RED RIVER GROUNDWATER INVESTIGATION

FINAL REPORT

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SURFACE WATER QUALITY BUREAU

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(Selected Excerpts)

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EXECUTIVE SUMMARY

RED RIVER GROUNDWATER INVESTIGATION, MARCH 1996

The Red River Groundwater Investigation was a two-year project funded by USEPA under a Clean Water Act Section 319(h) grant to the New Mexico Environment Department. 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. 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 is illustrated by increasing downstream concentrations of total dissolved solids, sulfate, and metals. 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.

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 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, the greatest impact to the Red River is ARD seepage. Sources of ARD from the Molycorp mine include sulfide material in the waste-rock dumps, open pit, underground workings, and 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 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. The scar areas are known to generate ARD and therefore have an impact on local groundwater and surfacewater 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.

In 1994 a series of twelve new groundwater monitoring wells were installed by Molycorp along the middle reach of the Red River. Water from all the new wells, as well as the seeps in the middle reach of the Red River, exceeded NM Groundwater Standards for certain constituents (TDS, sulfate, Fl, Al, Fe, Mn, Co, Cu, Ni, Zn, Cd). 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. In the vicinity of the mine, contaminant loading rates to the river have been estimated for sulfate and selected metals. At low flow, sulfate increases from 2768kg/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.

Reports by the NM Department of Game and Fish document that a significant and healthy population of native trout flourished Zn the middle reach of the Red River prior to the 1960's. 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 in the biologically impoverished condition that exists now in the reach between Molycorp Mine and Questa.

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. 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.

A total of 59 old mining sites are known to exist within seven 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. 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. Although sample data are limited and inconclusive, it is believed that a number of leaking or failing systems are probably contaminating shallow alluvial groundwater in the upper valley and hence may also be impacting the nearby river. 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 five lagoons 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. The ultimate discharge of the sewage effluent is to the Red River, where due to dilution by river water and by ground water 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. At the other sites hydrocarbon contamination was detected in the soil samples collected from borings, but 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 or 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. NMED's Ground Water Quality Bureau has required Molycorp to obtain discharge permits for boththe tailings area and the mine waste rock piles. The NM Mining Act is also requiring a mine permit, site assessment, and close-out plan from Molycorp. Within the NMED Surface Water Quality Bureau another 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 continuing activity by the Red River-Questa Watershed Association.

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 cfa, 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 Rivet 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 µmhos/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 mainstream 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 µmhos/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 µmhos/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 mainstream 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 mine sites 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 mainstream 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.

2.3.1.1 MOLYCORP MINE AND TAILING AREAS

- Mining History of Molycorp
- Waster Sources at Molycorp
- Hydrology of the Molycorp Mine Area
- Hydrology of the Molycorp Tailings Impoundments

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, Rl2E. 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), 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 rook 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 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-OH, 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/1) 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).

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 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 month 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).

3.2 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, 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 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-1l, 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 (i.e., 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 water (or in the monitoring wells) is not yet well known (the Capulin seep has been sampled by this project a total at 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 µmhos/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 µmhos/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 and1989), 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,l1,19). 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 (is, 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/1 upstream of the Town of Red River to >250 mg/1 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/1). For the above reach of river mean concentrations of dissolved Zn increase from .05 mg/1 to .11 mg/1. 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 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 (SRX, Apri 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, Cn=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/1. 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/1), 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 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), hefirst 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 scararea at Hansen Creek. The data show over a three-told 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/1), while seepage from the "scar area" (as identified by Molycorp) in Capulin Canyon has low concentrations of Zn (2.08 mg/1). 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 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 ShackSouth, 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 cf s of groundwater accretion to Red River. To further complicate an already confusing array of estimates, arguments are made byMolycorp 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, 8-5; 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-l1). 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 same 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.

