Table 3.2-2
Mean Annual Precipitation (inches)

Station	1944 - 1998	1981 - 1990	1991 - 1998	1985 - 1993
Elko	9.57	9.72	10.20	7.68
Battle Mountain	7.68	7.46	9.88	8.01

losses that may occur from a shallow lake or slow-moving river. Barrick has collected evaporation data at the Goldstrike Mine from spring to fall since 1990. These partial records also indicate an annual average for pan evaporation of about 60 inches. Free water surface evaporation estimates within the Humboldt River basin range from approximately 42 inches per year near Elko to approximately 54 inches per year near the Carson Sink (Houghton et. al., 1975). Evapotranspiration losses vary because of differences in plant species requirements and soil moisture storage. Evapotranspiration is estimated to consume up to 90 percent of the total precipitation in the hydrologic study area (McDonald Morrissey Associates, Inc. 1996b).

3.2.1.2 Hydrologic Study Area for Dewatering and Localized Water Management Activities

Ground Water

Hydrogeologic investigations have been performed to provide information on the existing ground water conditions of the study area. These include hydrogeologic investigations that (1) evaluate potential effects of mine dewatering (Adrian Brown Consultants, Inc. 1991, 1992; Balleau Groundwater Consulting and Leggette, Brashears & Graham, Inc. 1992; BLM 1991a; Leggette, Brashears & Graham, Inc. and Balleau Groundwater Consulting 1993; Barrick 1999a; Newmont 1997c; (2) summarize the effects of ground water use along the Carlin Trend (Maurer et al. 1996); (3) present a conceptual ground water flow model (McDonald Morrissey Associates, Inc. 1996a, b, 1997, 1998; and Hydrologic Consultants, Inc. 1997b, 1998a, 1999a); (4) summarize the effects of water use on the Humboldt River (RTi 1998; JBR 1996b, 1997; Hydrologic Consultants, Inc. 1997a); (5) report on the impacts of Gold Quarry Mine dewatering (Newmont 1992a); and (6) quantify ground water quality and chemistry (Radian International, LLC and Baker Consultants, Inc. 1997a, b; Water Management Consultants 1994; and Cohen 1962). These investigations describe the baseline information and hydrogeologic conditions of the hydrologic study area for evaluating dewatering impacts.

Recharge, storage, and movement of ground water is dependent in part upon geologic conditions. The general stratigraphic and structural framework throughout the hydrologic study area and the project site is described in Section 3.1, Geology. The generalized geologic conditions in the region are illustrated in Figures 3.1-1 and 3.1-2. The geologic formations in the study area can be grouped into six hydrostratigraphic units, as described in Section 3.1, and include (from oldest to youngest) marine carbonate rocks, marine clastic rocks, intrusive rocks, volcanic rocks, older basin fill, and younger basin fill.

In bedrock, the recharge, storage, flow, and discharge of ground water are largely controlled by the structure (i.e., fault and fracture zones, and solution cavities in carbonate rocks) of the geologic material. In the basin fill alluvium, ground water is stored and transmitted through interconnected pores within consolidated to unconsolidated sediments. In the study area, the main aquifers are found in carbonate rocks, volcanic rocks, and basin-fill deposits (Maurer et al. 1996)

Hydrostratigraphic Units. The six hydro-stratigraphic units and their hydrogeologic characteristics are discussed below. The hydraulic parameters for each hydrostratigraphic unit are summarized in Table 3.2-3.

Table 3.2-3
Summary of Hydrostratigraphic Unit Hydraulic Properties

Hydrostratigraphic Unit	Pumping Rate (gpm)	Estimated Hydraulic Conductivity (feet/day)	Estimated Transmissivity ($feet^2$/day)	Estimated Storage Coefficient (no units)
Younger Basin Fill	Up to 3,600 in Boulder Valley[2]	1 to 100[2]	4,500[1] - 13,400[2]	0.0025[1]
Older Basin Fill	<100 - 1,000[1]	0.05 - 5[2]	20 - 900[2]	0.0038[2]
Intrusive Rocks	Generally <10[2]	0.01 - 1	NA	NA
Volcanic Rocks	Up to 5,800 in Boulder Valley[2]	0.5 - 250[2]	300 - 100,000[2]	0.0007 - 0.003[2]
Marine Clastic Rocks	10 - 1,000[2]	0.0014 - 100[1]	30 - 800[2]	0.0001 - 0.004[2]
Marine Carbonate Rocks	330 - 4,100[2]	0.1 - 400[2]	13 - 300,000[2]	0.0002 - 0.014[1]

[1]Maurer et al. 1996.
[2]McDonald Morrissey Associates, Inc. 1996a, b, 1998.
NA - No data available.

Marine Carbonate Rocks. The Paleozoic marine carbonate rocks consist of limestone and dolomite and lesser amounts of shale, sandstone, and quartzite. These rocks are mainly Cambrian to Devonian in age but locally also include Pennsylvanian/Permian carbonate rocks. The western edge of the carbonate rock province is located approximately 6 miles northwest of the Betze-Post Pit. Carbonate rocks appear at the surface in the Tuscarora Mountains south of the Betze-Post Pit and in bedrock outcrops in the Maggie Creek and Susie Creek basins (Figure 3.1-2). Carbonate rocks are believed to underlie the younger units and the marine clastic rocks (beneath the Roberts Mountain Thrust) in areas within the carbonate rock province. In areas of carbonate rock outcrop, the overlying clastic rocks and younger volcanics are thought to have been removed by erosion (McDonald Morrissey Associates, Inc. 1996b).

The marine carbonate rocks have low primary permeability. The bulk hydraulic conductivity for most materials reportedly ranges from 0.2 to 10 feet per day (Maurer et al. 1996). However, where they are faulted or fractured coupled with dissolution, their transmissive properties greatly increase. For example, within the Meikle Mine, caverns with widths greater than 100 feet have been discovered in the carbonate rocks.

Marine Clastic Rocks. The Paleozoic marine clastic rocks consist of interbedded shale, siltstone, chert, quartzite, and limestone. Marine clastic rocks are believed to underlie the alluvium and volcanic rocks in most of the study area, and they form the upper plate of the Roberts Mountain Thrust. They have been mapped mainly as Vinini Formation in the study area. These clastic rocks are exposed in the Tuscarora Mountains, Independence Range, and Adobe Range (Figure 3.1-2). They have been extensively thrusted and eroded, and estimates of their thickness range from 50 to 5,000 feet. These rocks are fine-grained and have low hydraulic conductivity with most reported values ranging from 0.01 to 0.5 foot per day (McDonald Morrissey Associates, Inc. 1996b), but local faulting, fracturing, and solution widening can increase secondary permeability (Maurer et al. 1996).

Intrusive Rocks. Tertiary through Jurassic intrusive rocks are a minor component of the rock types in the study area (Figure 3.1-2) and consist mostly of granodiorite, quartz monzonite, monzonite, and diorite. The intrusive rocks form a relatively impermeable boundary immediately south of the Betze-Post Pit. They also mark the southern boundary of mineralization in the mine area. Reasonable estimates of hydraulic conductivity are 0.01 to 1 foot per day, and wells generally yield less than 10 gallons per minute (gpm) (McDonald Morrissey Associates, Inc. 1996b). Wells completed in the intrusive rocks may yield small quantities of water near some faults (Maurer et al. 1996).

Volcanic Rocks. Tertiary through Jurassic volcanic rocks consist of a wide range of igneous rock types: rhyolitic to basaltic lava flows, welded and nonwelded ash-fall tuffs, flow breccia, and tuffaceous sedimentary rocks. The volcanics occur throughout the area with most of the exposures in the western, northern, and south-central portions of the hydrologic study area (Figure 3.1-2). This wide range of rock types results in highly variable hydraulic parameters. The welded tuff, basalt, and andesite generally have low transmissive properties, while the rhyolite, particularly where fractured, is more transmissive. Overall, the hydraulic conductivity of volcanic rocks in the area is probably between 0.5 and 200 feet per day (McDonald Morrissey Associates, Inc. 1996b). In the northern margin of Boulder Valley the rhyolite is highly fractured, and its hydraulic conductivity could approach 250 feet per day.

Older Basin-fill Deposits. Pliocene to Miocene age basin-fill deposits in the area are primarily composed of poorly consolidated shale, claystone, mudstone, siltstone, sandstone, conglomerate, freshwater limestone, tuff and lava flow (Plume 1995; Maurer et al. 1996). These deposits accumulated in basins that developed in the earliest stages of extensional faulting. In the upper Maggie Creek basin, these deposits are estimated to be up to 6,000 feet thick. In Susie Creek and lower Maggie Creek basins, the deposits are generally less than 2,000 feet thick (HCI 1999b). Wells completed in the Carlin Formation have reported yields ranging from less than 100 to 1,000 gpm. In the Maggie Creek area, hydraulic conductivity ranges from 1 to 7 feet/day and transmissivity from 780 to 9,800 square feet/day (Maurer et al. 1996). In the northern part of Boulder Flat, transmissivity is estimated to range from 70 to 300 square feet/day (Stone et al. 1991). Locally, the fine-grained beds act as an aquitard producing confined ground water conditions in the underlying rocks (BLM 1991a).

Younger Basin-fill Deposits. The Quaternary alluvium contains a wide range of materials: sandy clay, silty sand, gravelly sand, and sandy gravel. The thickness and lateral extent of this material is also highly variable. In higher elevation mountain areas, the alluvium occurs as discontinuous to continuous strands of unconsolidated material covering or partially covering bedrock along the floor of the valley or ravine. Alluvium in higher elevation areas is generally less than a few tens of feet thick. In broad basin areas, such as Boulder Flat, and to a lesser extent in the Maggie Creek and Susie Creek basins, the alluvium occurs as sequences of unconsolidated to poorly consolidated material up to 1,000 feet thick (McDonald Morrissey Associates, Inc. 1996b). Overall, the alluvium is generally coarser-grained in the mountains and finer-grained in the basins, and it becomes finer toward the center of the basin. The alluvium also is characterized by significant lateral and vertical stratigraphic variation with clay typically occurring as thinly bedded lenses. The alluvium is generally presumed to be an unconfined aquifer; however, semi-confined conditions may exist locally where less permeable fine-grained units inhibit vertical flow. Values of hydraulic conductivity are estimated to range from 1 to 100 feet per day (McDonald Morrissey Associates, Inc. 1996b).

Hydrostructural Units. Ground water flow pathways are influenced by major faults that offset and displace rock units and older alluvial deposits. Depending on the physical properties of the rocks involved, faulting may either result in the fault zone behaving as an impediment or conduit for ground water flow relative to the surrounding hydrostratigraphic units. For example, faulting of softer, less competent rocks typically forms zones of crushed and pulverized rock material that tend to impede or reduce ground water movement across the fault zone. In addition, faulting may impede flow by juxtaposing rocks with low relative permeabilities against rocks with much higher permeabilities. In contrast, faulting of hard, competent rocks often creates conduits along the fault trace resulting in zones of higher ground water flow and storage capacity compared to the unfaulted surrounding rock. Depending on the rock materials and style of fault movement, it is possible for the fault to act as both an impediment to flow across the fault and a conduit to flow along the strike of the fault.

Long-term monitoring of drawdown and mounding in the vicinity of the Goldstrike property has resulted in the recognition of three major faults or fault zones that tend to impede the movement of ground water across the faults. These faults include the (1) Boulder Narrows Fault located in Boulder Valley; (2) Siphon Fault located between the TS Ranch Reservoir and the Betze-Post Pit; and (3) Post Fault located on the east side of the Betze-Post Pit. The locations of the major hydrostructural features are illustrated in Figure 3.2-5 (McDonald Morrissey Associated 1998), and a generalized cross-section is shown in Figure 3.2-6 (Barrick 1999a).

Boulder Narrows Fault. The Boulder Narrows Fault in Boulder Valley has no surface expression. McDonald Morrissey Associates, Inc. (1997) reports that evidence for this fault includes: (1) offset of rhyolite in the area of the fault by approximately 700 feet; (2) the presence of Green, Knob, and Sand Dune springs (see the section on Seeps and Springs below for a description of these springs); (3) Newmont gravity surveys indicating that the basin is 3,000 feet deep just to the south of the fault; and (4) water-table gradients in the alluvium that are noticeably steeper, and water levels appear to be elevated north of the fault. The Boulder Narrows Fault is thought to impede ground water flow across the fault (McDonald Morrissey Associates, Inc. 1997).

Siphon Fault. The Siphon Fault separates highly permeable marine carbonate rocks north of the fault from less permeable volcanic rocks south of the fault. As illustrated in Figure 3.2-6, the fault acts as a pronounced barrier that separates the drawdown cone developed from mine dewatering activity north of the fault from the ground water mound developed from the infiltration activities south of the fault (McDonald Morrissey Associates, Inc. 1996b). Wells located on either side of the fault record dramatically different water levels. For example, the water level in monitoring well NA-50D, located east of the Siphon Fault, was 4,375 feet amsl in late 1997, but the water level in monitoring well NA-7D, west of the fault, was 4,759 feet amsl. Both of these wells are completed in volcanic rocks, and their head difference of nearly 400 feet provides strong evidence that the Siphon Fault is a barrier to ground water flow (Barrick 1999b).

Post Fault. The Post Fault generally trends north-south and is exposed in the east wall of the Betze-Post Pit. Near vertical movement along the Post Fault has juxtaposed low permeability marine clastic rocks against the high permeability marine carbonate hydrostratigraphic unit. Exploratory drilling prior to active dewatering in the area revealed a 100-foot drop in ground water elevations across the fault from east to west (BLM 1991a). As mine dewatering has progressed, there has been a dramatic difference in the rates of observed water level decline in wells on either side of the Post Fault. As shown in Figure 3.2-6, much greater water level declines are seen on the west side of the Post Fault than on the east side (McDonald Morrissey Associates, Inc. 1996b). For example, monitoring well PZ95-1D, located on the east side of the Post Fault, had a water level of 4,819 feet amsl at the end of 1997. At the same time, monitoring well PZ96-2D, located on the west side of the fault, had a water level of 4,214 feet amsl. Both of these wells are completed in marine clastic rocks, and the difference in head of approximately 600 feet between the two wells is evidence that the fault is a barrier to ground water flow (McDonald Morrissey Associates, Inc. 1998). Again, this is probably controlled more by the juxtaposition of the different rock types across the fault than by the hydraulic characteristics of the fault itself.

