FINAL
HYDROGEOLOGIC EVALUATION OF THE DENISON MINES (USA) CORP. LA SAL MINES COMPLEX, SAN JUAN COUNTY, UTAH

Prepared for:

DENISON MINES (USA) CORP.

Prepared by:

CDM Inc.
555 17th Street, Suite 1100
Denver, CO 80202

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Acronyms

amsl	above mean sea level
BLM	U.S. Bureau of Land Management
CaSO4 + 2 H2O	gypsum
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cm/sec	centimeter per second
Denison	Denison Mines (USA) Corporation
ft	feet
in.	inches
KCl	Sylvite
NaCl	Halite
NOI	notice of intent
mg/L	milligrams per liter
MSHA	Federal Mine Safety and Health Administration
NEPA	National Environmental Policy Act of 1969
SPCC	spill, prevention, control, and countermeasures plan
SU	standard units
UAC	Utah Administrative Code
UC	Utah Code
UDOGM	Utah Division of Oil, Gas and Mining
UDWR	Utah Division of Water Rights
USFS	United States Forest Service
°C	degrees Celsius

Section 1
Introduction

1.1 Purpose of Report

This hydrogeologic evaluation report was prepared for Denison Mines (USA) Corp. (Denison) to provide information regarding hydrogeologic conditions at the La Sal Mines Complex located in San Juan County, Utah. This information is necessary to support on-going mine environmental management practices and future permitting activities. Denison is committed to protection of the environment and compliance with applicable environmental laws and regulations. Information regarding the hydrogeologic framework and potential effects of mining activities on groundwater resources is valuable to support on-going protection of the environment. The La Sal Mines Complex is an operating and fully permitted facility, but future permitting activities are anticipated to provide for modifications of existing mine facilities.

Future permitting activities will include modifications to both state and federal permits. The state permits are administered by the Utah Division of Oil Gas and Mining (UDOGM) in accordance with the Utah Mined Land Reclamation Act; Utah Code (UC), Title 40, Chapter 8. The federal permits are administered by the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) in accordance with federal regulations at 43 Code of Regulation (CFR) 3809 and 36 CFR 228 Subpart A, the National Environmental Policy Act of 1969 (NEPA), and other regulatory requirements. Aspects of the regulatory framework that are pertinent to groundwater resources in the La Sal Mines Complex area are discussed in Section 1.3 to provide information on the types of hydrogeologic information and analyses that are necessary to support future permitting activities.

The following investigation activities were completed during development of this report:

- Review of the regulatory framework related to groundwater;
- Reconnaissance of underground mine workings to identify potential groundwater within tunnels and stopes;
- Compilation of available information regarding the geologic and hydrogeologic framework; and
- Evaluation of potential for underground mining operations that affect groundwater within the context of applicable regulatory requirements.

Findings from these activities are summarized within this report.

1.2 Location of Mine Facilities

The La Sal Mines Complex is an underground uranium and vanadium mining complex located in southeast Utah approximately 20 miles west of the Colorado border. The mine complex is located near the town of La Sal, in San Juan County, Utah. The mine complex produces uranium and vanadium ore from mineral deposits of the Uravan District, which is one of the major uranium-producing mineral districts in the United States. The ore is transported to a mill located near Blanding, Utah for mineral processing. Mines in this area have been active on an intermittent basis since the early 1970's (Seth McCourt, Denison Mine Engineer, email communication September 23, 2009). The La Sal Mines Complex includes:

- The La Sal Mine;
- The Pandora Mine;
- The Beaver Shaft Mine; and
- The Snowball Mine.

The location of the La Sal Mines Complex is shown on Figure 1-1.

Surface facilities include equipment maintenance facilities, portal infrastructure, administrative offices, fuel storage areas, employee parking area and development rock stockpiles. No mineral processing is conducted at the La Sal Mines Complex and all ore is hauled to Denison's mill near Blanding, Utah for mineral processing. Therefore, no mineral processing chemicals are used or stored at the La Sal Mines Complex. General supplies to support mechanized mining operations are present including fuel and lubricants. Detailed information regarding the location of surface facilities at each mine location is presented in Figures 1-2 through 1-5.

Underground mine workings extend northward from the surface facilities and lie at an approximate depth of 250 to 600 feet (ft) beneath the surface. Underground mining is conducted by room and pillar methods, and underground workings consist of a series of tunnels and mine stopes with intervening pillars of rock to provide stability. Vent shafts are also associated with the underground workings. These structures are vertical shafts of approximately six ft diameter that extend from the underground tunnels to the surface. The purpose of these structures is to facilitate ventilation of the underground workings. All openings into the underground mine are secured to provide for public safety in accordance with federal Mine Safety and Health Administration (MSHA) requirements. The location of underground workings is also shown on Figure 1-1.

1.3 Regulatory Background

The La Sal Mines Complex has been in operation since the 1950's, with intervening periods of decreased or increased mining activity in relation to economic conditions. The mine complex is located on privately-owned land as well as land administered by the State of Utah, BLM, and the USFS with mine surface features located as follows:

- The La Sal Mine –BLM land;
- The Pandora Mine - BLM land, although the underground mine workings extend under USFS land and several vent shafts are located on USFS land;
- The Beaver Shaft Mine – State of Utah, BLM, and privately-owned land with underground mine workings extending under each land type; and
- The Snowball Mine – BLM land, although the underground mine workings extend under USFS land.

The following sections describe state and BLM permitting requirements that relate to groundwater including state requirements and federal requirements.

1.3.1 State Regulatory Requirements

Mining operations on State of Utah, BLM and USFS lands are subject to state permitting requirements. In addition, depending on the land status, BLM or USFS permits are also required. The state permit is called a Notice of Intention (NOI) and applicable regulations are set forth in Utah Administrative Code (UAC) Title R647. R647-004 contains requirements for a Notice of Intention for large scale mining operations, which are applicable to the La Sal Mines Complex. This regulation includes the following requirements relevant to groundwater:

> <u>*Maps, Drawings and Photographs…*</u>
> *1.12. (Identify) … boreholes, or other existing surface or subsurface facilities within 500 feet of the proposed mining operations;*
>
> *3.16. (Provide) baseline information maps and drawings including …geologic formations and structure… and other such maps which may be required for determination of existing conditions, operations, reclamation and postmining land use;(UAC R647-4-105)*
>
> <u>*Operation Plan*</u>*…*
> *The operator shall provide a narrative description referencing maps or drawings as necessary, of the proposed operations including:….8. Depth to groundwater….(UAC R647-4-106)*
>
> <u>*Impact Assessment*</u>*…*
> *The operator shall provide a general narrative description identifying potential surface and/or subsurface impacts. This description will include, at a minimum: 1. Projected impacts to surface and groundwater systems….(UAC R674-004-109(1))*

The State of Utah also regulates groundwater quality through the Utah Department of Environmental Quality (UDEQ) as set forth by regulations at R317-6. These regulations set groundwater quality standards, define Utah groundwater classes, establish groundwater protection levels, and set forth permit requirements for facilities that discharge pollutants to groundwater.

Groundwater quality standards are set forth in R317-6-2. This regulation sets forth standards for numerous pollutants that could be present in groundwater. Groundwater classes and groundwater class protection levels are set forth in R317-6-3 and R317-6-4. These regulations define how the groundwater quality standards are applied to various classes of groundwater in the state of Utah.