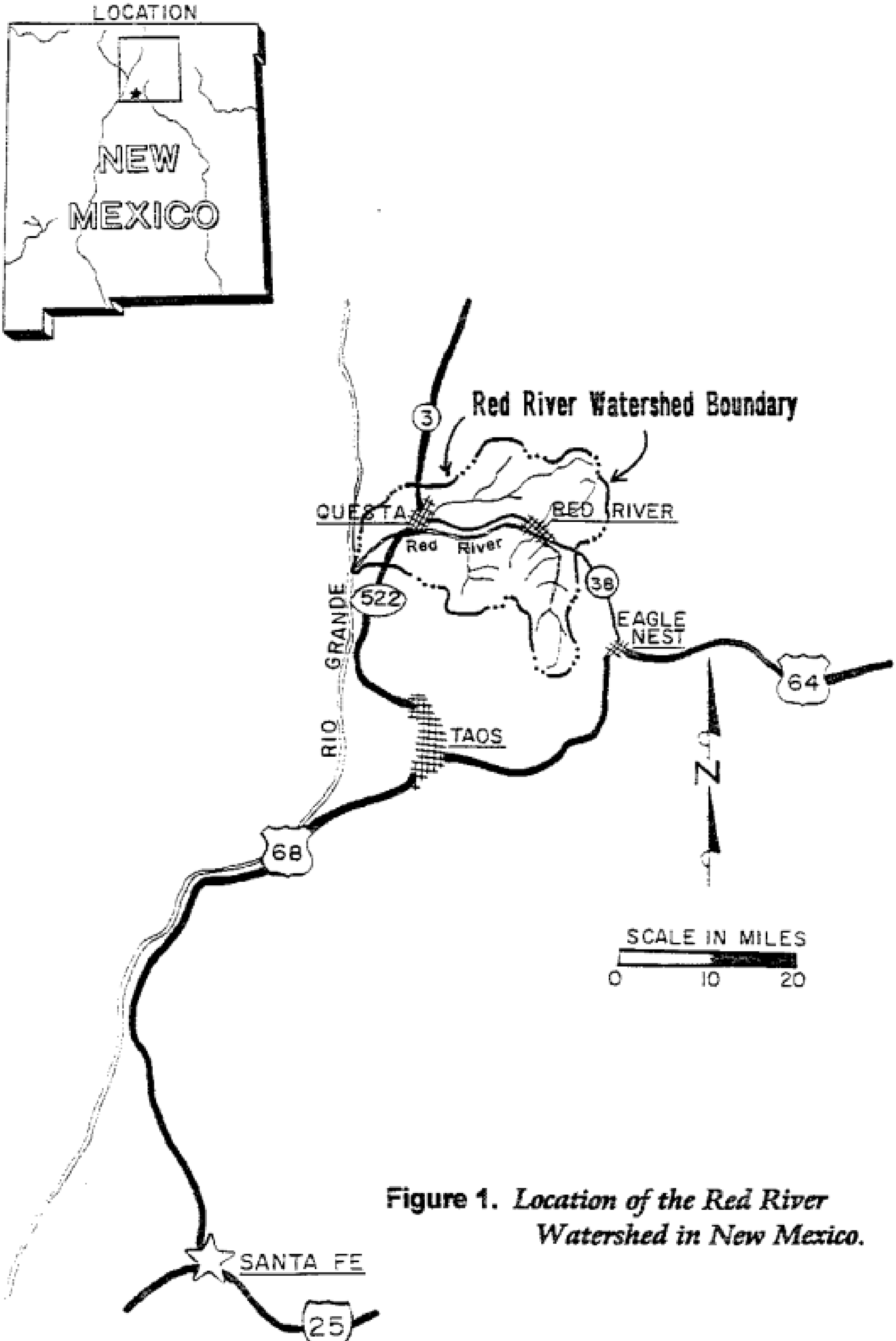

Figure 1. *Location of the Red River Watershed in New Mexico.*

FIGURE 2.

