2.0 GEOLOGY

2.1 Affected Environment

This section provides a general overview of the regional baseline geologic conditions pertinent to the cumulative impact evaluation. The geologic conditions discussed below also provide the information necessary to characterize the hydrogeologic conditions discussed in Chapter 3.0, Water Resources and Geochemistry.

2.1.1 Physiographic and Topographic Setting

The topography and physiographic features of the regional study area for geology and minerals are shown in Figure 2-1. The regional study area for geology is coincident with the hydrologic model area described in Chapter 3.0. This regional study area includes the Boulder Creek, Rock Creek, Willow Creek, Marys Creek, Maggie Creek, and Susie Creek drainage basins. All of these basins are tributary to the Humboldt River, which forms the southern boundary of the study area. Major mountain ranges within the study area include the Sheep Creek Range and portions of the Tuscarora Mountains, Independence Range, and Adobe Range. The elevation ranges from 8,700 feet amsl in the Tuscarora Mountains near the central portion of the study area to 4,500 feet amsl along the Humboldt River in the southwest corner of the study area.

The project area is located within the Great Basin region of the Basin and Range physiographic province and is characterized by a series of generally north-trending mountain ranges separated by broad basins. The Basin and Range physiography has developed from normal faulting that began approximately 17 million years ago and continues to the present (Stewart 1980). The extensional block faulting uplifted the mountains, which consist of Precambrian to Tertiary age bedrock units. The basins are filled with thick accumulations of unconsolidated and consolidated sediments that are derived from erosion of the adjacent mountain ranges.

2.1.2 Regional and Geographic Setting

The regional geologic conditions are presented in Figure 2-2, and the regional geologic cross sections are shown in Figure 2-3 (Maurer et al. 1996). Both the regional geologic map and cross sections are based on information presented by Maurer et al. (1996). Maurer et al. (1996) simplified the complex geology of the region into six regional map units. From oldest to youngest, these regional units include marine carbonate rocks, marine clastic rocks, intrusive rocks, volcanic rocks, older basin-fill deposits, and younger basin-fill deposits. Table 2-1 summarizes the age range, lithologic description, maximum estimated thickness, and lists the formations and other localized map units included within each of these six regional geologic map units.

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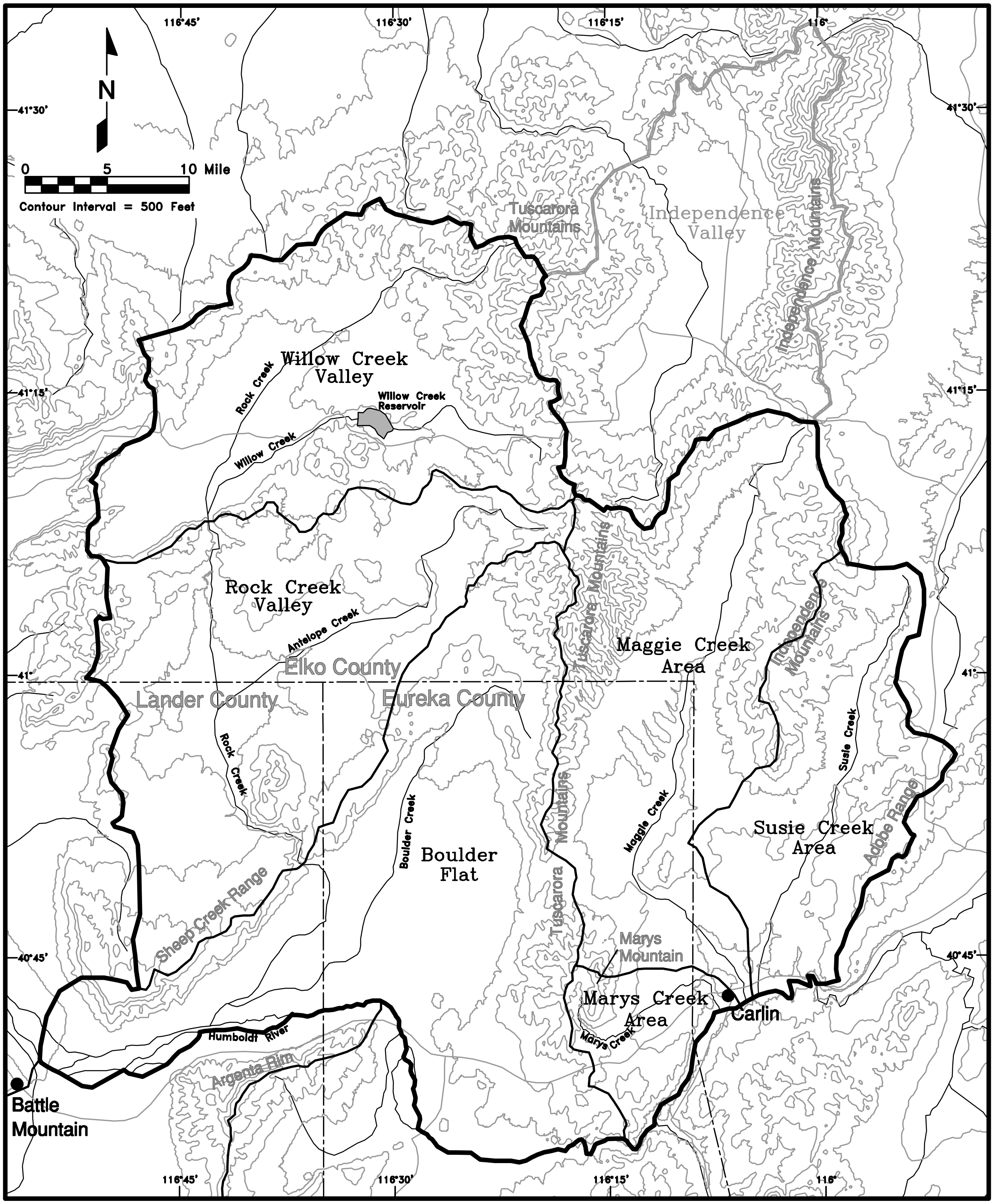