Regulation of facilities which discharge pollutants to groundwater is set forth in R317-6-6. Facilities that *discharge or would probably result in a discharge of pollutants that may move directly or indirectly into ground water* are required to apply for a groundwater discharge permit with the Utah Department of Environmental Quality. This regulation applies to numerous industries and actions including mining, milling and metallurgical facilities that discharge pollutants to groundwater.

Rule R317-6-6 also sets forth facilities that are *permitted by rule*, which do not require groundwater discharge permits. The facilities include several classes that are pertinent to activities conducted at the La Sal Mines complex, including drilling operations for metallic minerals when done in conformance with the UDOGM regulations.

1.3.2 Federal Regulatory Requirements

The BLM permitting requirements are set forth in 43 CFR 3809, which includes the following requirements pertinent to groundwater:

> *Where do I file my plan of operations and what information must I include with it?...*
> *(B)(4) Monitoring Plan. A proposed plan for monitoring the effect of your operations. You must design monitoring plans to meet the following objectives: To demonstrate compliance with the approved plan of operations and other Federal or State environmental laws and regulations, to provide early detection of potential problems, and to supply information that will assist in directing corrective actions should they become necessary… Examples of monitoring programs which may be necessary include surface- and ground-water quality and quantity, air quality, revegetation, stability, noise levels, and wildlife mortality*
>
> *(c) In addition to the requirements of paragraph (b) of this section, BLM may require you to supply…(1) Operational and baseline environmental information for BLM to analyze potential environmental impacts as required by the National Environmental Policy Act and to determine if your plan of operations will prevent unnecessary or undue degradation. This could include information on public and non-public lands needed to characterize ….geology, … hydrology in and around the project area… (43 CFR § 3809.401)*

The Forest Service permitting requirements are set forth in 36 CFR 228 Subpart A, which includes the following requirements pertinent to groundwater:

> *Plan of operations – notice of intent – requirements…*
> *(f) Upon completion of an environmental analysis in connection with each proposed operating plan, the authorized officer will determine whether an environmental statement is required. Not every plan of operations, supplemental plan or modification will involve the preparation of an environmental statement. Environmental impacts will vary substantially depending on whether the nature of operations is prospecting, exploration, development, or processing, and on the scope of operations (such as size of operations, construction required, length of operations and equipment required), resulting in varying degrees of disturbance to vegetative resources, soil, water, air, or wildlife. The Forest Service will prepare any environmental statements that may be required. (36 CFR 228.4)*
>
> *Requirements for environmental protection…*
> *(b) Water Quality. Operator shall comply with applicable Federal and State water quality standards, including regulations issued pursuant to the Federal Water Pollution Control Act, as amended (33 U.S.C. 1151 et seq.). [36 CFR 228.8(b)]*

Both the BLM and Forest service regulations require baseline information to support environmental analyses in accordance with NEPA. A detailed discussion of the NEPA process is beyond the scope of this document, but it is possible that issues related to groundwater may be considered in future NEPA analyses. Therefore, it is useful to evaluate the groundwater-related information that may be required for future NEPA analyses. The initial phases of NEPA analyses include:

1. Project Scoping; and
2. Evaluation of Significant Issues

During the scoping process, potential issues related to a proposed project are identified. These issues are then evaluated and significant issues are identified for detailed analysis in accordance with Council of Environmental Quality (CEQ) guidance for implementation of NEPA found at 40 CFR 1502.1.

It is difficult to foresee all potential issues that may be raised at some time in the future with regard to NEPA analyses. However, it is useful to consider potential groundwater-related issues to provide for evaluation of these issues in this investigation. Potential significant issues for future NEPA analyses include:

- The potential for mining at the La Sal Mines Complex to affect the supply of groundwater resources
- The potential for mining at the La Sal Mines Complex to affect the quality of groundwater resources

NEPA analyses require consideration of direct, indirect and cumulative effects. Cumulative effects include the effects of current actions (for example, approving a modification to the existing Plans of Operations) combined with the effects of past and reasonably foreseeable future actions. Therefore, NEPA analyses of future modifications to the Plans of Operations will likely require analysis of the existing operations as well. This hydrogeologic evaluation report provides information to assist in addressing these potential issues and consideration of direct, indirect, and cumulative effects.

1.4 Organization of Report

This report is organized to meet the general purpose described in Section 1.1 and to provide the permit-related information described in Section 1.3. The report contains the following sections:

- Section 1: Introduction
- Section 2: Underground Mine Reconnaissance
- Section 3: Geologic Setting
- Section 4: Hydrogeologic Framework
- Section 5: Potential Effects of Underground Mining

Section 2 Underground Mine Reconnaissance

On July 21, 2009, Mr. Mark Nelson (CDM Hydrogeologist) and Mr. Jon Showalter, (Denison Mine Geologist), conducted a site reconnaissance at the Pandora and Beaver Shaft mines. The purpose of this reconnaissance was to observe accessible underground mine workings to identify any evidence of groundwater, if present.

Exhibit 2-1. Pandora Mine Portal (Entrance into the Underground Mine).

The La Sal Mine Complex consists of the Pandora, Snowball, La Sal, and Beaver Shaft mines. Each of these mines has separate surface disturbance areas, although underground workings of the four mines are interconnected. The underground workings all access uranium-vanadium mineralization within a stratigraphic interval of the Morrison Formation referred to as the Top rim sandstone unit.

2.1 Pandora Mine

Exhibit 2-2. Haulage Tunnel within Pandora Mine.

The underground mine workings were accessed via the Pandora Portal (Exhibit 2-1), which is located at an elevation of approximately 6922 ft. The reconnaissance included the Pandora decline, numerous underground tunnels, and active and inactive mining stopes. The base of the Pandora decline is reported to be at an elevation of 6736 ft, indicating that the base of the decline is approximately 186 vertical ft below the surface portal. The decline extends into the hill for a distance of approximately 1500 ft where it intersects the mine workings of the Pandora mine. Active mining is currently being conducted at an elevation of approximately 6920 ft. As shown previously on

Figure 1-1, the Pandora decline is driven into a hill, and therefore the depth to the active mining areas ranges from approximately 300 to 600 ft.

The reconnaissance extended from the surface to the deepest parts of the mine. The primary purpose of the reconnaissance was to inspect the underground mine for indications of groundwater. No indications of groundwater were observed during the reconnaissance. Exhibit 2-2 shows the Pandora portal, and exhibits 2-3 and 2-4 are photographs taken underground that display the dry conditions within the underground mine.

The mine is excavated in the Top rim Sandstone, a rock within the Salt Wash member of the Morrison Formation, a light gray to beige medium grained sandstone. This rock unit was inspected for indications of water seepage into the underground workings. Both active and inactive mining areas were inspected during the reconnaissance.

Exhibit 2-3. Inactive Mining Area within Pandora Mine showing area of Rock Backfill

Inactive stopes were inspected for the potential presence of pooled mine water to identify any areas where water may have been slowly accumulating. No water was observed in the inactive mine workings. Active workings were also inspected. Water is currently pumped into the active areas of the mine from the surface to provide water for use in drilling operations and dust control. The current source of the water used at the Pandora Mine is a well located at the Redd Ranch, which is hauled to the mine. Areas of significant ponded water related to water use in the mine were not present, and it is thought that this water evaporates and is exhausted in the mine ventilation system. Discharge of water as vapor in the mine ventilation system is a major component of underground mine water balances (Younger et al. 2002).

