRAVELLY CLAY<br>clasts of andesite, rhyolite, basalt and quartz, 60% clay and 40% gravel and coarse-grained sand. |
| | | | 30–45 | | | CL | TAN CLAY<br>composition of clasts as above, with 10% less coarse-grained sand and gravel. |
| | | | 45–70 | | | GP/SP | SANDY GRAVEL/GRAVELLY SAND<br>fine- to coarse-grained sand and gravel, rounded, compositions as above. |
| | | | 70–80 | | | CL | TAN CLAY<br>with 10% to 15% thin beds of sand and gravel, composition as above. Black basalt common clast types. |

DRILL DATE
START: 9/7/94 FINISH: 9/20/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. EW-2<br>Molycorp<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/13/95 | | C7 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80–105 | | | | |
| | | | 110 | | | GP | SANDY GRAVEL |
| | | | 115 | | | CL | CLAYEY GRAVEL<br>basalt or andesite boulder at 116'. |
| | | | 120–130 | | | CL/GC | TAN CLAY<br>alternating layers of clay with vesicular black and red basalt fragments and rounded basalt gravel in a clay matrix. |
| | | | 135–145 | | | SP | SAND<br>fine-grained, cemented, basalt clasts. |
| | | | 150–160 | | | GP | SANDY CLAYEY GRAVEL<br>alternating layers of tan clay, rounded basalt gravel in a clay/sand matrix. Gravels 40% to 60% of interval. |

DRILL DATE
START: 9/7/94 FINISH: 9/20/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

**SOUTH PASS RESOURCES, Inc.**

PROJECT No. 001-05 DATE 1/13/95

# LOG OF BORING No. EW-2
Molycorp
Questa, New Mexico

FIGURE No. **C7a**

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 160 | | | | |
| | | | 165 | | | SP | GRAVELLY SAND<br>rounded vesicular basalt clasts mixed with angular chips (boulder) in matrix of basalt sand. |
| | | | 170 | | | | |
| | | | 175 | | | | |
| | | | 180 | | | GW | SANDY GRAVEL<br>rounded basalt, rhyolite and quartz clasts. Clay layer 182'–183'. |
| | | | 185 | | | GC | TAN CLAYEY GRAVEL<br>basalt clasts in clay matrix. |
| | | | | | | CL | TAN CLAY |
| | | | 190 | | | CL/GC | GRAVELLY CLAY/CLAYEY GRAVEL<br>black and red basalt chips mixed with clay. |
| | | | 195 | | | | |
| | | | 200 | | | | |
| | | | 205 | | | | |
| | | | 210 | | | | |
| | | | 215 | | | | Boring terminated at 214.0 feet and monitor well installed. |
| | | | 220 | | | | |
| | | | 225 | | | | |
| | | | 230 | | | | |
| | | | 235 | | | | |
| | | | 240 | | | | |

DRILL DATE
START: 9/7/94 FINISH: 9/20/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. EW-2<br>Molycorp<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | C7b |
| 001-05 | 1/13/95 | | |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0–5–10–15 | | | CL | SANDY GRAVELLY CLAY<br>volcanic clasts.<br>clayey gravel layer 17'–18' |
| | | | 20–25–30–35–40–45 | | | CL | GRAVELLY CLAY<br>clayey gravel layer 21'–22' |
| | | | 50 | | | SC | TAN CLAYEY SAND<br>fine-grained. |
| | | | 55–60–65 | | | CL | TAN SANDY CLAY<br>sandy clayey gravel layer 56'–57' |
| | | | 70 | | | CL/GC | TAN GRAVELLY CLAY/CLAYEY GRAVEL |
| | | | 75–80 | | | GC | CLAYEY GRAVEL<br>light and dark colored volcanic and quartz clasts. |

DRILL DATE
START: 9/21/94 FINISH: 9/22/94 LOGGED By: W. Opfel DRILL RIG: aIR rOTARY/ Casing Drive SAMPLE TYPE: Cuttings

**SOUTH PASS RESOURCES, Inc.**

PROJECT No. 001–05 | DATE 1/13/95

# LOG OF BORING No. EW–3
Molycorp
Questa, New Mexico

FIGURE No. **C8**

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | CL | BROWN SANDY CLAY |
| | | | 85 | | | | |
| | | | 90 | | | | |
| | | | 95 | | | CL | BROWN CLAY |
| | | | 100 | | | | |
| | | | 105 | | | | Boring terminated at 104.0 feet and monitor well installed. |
| | | | 110 | | | | |
| | | | 115 | | | | |
| | | | 120 | | | | |
| | | | 125 | | | | |
| | | | 130 | | | | |
| | | | 135 | | | | |
| | | | 140 | | | | |
| | | | 145 | | | | |
| | | | 150 | | | | |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 9/21/94 FINISH: 9/22/94 LOGGED By: W. Opfel DRILL RIG: aIR rOTARY/ Casing Drive SAMPLE TYPE: Cuttings

SOUTH PASS RESOURCES, Inc.

PROJECT No. 001-05 DATE 1/13/95

# LOG OF BORING No. EW-3
Molycorp
Questa, New Mexico

FIGURE No. C8a

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0–18 | | | GC | BROWN CLAYEY GRAVEL<br>coarse cobbly gravel, light-colored rounded volcanic clasts. |
| | | | 18–42 | | | CL | BROWN GRAVELLY CLAY<br>clasts composition as above. |
| | | | 42–58 | | | GC | CLAYEY GRAVEL<br>fine gravel, 20% fines, clasts composition as above. |
| | | | 58 | | | | Boring terminated at 58.0 feet and monitor well installed. |

DRILL DATE
START: 9/26/94 FINISH: 9/27/94 LOGGED By: W. Opfel DRILL RIG: Air Rotary/ Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. EW-4<br>Molycorp<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/13/95 | | C9 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 0–65 | | | GC | BROWN CLAYEY GRAVEL<br>fine to coarse cobbly gravel, rounded, welded tuffs, rhyolite, dark volcanic clasts matrix, 20% clay. |
| | | | 65–80 | | | CL | BROWN GRAVELLY CLAY<br>gravel as above but in a fine clay (85%). |

DRILL DATE
START: 9/23/94 FINISH: 9/26/94 LOGGED By: W. Opfel DRILL RIG: Casing Drive /Air Rotary SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MW-12<br>Molycorp<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/13/95 | | C10 |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 80 | | | | |
| | | | 85 | | | | |
| | | | 90 | | | | thin layer of basalt gravel, 92'-92.5' |
| | | | 95 | | | GP | BASALT GRAVEL |
| | | | 100 | | | GC | CLAYEY GRAVEL/GRAVELLY CLAY<br>light-colored volcanics and black basalt clasts. |
| | | | 105 | | | | |
| | | | 110 | | | | |
| | | | 115 | | | CL | BROWN CLAY |
| | | | 120 | | | GC | CLAYEY GRAVEL<br>black and red basalt clasts. |
| | | | 125 | | | | |
| | | | 130 | | | CL | BROWN CLAY |
| | | | 135 | | | CL | GRAVELLY CLAY<br>black and brown clasts. |
| | | | 140 | | | CL | BROWN CLAY |
| | | | 145 | | | | |
| | | | 150 | | | GC/CL | BROWN GRAVELLY CLAY TO CLAYEY GRAVEL<br>brown and black basalt clasts in clay, increasing percentage of basalt clasts with depth; 90% at 154'. |
| | | | 155 | | | | |
| | | | 160 | | | | |

DRILL DATE
START: 9/23/94 FINISH: 9/26/94 LOGGED By: W. Opfel /Air Rotary DRILL RIG: Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MW-12<br>Molycorp<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/13/95 | | C10a |

| REMARKS | Blows/0.5 Ft. | PID | SAMPLE DEPTH | SAMPLE INTERVAL | GRAPHIC LOG | USCS CLASS | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| | | | 160 | | | | |
| | | | 165 | | | | |
| | | | 170 | | | | |
| | | | 175 | | | | |
| | | | 180 | | | Rock | BLACK BASALT<br>bedrock contact, opal on fractures. |
| | | | 185 | | | | |
| | | | 190 | | | | |
| | | | 195 | | | GP | GRAVEL<br>fine to coarse rounded clasts of red and black massive and vesicular basalt, quartz clasts present. |
| | | | 200 | | | | |
| | | | 205 | | | | |
| | | | 210 | | | | |
| | | | 215 | | | | tan clay present 210'-220' |
| | | | 220 | | | | |
| | | | 225 | | | | |
| | | | 230 | | | Rock | BASALT |
| | | | 235 | | | | Boring terminated at 234.0 feet and monitor well installed. |
| | | | 240 | | | | |

DRILL DATE /Air Rotary

START: 9/23/94 FINISH: 9/26/94 LOGGED By: W. Opfel DRILL RIG: Casing Drive SAMPLE TYPE: Cuttings

| SOUTH PASS RESOURCES, Inc. | | LOG OF BORING No. MW-12<br>Molycorp<br>Questa, New Mexico | FIGURE No. |
|---|---|---|---|
| PROJECT No. | DATE | | |
| 001-05 | 1/13/95 | | C10b |

# APPENDIX D

## Tailings Area Water-Quality Data

# APPENDIX D

## Tailings Area Water-Quality Data

### LIST OF FIGURES

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Figure D7: Sulfate Concentrations - LAU
Figure D8: Sulfate Concentrations - Basalt Aquifer
Figure D9: TDS and Sulfate vs. Time - Perched Aquifer
Figure D10: TDS and Sulfate vs. Time - LAU Aquifer
Figure D11: TDS and Sulfate vs. Time - Basalt Aquifer

### LIST OF TABLES

Table D1: 1994 Monitor Well Water Quality Data for Tailings Area

# APPENDIX D

## Tailings Area Water-Quality Data

This discussion of Tailings Area ground-water quality is based on the analytic results of monitor well water samples collected as split samples with the New Mexico Environmental Improvement Department (NMEID) on August 17 and 18, 1993 and again on November 7, 8, and 9, 1994. Samples were also collected at EW-2, -3, and -4 at the completion of the aquifer tests on November 16 and 17, 1994. The results of the chemical analyses are presented in this appendix. Additional water-quality data from documents in Molycorp files or from other consultants' reports are also presented in this discussion.

A series of STIFF diagrams that provide a comparison of the ground-water chemistry between the monitoring wells sampled in 1993 and 1994 are shown in Figures D1 through D4. STIFF diagrams were replotted from the 1994 data for MW-2, MW-3, and MW-7A and compared to the 1993 diagrams for these wells. Although there have been changes in constituent concentrations, the patterns are similar. Most of the samples reflect the fact that the monitoring system is designed to detect leachate-impacted ground water from the tailings ponds. With some exceptions, the water is classified as a calcium sulfate ground water. In 1993, well MW-7C had a high pH (10.6), high hydroxide (300 mg/L), and high alkali to calcium water (probably as a result of the introduction of cement grout into the annulus prior to the setting of the bentonite seal). By 1994, the pH had lowered to 7.1, the hydroxide had disappeared, and MW-7C had a calcium sulfate water. Water samples from the Change House well in the alluvial material east of the Dam No. 1 pond are alkali (Na+K) bicarbonate and from MW-12 in the basalt aquifer are calcium bicarbonate. These well waters may be closer to the water quality of the regional systems in the alluvial and volcanic aquifers as illustrated in Winograd (1959).

### Upper and Main Perched Zones

With the striking exception of EW-4, water samples from the perched zones involving the UAU and the upper MAU are typically high Total Dissolved Solids (TDS) and high sulfate waters (Table D1). Because there is a close correlation between changes in TDS and changes in sulfate concentration, the sulfate values are shown on maps (Figures D5 and D6) to illustrate the sulfate concentration for 1993 and 1994. Figure D6 illustrates changes in the shallow perched zones above the main perched zone in the UAU. The highest sulfate concentrations in this area are at MW-C, the shallowest piezometer at the toe of the dam. This piezometer may be sampling water moving through the underdrains beneath the dam. MW-A shows lower concentrations from an intermediate zone, and both piezometers show a decline in

sulfate concentration. In contrast to MW-A and MW-C, the shallow level piezometer MW-9A shows a sharp increase in sulfate between 1993 and 1994. The sulfate concentration at MW-9A is also higher than that in MW-A, even though the latter is closer to the tailings ponds. If leachate moves from the tailings ponds into the UAU in pulses related to annual and/or nonperiodic changes in recharge, the distal increase in sulfate could reflect a slug of older water reaching this site. It is also possible that the ground water is near equilibrium conditions for gypsum and precipitation or dissolution of this species could change the sulfate concentration.

The distribution of sulfate in the main perched zone of the UAU is shown in Figure D6. Of the six wells, four were sampled in 1993. Three of these wells (MW-2, MW-3, and MW-4) show declines in sulfate in 1994. In contrast, MW-7A shows an increase in sulfate, although the reason is not clear. It is possible that MW-7A records an earlier slug of leachate from the Dam No. 1 area.