Geothermal System. A deep geothermal system exists in the carbonate aquifer in the vicinity of the Betze-Post Pit and Meikle Mine. High-yield wells located within the carbonate aquifer compartment (that extends from the Betze-Post Pit to a distance of approximately 6 miles northwest of the Betze-Post Pit) have reported temperatures at the well head of 140 to 145 degrees Fahrenheit. In contrast, wells drilled into the low-yield, marine clastic rocks located immediately east of the Betze-Post Pit have well-head temperatures that range from 70 to 90 degrees Fahrenheit. Identification and understanding of the deep geothermal system is important to understand the movement of ground water. For specific hydraulic characteristics and head distributions, the rate of

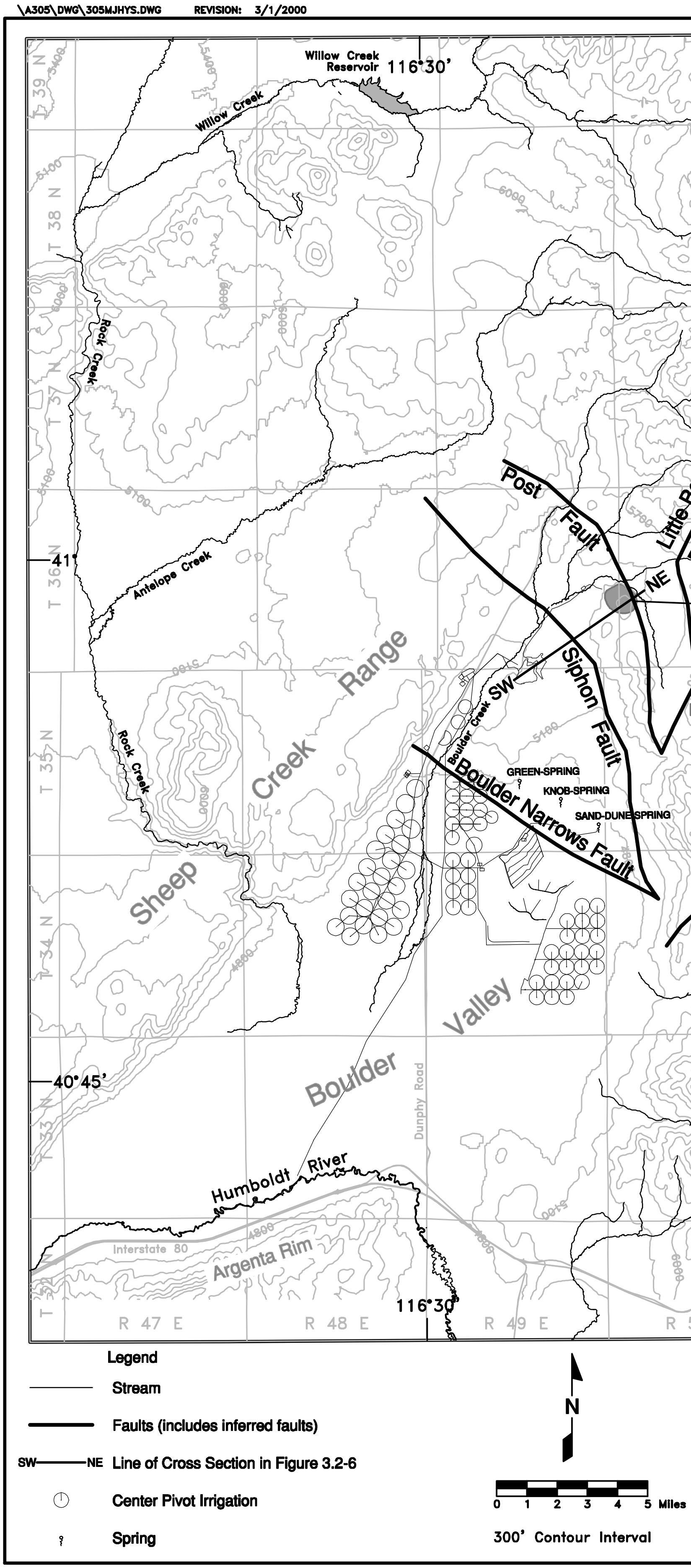


Figure 3.2-5

Major Hydrostructural Features

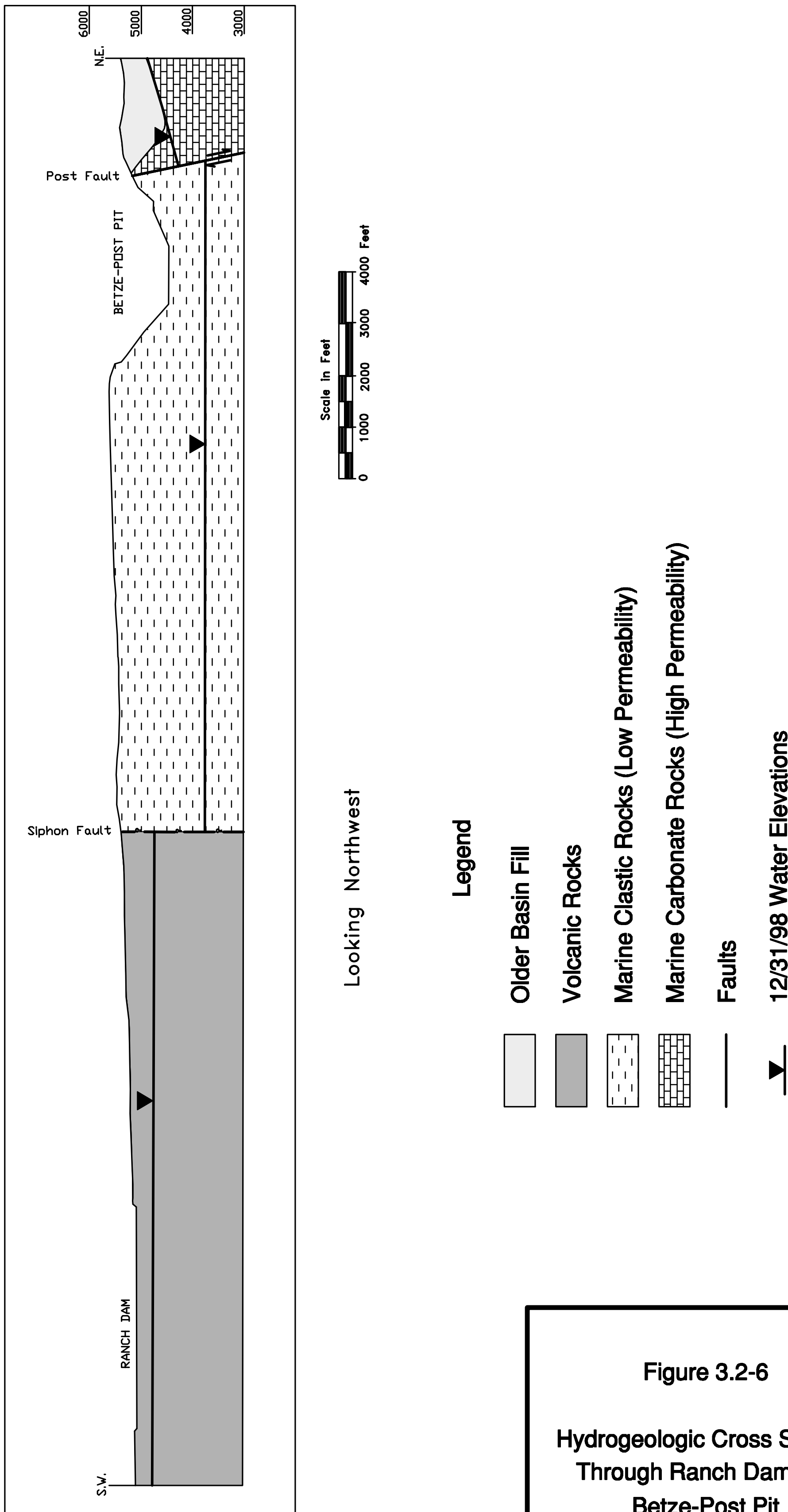


Figure 3.2-6

Hydrogeologic Cross Section Through Ranch Dam and Betze-Post Pit flow of ground water will increase with increasing temperature (or, conversely, decrease with decreasing temperature) (McDonald Morrissey Associates, Inc. 1998). However, to date the temperature of the dewatering water has been relatively constant throughout the life of the mine; therefore, substantial flow changes resulting from changing water temperatures are not anticipated.

Ground Water Levels (Prior to 1991 Initiation of Dewatering for the Betze Project). Limited data exist to define the ground water elevation (or potentiometric surface) throughout the region. Unconfined ground water levels in the hydrologic study area prior to active mine dewatering are presented in Figure 3.2-7. These unconfined water levels are based on water levels recorded in wells in the Boulder Flat area in 1990 and in the Maggie Creek area in 1988 (Maurer et al. 1996). According to this evaluation, the elevation of the potentiometric surface ranged from over 5,700 feet amsl on the western flank of the Tuscarora Mountains, to less than 4,600 feet amsl in the lower part of Boulder Flat, to over 5,900 feet amsl on the eastern flank of the Tuscarora Mountains, and to approximately 4,900 feet amsl adjacent to the Humboldt River near Carlin.

As illustrated in Figure 3.2-7, the general, inferred direction of ground water flow is away from the crest of the bedrock mountain blocks toward the basin fill deposits. The Tuscarora Mountains function as a ground water divide separating flow systems west of the divide from the flow system east of the divide. West of the divide, ground water in Willow Creek Valley, Rock Creek Valley, and Boulder Flat flows west out of the hydrologic study area and southwest toward the Humboldt River. East of the divide, ground water in the Maggie Creek, Marys Creek, and Susie Creek areas flows south toward the Humboldt River.

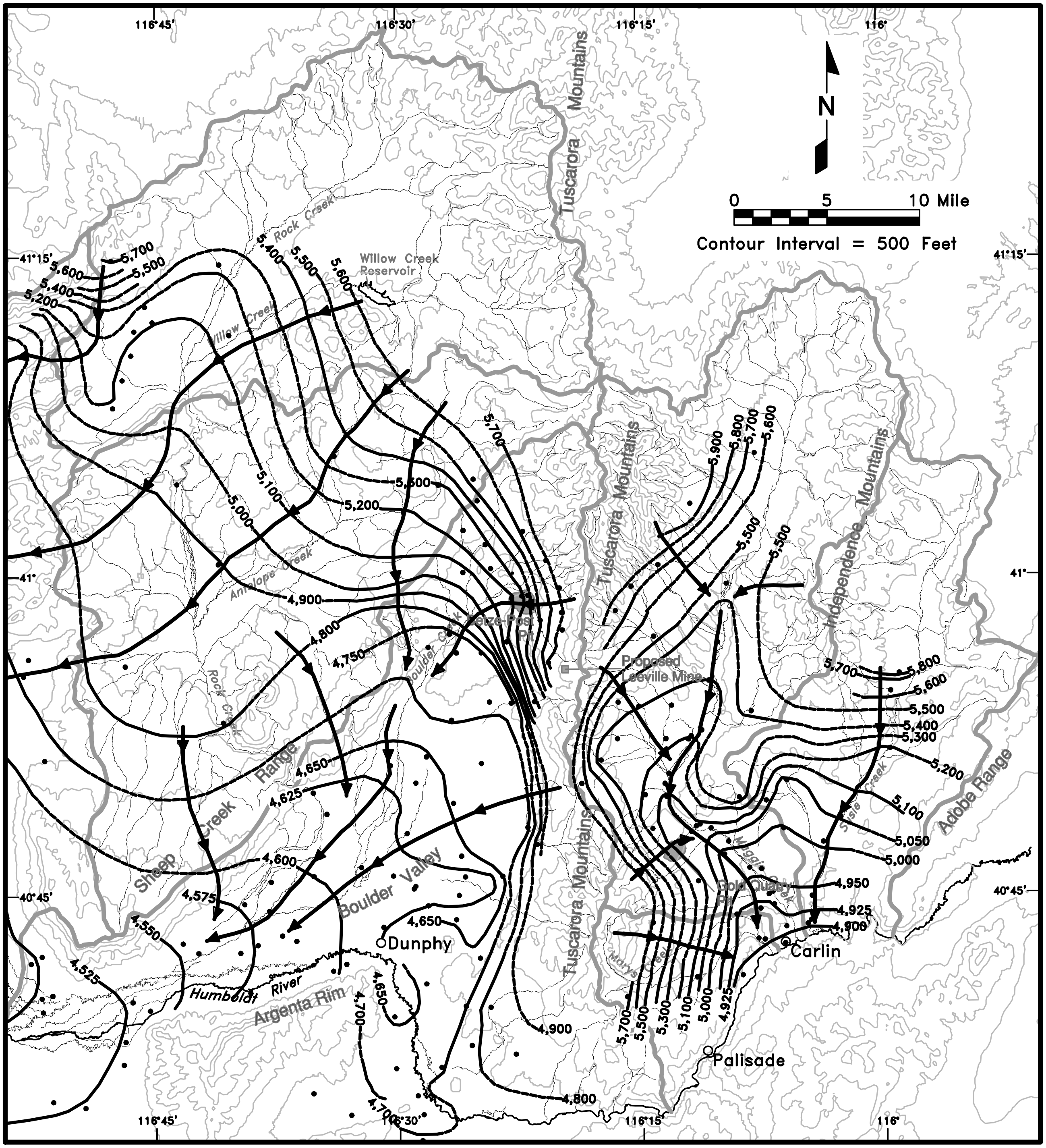
Ground Water Flow and Water Balance (Premining [Prior to 1991]). As shown in Figure 3.2-7, the general direction of ground water flow in Boulder Valley in the vicinity of Barrick's water management area prior to major mine dewatering was from the Tuscarora Mountains toward the discharge area in the southwestern part of Boulder Valley (McDonald Morrissey Associates, Inc. 1998).