Exhibit 2-4. Inactive Mining Area within Pandora Mine.

Based on observations collected during the mine reconnaissance, the mine appears to be located within the unsaturated zone. However groundwater may be present either at depth within the Salt Wash Member of the Morrison Formation or potentially in overlying perched zones.

2.2 Beaver Shaft Mine

The Beaver Shaft Mine was entered via the Beaver Shaft and reconnaissance of accessible underground tunnels and stopes was conducted in a similar manner to the Pandora Mine. The collar of the Beaver Shaft is located at an elevation of approximately 7014 ft, and the shaft access underground mine workings that extend from an elevation of approximately 6750 ft to 6350 ft. Therefore these workings range from approximately 400 to 600 ft below the surface.

Water was observed within the Beaver Shaft Mine at three locations during the reconnaissance. These locations consisted of a collapsed borehole called the 1280 borehole, the 1350 borehole, and an area of ponded water at the 6354 level. Water was flowing into the mine via the 1350 borehole and the collapsed 1280 borehole. Based on discussions with Randy Marsing, Beaver Shaft Mine Forman, this water reportedly flows through underground workings to a stope at the 6354 level, where it is collected and used in underground mining operations (CDM 2009a).

Access into the area of the collapsed 1280 bore hole was not possible because of safety hazards, but the general area of the borehole was observed. The 1280 borehole extended upward from the underground mine to the surface. Water was reported to be flowing into the underground mine working via the collapsed 1280 borehole at a rate of approximately 4 gallons per hour.

Access to the base of the 1350 bore hole was also not possible because of safety concerns, but an area of water collection was observed. This area consisted of an approximately 8 ft diameter galvanized metal tank which collects water diverted from the base of the bore hole. This water at this location exhibited a pH of 8.45 standard units (SU), temperature of 9.9 degrees Celsius (°C), and total dissolved solids concentration of 300 milligrams per liter (mg/L).

Water collection and pumping infrastructure is present in an area at the 6354 level of the mine. This water reportedly originates in the seepage areas of the 1280 and 1350 boreholes and flows though underground workings to the 6354 level where it is collected. This water is currently used for drilling and dust control purposes within the Beaver Shaft Mine, and a pipeline is reportedly being constructed to convey this water towards the Pandora Mine to support mining operations in that portion of the underground mine.

In September, 2009, after completion of this field reconnaissance, it was reported that inflow to the mine from the 1350 borehole and the collapsed 1280 borehole ceased, suggesting that this source of water is seasonal (Seth McCourt, Denison Mine Engineer, email communication September 23, 2009). Currently, water is being hauled to the Beaver Shaft mine from the Redd Ranch to support drilling and dust control activities within the mine.

Field measurements of water quality were collected at the collection facility on the 6354 level during the July 21, 2009 reconnaissance Water at this location exhibited a pH of 8.04 SU, temperature of 11.5 °C, and total dissolved solids concentration of 400 mg/L. The neutral to slightly alkaline pH of the water and the relatively low total dissolved solids concentration of the water suggests that the water is of relatively good quality. The pH of the water suggests that acid generation is not occurring within the underground workings.

Exhibit 2-5. Tunnel in Beaver Shaft Mine.

No seepage of groundwater was observed from the walls and ceiling of the underground mine tunnels within the Beaver Shaft Mine. This suggests that the Top rim sandstone unit within the mining area is unsaturated. The presence of seepage entering the mine though the 1280 and 1350 boreholes suggests that a perched saturated zone of water is present at a stratigraphic level above the Top rim sandstone. Anecdotal information provided by Denison employees that worked in the mine during it's early development also notes that this water originates hundreds of feet above the Salt Wash Member.

Underground reconnaissance was not conducted at the La Sal and Snowball mines during the July 23, 2009 investigation.

Section 3 Geologic Setting

This section describes phisiography, regional stratigraphy, and structural geology of the La Sal Mines Complex area.

3.1 Physiography

The La Sal Mines Complex is located in the Canyonlands Section of the Colorado Plateau, on the south side of the La Sal Mountains. The mines are located at an elevation of approximately 7000 feet above mean sea level (ft. amsl). Topography consists of a series of generally south trending valleys on the south flank of the La Sal Mountains.

The La Sal Mountains range in elevation from 11,000 to 13,000 ft. amsl. The La Sal mountains consist of three major peaks ranging 11,000 to 13,000 ft elevation surrounded by mesas and canyons typical of the Canyonlands section of the Colorado Plateau (Hunt 1958). The La Sal mountains receive much higher precipitation than the arid areas surrounding the mountains, and exhibit markedly different vegetation including alpine tundra at the highest elevations; aspen, spruce and fir in moderate elevations, and piñon-juniper at the base of the mountains.

The mine complex is located in a semi-arid environment, with sparse vegetation such as juniper, piñon pine, cacti, and sage brush. The Pandora and Snowball mines are located near the lower elevation extent of piñon-juniper forest at approximately 7000 ft elevation. Vegetation in the areas of the La Sal and Beaver Shaft mines is characterized by sage brush and cactus. The contrast in vegetation between the La Sal Mountains to the north and the La Sal Mines Complex to the south area exhibits the marked orographic effects on climate in the area with significantly more precipitation occurring in the La Sal mountains than in the area of the La Sal Mines Complex.

The La Sal Mines Complex is near the watershed boundary between the Dolores River to the east and the Colorado River to the west. The Pandora and Snowball mine are located within the Dolores River watershed, and the La Sal and Beaver Shaft mine are located in the Colorado River watershed. Perennial surface water is not present in the area of the La Sal Mines Complex, and surface water is generally only present during short-term snow melt or precipitation events.

The La Sal Mines Complex is located near the town of La Sal, which is a small community of approximately 300 people. Industry in the La Sal area includes agriculture and mining.

3.2 Regional Stratigraphy

The regional stratigraphy is an important facet that controls hydrogeologic characteristics of rock units in the La Sal Mines Complex area. The mine is located in an area of gently dipping sedimentary rocks, which include interbedded clastic and chemical sedimentary rocks. Clastic sedimentary rocks include shale, siltstone, sandstone and conglomerate. Chemical sedimentary rocks include limestone and evaporites such as halite and sylvite. Accumulations of unconsolidated quaternary sediments are present in the valley bottoms near the La Sal Mines Complex and in a large area south and west of the mines. Figure 3-1 shows the surface geology in the area of the La Sal Mines Complex based on geologic data provided by the Utah Geological Survey (Doelling 2004).

The mine is located on the south limb of the Pine Ridge anticline, and the rock units strike generally west-northwest and dip gently towards the south-southwest at approximately 3 to 5 degrees. Additional information regarding the structural geology of the area is provided below in Section 3.3.