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Study Area

Ground Water Basin Boundary

Stream

County

Figure 2-1

Regional Topographic Map

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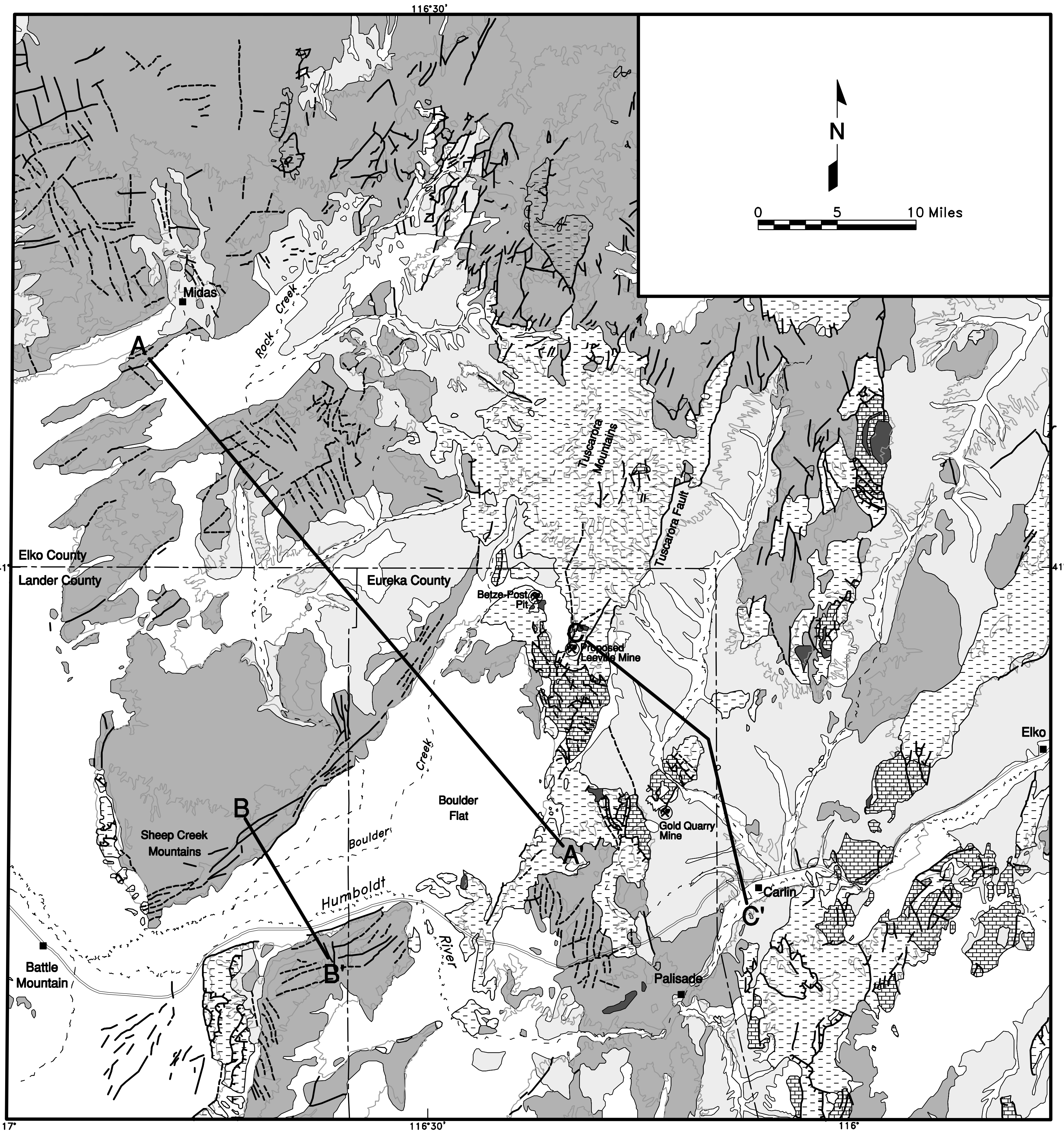

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	Younger Basin Fill		Interstate 80
	Older Basin Fill		Stream
	Intrusive Rocks	A———A'	Line of Regional Geologic Cross Section
	Volcanic Rocks		High-angle Fault (dashed where approximately located; dotted where inferred)
	Marine Clastic Rocks		Roberts Mountain Thrust Fault
	Marine Carbonate Rocks	▪	City, Town, or Community
	County		

Figure 2-2
Regional Geologic Map

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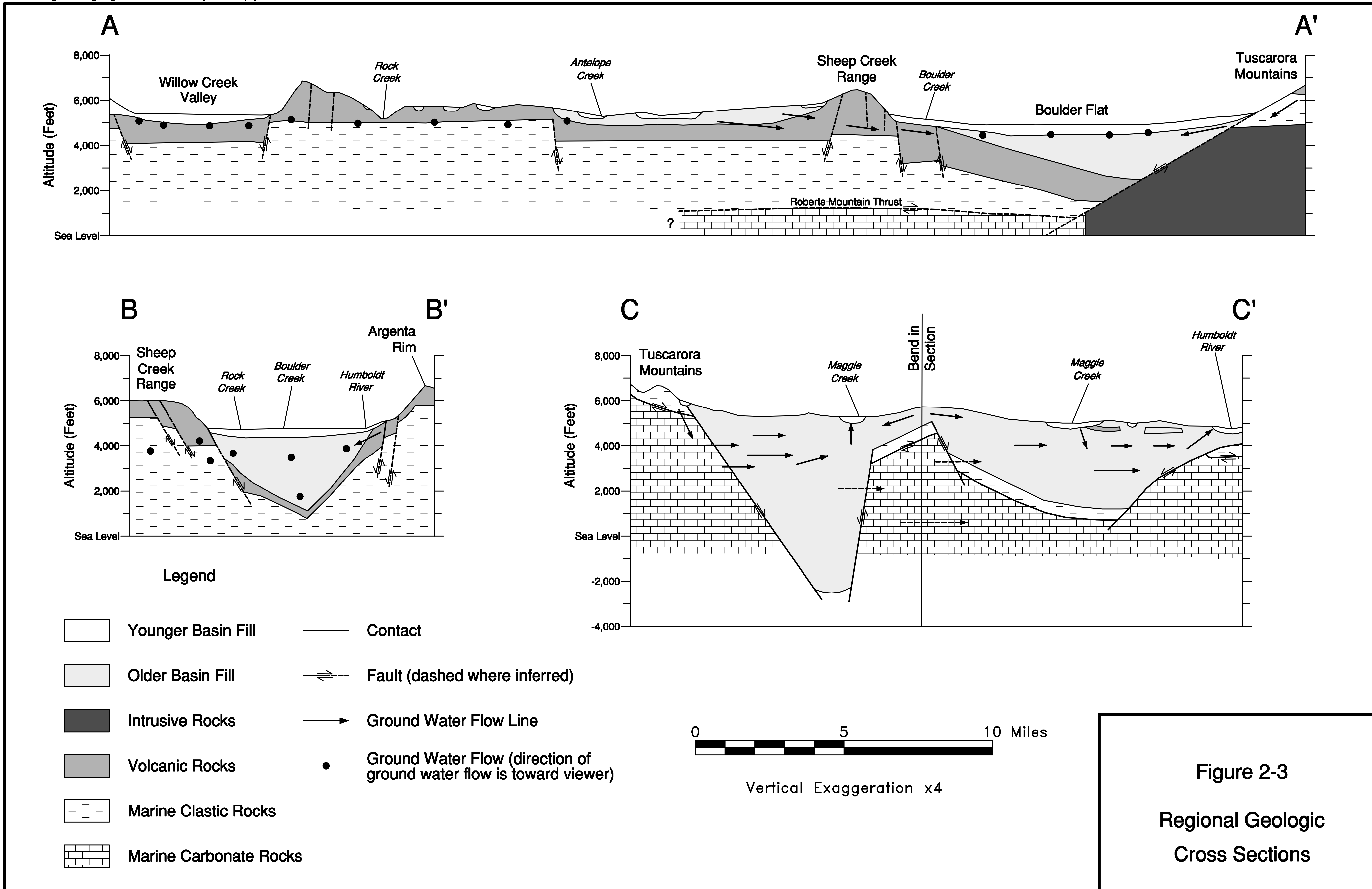