Estimates of ground water inflow and outflow for the Willow Creek, Rock Creek, Boulder Valley, Maggie Creek, Marys Creek, and Susie Creek ground water basins under premining (pre-Betze Project) conditions are summarized in Table 3.2-4. Precipitation is the ultimate source of recharge to the ground water system. A percentage of the precipitation falling in the higher elevation mountains returns to the atmosphere essentially where it falls. The remainder infiltrates the bedrock where it falls or runs off and then either infiltrates the ground water system through the bottom of the stream channel or leaves the basin as surface flow. Runoff is channelized in the mountains and then tends to rapidly infiltrate the course-grained alluvial fan as the stream channel emerges from the mountains. This type of recharge, referred to as mountain front recharge, is believed to be the primary recharge source for the basin-fill alluvial aquifers. In the lower portions of the basins, negligible recharge is expected to occur from direct infiltration of precipitation, but some infiltration does occur in irrigated areas.

The total recharge to the hydrologic study area is an estimated 82,000 acre-feet/year. This estimate includes 47,000 acre-feet/year received in the Willow Creek, Rock Creek, and Boulder Valley basin areas in the western portion, and approximately 35,000 acre-feet/year received in the Maggie Creek, Marys Creek, and Susie Creek basin areas in the eastern portion of the hydrologic study area.

In Boulder Flat, an estimated 29,000 acre-feet/year of ground water inflow occurs from infiltration of Humboldt River water. An additional 600 acre-feet of ground water inflow to Boulder Flat is estimated to occur from subsurface ground water flow from adjacent basins south of Boulder Flat.

Discharge from the bedrock and alluvial basin-fill aquifers occurs through evapotranspiration, ground water flow leaving the basins as subsurface outflow, discharge to streams and springs, and ground water pumping. Evapotranspiration accounts for an estimated 79,000 acre-feet/year (Maurer et al. 1996) of ground water outflow from the hydrologic study area. West of the Tuscarora Mountains, in the



Legend

- Ground Water Basin Boundary
- Stream
- Water-table contour, dashed where uncertain
- General Direction of Ground Water Flow
- • Wells

Figure 3.2-7

Unconfined Ground Water Levels, 1990-1991

Table 3.2-4
Pre-1991 Estimated Ground Water Budget
(published and unpublished estimates of water budget components for the Willow Creek, Rock Creek, Boulder Flat, Maggie Creek, Susie Creek, Marys Creek, and Rock Creek ground water basins
[acre-feet/year])

Budget Component	Willow Creek Basin	Rock Creek Basin	Boulder Flat Basin	Maggie Creek Basin	Marys Creek Basin	Susie Creek Basin
GROUND WATER INFLOW						
Recharge (Total)	20,000[3]	13,000[3]	14,000[3]	23,000[3]	2,100[3]	9,700[3]
Direct	14,000[1]	9,800[1]	19,300[1]	16,000[4] -13,900[1]		
Mountain Front		6,000[1]	11,200[1]	20,200[1]		
Subsurface Inflow			600[3]			
Infiltration from Rivers and Streams	0	0[1]	40,000[3]	0[1]	0	0
Humboldt		20,000[1]	29,000[1]	0[1]		
Others						
GROUND WATER OUTFLOW						
Evapotranspiration	9,000[3]	4,600[3]	30,000[4]-51,000[3]	5,434[5] - 11,000[3]	2,000[3]	1,700[3]
Subsurface Outflow	4,300[3]	2,800[3]	12,000[3]	0[3]	0[3]	0[3]
Discharge to:						
Humboldt River	0[3]	0[3]	0[3]	5,700[6]	500[6]	2,400[6]
Rivers, Streams						
Springs					3,400[3]	
Pumpage			3,000[1]	244[5]		
SURFACE WATER OUTFLOW (at Basin Outlet)	N/A	29,000[2]	N/A	18,000[3]	4,200[2]	9,500[3]

[1]McDonald Morrissey Associates, Inc. 1998.
[2]McDonald Morrissey Associates, Inc. 1996b, 1997.
[3]Maurer et al. 1996.
[4]Nevada State Engineer's Office 1971a, b.
[5]Plume and Stone 1992.
[6]Total ground water discharge from Susie Creek, Maggie Creek, and Marys Creek areas was estimated at 8,600 acre-feet/year by Maurer et al. (1996); this total was divided among the three areas in proportion to the recharge reported in Maurer et al. (1996).
N/A = No estimates available.
ET = Evapotranspiration.

Willow Creek, Rock Creek, and Boulder Flat basins, an estimated 19,000 acre-feet/year of ground water outflow occurs as flow into the Clovers area located west of the hydrologic study area. An estimated 8,600 acre-feet/year of ground water discharge occurs from the Maggie Creek, Marys Creek, and Susie Creek areas to the Humboldt River; an additional 3,400 acre-feet/year of ground water discharge occurs as spring flow at Carlin Springs and another nearby unnamed spring in the Marys Creek basin (Maurer et al. 1996).

Ground Water Rights. According to the records, a total of 234 ground water rights and applications for ground water rights are recorded within the hydrologic study area. Information on these rights and applications for rights is summarized in Appendix A, Table A-1; the point of diversion locations listed for the water right or application for water right are shown in Figure 3.2-8 (Nevada State Engineer's Office 1999, 2000). This inventory does not include rights and applications for rights owned by Barrick or Newmont that are classified as mining and milling. Since water rights are not necessary for most domestic wells, this inventory (based on information on file at the Nevada Division of Water Resources) does not include all domestic or stock watering wells that may exist within the regional study area. However, included in Table A-1 are five known water supply wells that are apparently used for domestic or stock watering and that do not have a water rights permit or application number. Other domestic water supply wells that are not included in this inventory likely exist in the vicinity of Carlin in the southeastern portion of the hydrologic study area. Primary uses for the water are domestic uses, irrigation, stock watering, and mining-related uses.

Seeps and Springs

All identified springs within the hydrologic study area are shown in Figure 3.2-9 (JBR 1992b, 1990a; RTi 1994; Newmont 1999c; McDonald Morrissey Associates, Inc. 1998; AATA International Inc. 1998a, 1997; Nevada Division of Wildlife 1998b, 1996b, 1978; Valdez et al. 1994; USGS quads). Two field investigations have been conducted to identify perennial seeps and springs located within the region surrounding the Goldstrike Mine. Both inventories were conducted in the fall in order to identify springs with perennial flow that represent discharge from the ground water system. The first inventory was conducted by JBR in the fall of 1989 (JBR 1990a) to identify all seeps and springs located within an approximately 10-mile radius of the Betze-Post Pit. The JBR inventory included Boulder, Bell, Brush, and Rodeo Creek watershed areas. The JBR study identified 131 seeps and springs as summarized in the original Betze Project EIS (BLM 1991a). The second inventory was conducted by RTi in the fall of 1993 (RTi 1994) and extended the area of coverage to approximately 600 square miles. This area included the Willow Creek, Rock Creek, and Antelope Creek watersheds, and springs located in the northern, southern, and eastern portions of the Tuscarora Mountains. The RTi (1994) inventory identified an additional 277 seeps and springs with perceivable flows and 211 seeps with no perceivable flow. The locations of all of the identified seeps and springs are presented in Figure 3.2-9. Springs are not evenly distributed throughout the area; they discharge throughout the Tuscarora Mountains and occur as clusters in the upper and lower Willow Creek area, upper Antelope Creek-Squaw Creek area, and east of the Tuscarora Mountains. Conversely, there are large areas in the Sheep Creek Range-Rock Creek area and lower Boulder Creek-Boulder Valley area that are devoid of identified natural springs.

Flows for all springs identified in the region surrounding the Goldstrike Mine area ranged from less than 1 gpm to 140 gpm, with most springs having discharges of less than 3 gpm. In this area, the flow rate measured in the fall, or low-flow season, for approximately 90 percent of the springs ranged from less than 1 gpm up to approximately 3 gpm. Only four inventoried springs had flows greater than 10 gpm. On the eastern slope of the Tuscarora Mountains (the region east, southeast, and northeast of the Betze-Post Pit) there are numerous springs. The majority of these springs are located at higher elevations (greater than 6,500 feet) in the Tuscarora Mountains. Flow rates for these springs show a similar pattern to springs on the western slope of the Tuscarora Mountains with most having low flow rates (less than 3 gpm). However, a few larger springs occur with flow rates of over 10 gpm.

Several seep and spring studies have been conducted in the region surrounding the Gold Quarry Mine. JBR (1992b) conducted a comprehensive spring and seep inventory in May and June 1992 that identified approximately 200 springs and seeps in this region. In addition, approximately 75 representative springs located within a 10-mile radius of the Gold Quarry Mine have been monitored biannually since 1990 (Newmont 1999c).

Within a 10-mile radial distance of the Gold Quarry Mine, the majority of inventoried springs and seeps have flow rates of less than 5 gpm. Based on measurements from 1991 to 1997 by

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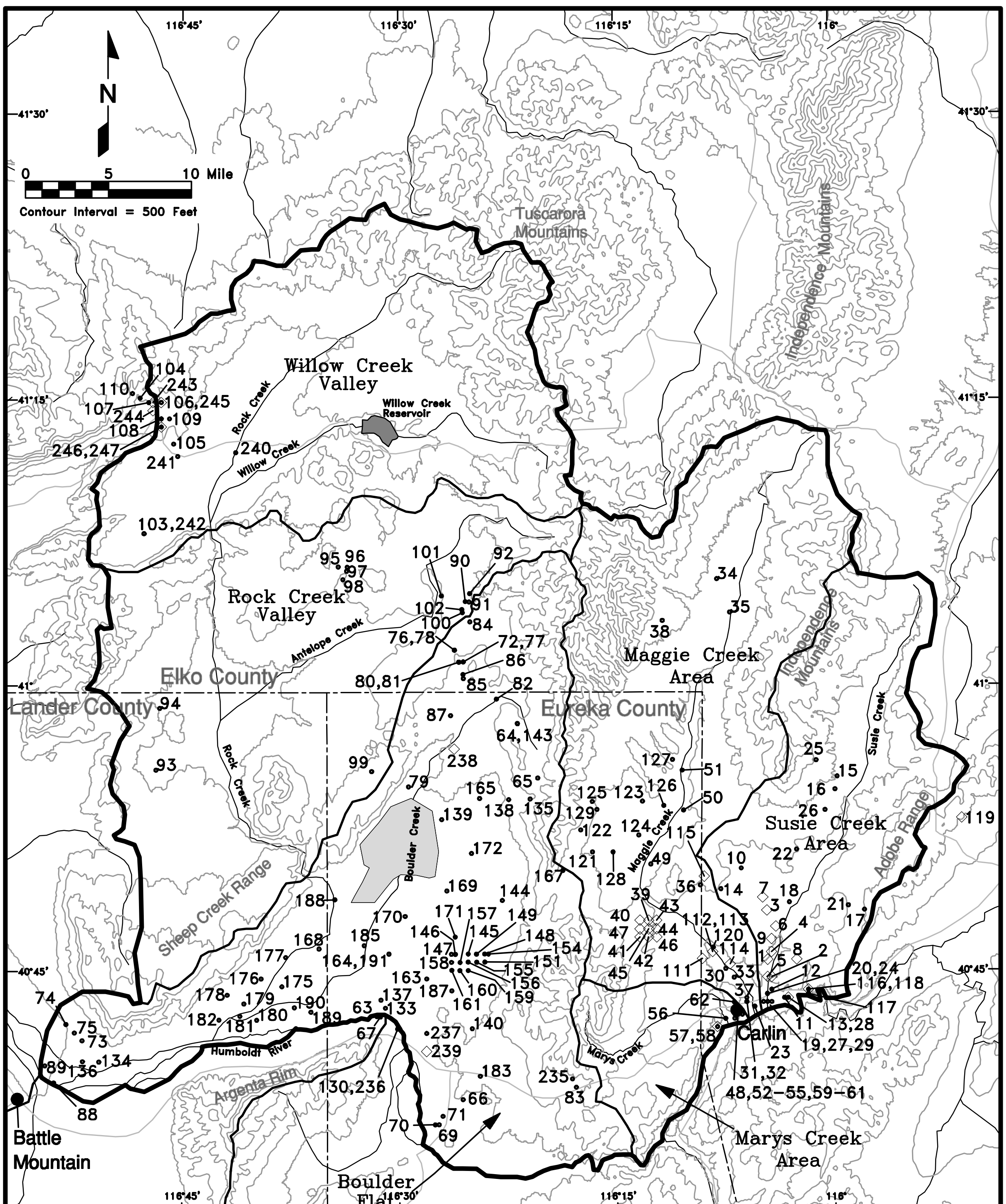

Legend

- Study Area
- Ground Water Basin Boundary
- Stream
- County
- 70 • Point of Diversion for Ground Water Right with Current Permit, Certificate, or Vested Status
- 47 ◇ Listed Point of Diversion for Applications for Ground Water Right (Application, Ready for Action, and Ready for Action Protested), and other known well locations
- This area contains 54 ground water rights and application for ground water rights (Numbers 68, 131, 132, 141, 142, 150, 152 153, 162, 166, 173, 174, 184 186, 192-215, and 218-233). The point of diversion locations are provided in Table A-1.