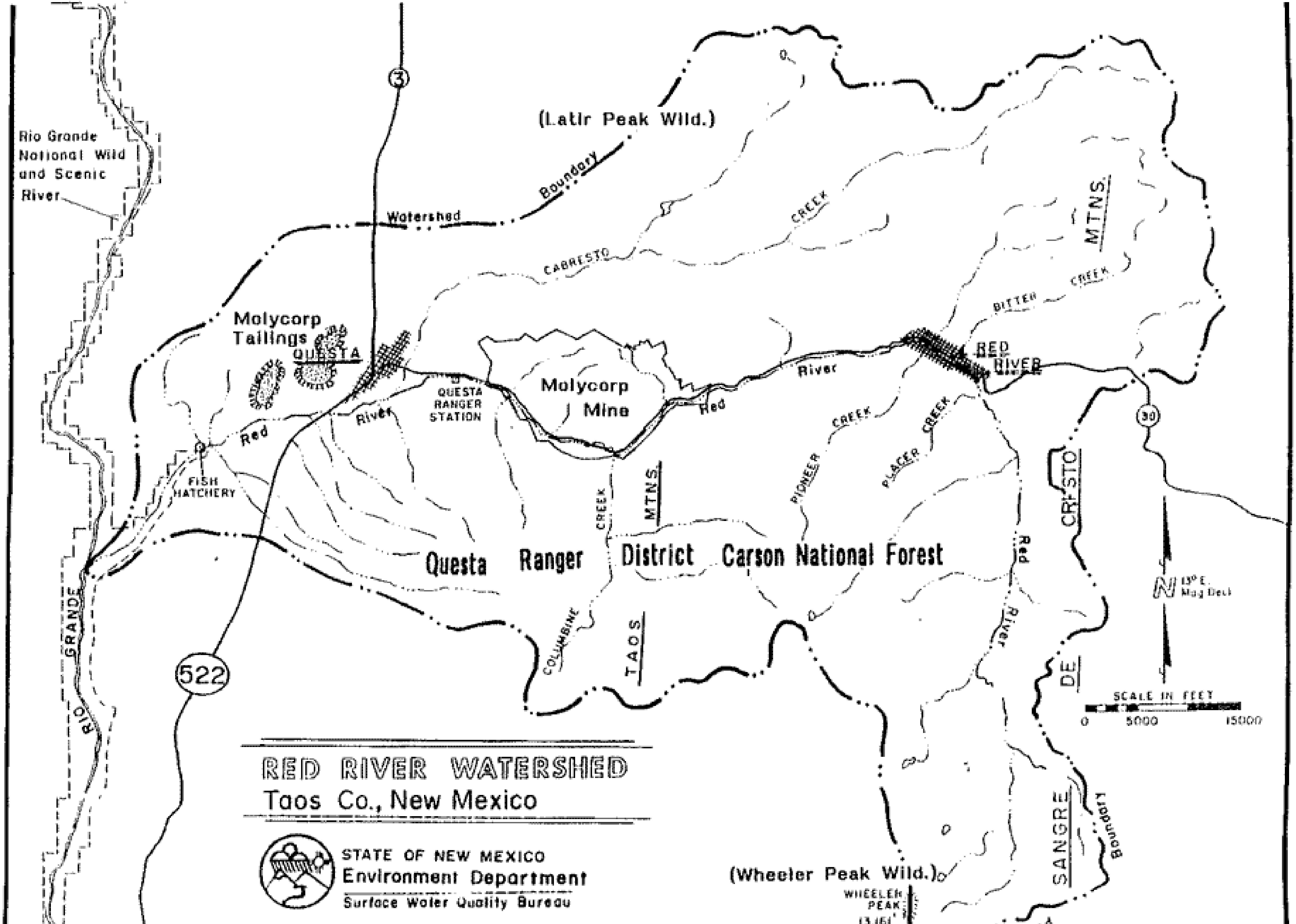

Figure 2. *Map of the Red River Watershed showing locations of features relative to this project.*

Figure 4.

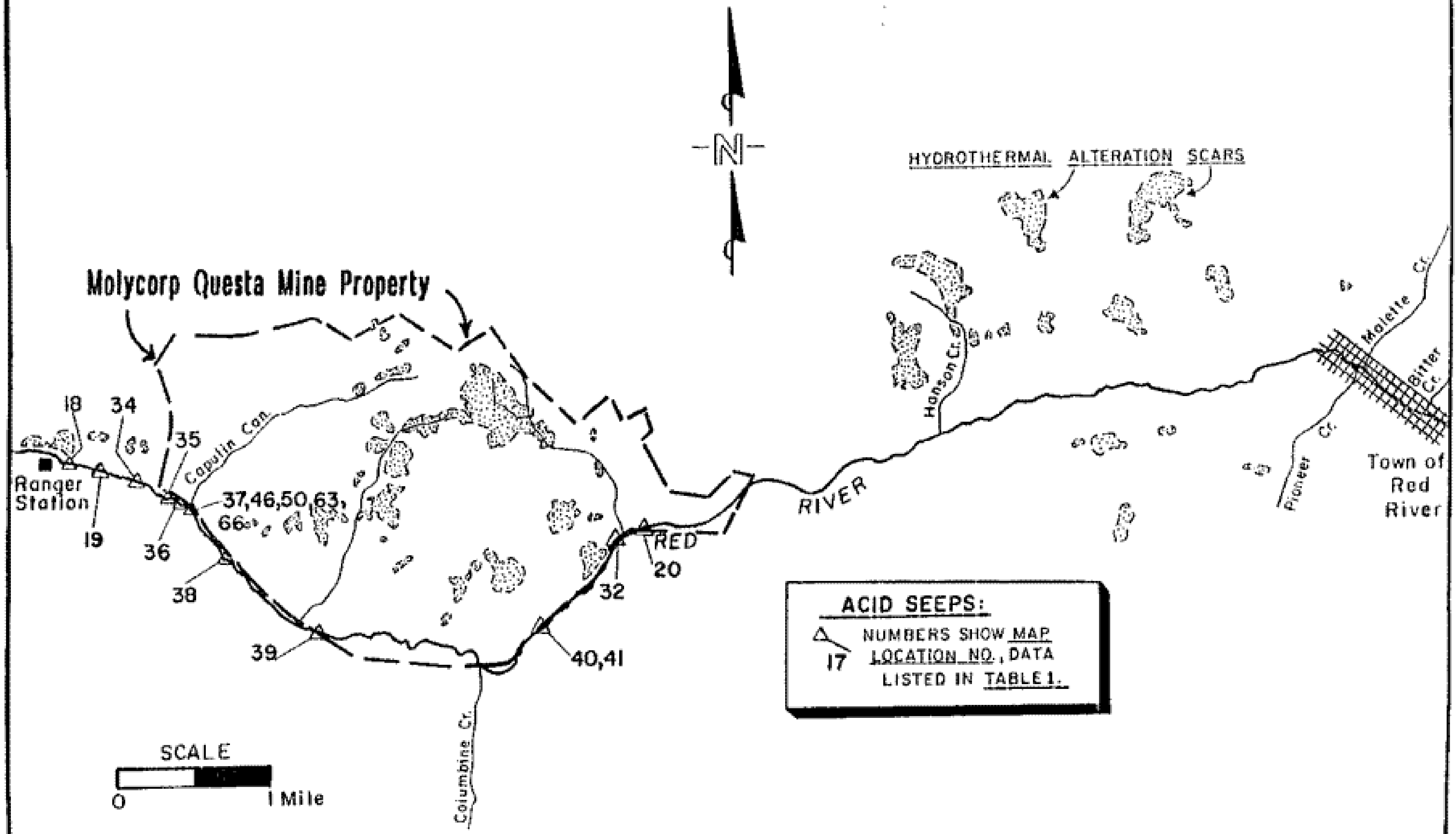

Figure 4. *Map of the middle reach of the Red River showing the Molycorp Questa Mine, acid seeps and natural hydrothermal scar areas.*

Figure 5.