Figure 2-3

Regional Geologic Cross Sections

Table 2-1
Generalized Description of the Regional Geologic Map Units

Hydrogeologic Unit	Geologic Age	Lithology	Rock or Stratigraphic Unit[1]	Maximum Thickness (feet)
Younger basin-fill deposit	Quaternary and Tertiary	Deposits of alluvial fans, basin lowlands, and stream flood plains	Includes unnamed deposits and Hay Ranch Formation of Regnier (1960)	1,600
Older basin-fill deposit	Tertiary and Cretaceous	Shale, claystone, siltstone, limestone, conglomerate, and sandstone; locally tuffaceous	Upper part of Raine Ranch Formation of Regnier (1960); Carlin Formation of Regnier (1960); Humboldt Formation (restricted) of Smith and Ketner (1976); Elko Formation, limestone, conglomerate, and cherty limestone of Smith and Ketner (1976); Rand Ranch Formation of Regnier (1960); Newark Canyon Formation	7,600
Volcanic rocks	Tertiary and Jurassic	Felsic flows, domes, and ash-flow tuffs; intermediate lava flows, pyroclastic rocks, and air-fall tuffs; mafic volcanic rocks; and ash	Big Island Formation, Banbury Formation, Palisade Canyon Rhyolite of Regnier (1960); Rhyolitic welded tuff of Smith and Ketner (1976); Safford Canyon Formation and lower part of Raine Ranch Formation of Regnier (1960); Indian Well Formation, mafic to intermediate units of Smith and Ketner (1976); and Frenchie Creek Rhyolite	13,000
Intrusive rocks	Tertiary and Jurassic	Plutons, dikes, and minor plugs of felsic to intermediate composition	Quartz monzonite plutons of Swales and Lone Mountains; also includes large plutons inferred from aeromagnetic data to underlie Mary's Mountain and west part of Sheep Creek Range	--
Marine siliciclastic rocks	Paleozoic (Devonian to Ordovician)	Sandstone, chert, shale, and siltstone	Valmy Formation, Vinini Formation, Silurian rocks of Mary's Mountain, Elder Sandstone, Woodruff Formation, and Slaven Chert	23,000
Marine carbonate rocks	Paleozoic (Permian to Mississippian; Devonian to Cambrian)	Mudstone, siltstone, quartzite, limestone, shale, and sandstone	Permian to Mississippian: Tripon Pass Limestone, Webb Formation, argillite of Lee Canyon, Chainman Shale, Diamond Peak Formation, Moleen Formation, Tomera Formation, Carlin Sequence (amended), sandstone and siltstone of Horse Mountain, and Edna Mountain Formation (part of the Antler Sequence)[2]	26,000
		Limestone, dolomite, limy siltstone, sandy dolomite, claystone, chert, and quartzite	Devonian to Cambrian: Hamburg Dolomite, Pogonip Group, Eureka Quartzite, Hansen Creek Formation, Ordovician rocks of Mary's Mountain, Roberts Mountains Formation, Lone Mountain Dolomite, Popovich Formation, Rodeo Creek unit of Ettner (1989), Nevada Formation, Devils Gate Limestone, and Wenban Limestone	19,000

[1]Stratagraphic units defined in Regnier 1960; Roberts et al. 1967; Smith and Ketner 1975, 1976; Stewart and McKee 1977; Stewart 1980; Radtke 1985; Coats 1987; and Ettner 1989.
[2]The Permian to Missippian Rock or Stratigraphic Units are included with the Marine siliciclastic rocks in Stewart (1980), and Ekburg and Rota (1987). Roberts et

The study area has undergone a complex geologic history, resulting in variable stratigraphic and structural geologic conditions. During the Early Paleozoic Era, marine clastic and carbonate rocks were deposited on the sea floor along the western continental margin of North America. The marine clastic rocks were deposited farther west, in a deep ocean setting, while the carbonate rocks were deposited in a shallow water setting adjacent to the land mass. The marine carbonate rocks consist of limestone and dolomite with minor shale, siltstone, sandstone, and quartzite. The marine siliciclastic rocks include interbedded metasedimentary mudstones, shale, chert, siltstone, quartzite, and greenstone (Stone et al. 1991). A transitional assemblage lies between the two sedimentary assemblages (Stewart 1980; Schull 1991). In the vicinity of the Carlin Trend, the transitional assemblage consists predominantly of limestones and siltstones. In an attempt to simplify the stratigraphy of this region, Maurer et al. (1996) combined these transitional assemblage rocks with the carbonate assemblage.

During the Late Devonian or Early Mississippian time, marine deposition was interrupted, and the Paleozoic sediments were uplifted, folded, and thrusted by the Antler Orogeny (orogeny is a geologic term for mountain building event). During the Antler Orogeny, the siliciclastic rocks were thrust over the carbonate rocks along the Roberts Mountain Thrust (Roberts 1966, Stewart 1980), a major structural feature within the regional study area. The clastic rocks form the upper plate, while the carbonate rocks form the lower plate of the thrust. The marine carbonate rocks underlie the siliciclastic assemblage throughout the study area. Stewart (1980) notes the clastic rocks in the upper plate have been displaced to the east by as much as 90 miles and are composed of interleaved broad, thin thrust sheets that are oriented sub-parallel to the bedding.

The Antler Orogeny also created a highland that persisted during much of the Mississippian period and perhaps during parts of the Pennsylvanian and Permian periods (Stewart 1980). During the Late Paleozoic Era, sediments shed from the highland resulted in deposition of clastic and carbonate rocks (Antler Sequence). These rocks are grouped by Maurer et al. (1996) with the Paleozoic marine carbonate rocks (Table 2-1), although the rocks are primarily siliciclastic.