Two wells (MW-2 and MW-3) have higher sulfate concentrations than MW-7A even though the latter is closer to Dam No. 1. Wells EW-3 and EW-4 are located between these wells and have significantly lower sulfate concentrations than the other three wells (MW-2, MW-3, and MW-7A). It is not likely that a single factor will explain these sulfate concentrations, but some combination of the following may be involved:

- Chemical reactions (such as the dissolution or precipitation of interstitial calcite or gypsum along specific flow paths) can cause down-gradient changes in the concentration of the dissolved phases. Monitor wells MW-2 and MW-3, although screened in the main perched zone, are screened across the sands and gravel of the lower UAU and clays of the upper MAU. EW-3 and EW-4 are screened in sandy gravels of the lower UAU only. Ground water entering MW-2 and MW-3 follows a different flow path (in part through clays) than water which is collected by EW-3 and -4. Depending on changes in concentrations over time, the clay is more likely to see fluctuations in dissolution and precipitation of relatively soluble minerals like calcite or gypsum.

- The source of sulfate beneath the tailings pond is not a point source but rather a line source or, in two dimensions, a blanket source (i.e., the area beneath the pond). Sulfate enters the UAU over the area of the pond and is, in turn, more widely distributed by moving laterally along numerous shallow perched zones. Because head relationships in the UAU are downward, ultimately leachate infiltrates to the top of the main perched zone. Once the sulfate (or leachate) reaches the main perched zone, it migrates westward as the water-level map for the zone (Figure D6) shows. With respect to the flow direction in this zone, the down-gradient wells (which are close to the 7,260-foot contour) are MW-7A,

MW-2, MW-3 and EW-4. Ignoring EW-4 for the moment, the sulfate concentrations at MW-7A, MW-2, and MW-3 could reflect the location in time and space of an earlier slug of leachate.

- EW-4 is highly anomalous when compared to other UAU wells. As shown on the chart below, the single water sample from this well had a very low TDS (440 mg/L) and sulfate content (150 mg/L). There is a significant decline in the calcium, magnesium, sodium, and sulfate concentrations in the EW-4 water compared to the MW-2 water. A similar decline in calcium and sulfate concentration occurs at EW-3. The reductions in calcium and sulfate concentrations are probably caused by precipitation of gypsum. There was no evidence of gypsum in the drill cuttings and it is likely that precipitation occurred between the time of sampling and the laboratory analysis. Elevated iron and manganese concentrations at MW-2 (relative to EW-4) result from bacterial oxidation of the steel casing at MW-2. The concentrations of zinc and copper at EW-4 increased slightly from the November 7, 1994 sampling to the post-aquifer test sampling on November 16, 1994. This could be an artifact of drilling lubricants introduced when the well was constructed.

| | pH | TDS (mg/L) | $SO_4$ (mg/L) | $HCO_3$ (mg/L) | Cl (mg/L) | Ca (mg/L) | Mg (mg/L) | K (mg/L) | Na (mg/L) | Fe (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| MW-2 | 7.96 | 1,400 | 860 | 80 | 15 | 241 | 52.2 | 3.1 | 95.6 | 4.6 |
| EW-4 | 7.78 | 440 | 150 | 152 | 26 | 101 | 17.8 | 1.5 | 15.5 | <0.05 |

## LAU Aquifer

Sulfate concentrations for the LAU and the underlying bouldery clay unit are shown on Figure D7. Although the water-quality data for the LAU at MW-10 and for the deeper private wells south of Molycorp property show little or no evidence of seepage water, the LAU water quality at MW-7C (near the toe of Dam No. 1) has an elevated TDS/sulfate concentration. Head relationships at MW-7 indicate a downward gradient between the LAU and MAU. Some tailings water may be migrating downward into the LAU from the main perched zone and flowing in a southerly direction within the saturated LAU beneath the ponds. MW-10 has high quality water because it is east of the flow path of LAU water from the area beneath the ponds and probably because of an upward gradient preventing tailings water in the UAU/MAU (MW-4) from moving downward.

EW-2 encountered a bouldery clay unit (mud flow deposit described in Section 2.2) beneath the sands and gravels of the LAU. This well is screened in a gravel lense within the bouldery clay and the water sample from this well is of good quality (TDS: 200 mg/L; sulfate: 66 mg/L). The clay matrix of the mud flow deposit effectively seals off these deeper sources from pond leachate.

**Basalt Aquifer**

South of Dam No. 4, monitor well MW-11, which is screened in the basalt aquifer (Figure D8), shows very low concentrations of TDS (200 mg/L) and sulfate (58 mg/L). This sulfate concentration is lower than that in the Red River north of Questa Springs (141 mg/L) according to unpublished data from Vail (1993). Any leachate that infiltrates form the tailings material behind Dam No. 4 must migrate downward through a thick unsaturated zone consisting of Santa Fe sediments and the upper part of the basalt before reaching ground water. If tailings leachate is moving down into the basalt aquifer, it is rapidly diluted by the southwesterly underflow in the basalt and the monitor well near the toe of the dam produces high quality water (for example, see STIFF diagram, Figure D3).

As a reference in Appendix B, except for seepage along clay beds in the upper UAU (Seepage Barrier 003) southeast of Dam No. 4, there is no clear evidence for saturated conditions in the deeper Santa Fe sediments or in the uppermost basalt flows underlying the Santa Fe Group. Water-level elevations at MW-1 and EW-1 are believed to be related to confined conditions for the basalt gravel unit below the upper basalt flows. The top of the basalt may be unsaturated below Dam No. 4 and west of the fault zone that extends along the west side of Dam No. 1. The fault appears to juxtapose the main perched zone on the east with the basalt on the west. It is more likely that the TDS and sulfate concentrations in MW-1 and EW-1 are related to leachate in the main perched zone which has migrated westward (in the direction of flow) across the fault zone.

**Seeps**

There is some evidence that the "fault" east of MW-1 may exert some control on the movement of ground water toward the Red River. The projection of this "fault" to the river would approximately correspond to the Questa Springs area and the springs may be directly related to the structure. Water from the Questa Springs area is piped to the Fish Hatchery (approximately 4.5 miles downstream from the springs). This water has a TDS of 173 mg/L and a sulfate concentration of 80 mg/L (Table 3, main text). These concentrations are comparable with LAU or volcanic aquifer water. The temperature of this water (8.3°C) is perhaps more compatible with shallow (LAU) ground water than the temperature (16°C) of the deeper flow system in the volcanics (Vail, 1993).

**Time/Concentration Plots**

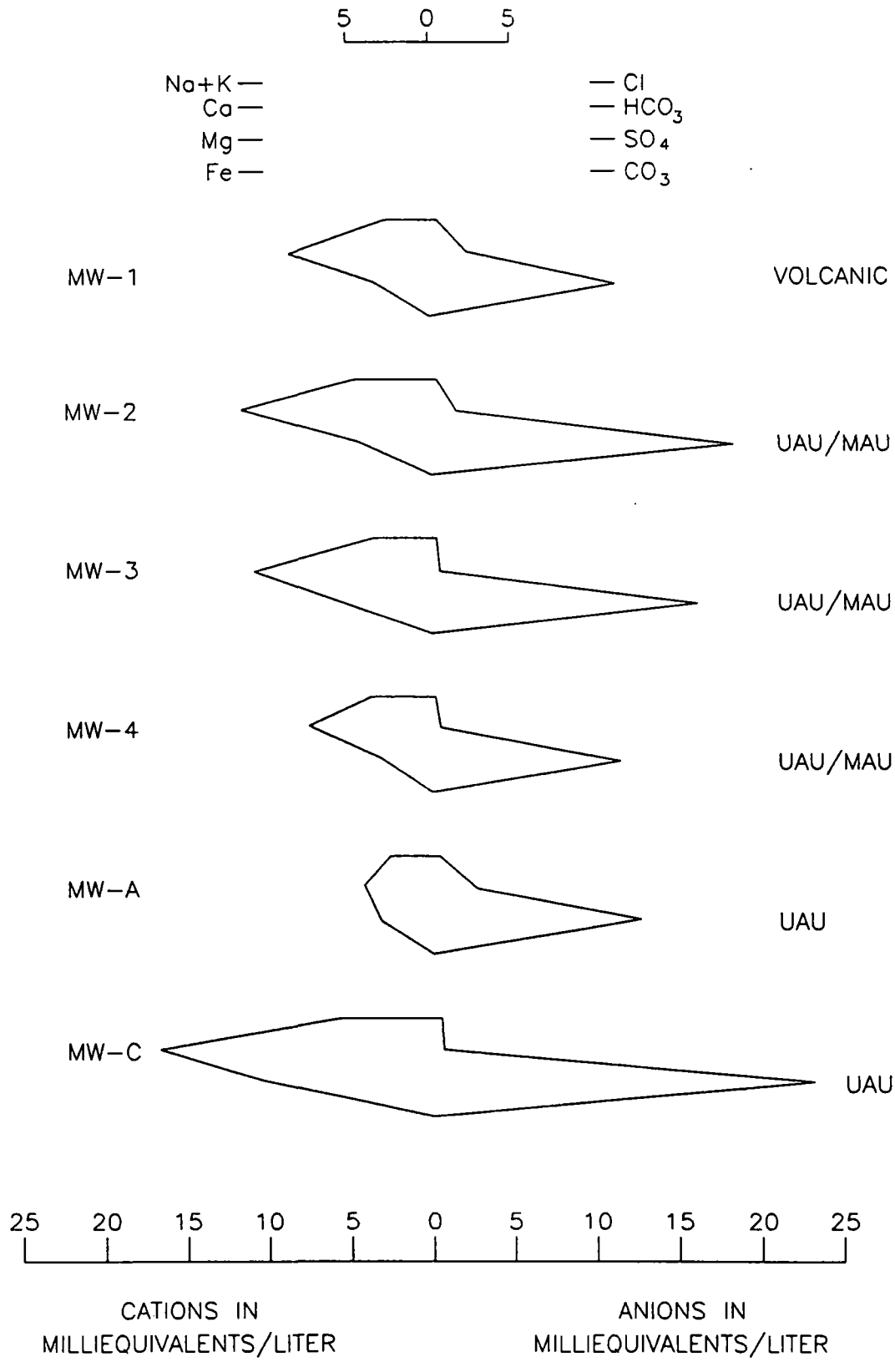
A number of variables impact the time/concentration plots for TDS and sulfate shown on Figures D9, D10, and D11:

- Sample collection or analytical errors are a possible cause of variation.
- The sampling periods do not represent the same time of year: 1991 and 1992 are spring samples, 1993 is August, and 1994 is a November set of samples. Concentration changes could be partly a function of variation in seasonal recharge.
- The older wells (MW-1, MW-2, MW-3, MW-4, MW-A, MW-B, and MW-C) have steel casing while the newer wells are all PVC construction. Purging of MW-4 on September 15, 1994 (1,100 gallons) released a significant amount of rust-colored debris (ferrihydrite). MW-1, MW-2, and MW-3 show measurable iron concentrations that may be the result of the release of iron related to bacterial activity. The purging at MW-4 may have temporarily flushed out the iron since its November water sample shows iron being below the detection limit. Once ferrihydrite ("limonite") forms in the casing, this material can selectively absorb trace metals (such as copper and zinc depending primarily on changes in pH. Adsorption is favored at higher pHs). The water quality of steel-cased wells can be influenced by chemical reaction between the casing and the ground water.

Figure D9 indicates that, in the case of the older wells in the perched aquifers, the concentrations of TDS and sulfates increased between 1992 and 1993. Concentrations decreased after 1993 for all of these wells except MW-3 which show a slight increase. Wells MW-2, MW-3, and MW-4 are all screened over a larger interval (lower UAU and upper MAU) in the main perched zone compared to MW-7A which is screened in the lower UAU. Well MW-7A shows a sharp increase in concentrations from 1993 to 1994. How much of this difference is related to non-hydrogeological factors (described above) is unknown. Hydrogeological causes would involve some combination of variations in (1) recharge superimposed on flow paths, (2) the position of the well along particular flow paths, and (3) chemical processes along the flow path. Similar explanations are involved in the MW-A and MW-C versus MW-9A patterns.