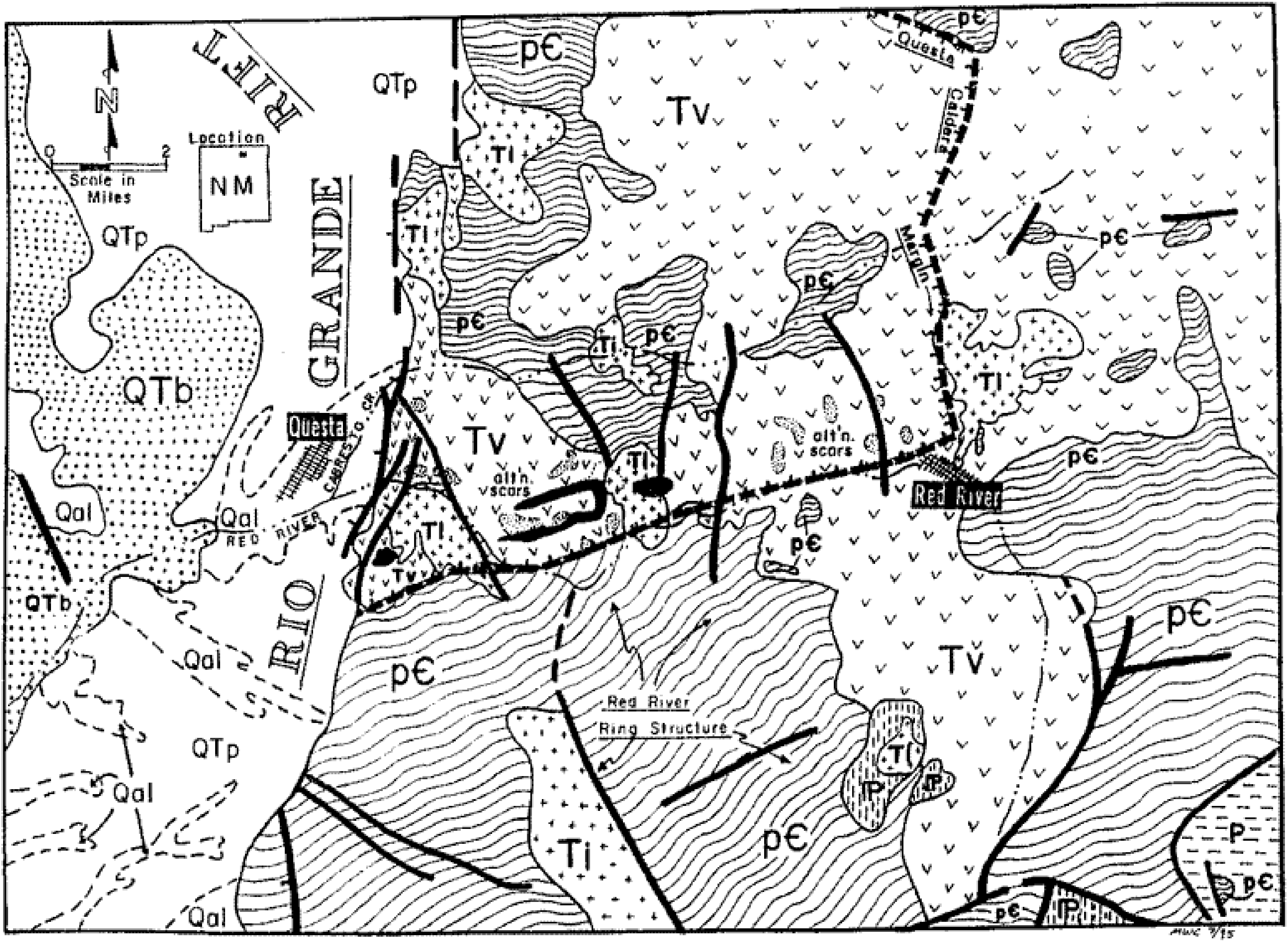

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Figure 5. Composite Geologic Map of Red River-Questa Area.

Explanation

Qal -- Quaternary Alluvium
Qtb -- Quat./Tertiary Basalt
Qtp -- Q/T Pediment Fill
Ti -- Tertiary Intrusives
Tv -- Tert. Volcanic and Igneous Rocks
P -- Permian Sediments
IP -- Pennsylvanian Rocks
pC -- Precambrian Basement

Symbols

Faults

Hydrothermal Alteration Scars

Molybdenum Mineralization

Sources of Geologic Information:
-Dane and Bachman, 1965, Geologic Map of New Mexico; USGS/NM BM&MR.
-McKinley, 1957, Geology of Questa Quad., NMBM&MR.
-Meyer and Leonardson, 1990, ...Alt'n. Scars...; NMGS 41st Conf.