This section describes the rock units extending from Pennsylvanian Hermosa Formation, which is located deep under the mine, to the Cretaceous Dakota Sandstone, which crops out on ridge tops near the mine complex area. The Paradox Member of the Hermosa Formation contains rock salt, which forms an impermeable barrier to groundwater flow and divides a deep Paleozoic aquifer from the overlying Mesozoic and Cenozoic aquifers (Weir et al. 1983). The rock salt is composed of 70 to 80 percent halite (NaCl) , potash salts such as sylvite (KCl), and gypsum (CaSO4 + 2 H2O) (Weir et al 1983, Cater 1955). Therefore, the Paradox Member of the Hermosa Formation provides a suitable base level for this investigation. The Pardox Member is also important in controlling the regional structural geology of the area. Information regarding the stratigraphy beneath the Pennsylvania Hermosa Formation is provided in Weir et al. (1983), Carter and Gualtierri (1965) and Doelling (2004).

A thick sequence of clastic sedimentary rocks containing various portions of sandstone, siltstone, shale, conglomerate and local limestone overlies the Hermosa Formation. These rock units range in age from Triassic to Cretaceous. This sequence of clastic sedimentary rocks is important both with regard to the hydrogeologic framework of the area and the occurrence of uranium-vanadium mineralization. This sequence includes the following formations:

- Permian Cutler Formation;
- Upper Triassic Chinle Formation;
- Jurassic Glen Canyon Group;
- Mid to Upper Jurassic San Rafael Group;
- Upper Jurassic Morrison Formation;
- Lower Cretaceous Burro Canyon Formation;
- Cretaceous Dakota Sandstone; and

- Unconsolidated Quaternary deposits.

The Permian Cutler Formation directly overlies the Hermosa Formation, and consists predominantly of arkosic sandstone and conglomerate. Small quantities of sandy shale are present within the formation. The thickness of this formations ranges widely within the La Sal Quadrangle ranging from 390 to 2,687 ft.

The Moenkopi Formation is overlain by the Upper Triassic *Chinle Formation*. This unit consists primarily of siltstone interbedded with fine grained sandstone, shale and conglomerate. The individual lithological units within the formation are lenticular and discontinuous. This unit is up to 600 ft. thick, but the thickness varies within the La Sal quadrangle (Carter and Gualtaieri 1965).

The Chinle Formation is overlain by the Jurassic *Glen Canyon Group*, which consists of three formations: the Wingate Sandstone, the Kayenta Formation, and the Navajo Sandstone. The *Wingate Sandstone* overlies the Chinle Formation. This formation consists of massive, fine grained sandstone composed of clean well-sorted quartz sand grains. The thickness of the Wingate Sandstone varies from 150 to 280 ft in the La Sal Quadrangle.

The *Kayenta Formation* overlies the Wingate Sandstone and consists of interbedded sandstone, siltstone and shale. The sandstone is thin bedded, flaggy to massive, and occurs in discontinuous beds that interfinger with siltstone and shale. The thickness of the Kayenta Formation is approximately 160 ft.

The *Navajo Sandstone* is massive fine-grained clean quartz sandstone, which overlies the Kayenta Formation. This unit is eolian in origin as evidenced by very large tangential cross-bedding. The formation ranges in thickness from 0 to 240 ft in the La Sal Quadrangle.

The Glenn Canyon Group is overlain by the Jurassic *San Rafael Group*, which includes the Entrada Sandstone and the Summerville Formation. The *Entrada Sandstone* consists of a combination of horizontally bedded and eolian, cross bedded sandstones with a bimodal grain size distribution including very fine grained sandstone (<0.0001 inches (in.) grain size) and medium grained sandstone (0.02 to 0.03 in. grain size). The Entrada Sandstone is subdivided to include the Dewey Bridge Member, the Slick Rock Member and the Moab Sandstone Member. The S*ummerville Formation* overlies the Entrada Sandstone, and consists primarily of sandy and silty shale. This unit also includes local sandstone and limestone layers. The unit is approximately 60 to 140 ft thick.

The Upper Jurassic *Morrison Formation* overlies the Summerville Formation. This formation is important because it hosts the uranium-vanadium mineralization and the undergound mine workings of the Las Sal Mine Complex. The Morrison Formation includes two Members: the Salt Wash Member and the Brushy Basin Member. The lowermost Member is the Salt Wash Member, which consist of sandstone with interbedded red shale and a few local beds of limestone. This unit ranges in thickness from 0 to 105 ft thick in the La Sal Quadrangle. The Top rim Sandstone Unit is a sub-unit within the Salt Wash Member, which contains the uranium-vanadium mineralization and the underground workings at the La Sal Complex.

The Salt Wash Member is overlain by shale of the Brushy Basin Member. The thickness of the Brushy Basin Member ranges from 200 to 400 ft, and is composed of variegated siltstone, shale and conglomerate. The Brushy Basin Member crops out in the area of the Pandora Mine portal and surface facilities. The Lower Cretaceous *Burro Canyon Formation* overlies the Morrison Formation. This formation is heterogeneous and includes conglomerate, sandstone, shale and thin lenses of limestone. The base of the Burro Canyon Member is composed of a massive coarse grained sandstone up to 110 ft. thick. Total thickness of the formation is estimated to be 260 ft. The Burro Canyon Formation crops out in the valley walls surrounding the surface facilities of the Pandora Mine.

The Cretaceous *Dakota Sandstone* is a flaggy sandstone unit, which overlies the Burro Canyon Formation. This formation also includes less abundant conglomerate, carbonaceous shale, and local impure coal. The sandstone ranges from fine grained and thin-bedded to coarse grained and cross-bedded. The Dakota Sandstone is approximately 200 ft. thick (Carter and Gualtaieri 1965; Cater 1955).

Unconsolidated Quaternary deposits are also present including alluvial deposits, eolian deposits, and landslide deposits. These units commonly form a thin veneer of unconsolidated sediments in areas where they are present. Alluvial sediments are present in the valley extending southward from the Pandora Mine surface facilities, and a large area of Quaternary sediments are present in an area extending south and west of the mine.

Figure 3-2 is a geologic cross-section that shows the regional stratigraphy as well as the stratigraphic interval that is mined at the La Sal Mines complex. As shown on the cross-section, mining takes place in the upper part of the Salt Wash Member of the Morrison Formation. This mining unit is overlain by approximately 300 to 400 feet of bentonitic shale of the Brushy Basin Member of the Morrison Formation, which separates the Burro Canyon Formation and near-surface alluvial rock units from the Salt Wash member. Figure 3-2 also shows hydrogeologic information, which is described in Section 4.

3.3 Structural Geology

Figure 3-3 shows the generalized structural geology of the area based on information provided by Hunt (1958). The La Sal Mines Complex lies in an area of northwesterly trending anticlines and synclines, which have been intruded by the igneous laccoliths that form the La Sal Mountains. The anticlines are cored by intrusive evaporites of the Paradox Member of the Hermosa Formation, and are the western extant of the series of evaporate-cored anticlines present in Paradox Valley, Gypsum Valley and

Disappointment Valley in Colorado. This structural fabric has been modified extensively by intrusion of igneous laccoliths in the La Sal Mountains, which caused doming of the sedimentary rocks around the margins of the mountains.

The La Sal Mines Complex lies on the southern limb of the Pine Ridge anticline, and rock units in the area dip gently towards the southwest. Broad undulations in the orientation of the sedimentary rock units in the mine area are present.

Section 4
Hydrogeologic Framework

4.1 Climate

The La Sal Mines Complex is located within a semi-arid environment. Climatic conditions in this area generally include moderate to cold winter night time temperatures with hot summer daytime temperatures, large daily temperature fluctuations typical of arid climates, and a large excess of evaporation over precipitation.