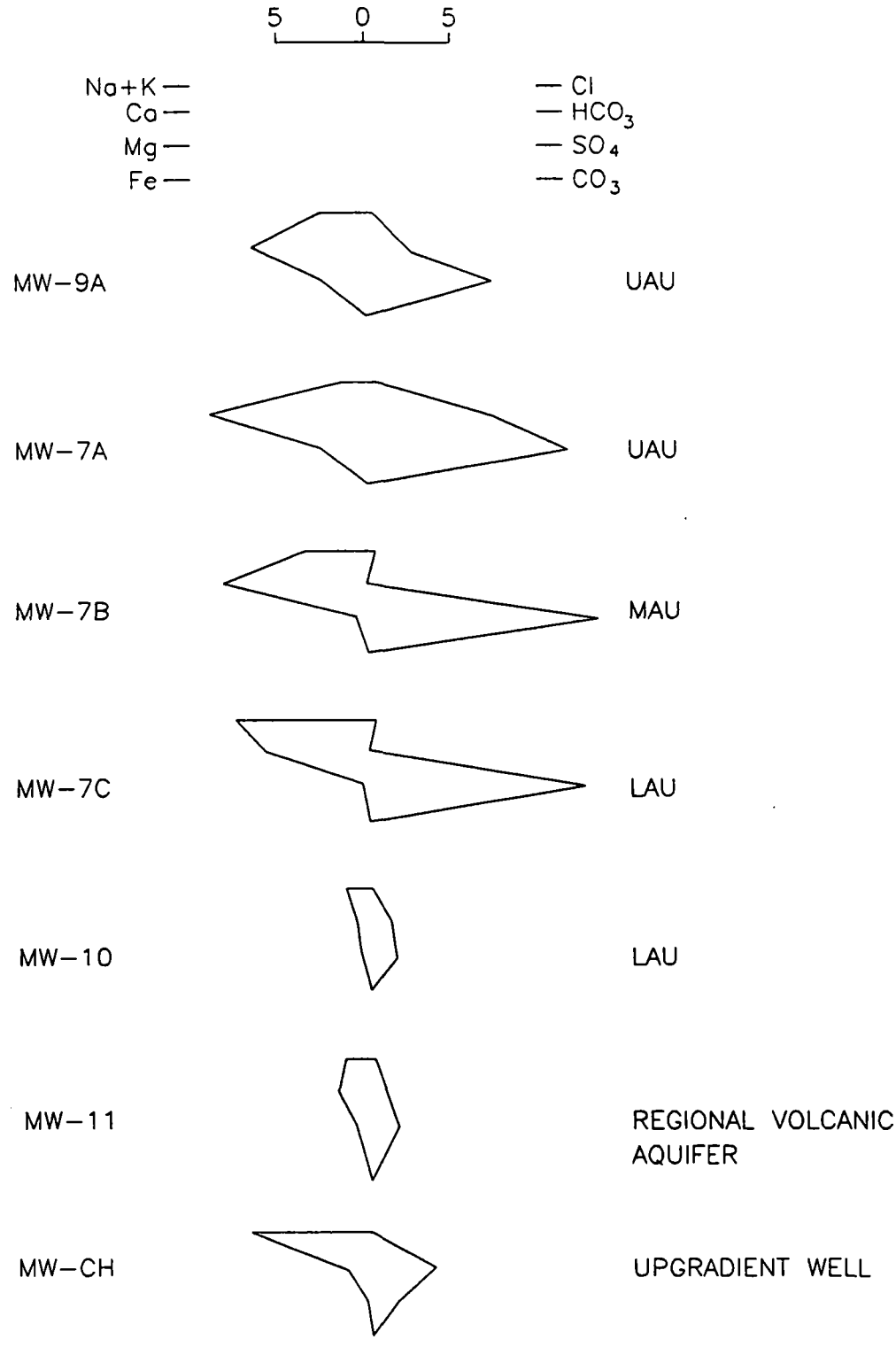
There is very little time/concentration data for the LAU or the volcanic (basalt) aquifer (Figures D10 and D11). Samples from well MW-1 show a decrease in concentration from 1992 to 1993 and a slight increase in 1994. This may reflect a time lag related to recharge of the volcanic aquifer from the main perched zone to the east. Samples from well MW-11 show

a decrease in concentrations from 1993 to 1994, possibly resulting from declining heads in the pond material and reduction of the amount of leachate reaching the water table. The two LAU samples (MW-7C and MW-10) show opposite trends. Samples from MW-7C parallels concentration changes in samples from MW-7A. The MW-10 sample may simply reflect annual variation as a function of regional variation in recharge.

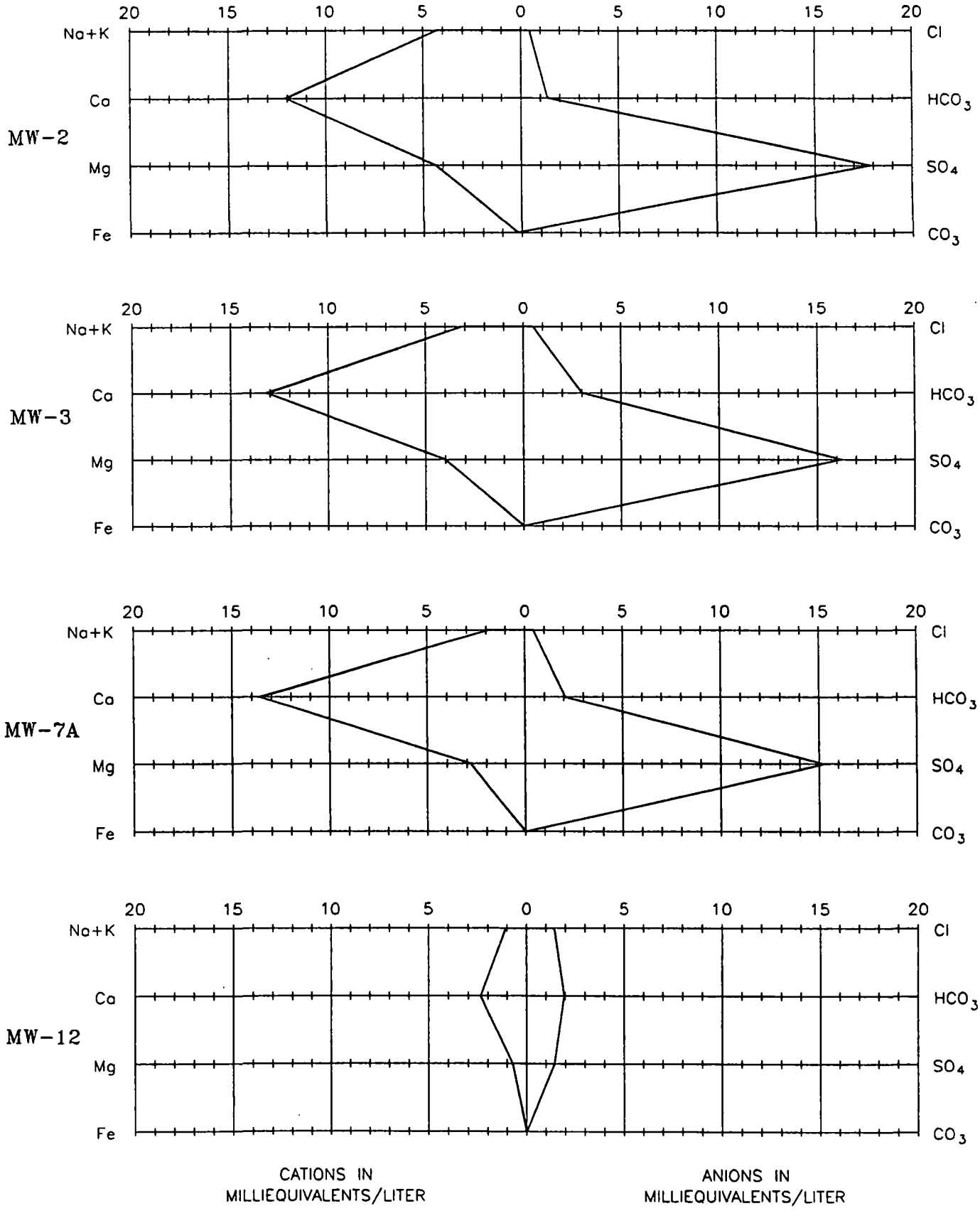



| SOUTH PASS RESOURCES, Inc. | | | | STIFF DIAGRAMS–1993 SAMPLING<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D1 |
|---|---|---|---|---|---|
| PROJECT No.: 001–06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

STIFF-2

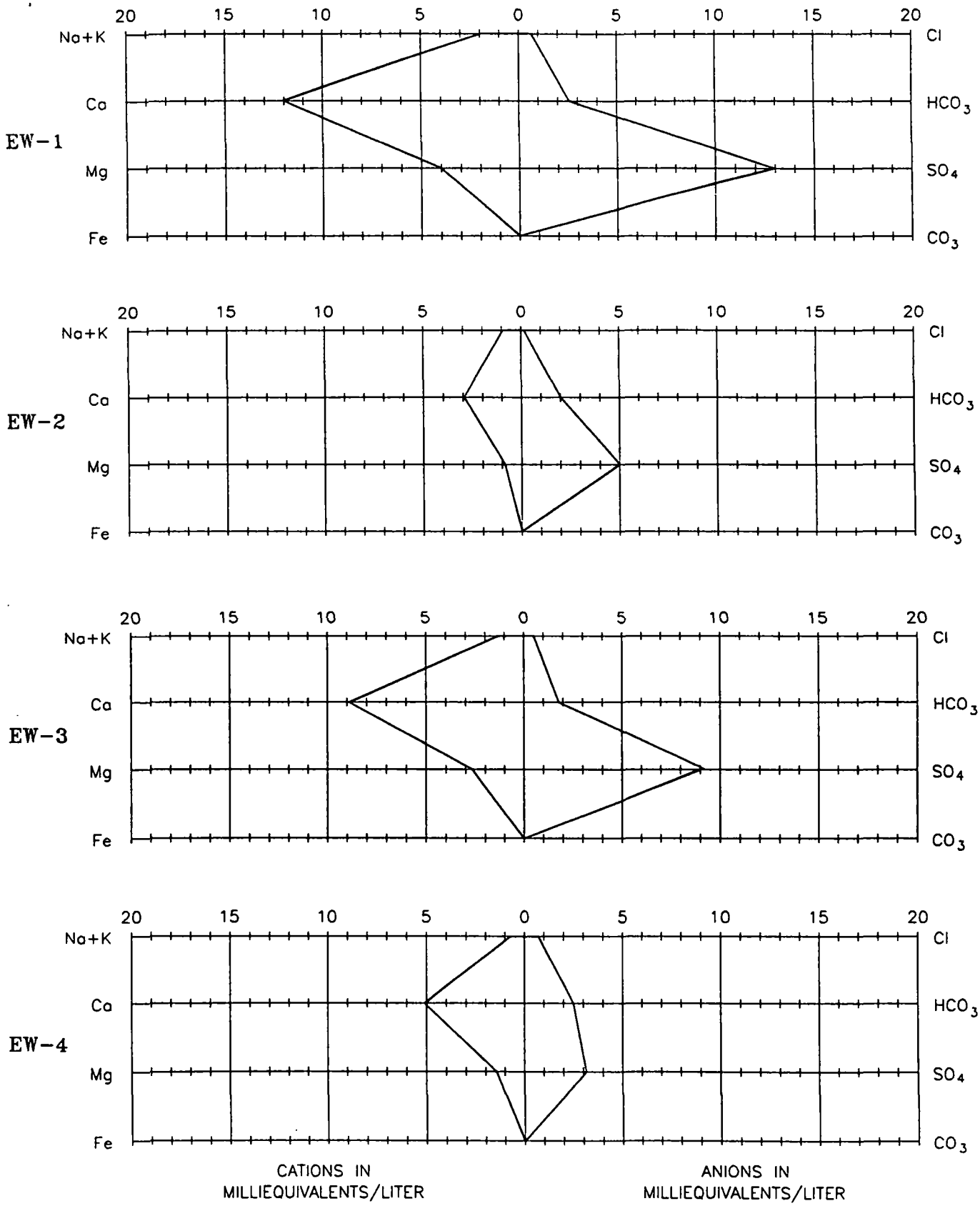



| SOUTH PASS RESOURCES, Inc. | | | | STIFF DIAGRAMS–1993 SAMPLING<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D2 |
|---|---|---|---|---|---|
| PROJECT No.: 001–06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | | |




| SOUTH PASS RESOURCES, Inc. | | | | STIFF DIAGRAMS–1994 SAMPLING<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D3 |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

STIFF-4




| SOUTH PASS RESOURCES, Inc. | | | | STIFF DIAGRAMS–1994 SAMPLING<br>Tailings Area – Molycorp, Inc.<br>Questa, New Mexico | FIGURE: D4 |
|---|---|---|---|---|---|
| PROJECT No.: 001-06 | DATE: 3/31/95 | AUTHOR: | DRAWN BY: M.O'M. | | |