See Table A-1 for details

Figure 3.2-8

Ground Water Rights, Application for Ground Water Rights, and Other Known Wells in the Hydrologic Study Area

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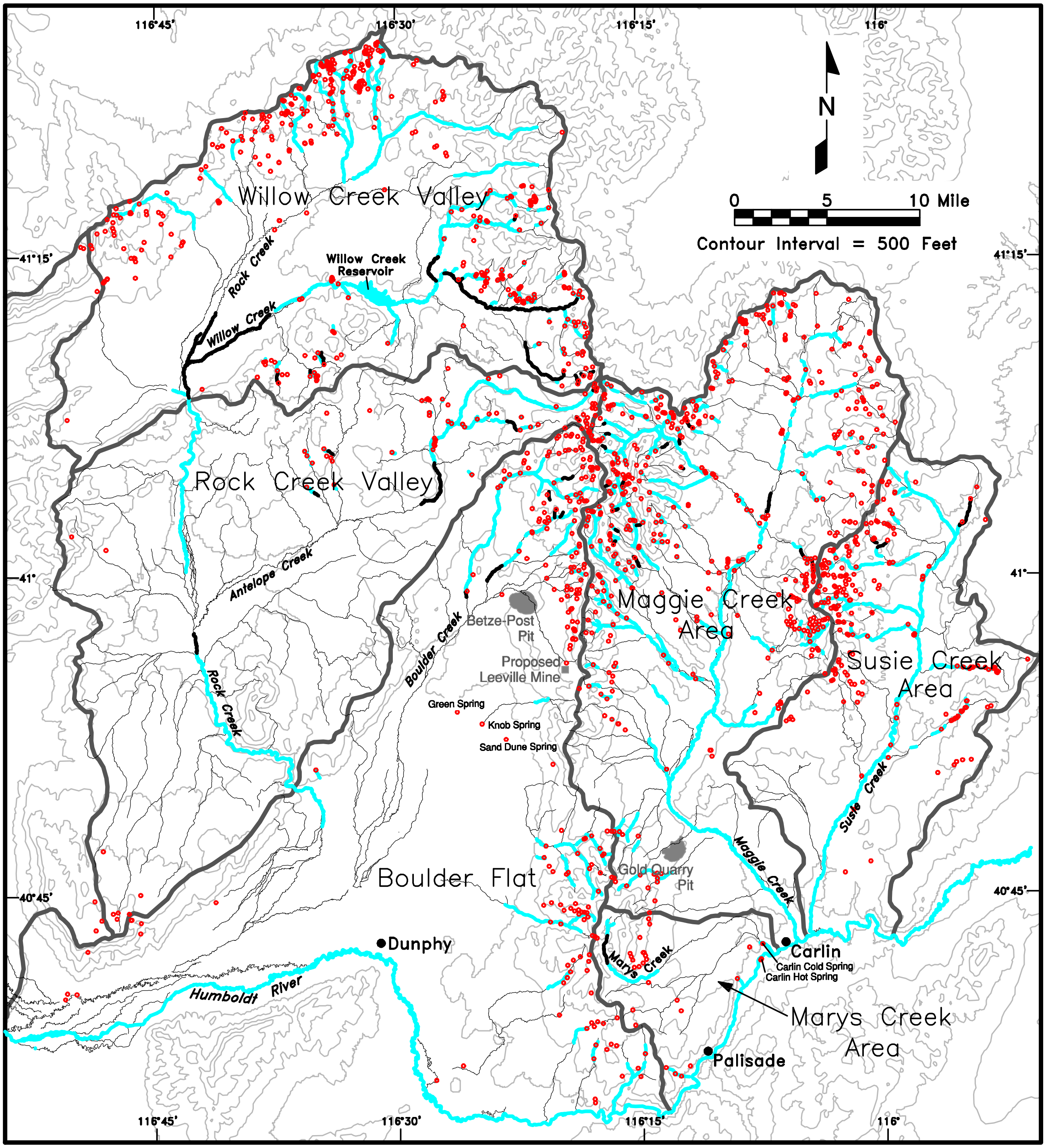


Legend

- Ground Water Basin Boundary
- Stream (Intermittent or Ephemeral)
- Perennial Steam
- Discontinuous Flowing Stream Reach
- Spring and Seeps

Note: Stream locations are taken from USGS line graph database. Hydrographic Area Boundary locations are approximate.

Figure 3.2-9

Areas of Perennial Stream Reaches, Springs, and Seeps in the Hydrologic Study Area

Newmont, only 12 springs exceeded flow rates of 5 gpm; four of these springs had flows greater than 50 gpm. Seasonal variations in flow occur with most springs, indicating shallow perched systems where flow is easily influenced by seasonal precipitation. Data from BLM files for 1982 field studies also show that the majority of springs observed in the South Operations Area were flowing at rates of less than 5 gpm.

For springs inventoried in the northern portion of the Tuscarora Range, and Boulder Flat, Rock Creek, and Willow Creek Hydrographic basins, the measured temperature of the springs ranged from 38 to 78 degrees Fahrenheit. Since most of the springs have very small flows (less than 3 gpm), the measured temperature is strongly influenced by air temperature. No hot (greater than 90 degrees Fahrenheit) springs were identified during the inventories (JBR 1990a; RTi 1994). For springs inventoried in the Maggie Creek, Marys Creek, and Susie Creek Hydrographic basins, five hot springs have been identified.

Surface Water

Surface Water Flows and Channel Characteristics

Local Watersheds. Surface water flows in the hydrologic study area originate from snowmelt, infrequent rainfall events, and ground water discharge from springs and seeps. A number of stream channels occur in the study area (Figure 3.2-1), and they all flow toward the Humboldt River. On the eastern side of the Tuscarora Mountains, Marys Creek, Maggie Creek, and Susie Creek flow directly into the Humboldt River. These three drainages have been investigated by Newmont Gold Company (1991), Maurer et al. 1996, and Zimmerman (1992a). On the western side of the Tuscarora Mountains, Rock Creek forms the major tributary to the Humboldt River. Willow Creek and Antelope Creek are major tributaries to Rock Creek to the north and west of Barrick's operations. Rock Creek traverses the southwest portion of Boulder Flat and receives flow from Blue House Slough as well as the Boulder Creek - White House Ditch - Blue House Ditch system before it joins the Humboldt River near Battle Mountain (Figure 3.2-1).

Smaller drainages such as Rodeo Creek, Brush Creek, and Bell Creek occur in closer proximity to the Goldstrike property and form tributaries to Boulder Creek. These drainages and their watershed characteristics were described previously in the Betze Project Draft EIS (BLM 1991a).

Barrick has conducted extensive water resources monitoring in the Boulder Valley area since 1989. Since the commencement of Goldstrike Mine operations, results have been presented in Boulder Valley Monitoring Plan quarterly reports, which have been issued since 1991. Flow information from these reports is summarized in Table 3.2-5, from upstream to downstream on individual drainages. The locations of surface water monitoring sites are shown in Figure 3.2-10 (Barrick 1999a; Mauer et al. 1996; Newmont 1999d).

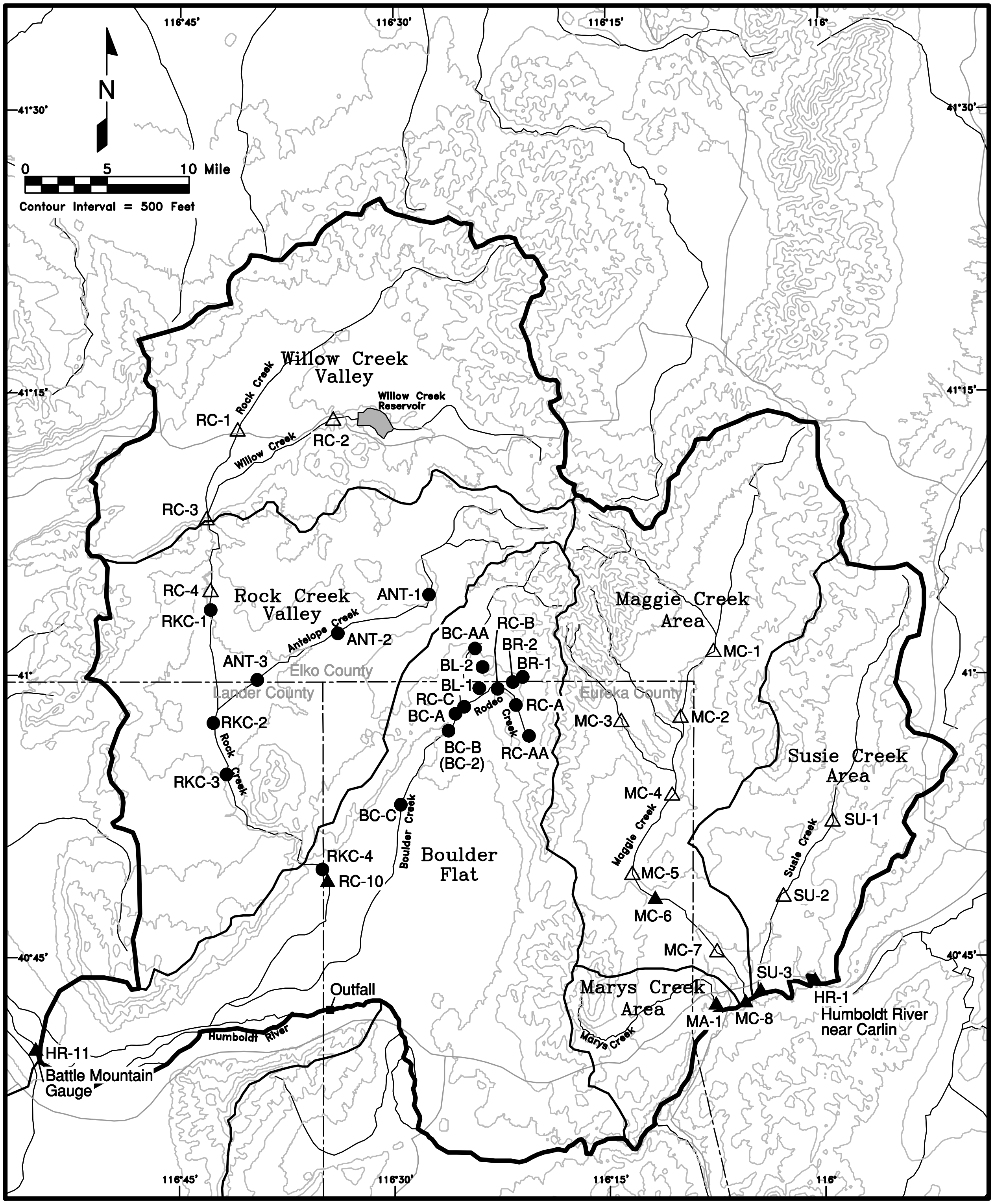
Many streams in arid climates have short perennial or intermittent reaches near their headwaters or in narrow rocky canyons where channel conditions are restricted by bedrock near the surface. This generally holds true in the hydrologic study area. Perennial reaches for streams in the hydrologic study area have been identified through field surveys (RTi 1994; AATA International, Inc. 1998a, b). These reaches are shown in Figure 3.2-1 and generally occur in remote locations above the most upstream stations in the monitoring program. As such streams flow downstream onto deeper unconsolidated deposits such as alluvial fans, they commonly lose large amounts of flow to seepage into the channel bed. During most years, flow occurrence in these downstream alluvial reaches may be intermittent or ephemeral. This is demonstrated by most of the streams in the project area, where flows often cease during the last half of the year. The major exception to this is Rock Creek, which has both intermittent and perennial reaches interspersed along its length.

Flow data for selected Boulder Valley streams prior to dewatering activities are available for the Betze Project EIS (BLM 1991a, b). These data indicate that Rodeo Creek was ephemeral in its uppermost reach (approximately one-third of its overall length), but flowed perennially because of springflow contributions immediately downstream. Proceeding downstream, the creek flowed during

Table 3.2-5
General Flow Characteristics, Humboldt River Tributaries[1]

Monitoring Station	Location	Average High Flow (cfs)	Average Low Flow (cfs)
BC-AA	Uppermost Boulder Cr.	50.6	0
BC-A	Boulder Cr. below Rodeo Cr.	64.3	0
BC-B[2]	Boulder Cr. near the Barrick treatment facilities		0
BC-C	Boulder Cr. at Dunphy Rd.	52.3	0
RC-AA	Uppermost Rodeo Cr.	1.1	0
RC-A	Rodeo Cr. above Betze Pit	3.9	0
RC-B	Rodeo Cr. below Betze Pit	3.0	0
RC-C	Rodeo Cr. above Boulder Cr.	19.3	0
BR-1	Upper Brush Cr.	13.3	0
BR-2	Middle Brush Cr.	5.6	0
BL-1	Lower Bell Cr.	14.4	0
BL-2	Bell Cr. above Rodeo Cr.	20.8	0
ANT-1	Upper Antelope Cr.	38.6	0
ANT-2	Middle Antelope Cr.	38.1	0
ANT-3	Lower Antelope Cr.	34.0	0
RKC-1	Middle Rock Cr	208.0	1.8
RKC-2	Middle Rock Cr.	216.8	1.3
RKC-3	Rock Cr. above the Sheep Cr. Range	207.3	1.8
RKC-4[2]	Rock Cr. below the Sheep Cr. Range	328.2	1.8
SU-3[2]	Susie Cr. at Carlin, NV	63.8	0.0
MC-5[2]	Maggie Cr. at Maggie Cr. Canyon nr. Carlin, NV	73.2	1.08
MC-8[2]	Maggie Cr. at Carlin, NV	102.0	4.09
MA-1[2]	Marys Cr. at Carlin, NV	13.7	3.05

[1]Average of peak monthly data as available for 1993 through 1998 for Rock Creek tributaries and various dates from 1989 through 1997 for Carlin area streams.
[2]A USGS gage is present at these locations.



Legend

- Study Area
- Ground Water Basin Boundary
- HR-1 ▲ USGS Active Streamflow Site ①
- MC-7 △ Former USGS Streamflow Site ①
- BC-C ● Barrick Surface Water Sampling Locations ②

① Abbreviations:
HR = Humboldt River; MC = Maggie Creek; BC = Boulder Creek; RC = Rock Creek and its tributaries

② Abbreviations:
RKC = Rock Creek; ANT = Antelope Creek; BC = Boulder Creek; BL = Bell Creek; BR = Brush Creek; and RC = Rodeo Creek

Figure 3.2-10

Streamflow Measurement Sites, Humboldt River Tributaries

a substantial part of the year, but flows diminished or ceased in late summer and fall. The stream was intermittent to ephemeral in the lower third of its length above Boulder Creek. The short perennial reaches interspersed along Rodeo Creek were largely a result of springflows along the channel.