Weir et al. (1983) investigated climatic fluctuations within the Dolores River Basin, and observed that precipitation is correlated with elevation, with highest precipitation amounts occurring within mountain areas such as the La Sal Mountains, and markedly lower precipitation occurring within the central lower-elevation basins.

Annual precipitation at the La Sal Mines Complex is estimated at 13.5 inches based on data from La Sal, Utah (National Climatic Data Center 2009), which is located ½ mile south of the Beaver Shaft. Average precipitation for a period of record extending from 1949 to 2009 is 13.53 in. Table 4-1 provides average monthly precipitation over the 60 year period of record.

Evaporation greatly exceeds precipitation at the La Sal Mines Complex area. The Utah Climate Center provides estimates of reference crop evapotranspiration based on temperature records and estimates of extraterrestrial radiation using the Hargreaves equation (CDM 2009b). The average daily and monthly reference crop evapotranspiration for a period of record extending from 1901 to 2009 is presented in Table 4-2, and Figure 4-1 compares the monthly average precipitation to reference crop evapotranspiration for the period of record. As shown on the figure reference crop evapotranspiration exceeds precipitation in the area by 6 to 7 times during the summer months.

4.2 Surface Water

The La Sal Mines Complex is located in the Dolores River and Colorado River watersheds. The mines straddle the watershed boundary between the Dolores and Colorado Rivers, with the Pandora and Snowball in the Dolores River Watershed and the La Sal and Beaver Shaft mines in the Colorado River Watershed. No perennial surface water is present in the direct vicinity of the La Sal Mines Complex, and drainages in the area are ephemeral (i.e. they flow seasonally or in response to intense precipitation events). The Dolores and Colorado Rivers are the nearest perennial surface water to the La Sal Mines Complex, but there is generally no direct surface water flow towards either river.

Surface water discharges from the La Sal Mines Complex are permitted under an Industrial Stormwater permit for construction activities as required by the Clean Water Act and associated state and federal water pollution control laws. A Stormwater Pollution Prevention Plan for the La Sal Mines Complex is in place at the mines, and stormwater pollution control facilities are in place and operating at the mines.

4.3 Hydrogeologic Units

The regional hydrogeology of the area encompassed by the La Sal Mines Complex has been described by US Geological Survey in *Regional Hydrology of the Dolores River Basin* (Weir et al 1983) and by Lowe (1996) in *Ground-Water Resources of San Juan County.* Both of these publications provide useful data to understand the hydrogeologic units in the area.

Weir et al. (1983) identifies two major hydrogeologic units: an upper unit and a lower unit. The lower unit is hosted by Precambrian and Paleozoic crystalline and metamorphic rocks. This unit is separated from the upper unit by the rock salt of the Paradox Member of the Hermosa Formation, which is essentially impervious to fluid flow. Groundwater within the lower unit is saline, and oil and gas deposits are locally present. The upper unit includes all rock stratigraphically above the Paradox Member, including the clastic sedimentary rocks present in the La Sal Mines Complex area.

This investigation considers only the upper hydrogeologic unit, because it is pertinent to potential groundwater uses in the area and to potential effects of mining on groundwater. The upper unit includes a series of predominantly sandstone aquifers, which are separated by confining units composed dominantly of shale. Weir et. al (1983) identified the following aquifers within the upper unit:

- Mesozoic sandstone aquifer:
- Tertiary to Upper Cretaceous aquifer; and
- Alluvial aquifers.

Lowe (1996) developed similar hydrogeologic units based on previous work in the area by Avery (1986) and Howells (1990). However, the Lowe (1996) hydrogeologic units use a different naming convention. Lowe (1996) subdivides the *Mesozoic sandstone aquifer* into the *N* and *M aquifers*, and refers to the *Tertiary to Upper Cretaceous aquifer* as the *D aquifer*. Table 4-3 provides a summary of the hydrogeologic characteristics of the rock units based on information provided by Hanna and Gandera (2000) and Weir et al (1983).

The Mesozoic sandstone aquifer includes the saturated portions of the Chinle Formation, Wingate Sandstone, the Navajo Sandstone, and the Salt Wash Member of the Morrison Formation. Each of these units is composed dominantly of sandstone. The aquifer is underlain by rock salt of the Paradox Member and is overlain by bentonitic shale of the Morrison Formation, which are both confining layers.

Several confining units and leaky confining units are present within the Mesozoic sandstone aquifer, which restrict vertical movement of water between individual sandstone aquifers. The Summerville shale is an internal confining unit within the aquifer that restricts movement of water between the Salt Wash aquifer and an underlying aquifer including the Chinle Formation, Wingate Sandstone and the Navajo Sandstone. In addition, the Carmel Formation and the Kayenta Formation contain interbedded shales which are likely leaky confining layers, which are less permeable than the adjacent sandstone layers but more permeable than confining layers such as rock salt and shale. So the Mesozoic aquifer is a layered aquifer with individual sandstone aquifers separated by confining and/or leaky confining units (Weir et al. 1983).

Lowe (1996) as subdivided the Mesozoic aquifer into the N aquifer and the M aquifer. The N aquifer includes the Wingate Sandstone, Kayenta Formation, Navajo Sandstone, Carmel Formation, and Entrada Sandstone. This is the portion of the Mesozic aquifer that lies underneath the confining layer formed by the Summerville Shale. The N aquifer is reported to be 750 to 1,250 ft thick when fully saturated.

The M aquifer occurs in saturated portions of the lower units of the Morrison Formation, which include the Bluff Sandstone, Salt Wash, Recapture, and Westwater Canyon Members. The Bluff Sandstone, Recapture and Westwater Canyon Members of the Morrison Formation are present in other areas of San Juan County, but these units are not present in the area of the La Sal Mines Complex. The underground mine workings of the La Sal Mines Complex are located in an unsaturated portion of the Saltwash Member of the Morrison Formation. Where saturated, this rock unit is a part of the M aquifer, and is approximately 150 ft thick in the vicinity of the La Sal Mines Complex. The Brushy Basin Member of the Morrison Formation is a bentonitic shale that forms a confining layer above the M aquifer. This confining layer restricts recharge to the M aquifer where it is present, and it may lead to confined conditions within the M aquifer in areas south and west of the La Sal Mines Complex.

The Tertiary to Upper Cretaceous aquifer is similar to the Mesozoic aquifer, but it occurs in sandstones that are higher in the stratigraphic sequence. This aquifer is bounded at the lower contact by bentonitic shale of the Brushy Basin Member of the Morrison Formation. The Tertiary to Upper Cretaceous aquifer contains a lower, dominantly sandstone aquifer hosted by the Burro Canyon Formation and the Dakota Sandstone, and an upper sandstone aquifer hosted by the Mesaverde Formation. The Mancos shale is a confining unit that separated the upper and lower sandstone aquifers. Lowe (1996) defines this aquifer as the D aquifer. It ranges from 150 to 400 ft thick in areas where it is fully saturated. However, in the direct vicinity of the La Sal Mines Complex, the areal distribution of the D aquifer is highly fragmented, and therefore recharge and discharge from these isolated islands of the D aquifer are local in extent. The D aquifer is a common target for water well drillers in San Juan County in areas where it is present, because it contains relatively good quality water and is shallow. The D aquifer is utilized for drinking water in areas south and west of the La Sal Mines Complex.