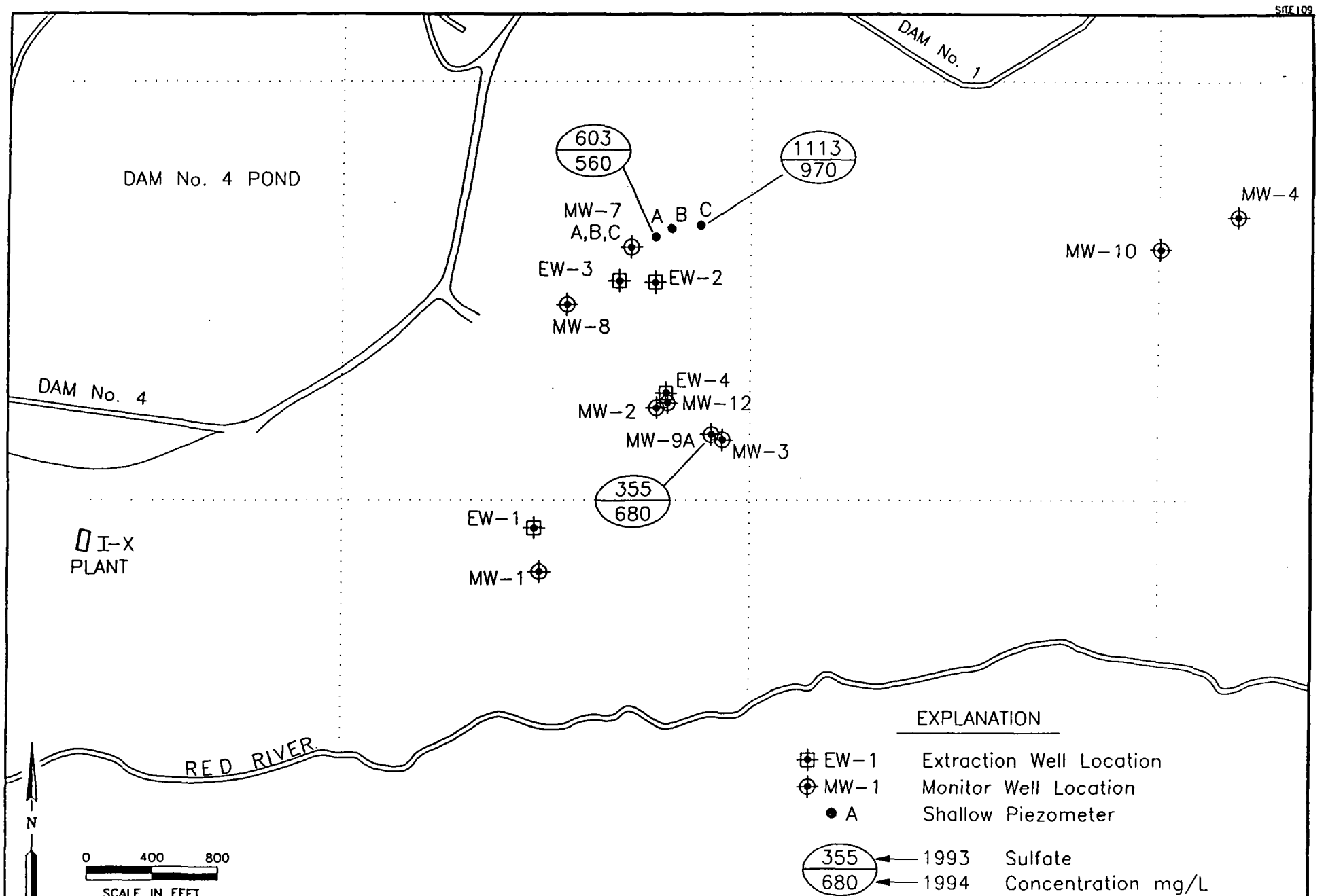



FIGURE: D5

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# SULFATE CONCENTRATIONS-UPPER PERCHED ZONES

ABOVE MAIN PERCHED ZONE IN UAU

Tailings Area, Molycorp, Inc., Questa, New Mexico

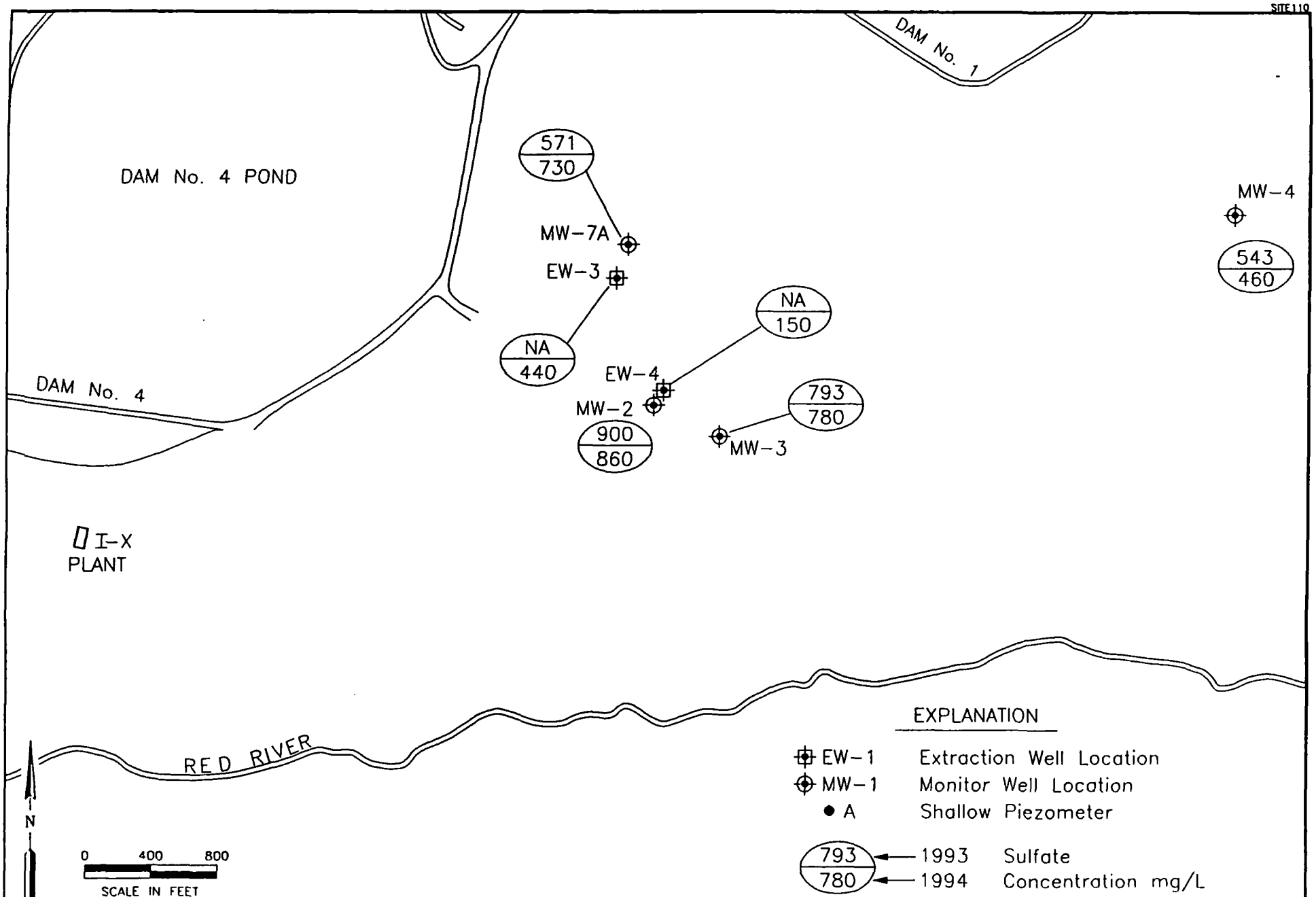



FIGURE: D6

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# SULFATE CONCENTRATIONS MAIN PERCHED ZONE UAU

Tailings Area - Molycorp, Inc.
Questa, New Mexico

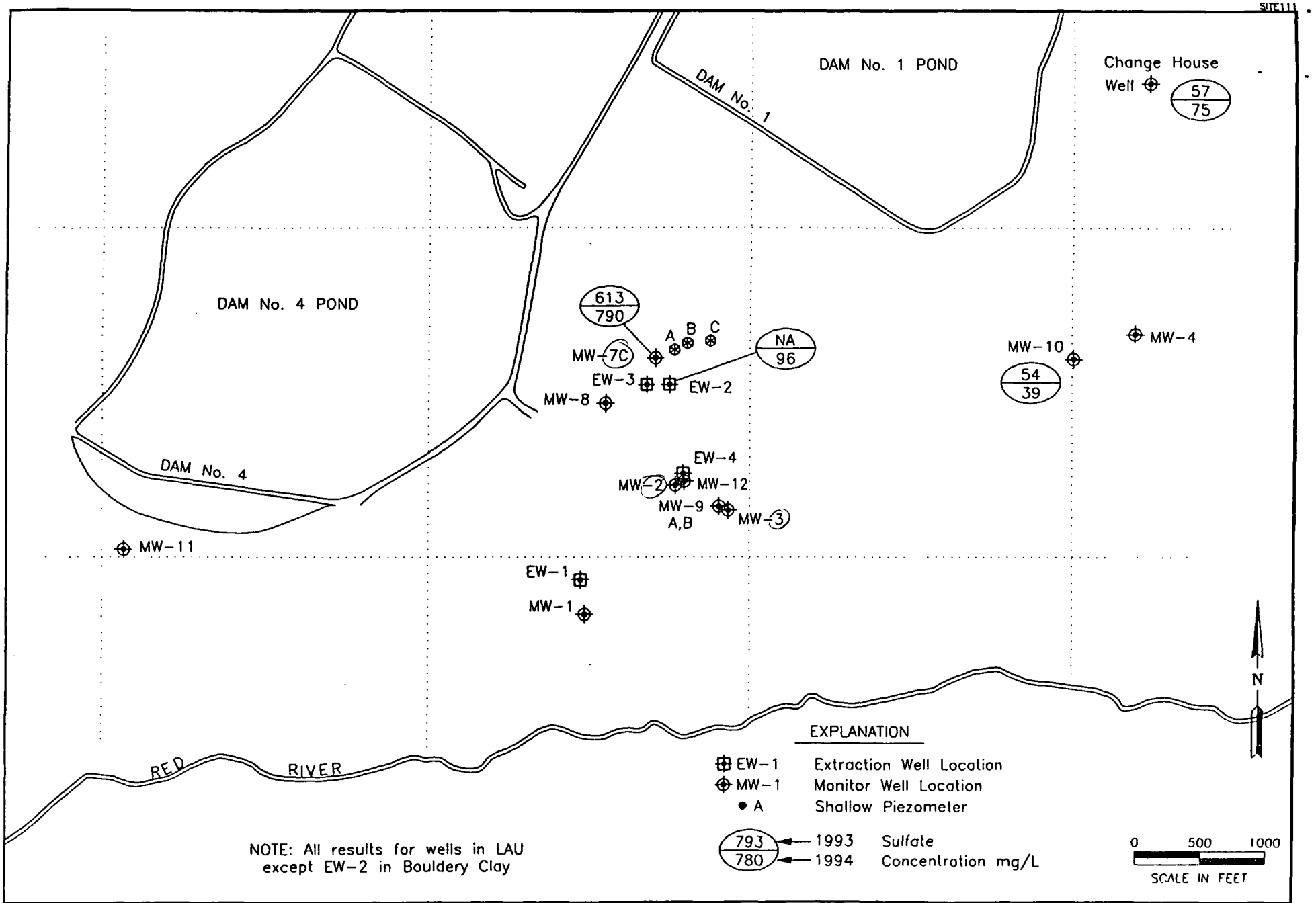



FIGURE: 7

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# SULPHATE CONCENTRATIONS - LAU