During the Mesozoic and Early Cenozoic Eras, the area was subjected to compression, which resulted in the Tuscarora Mountain anticline and may have fractured the rocks in the vicinity of the anticline, providing pathways for mineral-bearing fluids and ground water. Intrusive igneous activity accompanied this compression. The Marys Mountain intrusive complex, long postulated on the basis of geophysics and recrystallization (Evans 1974), is composed of rocks that span from Jurassic through Tertiary: the outcropping Goldstrike granodiorite is dated at 154 to 162 million years (Arehart 1992), the outcropping Richmond Mountain quartz monzonite is dated at 106 million years (Evans 1974), and the outcropping Welches Canyon granodiorite is dated at 37 million years (Evans 1974).

Beginning in the late Cenozoic Era, the area was block-faulted by a series of normal and listric faults that created the Basin and Range topography that characterizes the region. Broad valleys in the regional study area, such as Boulder Flat and the Maggie Creek basin, were formed as down-dropped blocks between uplifted mountain ranges. As shown on Figure 2-4 (Hydrologic Consultants, Inc.[HCI] 1998a and McDonald Morrissey Associates, Inc. [MMA] 1998), major normal faults bound the southeast flank of the Sheep Creek Range, the east flank of the Tuscarora Mountains, and the north side of the Argenta Rim. The regional

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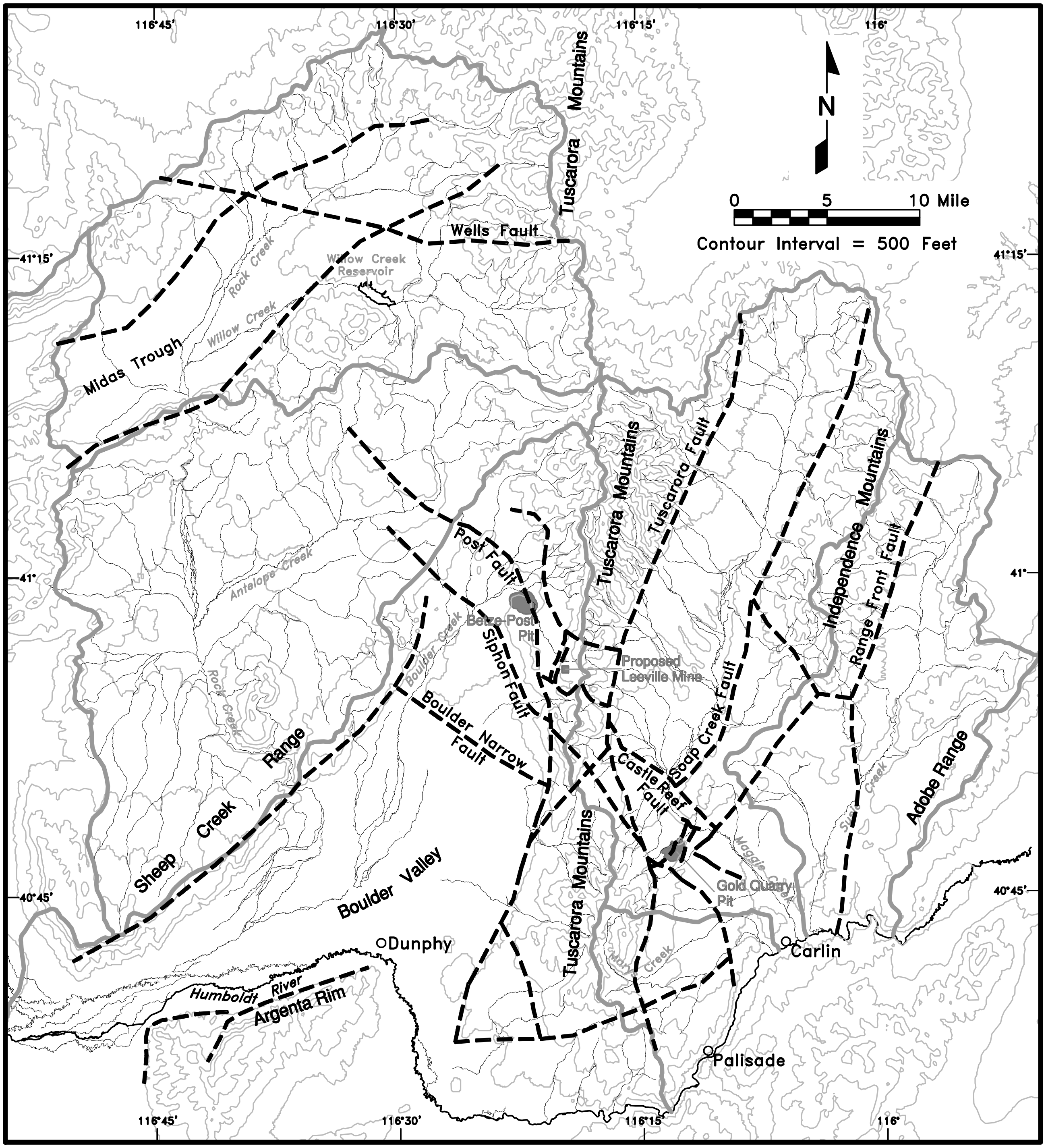

Legend

Ground Water Basin Boundary

Stream

Faults (Approximate) 1

1 Includes Known and Inferred Faults

Figure 2-4

Major Faults in the Hydrologic Study Area geologic cross sections (Figure 2-3 [Maurer et al. 1996]) shows several normal faults that bound ranges concealed by basin fill. These normal faults drop the basin side relative to the mountainside, may have displacements of thousands of feet, and usually are at high angles (Stone et al. 1991). Major normal faults within the study are listed below:

- The Post Fault, which trends north-northwest
- A fault zone along the southeast margin of the Sheep Creek Range
- Soap Creek Fault, located on the western margin of the Independence Mountains (HCI 1999b)
- Tuscarora Fault, located on the eastern slope of the Tuscarora Mountains

In addition to the above faults, the Siphon and Boulder Narrows faults were identified during Barrick's hydrogeologic studies (MMA 1998).

Uplift and subsequent erosion of the mountains during the late Cenozoic Era have partially filled the basins with poorly consolidated to unconsolidated silty clay, silt, clayey sand, sand, gravel, and boulders deposited primarily as a series of coalescing alluvial fans. These basin-fill deposits are mapped as two types: 1) older basin-fill deposits and 2) younger basin-fill deposits (Maurer et al. 1996).