According to the earlier baseline information (1988 through 1990), Bell Creek flowed perennially in its upper reaches, becoming intermittent approximately 2 miles above its confluence with Rodeo Creek. Subsurface flow maintained perennial pools that were observed by agency personnel over a short section of the lower intermittent reach. Brush Creek was perennial in its upper headwater reach and along its middle reach on the valley alluvium. It became ephemeral downstream approximately 1 mile above its confluence with Rodeo Creek. Boulder Creek was perennial in its upper headwater reaches, primarily because of springflow contributions. Flows became ephemeral approximately 1 mile above the confluence with Rodeo Creek and remained so downstream (BLM 1991a, b).

Based on recent data from the Boulder Valley Monitoring Plan (Barrick 1999c), Boulder Creek appears to be a predominantly losing stream (flow seeping from the channel to ground water recharge) in the vicinity of Barrick's operations, during both high-flow and low-flow seasons. The stream is perennial in its uppermost reaches and intermittent in the vicinity of the Goldstrike property. Substantial decreases in streamflow occur as Boulder Creek leaves its canyon headwaters and moves onto the valley alluvium in the vicinity of Barrick's treatment facilities. Downstream of Barrick's mining and processing operations, Boulder Creek is an ephemeral channel; based on records since 1991, it flows only in response to snowmelt or the occasional local thunderstorm. Rodeo Creek appears to lose flow in spite of its increasing watershed area until it is joined by Bell Creek. Below that confluence, Rodeo Creek flows substantially increase due to contributions from Bell Creek, but slight seepage losses to the alluvium may occur. Brush Creek flows do not exhibit a consistent pattern of losses or gains. Antelope Creek data for 1996 and 1997 do not indicate a discernible pattern of losses or gains, but it is probable that some flow was lost to recharge to valley alluvium along the middle and lower reaches. During the low flow season in 1993, the upper reaches of Antelope Creek and Squaw Creek (located 5 to 7 miles north of the Betze-Post Pit) exhibited flows of 15 to 20 gpm (RTi 1994). Although flows that year were 50 to 70 percent higher than average regionally, these suggest that perennial flows exist on these streams in the locale. These stream reaches are shown in Figure 3.2-9. Approximately 4 miles below its headwater springs, Antelope Creek had flows of approximately 15 gpm. Below this point, gaining and losing reaches alternated over short distances depending on springflow contributions and channel seepage. On September 30, 1993, Squaw Creek at its mouth contributed approximately 20 gpm to Antelope Creek, but a short distance downstream the latter was flowing at only 17 gpm. Approximately 2.5 miles farther downstream, Antelope Creek flowed at 22 gpm; another 3.5 miles farther downstream, the stream was dry (RTi 1994).

This last location approximates the most upstream monitoring station (ANT-1) for Antelope Creek in the Boulder Valley Monitoring Plan. The location of this station also is known as RC-6 (designation per Maurer et al. 1996). Data in the Boulder Valley Monitoring Plan through 1998 also indicate that Antelope Creek goes dry at this location during the late summer. Maurer et al. (1996) indicate that Antelope Creek is dominantly an ephemeral stream along its length, except for short reaches sustained by small ground water baseflows.

Rock Creek and its tributary, Willow Creek, are the principal streams in Willow Creek Valley northwest of Barrick's operations. Streamflows in both Willow Creek and Rock Creek downstream of their confluence are affected by irrigation diversions and releases from Willow Creek Reservoir. Both gaining and losing measurements were made in this area, but typically these upper reaches are probably gaining flows from ground water contributions (Maurer et al. 1996). Also, a discharge location known as Hot Lake occurs in the northern portion of the Rock Creek drainage near the confluence of Rock Creek and Willow Creek (Figure 3.2-10). This feature is a major discharge area that supplies most of the water in Rock Creek in the vicinity during low-flow periods. The name Hot

Lake is misleading because the water is similar in temperature to other flows in the area, which have normal surface water temperatures. Examination of the topography in the south end of Squaw Valley suggests that it is possible for the water in Rock Creek and the irrigated agricultural areas northeast of Hot Lake to move in the alluvium until a subsurface barrier is encountered near the hills in the vicinity of the lake. Such a barrier could force water to surface at Hot Lake. The flow may be a combination of water from Willow Creek, Rock Creek, and other watersheds in the area.

Along its length through Rock Creek Valley, the Sheep Creek Range, and Boulder Valley, Rock Creek exhibits both baseflow gaining reaches (flow returning to the channel from ground water contributions) and losing reaches (flow leaving the channel by seepage or other means). These fluctuations depend primarily on the amount of precipitation as well as contributions from Willow Creek Reservoir (see Figure 3.2-9). In Rock Creek Valley north of the Sheep Creek Range, Rock Creek typically loses flow to the valley alluvium as does Antelope Creek. Contributions to flows in Rock Creek from Antelope Creek are likely to be insignificant, given the ephemeral nature of Antelope Creek in the vicinity. Near or within the Sheep Creek Range farther downstream, Rock Creek may gain or lose flows depending on geologic factors and the occurrence of precipitation or snowmelt in different years. Still farther downstream, historical USGS gaging data suggest that flows are small but perennial just as the stream leaves the Sheep Creek Range. However, during lengthy drought periods such as the early 1990s, Rock Creek may go dry in this vicinity. Rock Creek frequently goes dry during the summer months within Boulder Valley farther downstream of the Sheep Creek Range.

Available data and interpretations for Susie Creek, Maggie Creek, and Marys Creek represent gaging conducted by the USGS and Newmont. Most of these data have been collected during a relatively short period from the late 1980s. The middle portion of Susie Creek gains flow, possibly from small tributary contributions or from ground water inflows. Farther downstream in its lower reach, the channel loses flows by seepage into the underlying aquifer. Periods of no flow occur during the summer and fall (Maurer et al. 1996; Newmont 1999d).

Maggie Creek is the principal creek located just east of the Newmont South Operations Area in Maggie Creek basin. Maggie Creek flows 41 miles southward to its confluence with the Humboldt River near Carlin. James, Soap, Simon, Cottonwood, Jack, Little Jack, Coyote, Spring, Haskell, Beaver, and Taylor creeks are tributaries of Maggie Creek. The Maggie Creek drainage area is approximately 400 square miles. Immediately north of the South Operations Area, Maggie Creek is confined by Maggie Creek Canyon, or the "narrows." This bedrock feature divides the Maggie Creek basin into upper and lower basins. Maggie Creek generally flows as a perennial stream above the canyon and as an intermittent stream through most of the lower basin.

Flow gaging on Maggie Creek by the USGS was continuous from 1913 until 1924 at a station located above its confluence with the Humboldt River. Currently, the USGS operates three gaging stations on Maggie Creek, installed in 1989, 1992, and 1996. During the 1913 to 1924 period of record, average daily discharge of lower Maggie Creek was 23.2 cfs. In general, average monthly flow in Maggie Creek at the mouth is less than 10 cfs during 7 months of the year and approximately 100 cfs during the months of April and May. High flows in Maggie Creek occurred in March 1993 and March 1996 with more than 100 cfs measured at all stations. In summer and fall, lower Maggie Creek commonly dries up while upper Maggie Creek maintains flow rates of 0.2 to 0.5 cfs.

Maggie Creek has both gaining and losing reaches along its length. The USGS has measured flow at several locations along Maggie Creek on the same day to evaluate water gain or loss. Flow measurements during the period 1988-92 suggest that Maggie Creek gains in flow above Maggie Creek Canyon and loses water through and below the canyon (USGS 1992). In its upper reach the stream loses flows, with losses ranging from approximately 0.5 to 1.2 cfs. The middle reach of Maggie Creek (to Maggie Creek Canyon) is an inconsistently gaining or losing reach depending on specific location, year, or season. Farther downstream, flows are lost along the length of Maggie Creek Canyon. Lower Maggie Creek, from the canyon to the mouth, is a generally losing reach except during occasional snowmelt contributions from the intervening watershed area (Maurer et al. 1996; Newmont 1999d).

Susie Creek flows 29 miles south to the Humboldt River and has a drainage area of approximately 212 square miles. A USGS surface water station was installed near the mouth of Susie Creek in April 1992. In addition, Newmont has established five streamflow measurement sites along Susie Creek. The segment of stream located in the immediate vicinity of the USGS gaging station (for about 1 mile upstream) dries up during the summer on an annual basis. However, above this reach, lower Susie Creek is perennial in most years. The single exception in recent years was during the 1994 drought when portions of lower Susie Creek, that are normally perennial, went dry. Susie Creek flow was measured by the USGS at a point 16 miles above its confluence with the Humboldt River during the period 1956 to 1958. Average annual flow at this location was approximately 6 cfs with average monthly flows ranging from 0.11 to 29.3 cfs (USGS 1963). Maximum annual flows for the 3 years of measurement were 184, 161, and 89 cfs (USGS 1963). Flow data on file with BLM show a high flow of 60 cfs recorded for April 30, 1985, at a location approximately 4 miles above Susie Creek's mouth. At the USGS surface water station on Susie Creek near its mouth, average annual flow is approximately 8 cfs for the period 1992 to 1996. In 1996, April flows peaked at approximately 276 cfs, and Susie Creek was dry from July through October (USGS 1999c). The middle portion of Susie Creek gains flow, possibly from small tributary contributions or from ground water inflows. Farther downstream in its lower reach, the channel loses flows by seepage into the lower aquifer.

Marys Creek flows approximately 13 miles southeast before entering the Humboldt River west of Carlin. The Marys Creek drainage area is approximately 75 square miles. A continuous-recording USGS stream gage has been operating on Marys Creek below the Carlin Springs since November 1989 (Lower Marys). In addition, Newmont maintains one streamflow measurement site along Marys Creek. Depending on the location, Marys Creek may be an ephemeral or intermittent stream, with the exception of the lowermost reach, which is sustained by spring flow from Carlin Spring. Flow characterization by the USGS based on gaging during the last part of the 1985 to 1993 drought indicates an ephemeral regime. Data collected in the uppermost reaches by Newmont from 1993 through 1998, however, indicate small flows occur year-round in the headwaters (Newmont 1999b). Although 1993 was a wet year (based on river flow at Carlin), 1994 was dryer than normal. These flows are probably lost to channel seepage as the stream traverses valley alluvium downstream.

High flows typically are recorded in March and April and low flows in October and November. Flow at the surface water station typically shows a sharp decline in April or May corresponding to the start of irrigation on the Maggie Creek Ranch upgradient from the Carlin Springs (Newmont 1999d). The city of Carlin also obtains some municipal water from the springs, which affects flow measurements downstream at the surface water station. The gage shows maximum and minimum discharges of 400 and 0.6 cfs, respectively (USGS 1999c).

Tributary Channel Characteristics. Channel conditions and flow conveyances for Boulder Creek and Rock Creek have been investigated as part of Barrick's water management program (Simons & Associates, Inc. 1995a). The natural channel cross-sections have a wide trapezoidal configuration or a shallow V-shape; these are asymmetric at bends. Over most of the length of upper Boulder Creek, the bankfull width:depth ratio is on the order of 35. The bed is composed mainly of cobbles and gravels, and the stream exhibits a relatively small amount of meandering until it reaches lower Boulder Valley. Channel slopes in the upper reaches of Boulder Creek near Barrick's operations are approximately 33 feet per mile and flatten to approximately 5 feet per mile in the downstream portions of Boulder Valley.

Rock Creek is moderately meandering in the upper part of its length in Boulder Valley; it becomes highly sinuous downstream as it approaches the Humboldt River. Width:depth ratios along Rock Creek are generally on the order of 16 in the lower reaches near the Humboldt River. The stream sediments are typically sands and silts. The channel slope along Rock Creek as it enters Boulder Valley is approximately 32 feet per mile; this slope flattens to approximately 4 feet per mile near the Humboldt River.

Surface Water Rights. An inventory of surface water rights and applications for surface water rights provided information on locations and status within the hydrologic study area.

According to the Nevada Division of Water Resources records, a total of 121 water rights and an additional 6 applications under *ready for actions* status are listed in the state database. Of the 121 water rights, 46 have *certificated* status, 38 are *vested* water rights, 24 have *permit* status, 9 are listed as *proofs* (or decreed water rights), and 4 are under *reserved* water rights status. Information on these rights and applications for rights is summarized in Appendix A, Table A-2; the point of diversion locations are shown in Figure 3.2-11 (Nevada State Engineer's Office 1999, 2000). Note that the inventory excluded all rights and applications for rights owned by Barrick or Newmont for mining and milling use. The primary uses for the water are stock watering, municipal uses, irrigation, and domestic uses.

<u>**Water Quality**</u>

Ground Water Quality Standards. Standards for protecting ground water used as a drinking water source have been adopted by the Nevada Bureau of Health Protection Services. Specifically, Nevada Administrative Code 445A.453 establishes primary standards in the form of maximum contaminant levels, and Nevada Administrative Code 445A.455 establishes secondary standards, also as maximum contaminant levels. Primary maximum contaminant levels are established to protect human health from potentially toxic substances in drinking water, while secondary maximum contaminant levels are established to protect aesthetic qualities of drinking water, such as taste, odor, and appearance. Since ground water in the vicinity of the project area is used or is potentially usable as a drinking water source, Nevada primary and secondary maximum contaminant levels listed in Table 3.2-6 would apply to the protection of area ground waters. In addition, Nevada's regulations governing mining facilities specifically state that ground water quality cannot be degraded beyond established maximum contaminant levels. If the ground water quality already exceeds maximum contaminant levels, the quality of the ground water may not be lowered to a level that would render the waters unsuitable for the existing or potential municipal, industrial, domestic, or agricultural use (Nevada Administrative Code 445A.424).