Tailings Area - Molycorp, Inc.
Questa, New Mexico

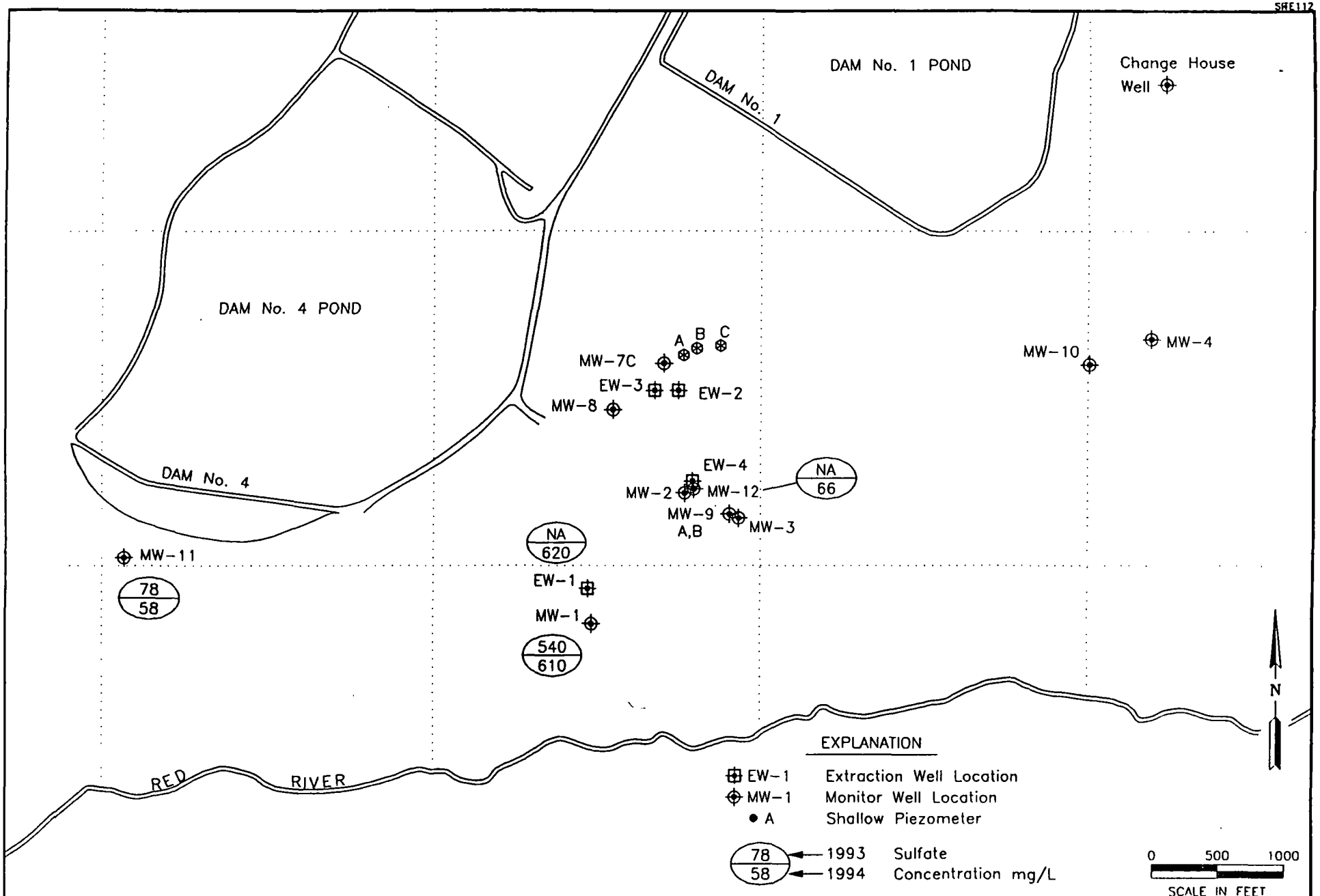



FIGURE: D8

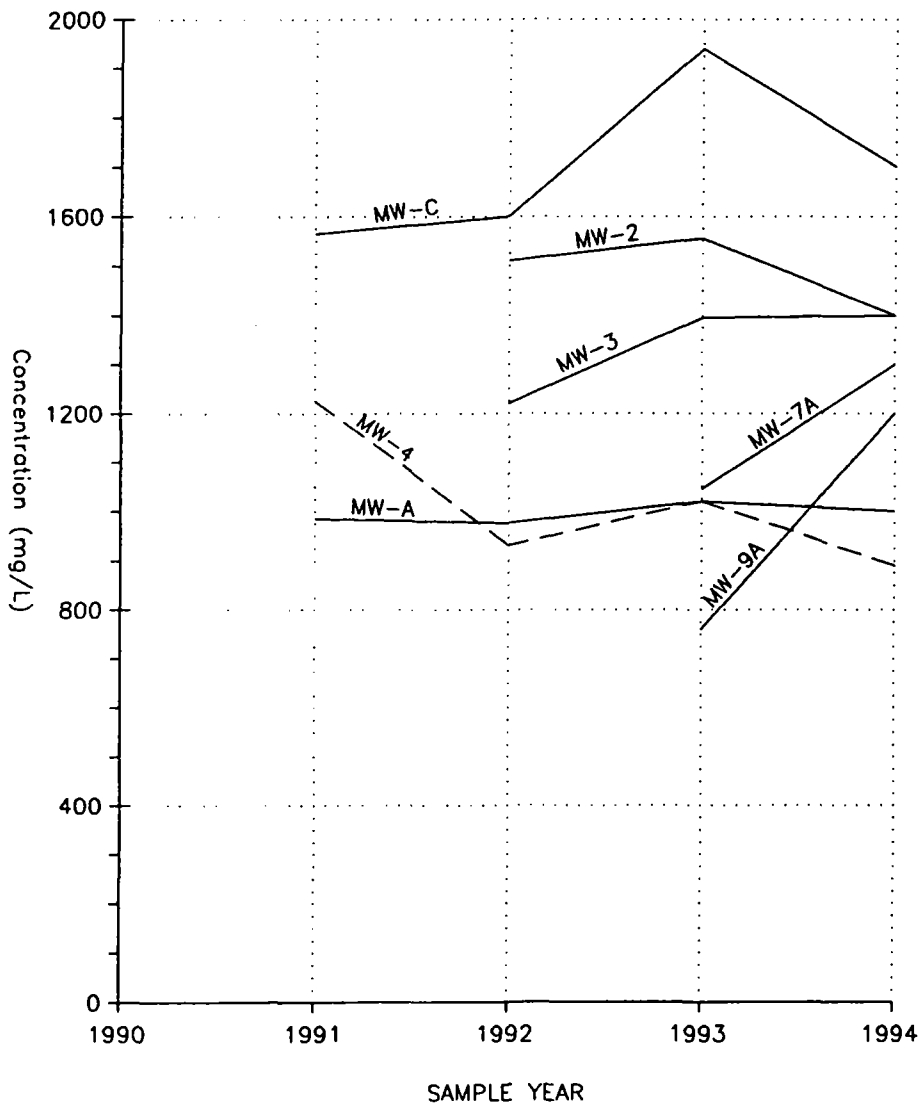
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# SULPHATE CONCENTRATIONS - BASALT AQUIFER

Tailings Area - Molycorp, Inc.
Questa, New Mexico

## TOTAL DISSOLVED SOLIDS (TDS)




## SULFATE

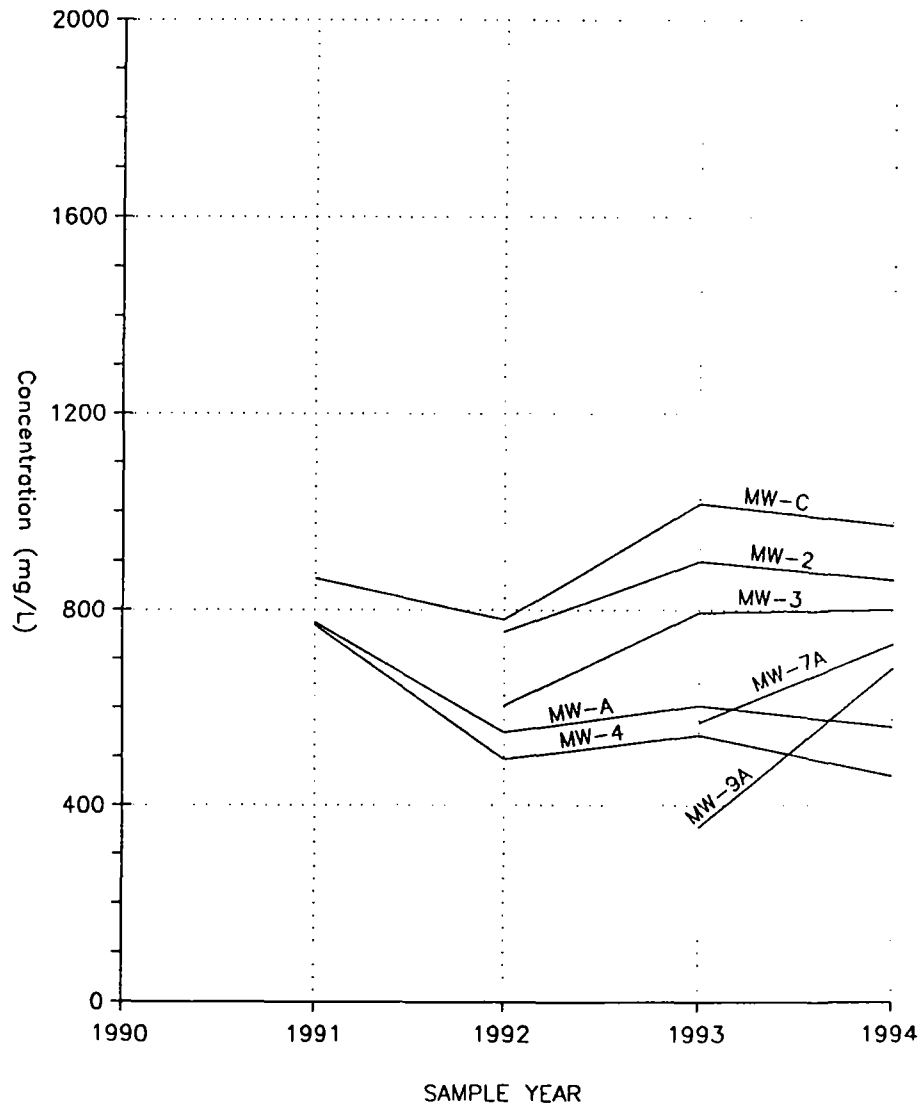



FIGURE: D9

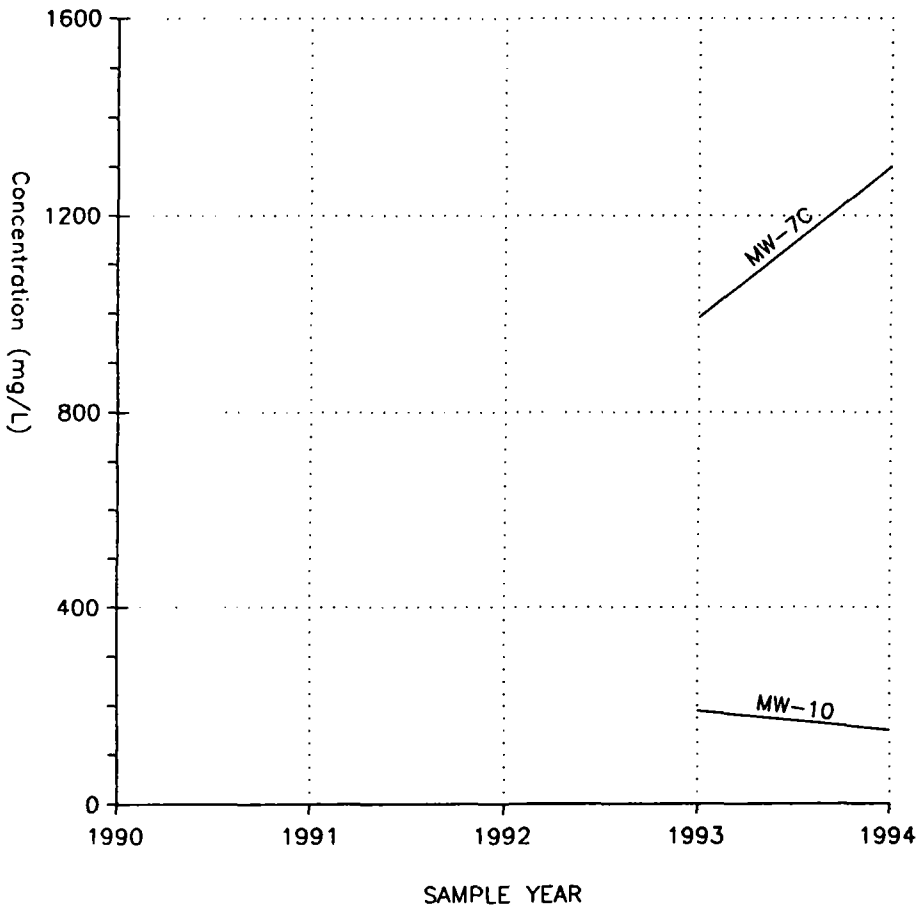
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# TDS AND SULFATE vs TIME - PERCHED AQUIFER