The older basin-fill deposits are Miocene to Pliocene in age and consist of fluvial and lacustrine sediments, volcaniclastic rocks, and volcanic rocks. The younger basin-fill deposits (alluvium) consist of unconsolidated alluvium deposits that underlie present-day streams, flood plains, and associated stream terraces. These deposits are highly variable and consist of silty clay, sandy clay, silty sand, clayey sand, gravel sand, conglomerate, and boulders. The younger deposits are erosion products from the adjacent mountains and the older basin-fill deposits. The deposits of the basin lowlands are somewhat better sorted than the basin margins. In Boulder Flat, the basin-fill deposits (younger and older) are estimated to be 3,500 feet in the deepest part of the basin. In the upper reach of Maggie Creek, the basin-fill deposits are estimated to be 7,000 to 8,000 feet thick, while in lower Maggie Creek the basin is estimated to be 3,000 to 4,000 feet thick (Maurer et al. 1996). Table 2-2 presents the characteristics of the basins in the study area.

2.2 Impacts from Mine Dewatering and Localized Water Management Activities

The primary issue identified for this assessment of cumulative impacts to geology and minerals is the potential for development of sinkholes or other karst-type collapse features that could result from mine induced drawdown and water management activities. The cumulative study area for this evaluation includes the six designated ground water basins established by the Nevada Division of Water Resources (NDWR) (Figure 2-1).

Table 2-2
Basin Characteristics

Basin	Thickness of Basin-fill Deposits (feet)	Structural Characteristics	Bedrock
Upper Maggie Creek Area	7,000 to 8,000	Deepest basin that is formed by down-faulted rocks	Paleozoic clastic rock that overlies carbonate rock
Lower Maggie Creek (LMC) and Susie Creek Area	LMC - 3,000 to 4,000; Susie Creek - 2,000	Broad structural basin	Paleozoic clastic rock thrust by the Roberts Mountain thrust over the carbonate rock
Willow Creek Valley	< 500	A relatively narrow basin oriented northeast to southwest	Basin underlain by volcanic rocks on top of Paleozoic clastic rocks
Rock Creek Valley	800 to 2,000	A relatively shallow, bowl-shaped depression	Basin underlain by volcanic rocks that lie on top of Paleozoic clastic rocks
Boulder Flat	Over 2,500; the southwest part of the basin (north of Argenta Rim) is estimated to be 3,500 to 5,000	Bound by range-front faults	Underlain by 500 feet of volcanic rock, which overlies Paleozoic clastic rocks

Source: Maurer et al. 1996.

2.2.1 Introduction

Karst refers to solution features that occur in some areas underlain by limestone or carbonate rocks. Karst-type features include solution cavities and sinkholes that form with the dissolution of calcium carbonate. Areas affected by dissolution processes can experience occasional rapid (localized) subsidence where the solution cavities are located near the surface. The solution process may be accelerated by man-made changes in ground water conditions, including: 1) discharging excessive water into geologic materials susceptible to karst development and 2) lowering the water table, which can both increase vertical seepage rates and cause collapse of near-surface caverns that were buoyed by the water table.

Most younger sinkholes are caused by a collapse process. The development of sinkholes can pose a hazard to livestock, humans, and wildlife. If the sinkhole develops in the area of buildings, roads, and other structures, damage to these structures may result.

Accelerated sinkhole development caused by mine dewatering has been documented worldwide (Brink 1984; Kath et al. 1995; Wagner and Day 1984). One well-documented sinkhole problem caused by mine dewatering occurs in the dolomites of South Africa. The dolomites are above the gold-bearing conglomerates that were dewatered to enable mining. Hundreds of sinkholes have developed since the 1960s; several of these sinkholes have been very large causing loss of life and damage to buildings and other structures (Brink 1984; Wagner and Day 1984). Additional sinkhole development has occurred from dewatering of limestone quarries in the southeastern United States (Kath et al. 1995).

Several different processes can cause sinkhole or doline development. A doline is a basin or funnel-shaped hollow in limestone and does not imply a specific genesis. The processes that cause dolines are shown schematically in Figure 2-5 (Ogden 1984). The top two block diagrams in Figure 2-5 (Ogden 1984) show dolines that occur when carbonate rocks are at the ground surface or are covered by a thin layer of soil. These dolines form by either collapse of an underground cavity near the ground surface (collapse doline) or slow preferential dissolution of rock along fractures (solution doline). The bottom two block diagrams depict limestone covered by soil or loosely consolidated rock material. These dolines form by either gradual subsidence caused by vertical erosion or piping of the cover material into subterranean voids (subsidence dolines) or collapse of the overlying material into underlying cavities (subjacent karst collapse dolines).

2.2.2 Karst Development in the Region

In the carbonate province of Nevada, caves and caverns have been documented in the limestone (Hess 1992). The only known caves or caverns identified in the cumulative study area occur in the carbonate rocks encountered in Barrick's Meikle Mine (part of the Goldstrike Project). The cavities encountered in the Meikle Mine range up to an estimated 100 to 150 feet wide, 30 to 50 feet high, and several hundreds of feet long. In the Meikle Mine these caverns are characterized by having a massive rind of coarse calcite and barite crystals up to several feet thick. To date, none of the cavities encountered during mining have shown evidence of collapse during dewatering, or present any stability concerns for the mining operations.

Three sinkholes have been documented to date in the study area: 1) a sinkhole approximately 3.5 miles northwest of the center of the Betze-Post Pit, 2) a sinkhole approximately 2.8 miles west of the center of the Betze-Post pit located near spring 6, and 3) a sinkhole along Maggie Creek in an area referred to as the Maggie Creek Narrows. The locations of these features are shown in Figure 2-6 (BLM 1998b, 1993c; Adrian Brown Consultants, Inc. [ABC] 1997, 1998) and are described below.

1. The sinkhole 3.5 miles northwest of the Betze-Post Pit was reported to be approximately 80 feet long, 60 feet wide, and 40 feet deep on September 29, 1993 (BLM 1993c). Barrick has filled the sinkhole by pushing material into the hole. The actual site-specific conditions in the vicinity of this collapse feature are not known. It is inferred that a cavity existed in this area prior to dewatering. The sinkhole development appears to have resulted from dewatering activity.

2. ABC (1997, 1998) reported a circular sinkhole approximately 4 feet deep and 30 feet across located near spring 6. Dewatering of the Betze-Post Pit had lowered the water table in this area by approximately 1,100 feet at the end of 1996, causing the hydrostatic pressure to drop. Since this spring is located approximately 1 mile south of sinkhole 1, it is possible the mechanisms for sinkhole development are similar to those suggested above; however, the mechanism for development is not known.