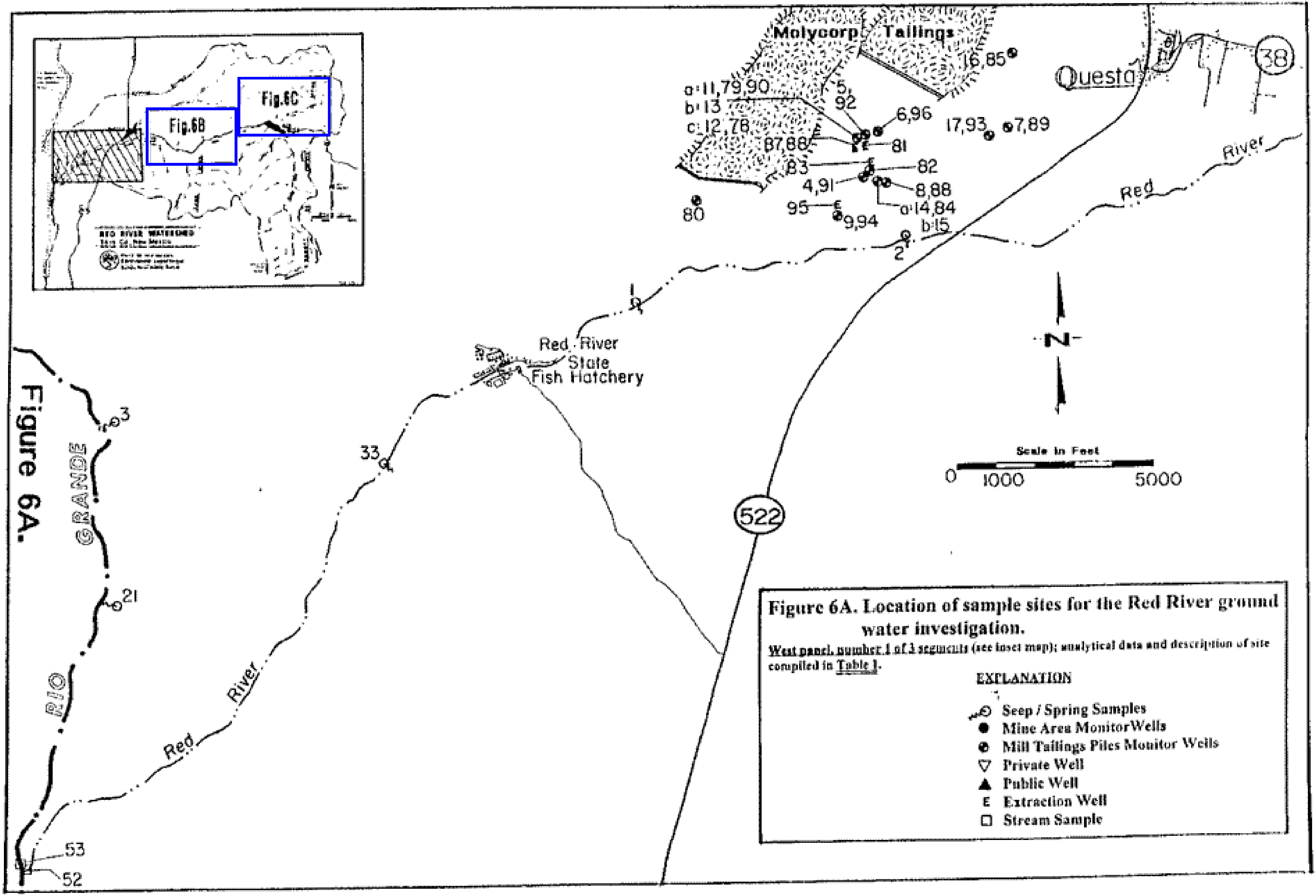

Figure 6A. Location of sample sites for the Red River ground water investigation.

West panel, number 1 of 3 segments (see inset map); analytical data and description of site compiled in Table 1.

EXPLANATION

- Seep / Spring Samples
- Mine Area MonitorWells
- Mill Tailings Piles Monitor Wells
- Private Well
- Public Well
- E Extraction Well
- Stream Sample