Ground Water Quality. Ground water quality near the Goldstrike Mine was characterized as part of the original Betze Project Draft EIS (BLM 1991a) and from 61 wells in the Betze-Screamer Pit Lake Study (Radian International, LLC and Baker Consultants, Inc. 1997b). In addition, a ground water chemistry database consisting of 36 selected regional wells (Barrick 1998a) was used to characterize the water chemistry of the Boulder Valley alluvium and tertiary volcanics. The locations of these regional well sites are shown in Figure 3.2-12 (Balleau Groundwater Consulting 1995).

The chemistry of ground water is a result of the chemical characteristics of the source water and the geochemistry of the rocks through which the ground water flows. In the original Betze Project Draft EIS (BLM 1991a), exploration drill holes and springs were used to sample ground water from the Carlin Formation, intrusive rocks (granodiorite), and Paleozoic sedimentary rocks. This analysis expands on the original EIS and includes ground water analyses from volcanic rocks and alluvium, as well as additional analyses from the Carlin Formation, intrusive rocks, and Paleozoic sedimentary rocks (marine clastic and marine carbonate rocks).

The general ground water chemistry for the six major hydrostratigraphic units defined for the region is presented in Table 3.2-7.

<u>Major Constituents</u>. Relative concentrations of the major ions dissolved in each formation water are graphically depicted on a trilinear diagram in Figure 3.2-13 (Radian International, LLC and Baker Consultants, Inc. 1997b). In addition, the following paragraphs summarize the ground

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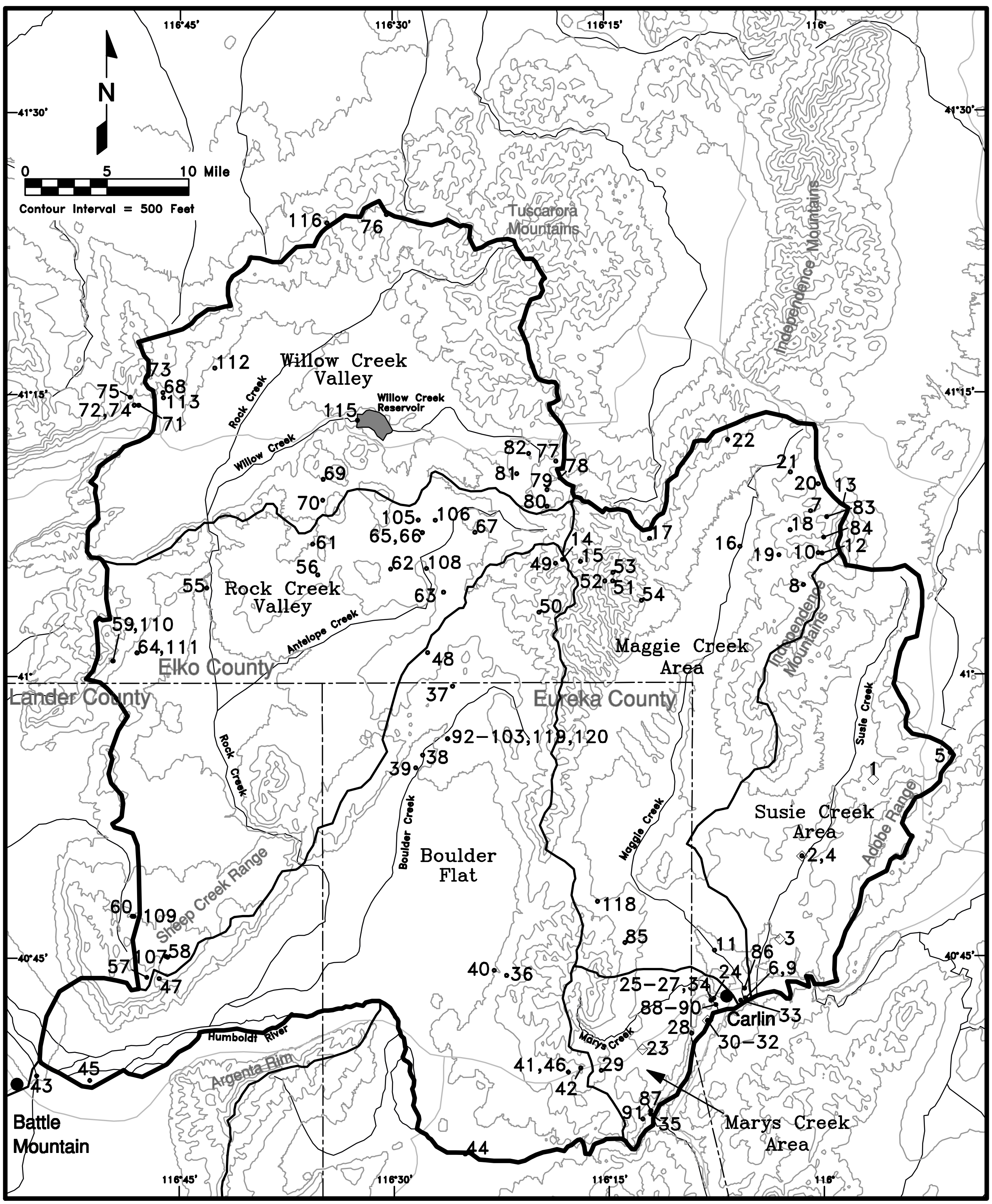


Legend

- Study Area
- Ground Water Basin Boundary
- Stream
- County
- 46 • Point of Diversion for Surface Water with Current Permit, Certificate, or Vested Status
- 23 ◇ Listed Point of Diversion for Applications for Surface Water Right (Application, Ready for Action, and Ready for Action Protested)

See Table A-2 for details

Figure 3.2-11

Surface Water Rights, and Application for Surface Water Rights in the Hydrologic Study Area

Table 3.2-6
Drinking Water Standards Applicable to Ground Water

		Nevada Drinking Water Standards		Federal Drinking Water Standards	
Constituent	**Units**	**Primary**	**Secondary**	**Primary**	**Secondary**
Physical and Aggregate Properties					
TDS	mg/L @180°C	---	500[1]/1000[2]	---	500
Inorganic Nonmetallic Constituents					
Chloride	mg/L as Cl	---	250[1]/400[2]	---	250
Cyanide	mg/L as CN	0.2	---	0.2	---
Fluoride	mg/L as F	4	---	4	2.0
Nitrate	mg/L as N	10	---	10	---
Nitrite	mg/L as N	1	---	1	---
pH	standard units	---	(6.5-8.5)[1]	---	6.5-8.5
Sulfate	mg/L as SO_4	---	250[1]/500[2]	---	250
Metals/Semimetals					
Aluminum	mg/L as Al	---	---	---	0.05 to 0.2
Antimony	mg/L as Sb	0.006	---	0.006	---
Arsenic	mg/L as As	0.05	---	0.05	
Barium	mg/L as Ba	2	---	2	---
Beryllium	mg/L as Be	0.004	---	0.004	---
Cadmium	mg/L as Cd	0.005	---	0.005	---
Chromium	mg/L as Cr	0.1	---	0.1	---
Copper	mg/L as Cu	1.3[3]	1.0[1]	1.3[3]	1.0
Iron	mg/L as Fe	---	0.3[1]/0.6[2]	---	0.3
Lead	mg/L as Pb	0.015[3]	---	0.015[3]	---
Magnesium	mg/L as Mg	---	125[1]/150[2]	---	---
Manganese	mg/L as Mn	---	0.05[1]/0.1[2]	---	0.05
Mercury	mg/L as Hg	0.002	---	0.002	---
Selenium	mg/L as Se	0.05	---	0.05	---
Silver	mg/L as Ag	---	---	---	0.1
Thallium	mg/L as Tl	0.002	---	0.002	---
Zinc	mg/L as Zn	---	5.0[1]	---	5

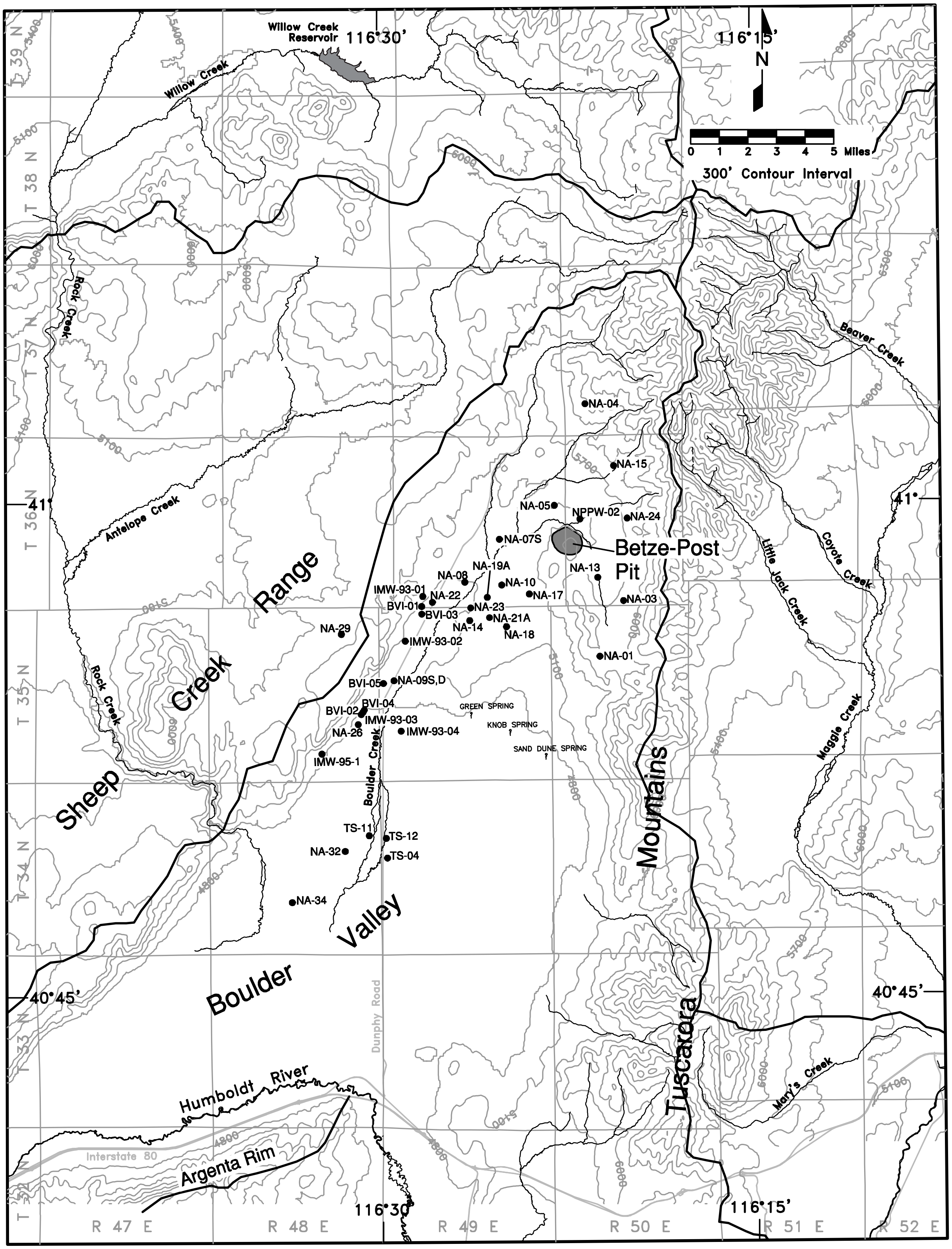
Sources: Nevada Administrative Code 445A.453, and 445A.455.

Federal Drinking Water Regulations and Health Advisories (EPA822-B-96-002) Oct. 96.

[1]Nevada Secondary recommended maximum contaminant levels (MCLs).

[2]Nevada Secondary (Enforceable) MCL.

[3]Federal Treatment Technique (Action Level for Lead and Copper Rule).



Legend

- Stream
- Ground Water Basin Boundary
- Road
- GREEN SPRING — Spring
- NA-32 — Water Quality Well

Figure 3.2-12

Selected Regional Water Quality Monitoring Wells

Table 3.2-7
Summary of Ground Water Chemistry by Hydrostratigraphic Unit

		Alluvium[1]				Volcanic[1]				Carlin Formation[2]			
Constituent	**Units**	**Number of Wells**	**Minimum**	**Maximum**	**Average**	**Number of Wells**	**Minimum**	**Maximum**	**Average**	**Number of Wells**	**Minimum**	**Maximum**	**Average**
Physical and Aggregate Properties													
TDS	(mg/L)	10	160	750	323	20	170	760	375	16	180	630	478
Inorganic Nonmetallic Constituents													
Chloride	(mg/L)	10	6.7	82	23	20	11.0	64	21	16	4.0	41.0	16.6
Fluoride	(mg/L)	10	0.24	2.8	0.64	20		3	1.4	16	0.29	1.60	1.14
pH	(pH units)	10	7.0	8.9	7.6	20	3.5	9.3	7.7	16	6.3	9.8	7.4
Sulfate	(mg/L)	10	20	82	45	20	11.0	180	58	16	29.0	130.0	73.2
Temperature	(degrees C)	10	9.0	61.3	12.4	20	12.0	63	24	16	11.0	55.0	38.9
Alkalinity	(mg/L)	10	67	203	153	20	2.5	440	228	16	100	440	273
Bicarbonate	(mg/L)	10	82	248	186	20	3.0	536	277	16	122	536	333
Sodium	(mg/L)	10	17	57	34	20	18.0	92.6	50.9	16	16.0	85.0	58.2
Potassium	(mg/L)	10	3.3	28	7.3	20	2.4	21	10	16	4.40	35.00	16.61
Calcium	(mg/L)	10	15.0	75	42	20	15.0	88	53	16	26.0	100.0	74.1
Dissolved Metals/Semimetals													
Antimony	(mg/L)	10	0.0025	0.025	0.006	20	0.0020	0.025	0.008	16	<0.019	<0.019	*
Arsenic, Total	(mg/L)	10	0.002	0.170	0.023	20	0.003	0.21	0.022	16	0.005	0.410	0.027
Boron	(mg/L)	10	0.05	0.60	0.12	20	0.05	0.84	0.31	16	0.091	1.080	0.685
Iron	(mg/L)	10	0.005	100	2.8	20		59	1.7	16	0.010	220	1.558
Lead	(mg/L)	10	0.025	0.025	0.02	20	0.025	0.025	0.025	16	0.001	0.310	0.018
Magnesium	(mg/L)	10	3.7	35	12	20	5.8	30	13	16	10.0	48.0	21.0
Manganese	(mg/L)	10	0.001	2.8	0.1	20		2.9	0.1	16	0.005	2.000	0.036
Mercury	(mg/L)	10	0.0001	0.0002	0.0001	20	0.00005	0.00015	0.00007	16	0.00010	0.00500	0.00052
Selenium	(mg/L)	10	0.0025	0.05	0.01	20	0.0025	0.05	0.01	16	0.001	0.007	0.004
Thallium	(mg/L)	10	0.001	0.0025	0.001	20	0.0025	0.025	0.01	16	0.011	0.210	0.107
Zinc	(mg/L)	10	0.0025	0.042	0.01	20	0.0025	0.071	0.02	16	0.003	2.200	0.031