Tailings Area - Molycorp, Inc.
Questa, New Mexico

## TOTAL DISSOLVED SOLIDS (TDS)




## SULFATE

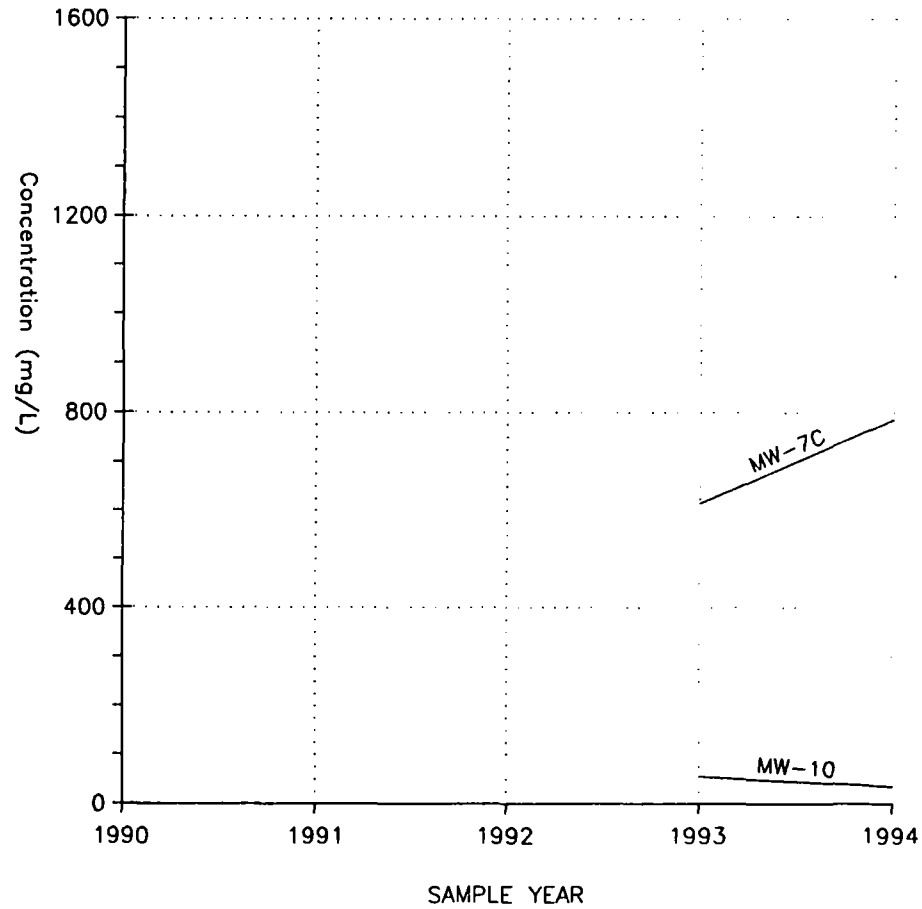



FIGURE: 10

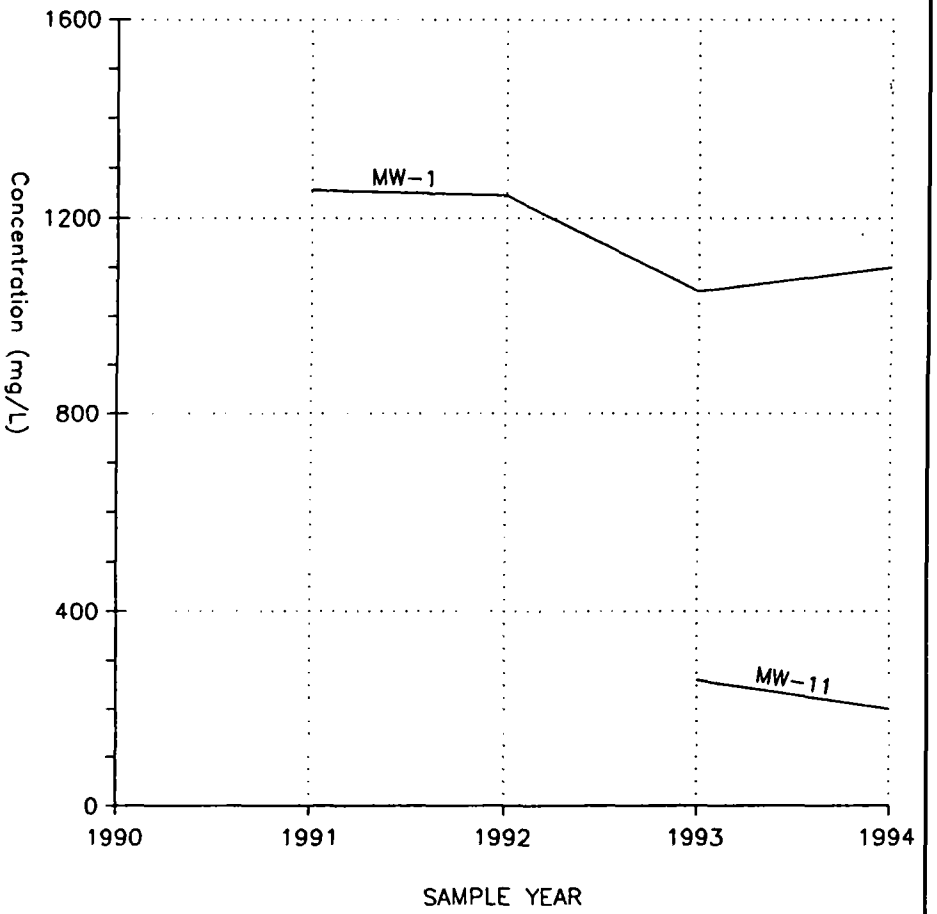
SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# TDS AND SULFATE vs TIME - LAU AQUIFER

Tailings Area - Molycorp, Inc.
Questa, New Mexico

## TOTAL DISSOLVED SOLIDS (TDS)




## SULFATE

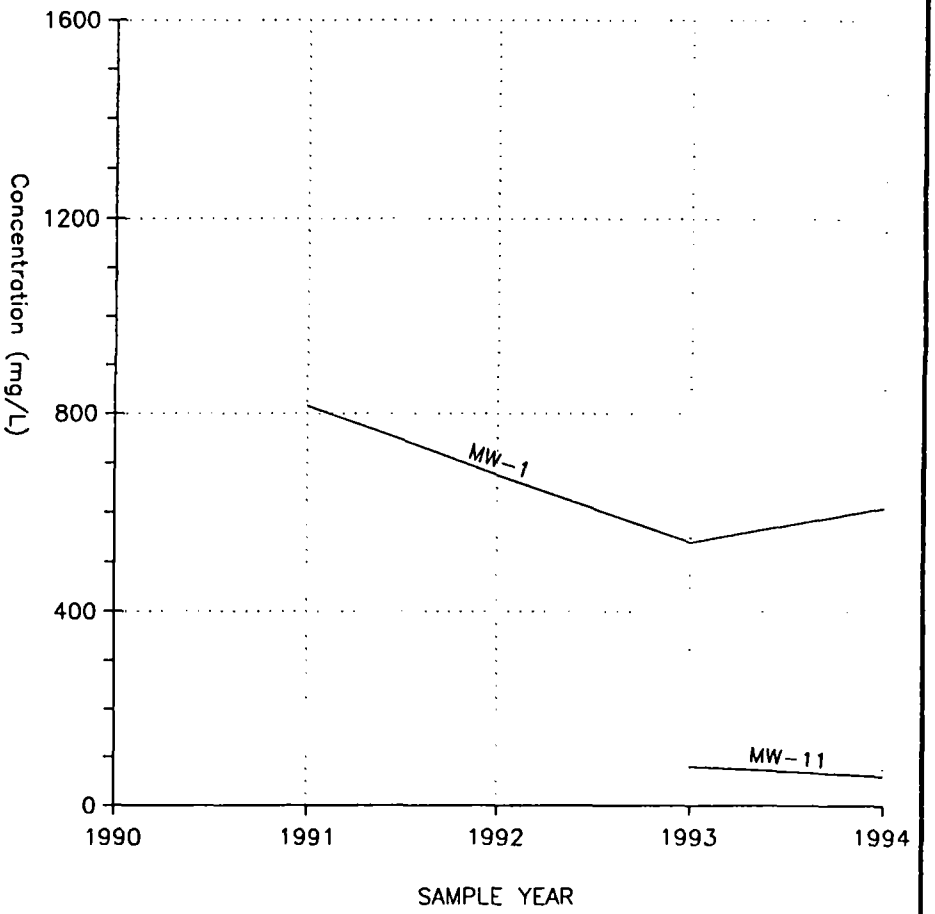



FIGURE: D 11

SOUTH PASS RESOURCES, Inc.

| PROJECT No.: | DATE: | AUTHOR: | DRAWN BY: |
|---|---|---|---|
| 001-06 | 3/31/95 | | M.O'M. |

# TDS AND SULFATE vs TIME – BASALT AQUIFER

Tailings Area – Molycorp, Inc.
Questa, New Mexico

# TABLE D1
## 1994 MONITOR WELL WATER QUALITY DATA FOR TAILINGS AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | SAMPLE DATE 1994 | WELL TD (feet) | Corrected DEPTH TO WATER (feet) | DEPTH TO PUMP INTAKE (feet) | pH (1) | CONDUC-TIVITY (1) (uhmos) | TEMP (1) (°C) | CARBO -NATE (mg/L) | BICARBO -NATE (mg/L) | HYDR-OXIDE (mg/L) | TOTAL ALK (mg/L) | CHLORIDE (mg/L) | FLUORIDE (mg/L) | NITRATE (mg/L) | SUFATE (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW-1 | 7-Nov | 157 | 83.00 | 102 | 7.50 | 1,460 | NA | <1 | 156 | <1 | 156 | 23 | 0.25 | 0.72 | 620 |
| EW-2 | 8-Nov | 204 | 147.91 | 170 | 7.48 | 850 | 12.9 | <1 | 122 | <1 | 122 | 4.8 | 0.49 | 0.2 | 96 |
| EW-2 | 17-Nov | NA | NA | NA | NA | NA | NA | <1 | 118 | <1 | 118 | 4.6 | 0.5 | 0.38 | 90 |
| EW-3 | 8-Nov | 78 | 57.74 | 70 | 7.48 | 1,135 | 11.4 | <1 | 110 | <1 | 110 | 17 | 0.16 | 0.6 | 440 |
| EW-3 | 19-Nov | NA | NA | NA | NA | NA | NA | <1 | 136 | <1 | 136 | 18 | 0.19 | 0.49 | 410 |
| EW-4 | 7-Nov | 58 | 18.49 | 50 | 7.78 | 650 | 11.6 | <1 | 152 | <1 | 152 | 26 | 0.21 | 0.35 | 150 |
| EW-4 | 16-Nov | NA | NA | NA | NA | NA | NA | <1 | 156 | <1 | 156 | 26 | 0.2 | 0.36 | 160 |
| MW-1 | 7-Nov | 100 | 53.17 | 80 | 7.28 | 1,322 | NA | <1 | 136 | <1 | 136 | 14 | 0.27 | 0.45 | 610 |
| MW-2 | 7-Nov | 80 | 22.07 | 60 | 7.96 | 1,701 | NA | <1 | 80 | <1 | 80 | 15 | 0.96 | <0.06 | 860 |
| MW-3 | 8-Nov | 60 | 19.97 | 55 | 7.38 | 1,679 | 12.4 | <1 | 183 | <1 | 183 | 18 | 0.44 | 0.31 | 780 |
| MW-4 | 8-Nov | 96 | 40.77 | 65 | 7.61 | 1,157 | 12.3 | <1 | 184 | <1 | 184 | 7.3 | 0.73 | 0.24 | 460 |
| MW-7A | 7-Nov | 90 | 58.84 | 80 | 7.50 | 1,565 | 11.9 | <1 | 126 | <1 | 126 | 16 | 0.18 | 0.72 | 730 |
| MW-7C | 9-Nov | 146 | 111.79 | 135 | 7.10 | 2,160 | 12.4 | <1 | 124 | <1 | 124 | 16 | 0.17 | 0.32 | 790 |
| MW-9A | 8-Nov | 44 | 26.30 | 35 | 7.32 | 1,021 | 13.1 | <1 | 174 | <1 | 174 | 20 | 0.44 | 0.33 | 680 |
| MW-10 | 8-Nov | 129 | 26.23 | 100 | 8.16 | 236 | 12.3 | <1 | 77 | <1 | 77 | 1.6 | 0.36 | 0.27 | 35 |
| MW-11 | 9-Nov | 249 | 191.93 | 210 | 7.00 | 440 | 19.8 | <1 | 82 | <1 | 82 | 10.3 | 1.28 | 0.39 | 58 |
| MW-11AB | 9-Nov | NA | NA | NA | NA | NA | NA | <1 | 79 | <1 | 79 | 10.1 | 1.29 | NA | 58 |
| MW-12 | 7-Nov | 234 | 128.11 | 210 | NA | NA | NA | <1 | 120 | <1 | 120 | 5.1 | 0.46 | NA | 66 |
| MW-A | 7-Nov | 38 | 30.58 | NA | 7.28 | 1,332 | NA | <1 | 154 | <1 | 154 | 14 | 0.35 | 0.37 | 560 |
| MW-C | 7-Nov | 14.5 | 1.80 | NA | 7.24 | 1,902 | NA | <1 | 185 | <1 | 185 | 19 | 1.16 | <0.06 | 970 |
| CH | 8-Nov | NA | NA | NA | 7.97 | 539 | 13.5 | <1 | 206 | <1 | 206 | 2.3 | 0.71 | 0.44 | 75 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

SOURCE: SAMPLES TAKEN BY SPRI. ANALYTICAL RESULTS FROM MOLYCORP.

NA - NOT AVAILABLE

# TABLE D1
## 1994 MONITOR WELL WATER QUALITY DATA FOR TAILINGS AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | TDS (mg/L) | SILVER (mg/L) | ALUMINUM (mg/L) | ARSENIC (mg/L) | BARIUM (mg/L) | BERYLLIUM (mg/L) | CALCIUM (mg/L) | CADMIUM (mg/L) | COBALT (mg/L) | CHROMIUM (mg/L) | COPPER (mg/L) | IRON (mg/L) | MERCURY (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW-1 | 1,200 | <0.10 | <0.05 | <0.005 | 0.053 | <0.004 | 240 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-2 | 240 | <0.10 | <0.05 | <0.005 | 0.068 | <0.004 | 59.4 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-2 | 290 | <0.010 | <0.05 | <0.005 | 0.065 | <0.004 | 57.8 | 0.0036 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-3 | 830 | <0.10 | <0.05 | <0.005 | 0.074 | <0.004 | 179 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-3 | 750 | <0.010 | <0.05 | <0.005 | 0.054 | <0.004 | 158 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-4 | 440 | <0.10 | <0.05 | <0.005 | 0.065 | <0.004 | 101 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| EW-4 | 450 | <0.010 | <0.05 | <0.005 | 0.068 | <0.004 | 104 | <0.0005 | <0.010 | <0.010 | 0.012 | <0.050 | <0.0002 |
| MW-1 | 1,100 | <0.10 | <0.05 | <0.005 | 0.025 | <0.004 | 207 | <0.0005 | <0.010 | <0.010 | <0.010 | 0.068 | <0.0002 |
| MW-2 | 1,400 | <0.10 | <0.05 | <0.005 | 0.022 | <0.004 | 241 | <0.0005 | <0.010 | <0.010 | <0.010 | 4.6 | <0.0002 |
| MW-3 | 1,400 | <0.10 | <0.05 | <0.005 | 0.032 | <0.004 | 264 | <0.0005 | <0.010 | <0.010 | <0.010 | 0.07 | <0.0002 |
| MW-4 | 890 | <0.10 | <0.05 | <0.005 | 0.084 | <0.004 | 166 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-7A | 1,300 | <0.10 | <0.05 | <0.005 | 0.028 | <0.004 | 273 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-7C | 1,300 | <0.10 | <0.05 | <0.005 | 0.028 | <0.004 | 279 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-9A | 1,200 | <0.10 | <0.05 | <0.005 | 0.061 | <0.004 | 247 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-10 | 150 | <0.10 | <0.05 | <0.005 | 0.038 | <0.004 | 28.2 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-11 | 200 | <0.10 | <0.05 | <0.005 | 0.014 | <0.004 | 28.6 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-11AB | 220 | <0.10 | <0.05 | <0.005 | 0.015 | <0.004 | 28.5 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-12 | 260 | <0.10 | <0.05 | <0.005 | 0.096 | <0.004 | 47.1 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| MW-A | 1,000 | <0.10 | <0.05 | <0.005 | 0.03 | <0.004 | 214 | <0.0005 | <0.010 | <0.010 | <0.010 | 0.066 | <0.0002 |
| MW-C | 1,700 | <0.10 | <0.05 | <0.005 | 0.04 | <0.004 | 334 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |
| CH | 340 | <0.10 | <0.05 | <0.005 | 0.059 | <0.004 | 48.5 | <0.0005 | <0.010 | <0.010 | <0.010 | <0.050 | <0.0002 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.
SOURCE: SAMPLES TAKEN BY SPRI. ANALYTICAL RESULTS FROM MOLYCORP.