Alluvial aquifers are locally present in valley bottoms and other areas that contain significant accumulations of unconsolidated alluvial deposits. Extensive alluvial deposits classified as eolian and alluvial deposits by Doelling (2004). Based on a review of well drillers reports acquired from the Utah Division of Water Rights, unconsolidated aquifers within the eolian and alluvial deposits south and west of the La Sal complex are also used for water wells in the area. Additional information regarding groundwater use is provided in Section 4.6.

A cross-section showing the geologic and hydrogeologic units present in the area of the La Sal Mines complex was shown previously as Figure 3-2.

4.4 Recharge Areas

The primary recharge areas for aquifers that are present near the La Sal Mines Complex are the high altitude areas of the La Sal Mountains, which are located north of the mine. The laccolithic intrusions of the La Sal Mountains cause doming of the older sedimentary formations, and the hydrogeologic units described above crop out around the periphery of the La Sal Mountains. As described in Section 3.1, the La Sal Mountains receive more precipitation than the town of La Sal, because of the higher elevation. The abundant precipitation and the exposed outcrop area of the hydrogeologic units are the primary controls on recharge. Lowe (1996) reports that most of the recharge within San Juan County occurs at elevations in excess of 8,000 ft.

In the direct vicinity of the La Sal Mines Complex, recharge to the hydrogeologic units beneath the Brushy Basin Member of the Morrison Formation is restricted by the bentonitic shale confining layer of the Brushy Basin Member. Hydrogeologic units below the Brushy Basin member include the M and N aquifers of Lowe (1996) (i.e. the Mesozoic Sandstone aquifer defined by Weir et al. 1983). The underground mine workings of the La Sal Mines Complex are located in an unsaturated portion of the Saltwash Member of the Morrison Formation. Where saturated, this rock unit is a part of the M aquifer. Therefore, recharge into underlying aquifers that would flow through the underground workings is restricted by the Brushy Basin of the Morrison Formation in the area of the mines. Some recharge may occur though fault zones and fractures into the M and N aquifers. Several fault zones are shown on the geologic map, Figure 3-1. These faults are located approximately 1 to 2 miles north of the La Sal Mines Complex.

The Burro Canyon Formation and the Dakota Sandstone crop out in the vicinity of the La Sal Mines Complex. In areas were these units are saturated, they form the D aquifer of Lowe (1996)(i.e. the Tertiary to Upper Cretaceous aquifer of Weir et al. 1983). These units receive recharge from precipitation within the mine area; however, annual precipitation is significantly lower in the La Sal area as compared to the La Sal Mountains to the north. The D aquifer is present in La Sal area, and is perched in the general area of the La Sal Mines complex. A perched aquifer is a water table aquifer that overlies a deeper unsaturated zone. Based on review of water well data from the Utah Division of Water Rights, the D aquifer is used for water wells in areas south and west of the La Sal Mines Complex. Water usage is discussed further in Section 4.6.

4.5 Groundwater Flow

4.5.1 Direction of Groundwater Flow

The principle direction of groundwater flow within the Mesozoic and Tertiary to Upper Cretaceous aquifers is lateral, because the confining layers restrict groundwater flow between the individual sandstone aquifers (Weir et al. 1983). In the vicinity of the La Sal Mines Complex, groundwater flows from the recharge areas in the La Sal Mountains generally towards the south.

4.5.2 Hydraulic Conductivity

Jobim (1962) analyzed intrinsic permeability within rock units of the Mesozoic and Tertiary to Upper Cretaceous aquifers in relation to the distribution of uranium deposits in the Colorado Plateau. This work included measurement of intrinsic permeability at numerous localities within the Colorado Plateau, including the La Sal area. Jobim developed a series of isopermeabilty contour maps that provide intrinsic permeability data for the general vicinity of the La Sal Mines Complex. Intrinsic permeability data from Jobim (1962) are provided for the various sandstone units within the Mesozoic and Tertiary to Upper Cretaceous aquifers in Exhibit 4-1. In addition, Exhibit 4-1 provides hydraulic conductivity data for the rock units, which were calculated from the intrinsic permeability data. Exhibit 4-1 also shows available estimates of hydraulic conductivity for hydrogeologic units that are reported by other authors including Coley et al. (1969), and Goodnight and Smith (1996).

Exhibit 4-1. Intrinsic Permeability and Hydraulic Conductivity of Sandstone Units Present in Dolores River Basin.

Formation	**Aquifer**	**Intrinsic Permeability(1) (millidarcy)**	**Calculated Hydrualic Conductivity (cm/sec)(1)**	**Other Reported Hydraulic Conductivity Values (cm/sec)**
Dakota Sandstone	D aquifer	740	7.1E-04	1.4E-4 to 2.3E-2(2)
Burro Canyon Formation	D aquifer	NA	NA	2E-5(3)
Sandstones of Morrison Formation	M aquifer	110	1.1E-04	3.5E-6 to 7.1E-4(2)
Entrada Sandstone	N aquifer	200	1.9E-04	NA
Navajo Sandstone		160	1.5E-04	NA
Kayenta Formation		67	6.5E-05	NA
Wingate Sandstone		60	5.8E-05	NA
Lower Sandstone of Chinle Formation		3.3	3.2E-06	NA

Notes:
(1) Jobim (1962)
(2) Cooley et al. (1969)
(3) Goodknight and Smith (1996)
cm/sec= centimeters per second
Millidarcy = 1 x 10^{-3} Darcy. A Darcy is equivalent to the passage of one cubic centimeter of fluid of one centipoise viscosity flowing in one second under a pressure differential of one atmosphere through a porous medium having a cross-section of one square centimeter and a length of one centimeter (Bates and Jackson 1984).

4.6 Existing and Future Uses of Groundwater

The La Sal Mines Complex is located near the town of La Sal. Current uses of groundwater in the area include: (1) local uses such as domestic drinking water, stockwatering water, irrigation water, and (2) Denison's industrial water for their mining operations. The existing and future uses of groundwater in these two categories are discussed below.

4.6.1 Local Groundwater Use

A query of the water well records maintained by the Utah Division of Water Rights (UDWR) was completed to identify local wells within two miles of the La Sal Mine Complex (http://www.waterrights.utah.gov/cgi-bin/wellview.exe?Startup). Table 4-4 provides a list of identified water wells within the area and Figure 4-2 shows the relative location of the wells to the La Sal Mines Complex is shown on Figure 4-2. Additional local water well completion data was collected from UDWR including the finished well depth, the well intake depth, the static water level and the lithology or formation name at the depth of the well intake (see Table 4-4). The aquifer units exploited by the local water wells can be generally interpreted from the well files and indicate water use from the following aquifers:

- Alluvial aquifers hosted by Quaternary alluvial sediments such as sand and gravel;
- The Dakota Formation, which is a part of the D aquifer as defined by Lowe (1996); and
- The Morrison Formation, which is likely a part of the M aquifer as defined by Lowe (1996).

The majority of the wells appear to be completed in the D aquifer and in alluvial aquifers located south and west of the La Sal Mines Complex near the town of La Sal. As discussed previously, the D aquifer is separated from the areas of mining by the Brushy Basin Member of the Morrison Formation, which is a low-permeability confining unit.