Table 3.2-7 (Continued)
Summary of Ground Water Chemistry by Hydrostratigraphic Unit

Constituent	Units	Intrusive[2]				Marine Clastic[2]				Marine Carbonate[2]			
		Number of Wells	Minimu m	Maximum	Average	Number of Wells	Minimum	Maximum	Average	Number of Wells	Minimu m	Maximum	Average
Physical and Aggregate Properties													
TDS	(mg/L)	7	270	510	392	13	185	450	305	24	310	672	566.2
Inorganic Nonmetallic Constituents													
Chloride	(mg/L)	7	4.0	81.0	46.3	13	3.4	69.0	17.0	24	3.0	19	14.9
Fluoride	(mg/L)	7	0.21	0.90	0.47	13	0.36	0.70	0.50	24	0.6	1.6	1.3
pH	(pH units)	7	6.3	8.9	8.0	13	6.4	9.2	7.6	24	5.1	8	6.7
Sulfate	(mg/L)	7	45.0	190.0	134.1	13	43.0	190.0	80.4	24	48.0	160	77.0
Temperature	(degrees C)	7	11.0	35.0	21.1	13	11.0	40.0	23.5	24	29.0	60	51.3
Alkalinity	(mg/L)	7	75	170	127	13	100.0	180	140	24	160.0	480	422.0
Bicarbonate	(mg/L)	7	91	207	155	13	122	219	171	24	195.1	585.216	514.5
Sodium	(mg/L)	7	20.0	44.0	30.7	13	15.8	36.0	23.6	24	21.0	85.5	73.9
Potassium	(mg/L)	7	2.60	8.10	5.51	13	4.40	8.90	6.35	24	6.6	25	20.9
Calcium	(mg/L)	7	32.0	80.0	51.8	13	28.0	57.0	38.7	24	39.0	109	88.9
Dissolved Metals/Semimetals													
Antimony	(mg/L)	7	0.039	0.039	0.039	13	<0.019	<0.019	*	24	0.022	0.050	0.035
Arsenic, Total	(mg/L)	7	0.020	0.200	0.095	13	0.002	0.570	0.113	24	0.008	0.451	0.021
Boron	(mg/L)	7	0.084	0.100	0.094	13	0.047	0.107	0.094	24	0.600	0.847	0.767
Iron	(mg/L)	7	0.020	4.300	0.463	13	0.020	3.400	0.468	24	0.030	14.7	0.308
Lead	(mg/L)	7	0.001	0.012	0.007	13	0.001	0.007	0.004	24	<0.001	0.012	0.007
Magnesium	(mg/L)	7	12.0	38.0	25.5	13	11.0	37.2	20.3	24	19.0	32.0	21.9
Manganese	(mg/L)	7	0.002	1.200	0.114	13	0.005	0.342	0.083	24	0.007	0.092	0.013
Mercury	(mg/L)	7	0.0001	0.0001	0.0001	13	0.00010	0.00028	0.00019	24	0.0001(	0.00222	0.0007
Selenium	(mg/L)	7	0.006	0.013	0.010	13	0.001	0.001	0.001	24	0.002	0.004	0.004
Thallium	(mg/L)	7	0.002	0.002	0.002	13	<0.001	<0.001	*	24	<0.001	<0.001	*
Zinc	(mg/L)	7	0.005	0.069	0.017	13	0.005	0.100	0.026	24	0.002	0.180	0.017

Source:
[1]Barrick 1998h.
[2]Radian International, LLC and Baker Consultants, Inc. 1997b.
[3]Average below detection limit.

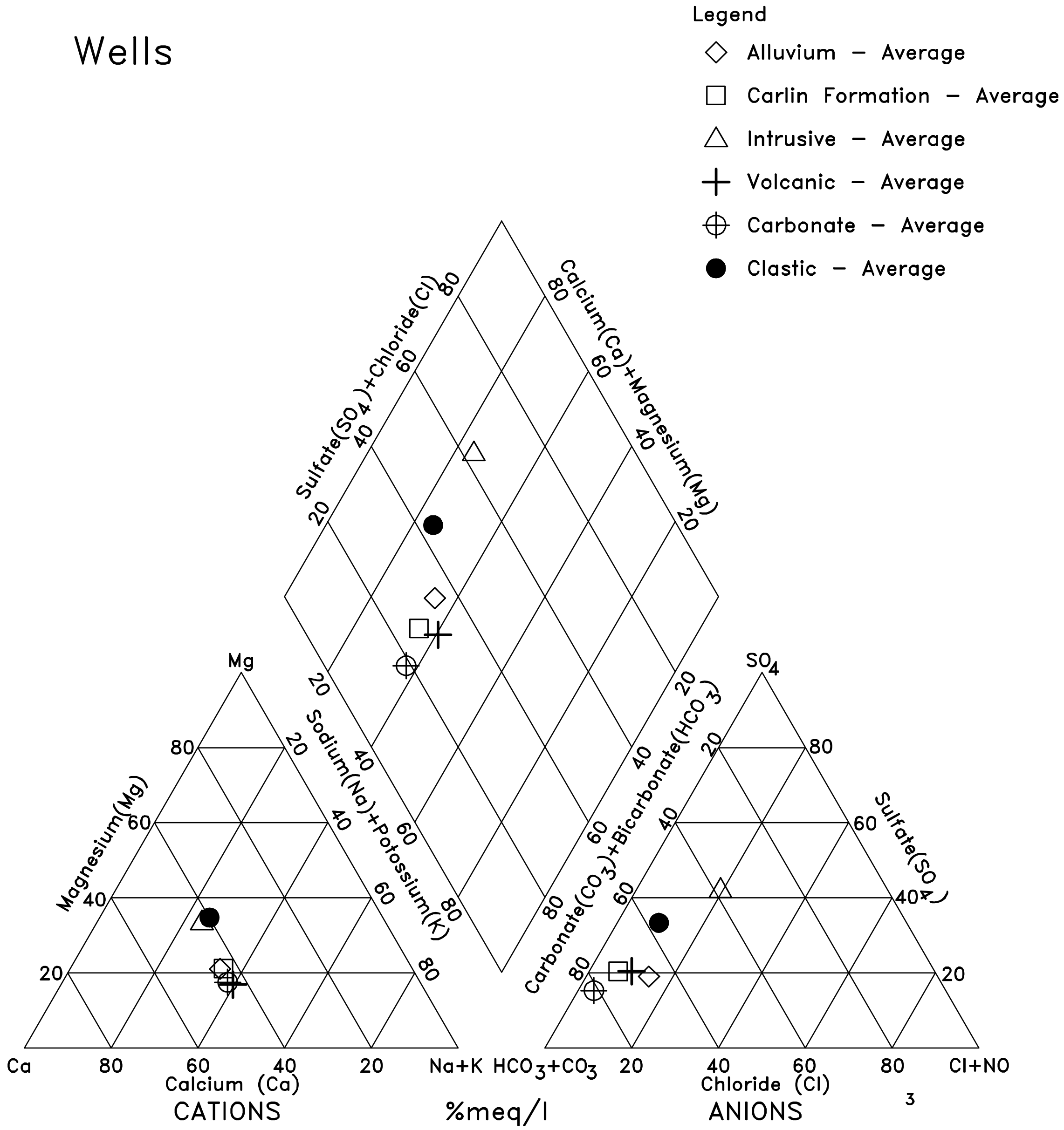


Figure 3.2-13

Piper Trilinear Diagram of Baseline Ground Water Chemistry water in each of the six major hydrostratigraphic units in the hydrologic study area.

Marine Clastic Rocks. The marine clastic rocks near the Betze-Post Pit primarily contain a calcium-magnesium-bicarbonate-type water with elevated concentrations of sulfate and silica. The average pH of these waters is 7.6, and the average total dissolved solids (TDS) concentration is 305 milligrams per liter (mg/L) (Radian International, LLC and Baker Consultants, Inc. 1997b). These water chemistry characteristics also generally apply to ground water sampled from marine clastic rocks located within several miles of the mine.

Marine Carbonate Rocks. Ground water sampled from the marine carbonate rocks near the Betze-Post Pit is a strong calcium-bicarbonate-type water that contains less sodium and sulfate. The pH of these waters averages 6.7 to 6.8, and the TDS concentration averages 566 mg/L (Radian International, LLC and Baker Consultants, Inc. 1997b). However, NA-15, which is located several miles upgradient of the pit, has a pH of 8.2 and a TDS concentration of 280 mg/L.

Intrusive Rocks. The intrusive rocks near the Betze-Post Pit generally contain a calcium-sulfate-type ground water with elevated concentrations of chloride and lower concentrations of potassium and silica. The pH of these waters averages 8.0, and the average TDS concentration is approximately 392 mg/L (Radian International, LLC and Baker Consultants, Inc. 1997b).

Volcanic Rocks. Ground water sampled from volcanic rocks in the study area is generally a bicarbonate-type water with no dominant cations. Calcium and sodium are present in approximately equal proportions with smaller amounts of potassium and magnesium. The pH averages 7.7, and the average TDS concentration is approximately 375 mg/L. These characteristics are based on the evaluation of chemical analyses from 20 wells completed in volcanic rocks.

Carlin Formation. Ground water sampled from the Carlin Formation near the pit is generally a calcium-bicarbonate-type water with smaller amounts of sodium, silica, and sulfate. These waters have an average pH of 7.4 and an average concentration of TDS of approximately 478 mg/L (Radian International, LLC and Baker Consultants, Inc. 1997b).

Alluvium. Based on samples from 10 wells, the alluvium in the study area contains a bicarbonate-type water with no dominant cations. There are approximately equal amounts of calcium and sodium and smaller amounts of potassium and magnesium. The pH of ground water in the alluvium averages 7.6, and the TDS concentration averages 330 mg/L.

Betze-Post Pit Area. Overall, the ground water sampled near the Betze-Post Pit can be separated into two general types based on a statistical discriminate analysis. Ground water from the marine carbonate rocks is calcium-bicarbonate enriched. The Carlin Formation and marine clastic rocks near the mine also contain calcium-bicarbonate type water, but there are also relatively higher concentrations of silica, manganese, and chloride in these waters (Radian International, LLC and Baker Consultants, Inc. 1997b).

Ground water encountered near the Betze-Post Pit generally has low concentrations of trace metals; however, arsenic, barium, boron, fluoride, iron, and manganese are commonly detected. Arsenic concentrations average 0.06 mg/L and are highest in the ground water found in marine clastic and intrusive rocks. Barium, boron, and fluoride concentrations are elevated in the thermal ground water in the marine carbonate rocks and Carlin Formation near the pit. The mean concentration of iron is highest (1.6 mg/L) in the Carlin Formation, and manganese concentrations are about an order of magnitude greater in ground water from the marine clastic rocks and intrusive rocks than from other rocks near the mine. Antimony is detected primarily in ground water from the marine carbonate rocks and intrusive rocks where it is found in concentrations that average between 0.03 and 0.04 mg/L. In approximately 5 percent of the ground water samples near the mine, chromium and copper were detected below 0.03 and 0.1 mg/L, respectively. The average concentration of zinc in ground water near the mine is approximately 0.02 mg/L. Cadmium, lead, mercury, nickel, selenium, silver, and thallium have been detected in less than 5 percent of the ground water samples near the mine and at concentrations that are generally less than 0.01 mg/L (Radian International, LLC and Baker Consultants, Inc. 1997b).

Boulder Valley Area. State and/or Federal drinking water standards for pH were exceeded in only 6 ground water samples (Barrick 1997e, 1998h): 1 sample out of 87 was high in alluvium, 4 out of 232 were high in volcanic rock, and 1 sample from volcanic rock had a low pH (3.5). The average pH of alluvial and volcanic rock ground water was just slightly alkaline. Drinking water standards for TDS were exceeded in 24 samples: 1 out of 85 alluvial ground water samples and 23 out of 227 ground water samples taken from wells completed in volcanic rock. However, 17 of these samples were from one well-NA-17 (Barrick 1998h).

Trace elements detected in ground water from alluvial wells include arsenic, barium, boron, copper, fluoride, iron, lead, manganese, selenium, and zinc. However, exceedences of drinking water standards were infrequent and included arsenic, iron, and manganese with maximum values of 0.14 mg/L, 100 mg/L, and 2.8 mg/L, respectively. Ground water samples taken from wells completed in volcanic rocks had trace element detections of aluminum, arsenic, barium, boron, chromium, copper, fluoride, iron, lead, manganese, selenium, thallium, and zinc. State and/or Federal drinking water standards were exceeded in at least one ground water sample from volcanic rocks for aluminum, arsenic, fluoride, iron, lead, and manganese with maximum values of 0.7 mg/L, 0.21 mg/L, 3.0 mg/L, 59 mg/L, 0.018 mg/L, and 2.9 mg/L, respectively.