3. A sinkhole was discovered in July 1996 along Maggie Creek. This sinkhole temporarily captured the Maggie Creek flow. This sinkhole was linear in nature and may be associated with a fracture or fault zone. Newmont diverted Maggie Creek around the sinkhole and plugged the crack with timbers, filter fabric, rock riprap, bentonite, and poured fiber-reinforced concrete. Newmont reconstructed the natural channel for 300 cubic feet per second (cfs) and then removed the diversion structure (BLM 1998a,

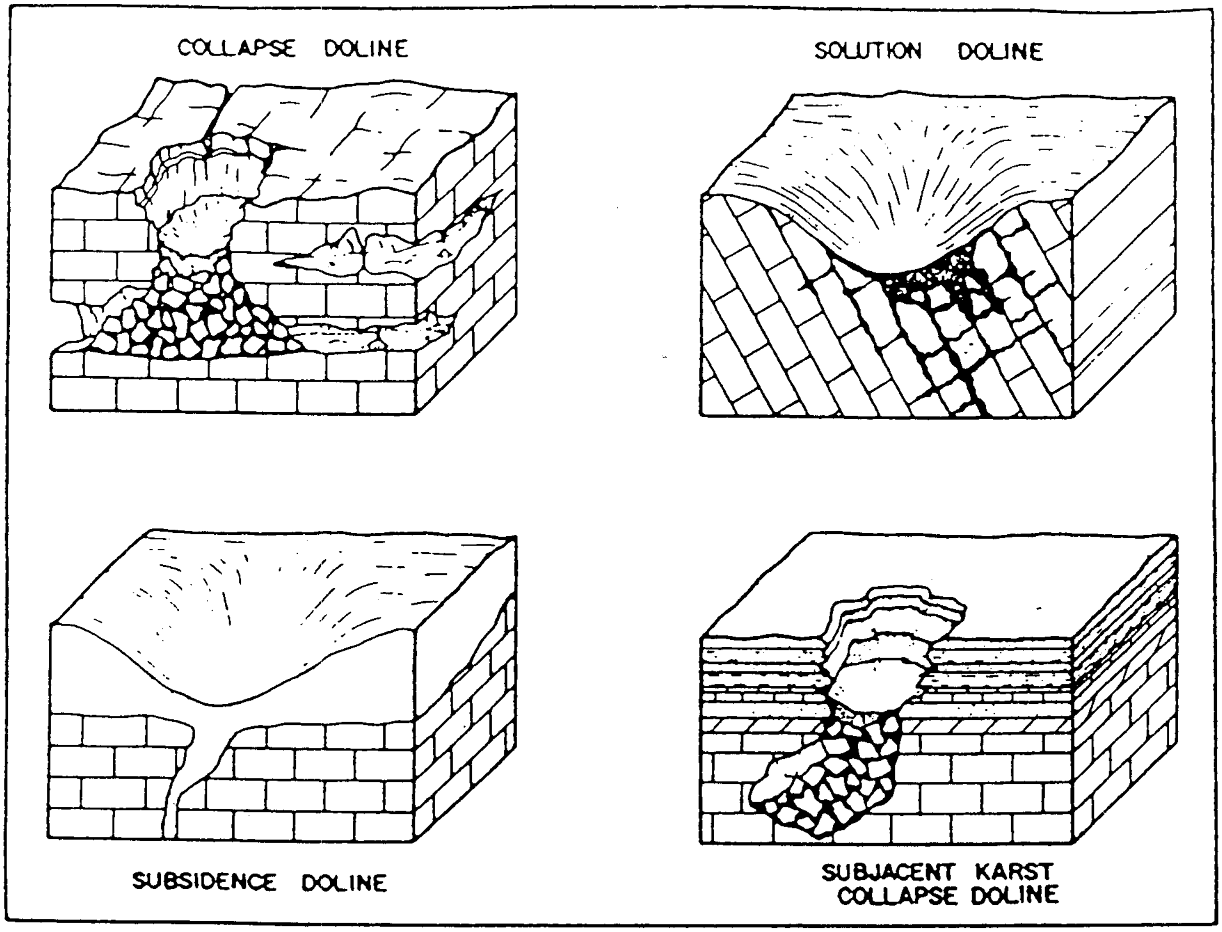

Figure 2-5

Block Diagrams of Sinkhole Development

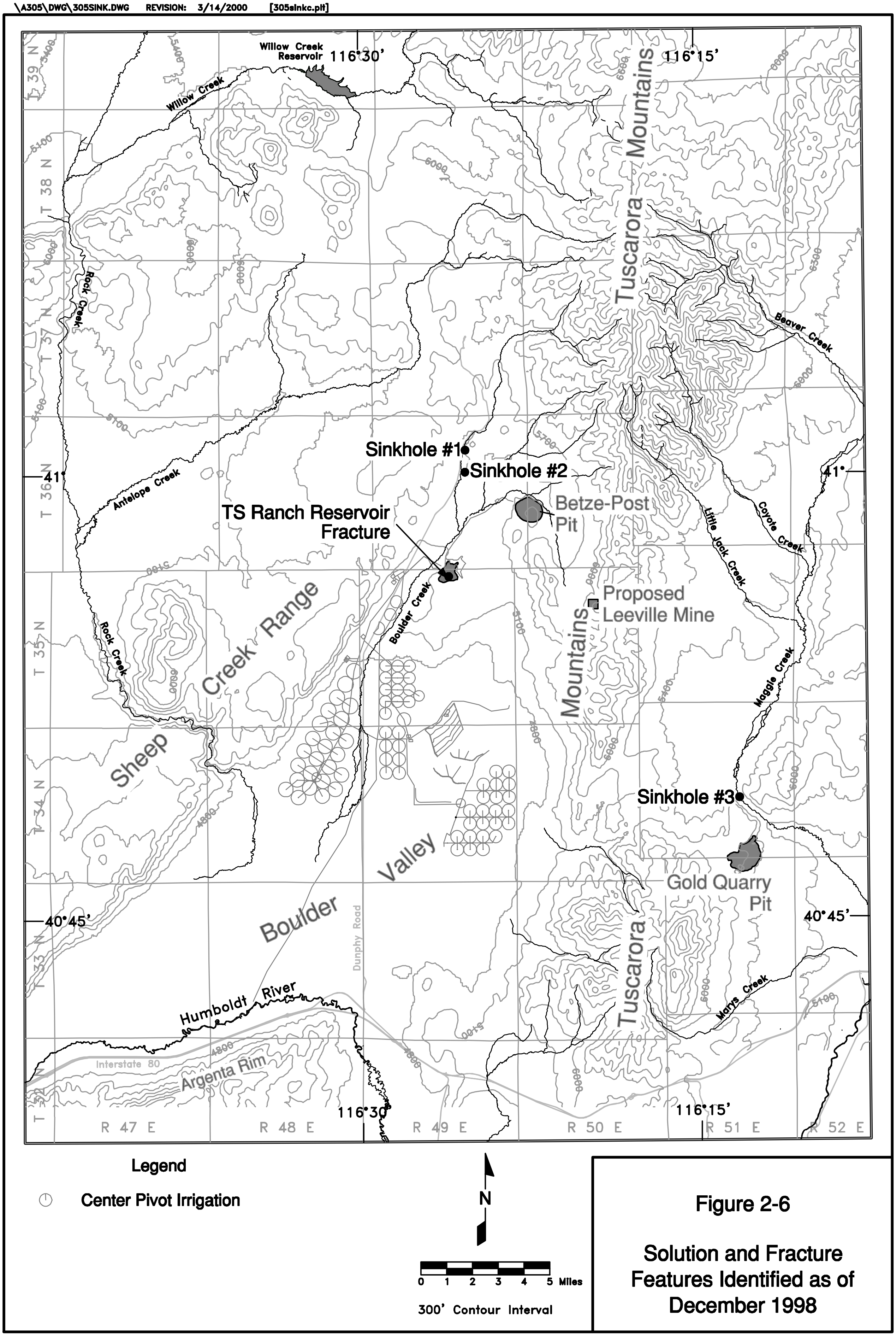

Figure 2-6

Solution and Fracture Features Identified as of December 1998

1998b). Dewatering of the Gold Quarry Mine had lowered the water table 350 feet in the pit area as of October 1996; before dewatering operations began, the water table near Maggie Creek was at creek level (BLM 1996a). A seismic refraction survey by Zonge Geosciences, Inc. (1997) was conducted in the Maggie Creek canyon area during the end of 1996 to determine the depth to bedrock. Through the main part of the canyon, the depth to bedrock was interpreted to be approximately 10 to 40 feet beneath the survey line. South of the canyon area, material that is thought to be poorly consolidated, water-saturated basin fill material (alluvium and/or Carlin Formation) exists at depths of 10 to 20 feet. A minimum depth of 100 feet is estimated to material that represents consolidated bedrock. North of the canyon, material interpreted to be water-saturated alluvium occurs at relatively shallow depths (Zonge Geosciences, Inc. 1997). Although development of the sinkhole is likely related to mine-induced drawdown, the mechanism for development of this sinkhole is not completely understood.

The mechanism for development of the surface features to date is not completely understood; however, the linear geometry of sinkhole 3 indicates it may be structurally controlled along a fracture or fault zone in the bedrock. The void in the carbonate rock could have existed prior to dewatering, and one possible explanation is that this sinkhole was formed when mine-induced drawdown caused piping of the alluvial material into solution voids in the underlying bedrock.

2.2.3 TS Ranch Reservoir Fracture

An open fracture was discovered in the bottom of the south-central portion of TS Ranch Reservoir in the summer of 1990. This fracture can be traced on the surface for several hundred feet south of the reservoir. The fracture occurs in Tertiary Rhyolite and is open, with the width of the void space along the fracture ranging up to several inches. This fracture presumably existed prior to reservoir development; however, piping and/or dissolution of the fracture-filling material occurred after the reservoir was used to store water. Initially, a fraction of the water stored in the reservoir flowed out of the reservoir through the fracture. In the last several years, a series of dikes have been constructed in the reservoir to isolate and control flow out of the reservoir through the fracture.

2.2.4 Areas Susceptible to Future Sinkhole Development