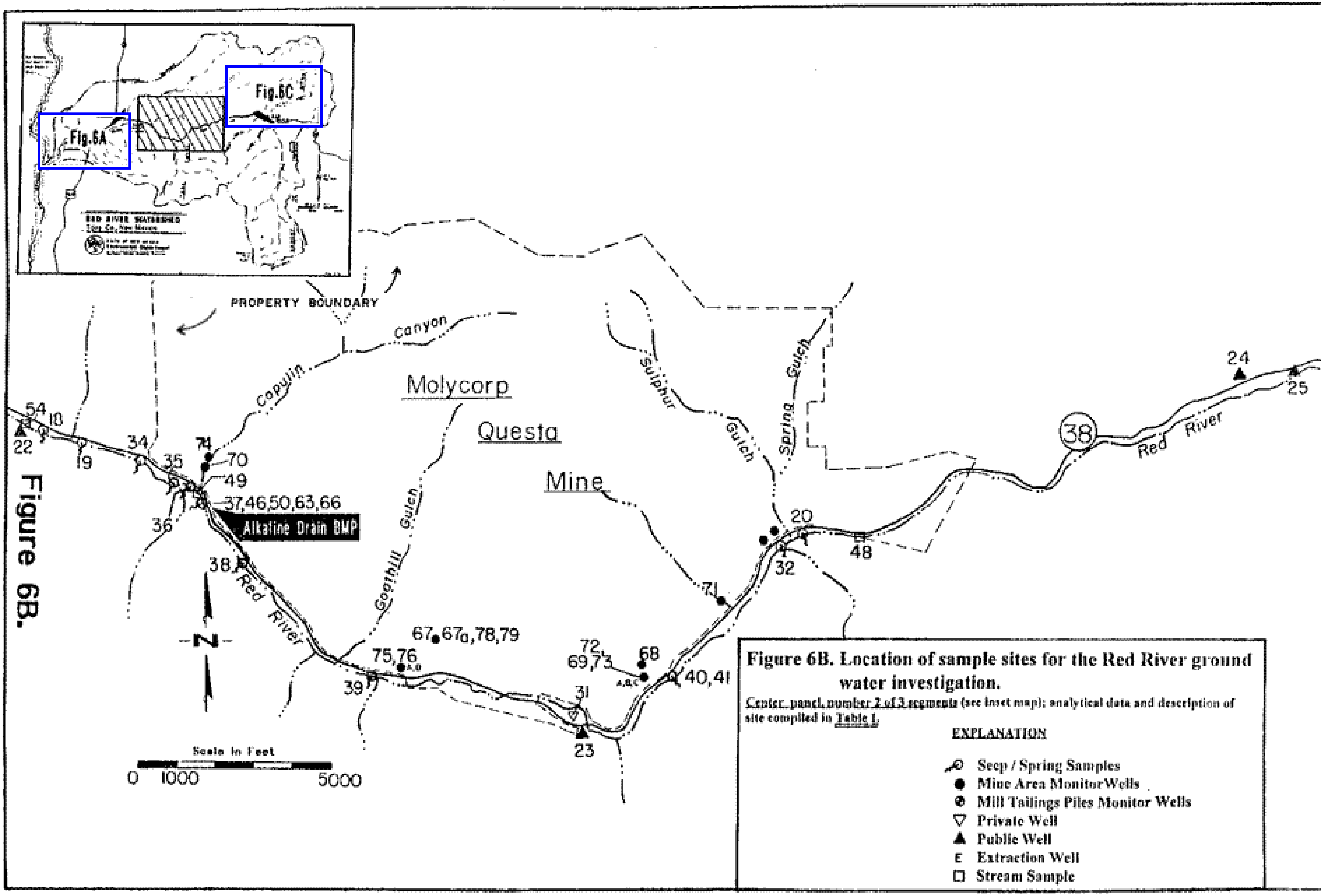

Figure 6B. Location of sample sites for the Red River ground water investigation.

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
- E Extraction Well
- Stream Sample

Figure 6C.