The well intake depths range from 0 to 460 ft below the surface, and the static water levels range from 0 to 385 ft below the surface. Based on reported static water level depths of 0 ft below the surface in areas several miles south of the La Sal Mines Complex, it appears that artesian conditions are present in some areas.

San Juan County, Utah is a rural community with approximately 14,000 residents over an area of approximately 8,000 square miles (less than 2 residents per square mile) (USCB 2000). It is anticipated that local uses of groundwater near the La Sal Mines Complex will remain similar in the future.

4.6.2 Denison Groundwater Use for Mine Operations

As discussed previously, Denison utilizes water from the following locations for underground mining operations including drilling operations and dust control:

- Beaver Shaft Mine: Perched groundwater from aquifers stratigraphically above the Brushy Basin member drains into the Beaver Shaft Mine through the 1280 borehole and the collapsed 1350 borehole on a seasonal basis. Water was reported to be flowing into the underground mine workings via the 1280 bore hole at a rate of approximately 4 gallons per hour in July, 2009. This groundwater flows through underground workings to a stope at the 6354 level, where it is collected and used in underground mining operations (CDM 2009a). However, flow of water into the mine from these borehole is reported to have ceased in September, 2009 (Seth McCourt, Denison Mine Engineer, email communication September 23, 2009), which suggests that these inflows are seasonal. Currently water trucked to the mine from the Redd Ranch is used to support mining activities at the beaver Shaft Mine

- Pandora Mine: Water from the Redd Ranch is transported to at the Pandora Mine and is currently pumped for use into the active underground areas of the mine. Denison is investigating alternative sources of water to support mining activities at the Beaver Shaft and Pandora mines. If suitable alternative sources are located, Denison will obtain water rights for this usage in accordance with Utah regulations.

Section 5
Potential Affects of Underground Mining
5.1 Groundwater Quality
Potential effects of mining on groundwater quality could occur as a result of underground activities or surface activities at the La Sal Mines Complex. In the following sections, the potential effects of underground operations are discussed first followed by potential effects of the surface activities.

5.1.1 Underground Activities
Undergound mining involves a number of activities that could potentially affect groundwater quality. However, potential risks to groundwater are mitigated by the hydrogeologic framework of the mineral deposit and the location of the underground mining activities in relation to the water table. Several factors developed in previous sections are pertinent to this discussion:

- Underground mining activities are located in the unsaturated zone of the Salt Wash Member of the Morrison Formation as discussed in Sections 3 and 4, and groundwater was not observed to be present in the underground workings;

- There is potential that groundwater is present in the M and N aquifers at depth beneath the underground mine workings and in perched zones in the overlying D aquifer or in overlying aquifers within unconsolidated alluvial and/or eolian sediments;

- Potential recharge through the underground workings and into a deeper aquifer is restricted by the overlying bentonitic shale of the Brushy Basin Member of the Morrison Formation, which is a confining layer that restricts groundwater flow.

- Potential leakage from the overlying aquifers into the underground mine workings is limited by proper sealing of vent shafts and drill holes in the area.

Two major classes of environmental risks related to underground mining are relevant to this discussion: 1) risks of spills of petroleum products used in underground mining equipment; and 2) risks of natural oxidation of ore minerals, dissolution of potentially hazardous metals and metalloids, and subsequent mobilization downward to the water table.

Underground mining requires the use of mechanized equipment within the mine. This equipment is powered by diesel fuel and requires hydraulic fluids and other petroleum products, which are similar to fluids used in surface construction operations. There is potential for spills or other unanticipated releases of petroleum products to occur within the underground mine workings. Denison has a spill prevention, control and countermeasures plan in place at the mine, and Denison has procedures in place to address spills that occur within the underground workings.

Therefore, the risks of these types of effects to groundwater underlying the mine are considered low.

Minerals that are associated with uranium-vanadium mineralization may oxidize when exposed to the surficial oxidized conditions during mining and ventilation. The process of drilling and blasting the rock followed by mine ventilation can lead to mineral oxidation and potentially to dissolution of metals or metalloids from the ore minerals. This process can occur in surficial rock piles or in exposed rock surfaces within the underground mine. It is possible that mineral oxidation is occurring within the underground mine. However, groundwater is not present in the underground workings and it is unlikely that significant water percolates downward through the mine workings to underlying groundwater, because the mining areas are overlain by the low permeability confining unit of the Brushy Basin Member of the Morrison Formation. Although there is potential for oxidation reactions to change the mineralogical forms of metals and metalloids within the mine, there is not sufficient water percolating through the underground workings to cause a significant risk of mobilizing the products of mineral oxidation reactions.

5.1.2 Surface Activities

The following surface activities are also associated with the operations at the La Sal Mines Complex:

- Operation of equipment maintenance facilities to support mechanized equipment used in the underground mine;
- Operation of fuel storage facilities;
- Operation of offices, restroom and shower facilities; and
- Storage of non-mineralized rock excavated from the mine in the development rock storage area.

Denison has in place a Spill Prevention, Control, and Countermeasure Plan (SPCC) (Denison 2008), which complies with federal regulations at 40 CFR Part 112. This plan addresses storage of petroleum products at the mine and provides information regarding facility management, a description of facilities, spill information, and spill prevention and control measures. The risks to groundwater from spills of stored petroleum products are managed and mitigated by the infrastructure and practices identified in the SPCC and on-going site management in accordance with the SPCC.

Storage of development rock at mining operations can lead to water quality risks based on site specific factors including the geochemistry of the rock, the local climate, and rock storage and reclamation methods. Potential risks to groundwater from development rock stockpiles are evaluated in *Final Evaluation of Development Rock Piles at the La Sal Mines Complex* (Denison 2009).

5.2 Groundwater Quantity

It is unlikely that groundwater use at the mine would result in significant affects to the quantity of groundwater available to existing or future wells in the La Sal area. Groundwater is only used at the mine for dust control, drilling fluids and ancillary needs, and this use complies with Utah water rights law. Mineral processing is not conducted at the La Sal Mines Complex, and therefore ground water is not necessary to support mineral processing activities.

As discussed in Section 4, perched aquifers are present in local areas overlying the unsaturated underground workings. This presents some risk that exploration drilling or installation of ventilation shafts could penetrate the confining layer between the perched aquifers and the underlying unsaturated underground mine workings. This could lead to groundwater flow into the workings and potential to lowering of the water table within the perched aquifer. These risks are mitigated by sealing of vent shafts, and plugging of exploration drill holes in the area in accordance with UDOGM requirements.