Predicting sinkhole development from mining activities requires consideration of site-specific geology, hydrology, topographic information, and climate. Sinkhole development is most likely in areas where carbonate rocks are at or sufficiently near the ground surface. These conditions would allow for the collapse of subsurface cavities, or piping (washing out of granular material) of the overlying soils into those cavities. Either of these processes would result in enough displacement of the cover materials to impact the surface topography. If the cavities occur within deep carbonate deposits overlain by thick consolidated material, a collapse would be unlikely to impact the surface topography.

To delineate areas that could potentially be susceptible to future sinkhole development, the following were considered:

1. Areas where mine dewatering and water management activities are predicted to result in either lowering the water table and/or increasing the amount of infiltration (in areas where excess water is discharged)

2. Areas where soluble carbonate rock units exist at, or near, the ground surface

3. The depth to the carbonate rock below the ground surface

Several scenarios of soil cover, and carbonate rock depth, and approaches were evaluated in an attempt to develop criteria for use in identifying areas that could potentially be susceptible to sinkhole (or doline) development. For the purpose of this evaluation, it was assumed that the dimensions of the largest cavity that could potentially be encountered in the subsurface was 150 feet in width and about 50 feet high (based on observations in the Meikle Mine). These dimensions were used to predict the maximum thickness of the overburden material (soil or rock) required to completely contain any stoping or dome fallouts that could occur without breaking through to the ground surface.

The first approach assumed a scenario where a karst cavity is overlain by weakly cemented sand. Assuming a maximum cavity diameter, thickness of weakly cemented overburden, cohesion shear strength for the cemented sand, and unit weight, Abdulla and Goodings (1996) developed a design chart for relating dimensionless geometrical and stability parameters. Using the relationships developed by Abdulla and Goodings for a weakly cemented sand over a karst cavity, the sand is predicted to develop a stable arch spanning the void at thicknesses greater than approximately 50 feet.

The second approach used methods developed to predict maximum stoping height above collapsed mines. Dunrud (1987) determined the maximum stoping height for a cylinder and rectangle prism, ellipsoid, wedge, and cone. Applying the method developed to predict stoping height and assuming the collapse of a 50-foot high cavern with the collapse feature having a cylinder or rectangular prism shape (most common according to Dunrud 1987), the maximum theoretical stoping height is approximately 250 feet. In other words, based on this method, a collapse of a 50-foot cavern could result in collapse of the fractured bedrock overlying the cavity for a distance of 250 feet. The results of this evaluation are very conservative since they do not take into account the arching potential and strength of the overlying materials.

The third approach was a study of frequency of sinkhole occurrence in Florida (Beggs and Ruth 1984). This study of over 500 sinkholes recognized that the frequency of sinkhole occurrence diminished substantially when the depth to carbonate exceeded about 30 meters (approximately 100 feet), and/or the water depth was greater than about 90 meters (300 feet).