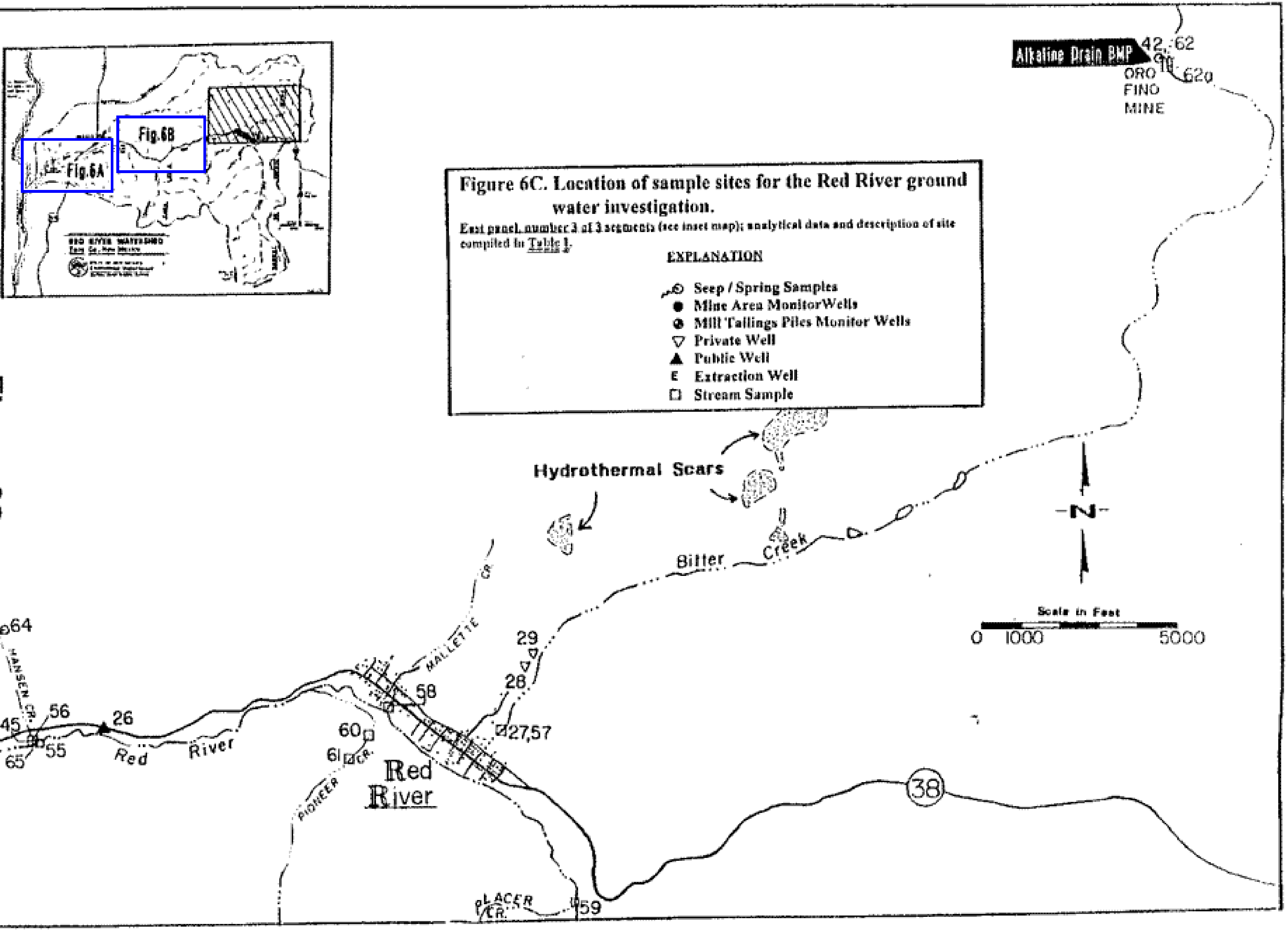

Figure 6C. Location of sample sites for the Red River ground water investigation.
East panel, number 3 of 3 segments (see inset map); analytical data and description of site compiled in Table 1.