NA - NOT AVAILABLE

# TABLE D1
## 1994 MONITOR WELL WATER QUALITY DATA FOR TAILINGS AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO


| MONITOR WELL | POTASSIUM (mg/L) | MAGNESIUM (mg/L) | MANGANESE (mg/L) | MOLYBDENUM (mg/L) | SODIUM (mg/L) | NICKEL (mg/L) | LEAD (mg/L) | ANTIMONY (mg/L) | SELENIUM (mg/L) | SILICON (mg/L) | THALLIUM (mg/L) | VANADIUM (mg/L) | ZINC (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EW-1 | 3.7 | 47.9 | 0.017 | <0.02 | 41.7 | <0.020 | <0.002 | <0.05 | <0.005 | 13.8 | <0.005 | <0.010 | <0.050 |
| EW-2 | 3.3 | 10.4 | 0.169 | <0.02 | 20.0 | <0.020 | <0.002 | <0.05 | <0.005 | 15.7 | <0.005 | <0.010 | <0.050 |
| EW-2 | 3.6 | 10 | 0.138 | <0.02 | 19.6 | <0.020 | <0.002 | <0.05 | <0.005 | 17.3 | <0.005 | <0.010 | 0.091 |
| EW-3 | 2.6 | 31.8 | 0.056 | <0.02 | 28.6 | <0.020 | <0.002 | <0.05 | <0.005 | 12.4 | <0.005 | <0.010 | <0.050 |
| EW-3 | 2.2 | 27.8 | 0.036 | <0.02 | 28.9 | <0.020 | <0.002 | <0.05 | <0.005 | 11.9 | <0.005 | <0.010 | 0.364 |
| EW-4 | 1.5 | 17.8 | <0.010 | <0.02 | 15.5 | <0.020 | <0.002 | <0.05 | <0.005 | 12.4 | <0.005 | <0.010 | <0.050 |
| EW-4 | 2.1 | 18.1 | 0.019 | <0.02 | 16 | <0.020 | <0.002 | <0.05 | <0.005 | 12.7 | <0.005 | <0.010 | 0.364 |
| MW-1 | 3.0 | 41.2 | 0.035 | 0.04 | 55.4 | <0.020 | <0.002 | <0.05 | <0.005 | 11.9 | <0.005 | <0.010 | <0.050 |
| MW-2 | 3.1 | 52.2 | 0.37 | 1.7 | 95.6 | <0.020 | <0.002 | <0.05 | <0.005 | 1.8 | <0.005 | <0.010 | <0.050 |
| MW-3 | 1.5 | 48.6 | 0.032 | <0.02 | 71.6 | <0.020 | <0.002 | <0.05 | <0.005 | 10.3 | <0.005 | <0.010 | <0.050 |
| MW-4 | 1.1 | 32.7 | <0.010 | 0.21 | 64.2 | <0.020 | <0.002 | <0.05 | <0.005 | 10.3 | <0.005 | <0.010 | <0.050 |
| MW-7A | 2.6 | 47.1 | <0.010 | <0.02 | 39.5 | <0.020 | <0.002 | <0.05 | <0.005 | 12.3 | <0.005 | <0.010 | <0.050 |
| MW-7C | 3.9 | 48.4 | <0.010 | <0.02 | 45.1 | <0.020 | <0.002 | <0.05 | <0.005 | 12.1 | <0.005 | <0.010 | <0.050 |
| MW-9A | 1.7 | 45.5 | 0.111 | <0.02 | 66.0 | <0.020 | <0.002 | <0.05 | <0.005 | 10.5 | <0.005 | <0.010 | <0.050 |
| MW-10 | 1.3 | 4.4 | <0.010 | <0.02 | 14.7 | <0.020 | <0.002 | <0.05 | <0.010 | 10.8 | <0.005 | <0.010 | <0.050 |
| MW-11 | 2.8 | 8.6 | <0.010 | 0.06 | 25.8 | <0.020 | <0.002 | <0.05 | <0.005 | 15.5 | <0.005 | <0.010 | <0.050 |
| MW-11AB | 2.6 | 8.6 | <0.010 | 0.06 | 25.7 | <0.020 | <0.002 | <0.05 | <0.005 | 15.5 | <0.005 | 0.01 | <0.050 |
| MW-12 | 2.9 | 8.5 | <0.010 | 0.02 | 24.5 | <0.020 | <0.002 | <0.05 | <0.005 | 13.6 | <0.005 | <0.010 | <0.050 |
| MW-A | 2.8 | 35.7 | 0.04 | 0.63 | 50.6 | <0.020 | <0.002 | <0.05 | <0.005 | 10.9 | <0.005 | <0.010 | <0.050 |
| MW-C | 2.1 | 56.1 | 0.774 | 1.12 | 82.2 | <0.020 | <0.002 | <0.05 | <0.005 | 11.6 | <0.005 | <0.010 | <0.050 |
| CH | 1.2 | 9.4 | <0.010 | <0.02 | 57.8 | <0.020 | <0.002 | <0.05 | <0.005 | 9.8 | <0.005 | <0.010 | 0.946 |

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.
SOURCE: SAMPLES TAKEN BY SPRI. ANALYTICAL RESULTS FROM MOLYCORP.

NA - NOT AVAILABLE

**APPENDIX E**

# APPENDIX E

## Data from Tailings Area Aquifer Drawdown and Recovery Tests

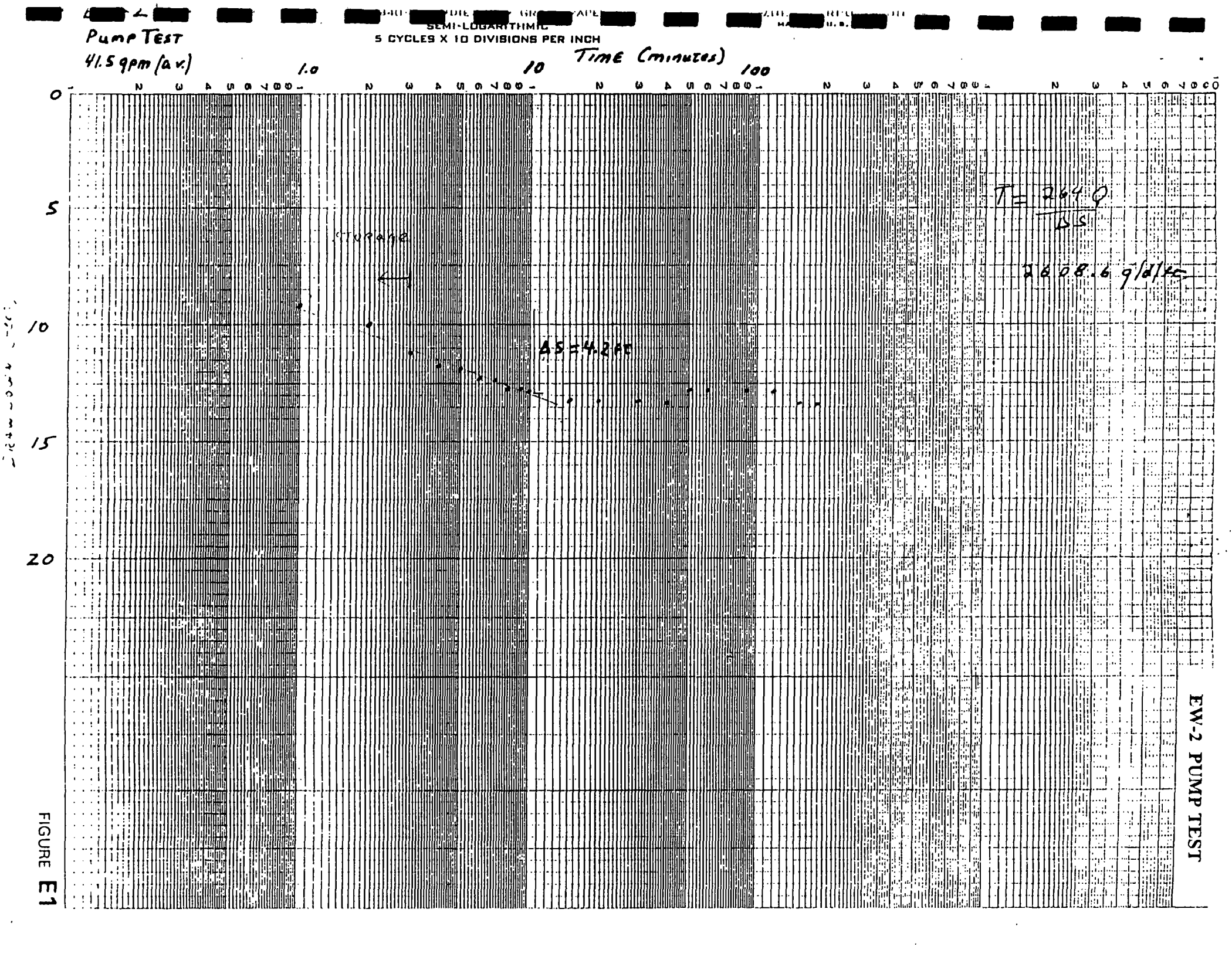

Pump Test
41.5 gpm (a.v.)
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
Time (minutes)
1.0
10
100
Drawdown
Δs = 4.2 ft
T = 264 Q / Δs
2608.6 gpd/ft
EW-2 PUMP TEST

FIGURE E1

Recovery Test
41.5 gpm (av)
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
t/t'
10
100
1000
0
1.0
2.0
3.0
4.0
5.0
s'
Δs'
T = 2440 / Δs'
= 27,340 g/d/FT
EW-2 RECOVERY TEST