Seep and Spring Water Quality. As described in the discussion of seeps and springs above, field inventories have been conducted to identify seeps and springs located throughout the region (JBR 1990a; RTi 1994). Field measurements of temperature, pH, and conductivity were collected at each spring identified during the seep and spring inventories. In addition, water samples were collected at representative springs as part of the seep and spring inventories (JBR 1990a; RTi 1994) to characterize the water chemistry for representative springs to determine the origin of the spring waters. The laboratory analysis included TDS, major anions and cations, metals, and (in selected springs) stable isotopes and tritium.

The measured temperature of the springs ranged from 38 to 78 degrees Fahrenheit. Since most of the springs have very small flows (less than 3 gpm), the measured temperature is strongly influenced by air temperature. No hot (greater than 90 degrees Fahrenheit) springs were identified during the inventories. The pH values for 399 of the seep and spring sites measured in the field ranged from 6.4 to 8.9. Two springs (S36-51-07L and S36-51-07M) located below an historic mine dump had acidic values of 4.0 and 3.3, respectively; four springs in the upper Antelope Creek area had pH values ranging from 9.0 to 10.3 (RTi 1994).

Excluding a few apparently anomalous springs, discharge from springs sampled had a low to moderate TDS concentration ranging from 32 to 550 (RTi 1994). Springs with the lowest TDS concentrations discharge at high elevations in the Tuscarora Mountains. The results of the trace metal analyses indicate that again, excluding a couple of anomalous springs, the concentration of metals in spring water is generally low throughout the region.

Tritium concentrations were determined in selected representative springs to distinguish the relative age of the water discharging from the ground water system. Tritium is a radioactive isotope with a half life of 12.4 years. Because of rapid decay, water that entered the subsurface (as precipitation recharge to the ground water system) pre-1954 would today contain less than 1 tritium unit (TU). In contrast, tritium concentrations in precipitation in the last few years generally range from approximately 10 to 20 TU. Concentrations of tritium in several samples from the east slope of the Tuscarora Mountains indicate that the ground water in this area has a very short residence time that probably spans no more than a few years (RTi 1994). In contrast, tritium samples from the upper Antelope Creek-Squaw Creek area and upper and lower Willow Creek area had very low tritium concentrations, indicating that these waters contain little if any post-1954 water. Several other samples collected throughout the region contained intermediate tritium concentrations that either reflect an intermediate age of the water or mixing of somewhat older water (pre-1954) with younger water (RTi 1994).

Surface Water Quality Standards. Surface water quality standards are established by the State of Nevada for designated beneficial uses associated with waters of the state. "Waters of the state" means all waters situated wholly or partly within or bordering upon this state, including but not limited to (1) all streams, lakes, ponds, impounding reservoirs, marshes, water courses, waterways, wells, springs, irrigation systems, and drainage systems; and (2) all bodies or accumulations of water, surface and underground, natural or artificial (Nevada Revised Statutes 445A.415). Designated beneficial uses are defined in Nevada Administrative Code 445A.122 and water quality standards applicable to the hydrologic study area are prescribed in Nevada Administrative Code 445.144 and 445A.124 through 445A.126, inclusive.

As shown in Figure 3.2-14 (Nevada Administrative Code 445.144 and 445A.124 through 445A.126), surface waters in the hydrologic study area have been classified as either Class A, B, C, or waters upstream and tributary to the Humboldt River. The purpose of the classification is to establish beneficial uses and appropriate water quality standards for stream segments. Table B-1 and Table B-2 in Appendix B list water quality standards applicable to surface waters in the hydrologic study area.

Surface Water Quality. Stream water quality within the hydrologic study area is monitored by Barrick on a monthly basis (Barrick Boulder Valley Monitoring Plan Reports [1991-1998]). The following streams are monitored (Figure 3.2-15) (Barrick 1999a):

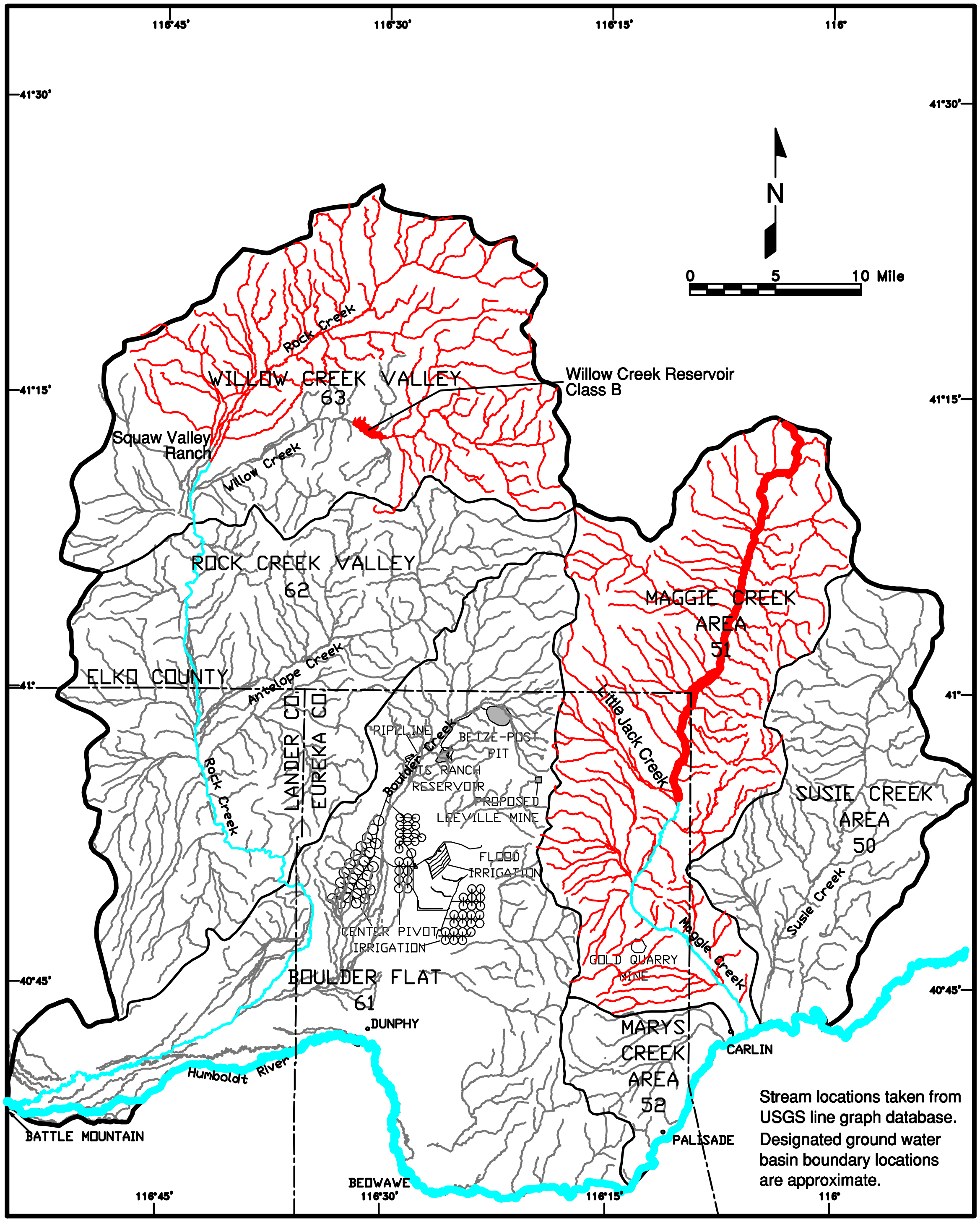
Boulder Flat	Rock Creek Valley	Maggie Creek Area
Bell Creek	Antelope Creek	Maggie Creek
Boulder Creek	Rock Creek	
Brush Creek		
Rodeo Creek		

Stream water quality data have been collected as single samples during short-term intensive surveys (RTi 1994; AATA International, Inc. 1997); as single samples during arbitrarily selected times by the USGS; and as part of the Barrick monitoring program (Barrick 1999a). Only the stream water quality data collected by the USGS and data collected during the Barrick monitoring program (Barrick 1999a) were used to produce a water quality summary for each stream (see Appendix B, Table B-3). In addition, the data summaries only include data collected through 1997. Monitoring program data collected in 1998 (Barrick 1999a) were evaluated, however, and are consistent with the data summaries and interpretations presented.

The streams contained combinations of calcium, magnesium, and sodium as dominant cations, though bicarbonate was the dominant anionic water type for all streams (Barrick 1999a). Concentrations of TDS ranged from 72 mg/L in Bell Creek to 2,300 mg/L in Rodeo Creek. Values of pH were typically neutral to alkaline ranging from a low of 7.1 in Boulder and Rodeo creeks to 10.0 in Rodeo Creek (Table B-3).

Average metals concentrations were typically below applicable Nevada Standards for Toxic Materials (see Appendix B, Table B-1), but there were incidences of elevated arsenic, iron, manganese, and thallium concentrations. Concentrations that exceeded toxic materials standards are presented in bold type in Table B-3. For the constituents measured, standards were met during the sampling periods except for the following:

- Maggie Creek (thallium)
- Rock Creek (thallium, fluoride)
- Boulder Creek (fluoride, arsenic, iron, and manganese)
- Antelope Creek (fluoride)
- Bell Creek (manganese)
- Brush Creek (fluoride)
- Rodeo Creek (fluoride, arsenic, iron, and manganese)



Legend

- Ground Water Basin Boundary
- County
- Streams Tributary to the Humboldt River
- Humboldt River
- Class A
- Class B
- Class C
- Center Pivot Irrigation

Betze Supplemental EIS

Figure 3.2-14

Stream Classification for Beneficial Uses and Associated Standards

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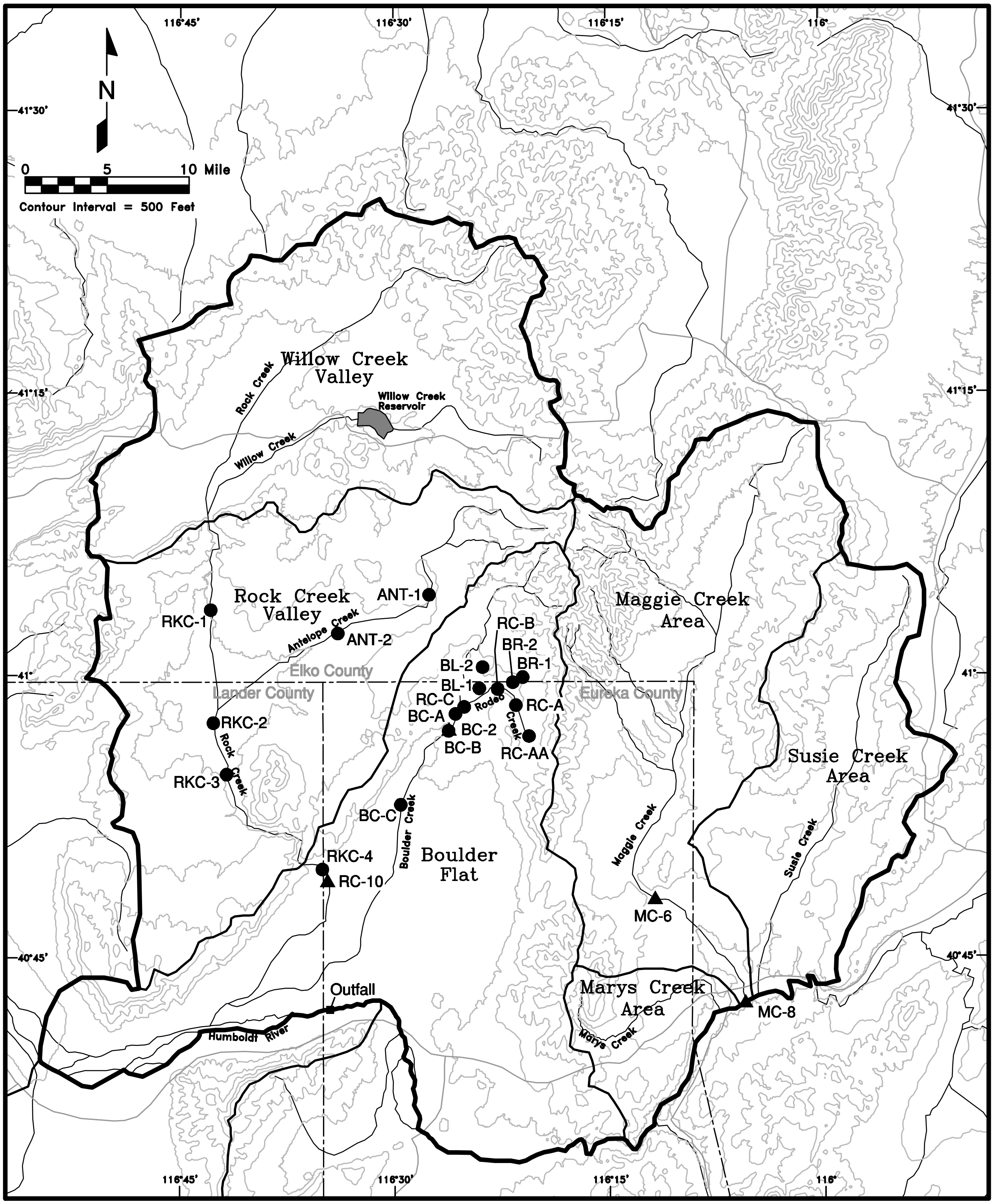

Legend

Study Area

Ground Water Basin Boundary

HR-1▲ USGS Active Stream-gaging Station①

BC-C● Barrick Surface Water Sampling Locations②

①Abbreviations:
MC = Maggie Creek;
BC = Boulder Creek;
RC = Rock Creek and its tributaries

②Abbreviations:
RKC = Rock Creek; ANT = Antelope Creek;
BC = Boulder Creek; BL = Bell Creek;
BR = Brush Creek; and RC = Rodeo Creek

Figure 3.2-15

Stream Sampling Sites with Summarized Water Quality Data