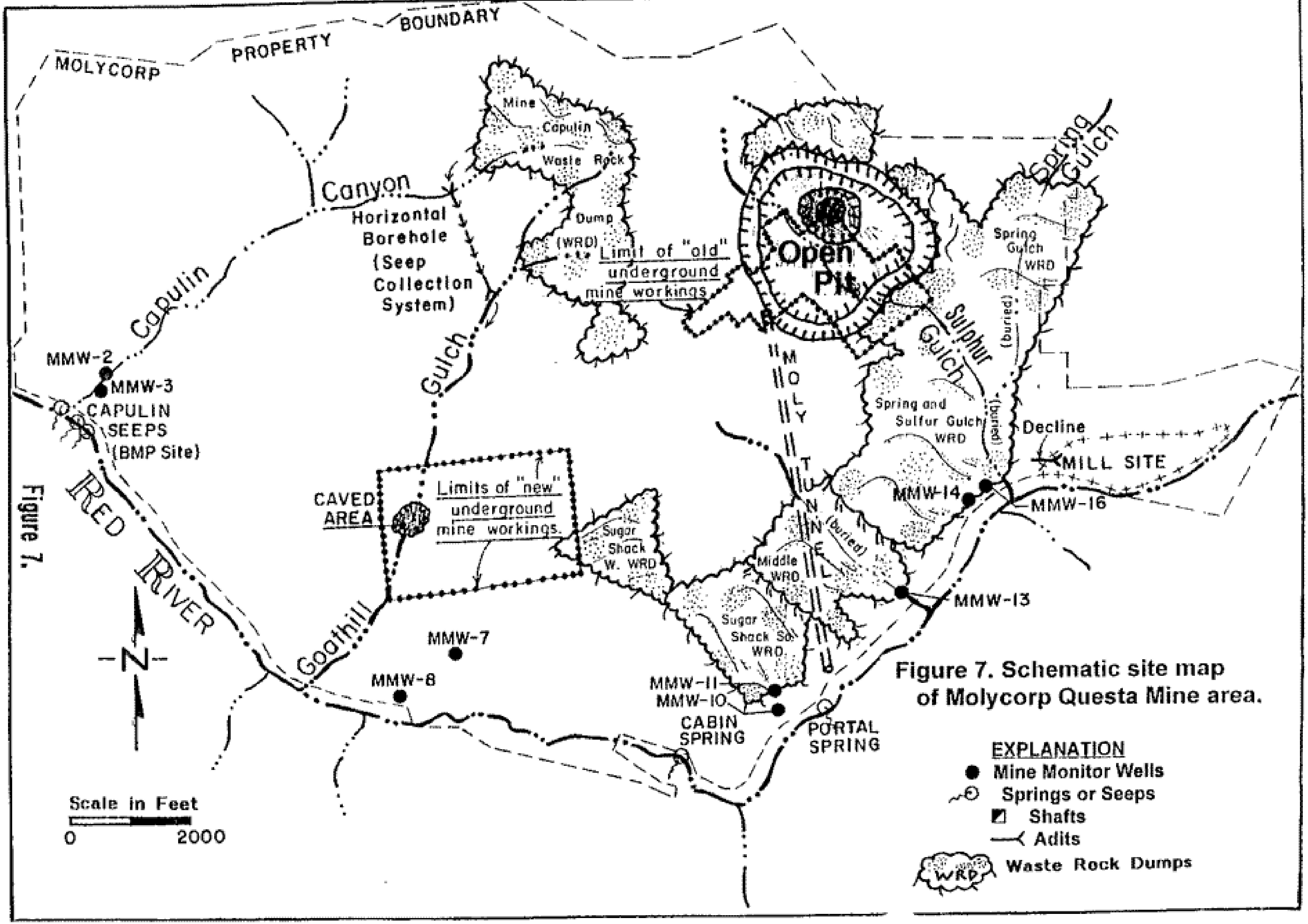

Figure 7. Schematic site map of Molycorp Questa Mine area.

Figure 9.

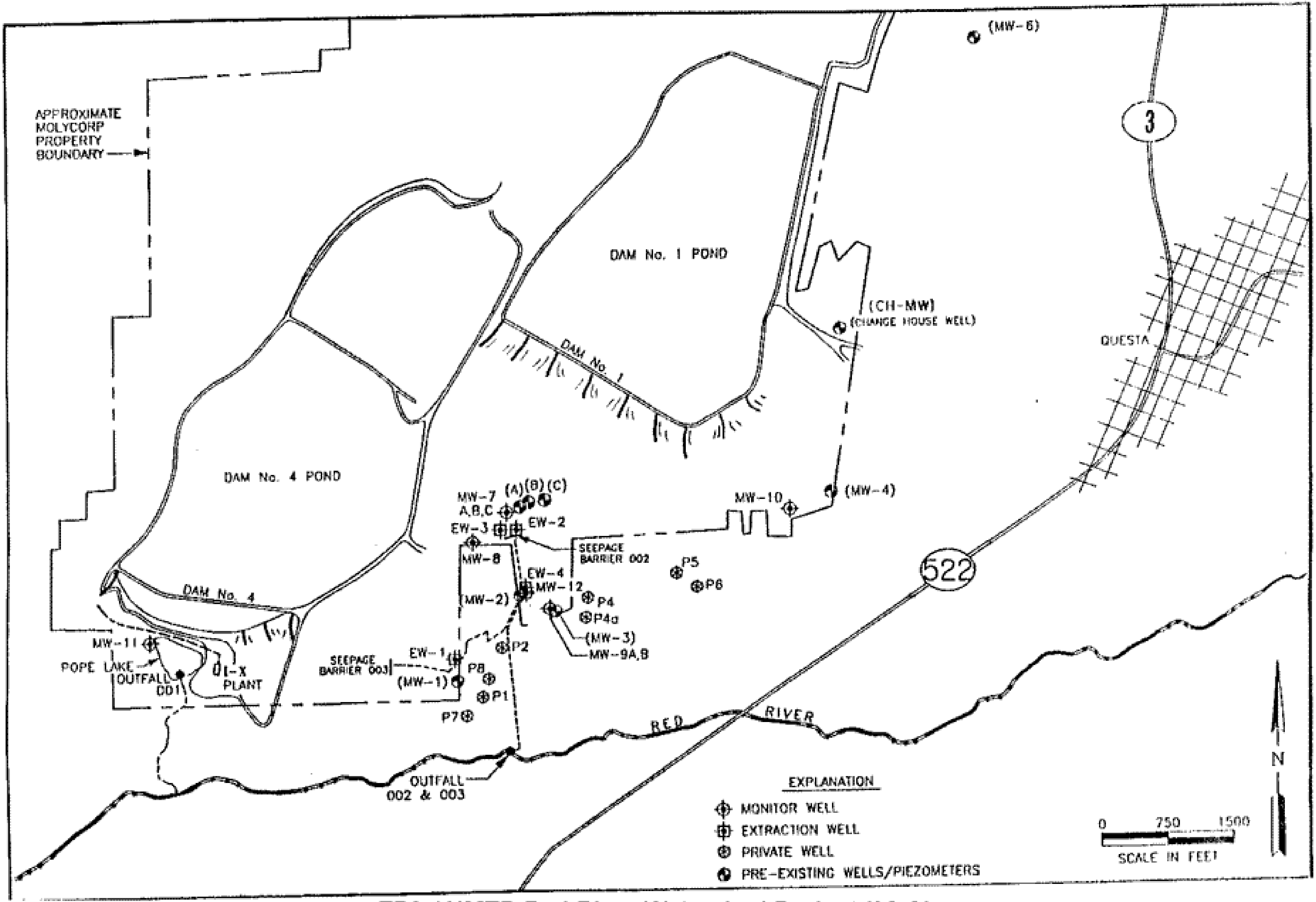

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Figure 9, Molycorp Questa Mine -- Tailings Area Map

(Modified after South Pass Resources report to Molycorp, Fig. 3, dated 2/10/95)