FIGURE E1a

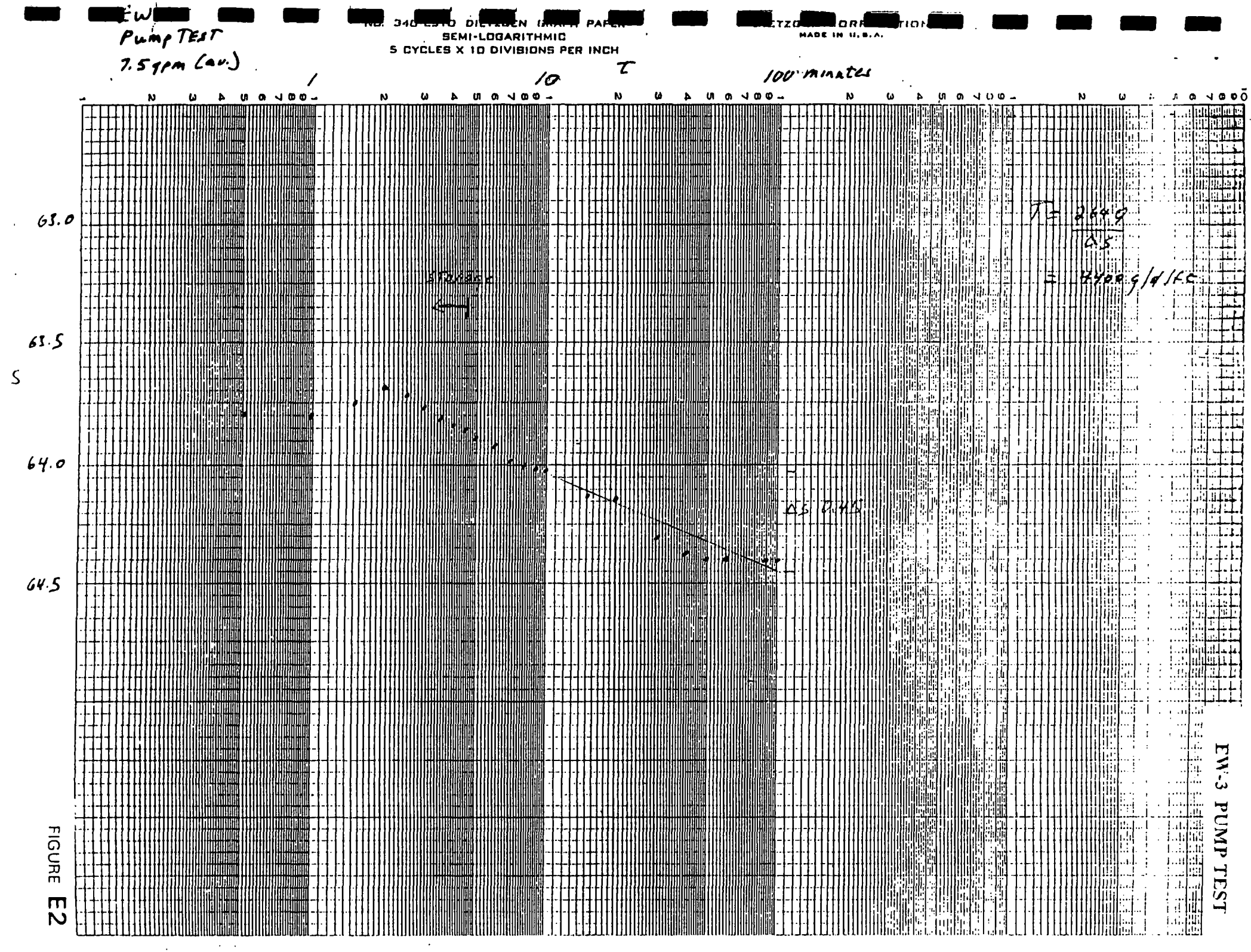
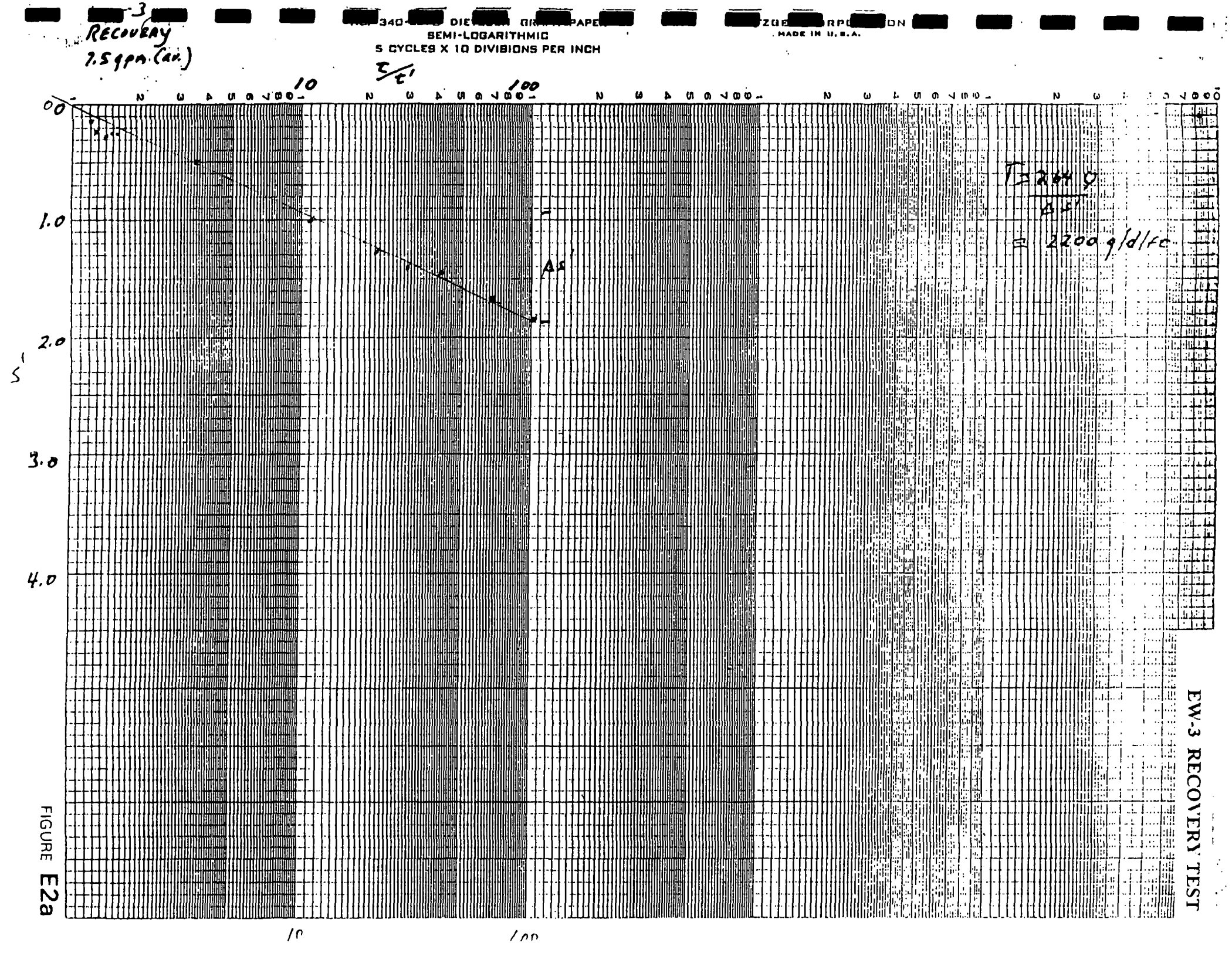

EW
Pump TEST
7.5 gpm (av.)
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
MADE IN U.S.A.
1
10
τ
100 minutes
63.0
63.5
64.0
64.5
S
Storage
Δs 0.45
T = 264 Q / Δs
= 4400 g/d/ft
EW-3 PUMP TEST

FIGURE E2




EW-3 RECOVERY TEST

FIGURE E2a

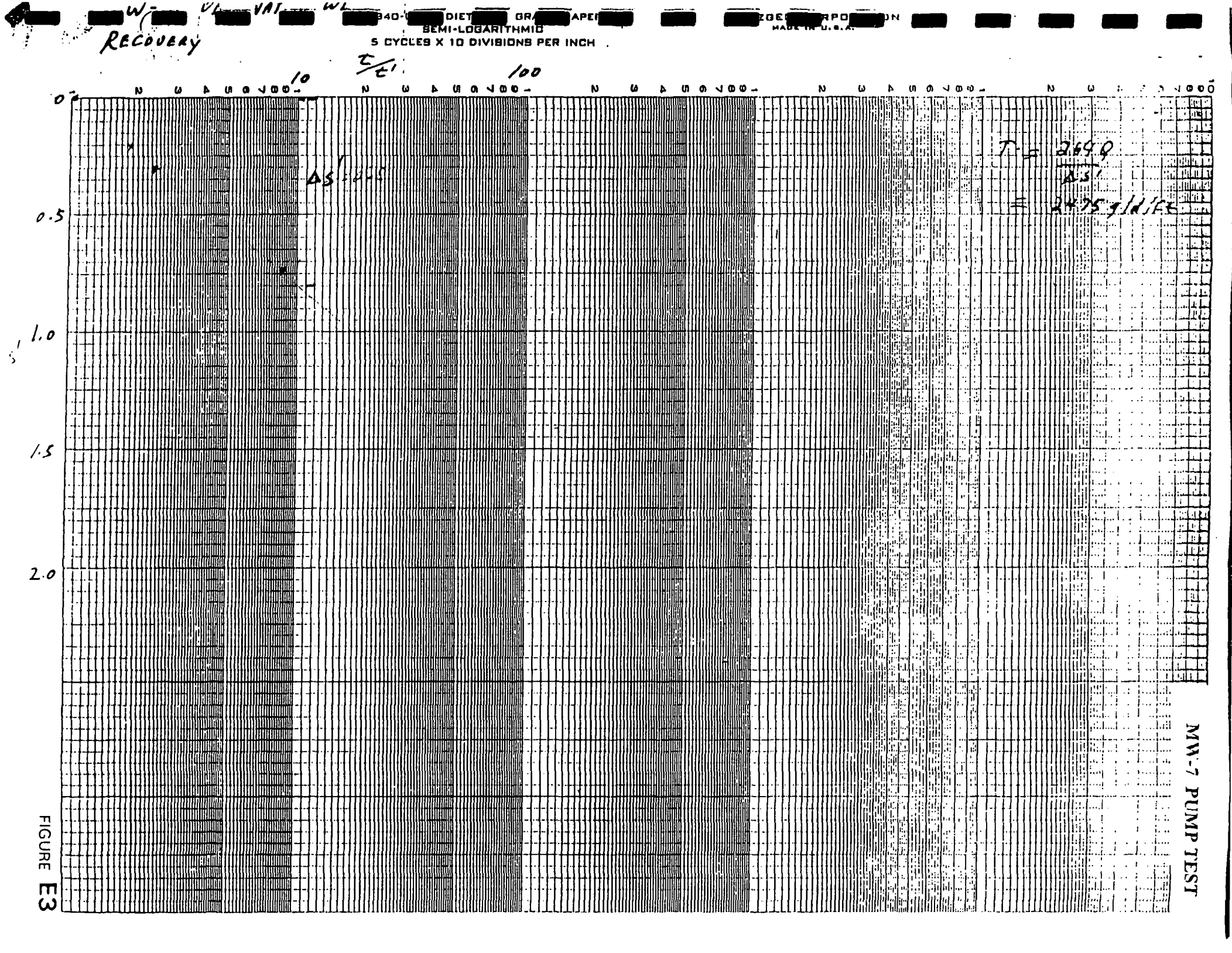

RECOVERY
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
MADE IN U.S.A.
t/t'
10
100
0
0.5
1.0
1.5
2.0
Δs' = 0.5
T = 264Q/Δs'
= 2475 gpd/ft
MW-7 PUMP TEST

FIGURE E3

**PROBABLE BAROMETRIC-INDUCED CHANGES IN STATIC WATER LEVEL AT MW-7C DURING PASSAGE OF A WEATHER FRONT - NOVEMBER 17, 1994**

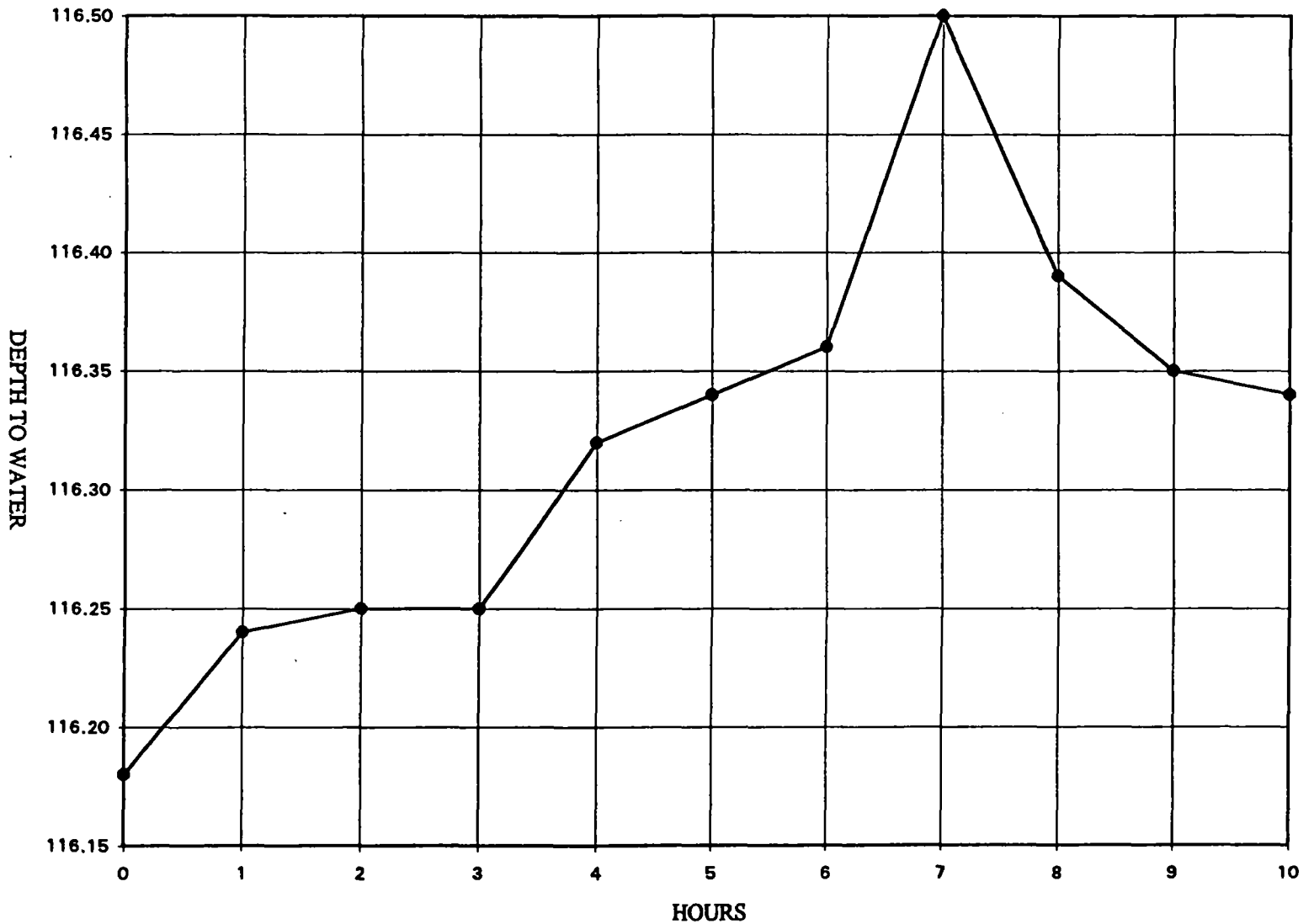



FIGURE **E3a**