These approaches were used to establish general criteria for defining areas that could be susceptible to sinkhole development under changing ground-water conditions (increased infiltration and/or lowering of the water table). In summary, areas where the carbonate rocks are located either at the ground surface, or at depths of less than 250 feet and covered by unconsolidated (e.g., alluvial or colluvial) materials are susceptible to sinkhole development. Areas where the carbonate rock is overlain by consolidated, insoluble layers less than about 50 feet thick are also considered susceptible to sinkhole development. Conversely, areas where carbonate rocks are overlain by more than about 50 feet of consolidated, insoluble rock materials, and/or are deeper than about 250 feet below the ground surface are considered to have low risk of sinkhole development.

The criteria described previously, were combined with available information on the geology in the region (including location of carbonate outcrop areas, and materials above the carbonate rocks), and prediction of ground water drawdown (presented in Section 3.2) to develop a map illustrating areas that could potentially be susceptible to sinkhole development. The areas where carbonate rocks are located at or near surface, and assumptions of overburden materials (alluvium or insoluble bedrock) were based on available regional geologic information (Maurer et al. 1996; Newmont 1998). The general depth to the carbonate rocks was based on available well completion logs for monitoring wells completed by Barrick and Newmont. As illustrated in Figure 2-7, areas potentially susceptible to sinkhole development include the large area underlain by carbonate rock located between the Betze-Post Pit and Gold Quarry Pit, the area northwest of the Betze-Post Pit, the Maggie Creek area located north of the Gold Quarry Pit, and an area located west of the Gold Quarry Pit.

The results of this evaluation delineate several areas that could potentially be susceptible to sinkhole development. These areas contain few buildings, major roads, or other infrastructure. Critical mine-related facilities such as waste rock storage facilities, heap leach pads, and mill and tailings facilities are not located within these areas. A segment of a power line associated with the Carlin Mine occurs within an area that could be susceptible to karst development. Other non-mine-related features of note located within these areas include a 1-mile segment of Boulder Creek, a 1-mile segment of Sheep Creek, a 2.5-mile segment of Maggie Creek, several springs and intermittent streams, a corral, and several unpaved dirt roads.

It is important to note that information on the depth to carbonate rock and thickness of cover materials is based on limited subsurface information. The site specific risk of sinkhole development will depend, in part, on site conditions including depth to carbonate rocks, mineralogical and hydrological characteristics of the carbonate rock, size of new or pre-existing voids in the carbonate rock, properties of the overlying materials, and hydrologic changes induced by the cumulative mine dewatering and water management activities.

2.3 Impacts to the Humboldt River

Because the Humboldt River is separate from any identified geologic features that would be potentially affected by mining operations, no cumulative impacts to geologic or mineral resources are anticipated to the Humboldt River as a result of water management activities. Potential impacts to the river from mining and water management activities, such as stream erosion, sedimentation, and channel geometry are addressed in Section 3.3.

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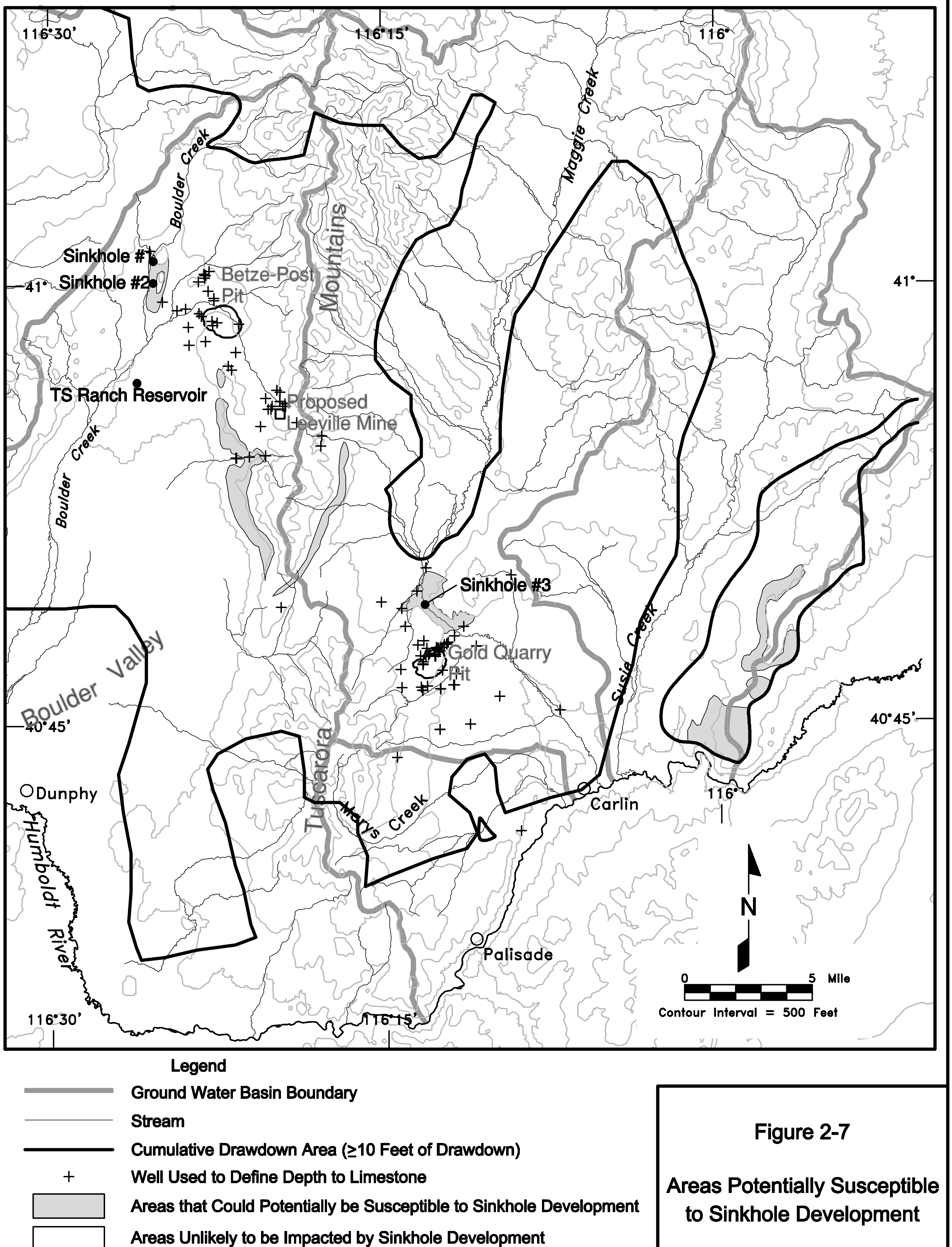

Figure 2-7

Areas Potentially Susceptible to Sinkhole Development