Section 6
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Figures

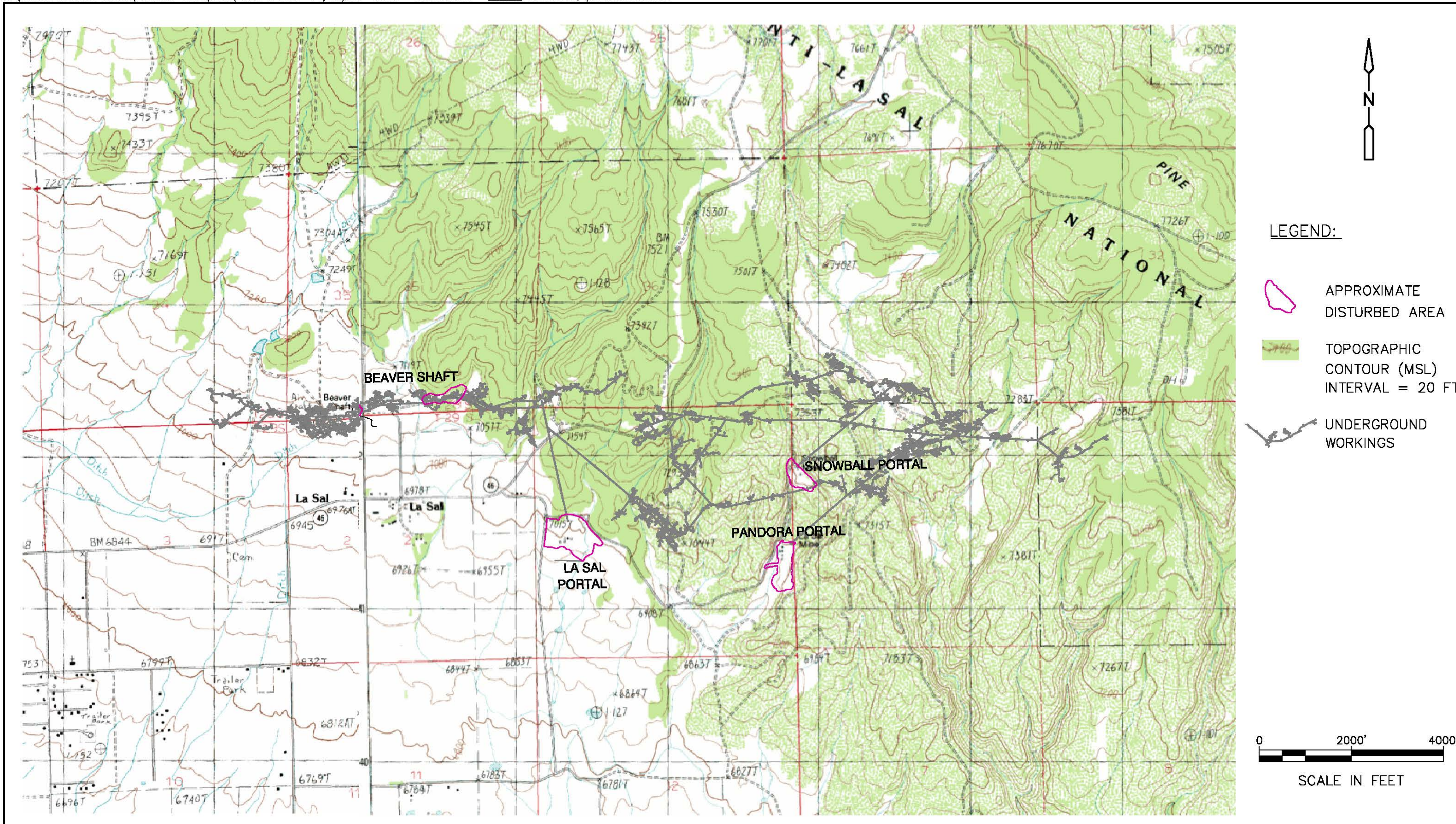

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Figure 1-1
La Sal Mines Complex
Site Location map

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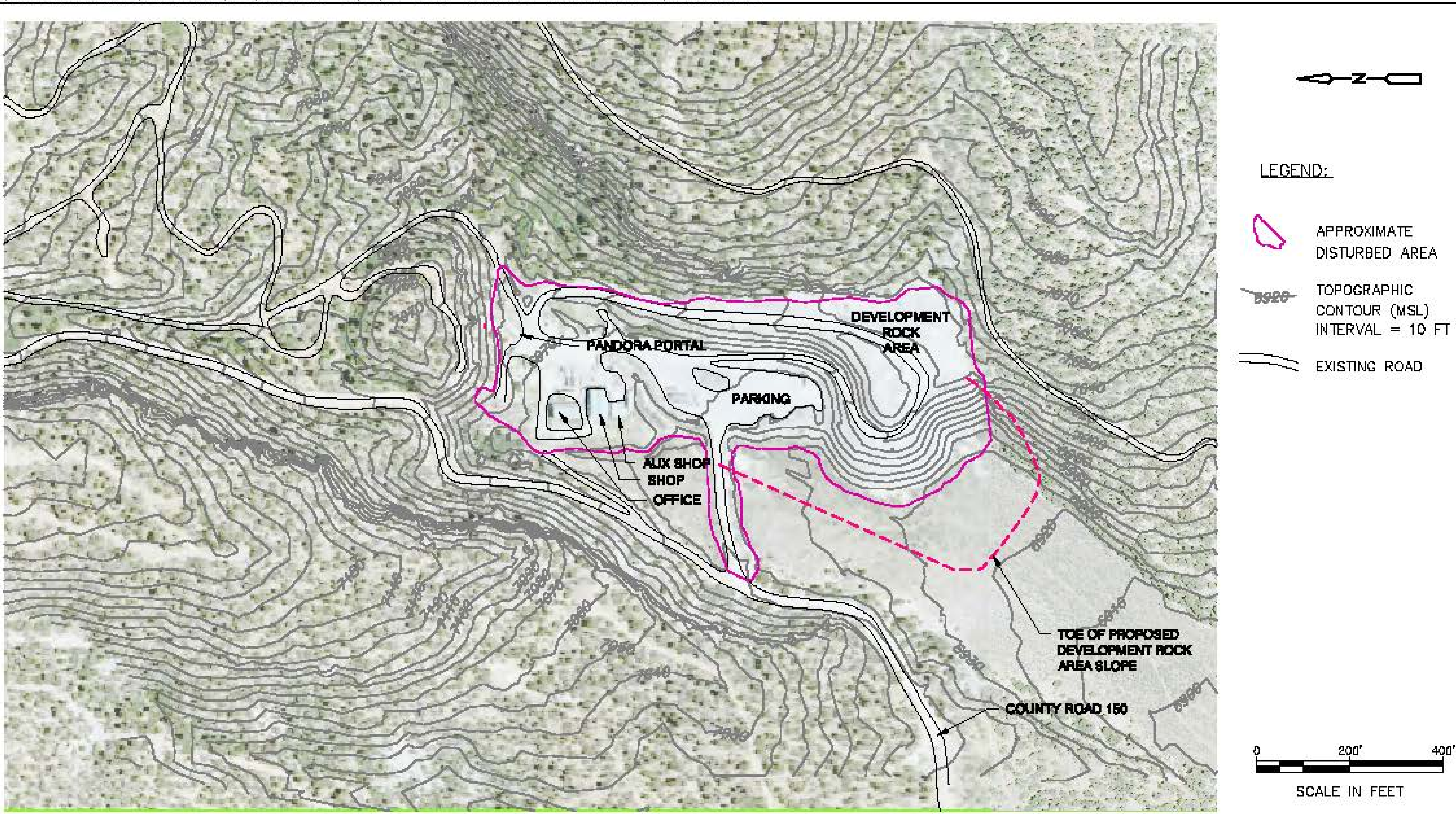

AERIAL IMAGE: DENISON MINE AERIAL SURVEY, 2008

CDM

Figure 1-2
Pandora Mine Area
Site Map

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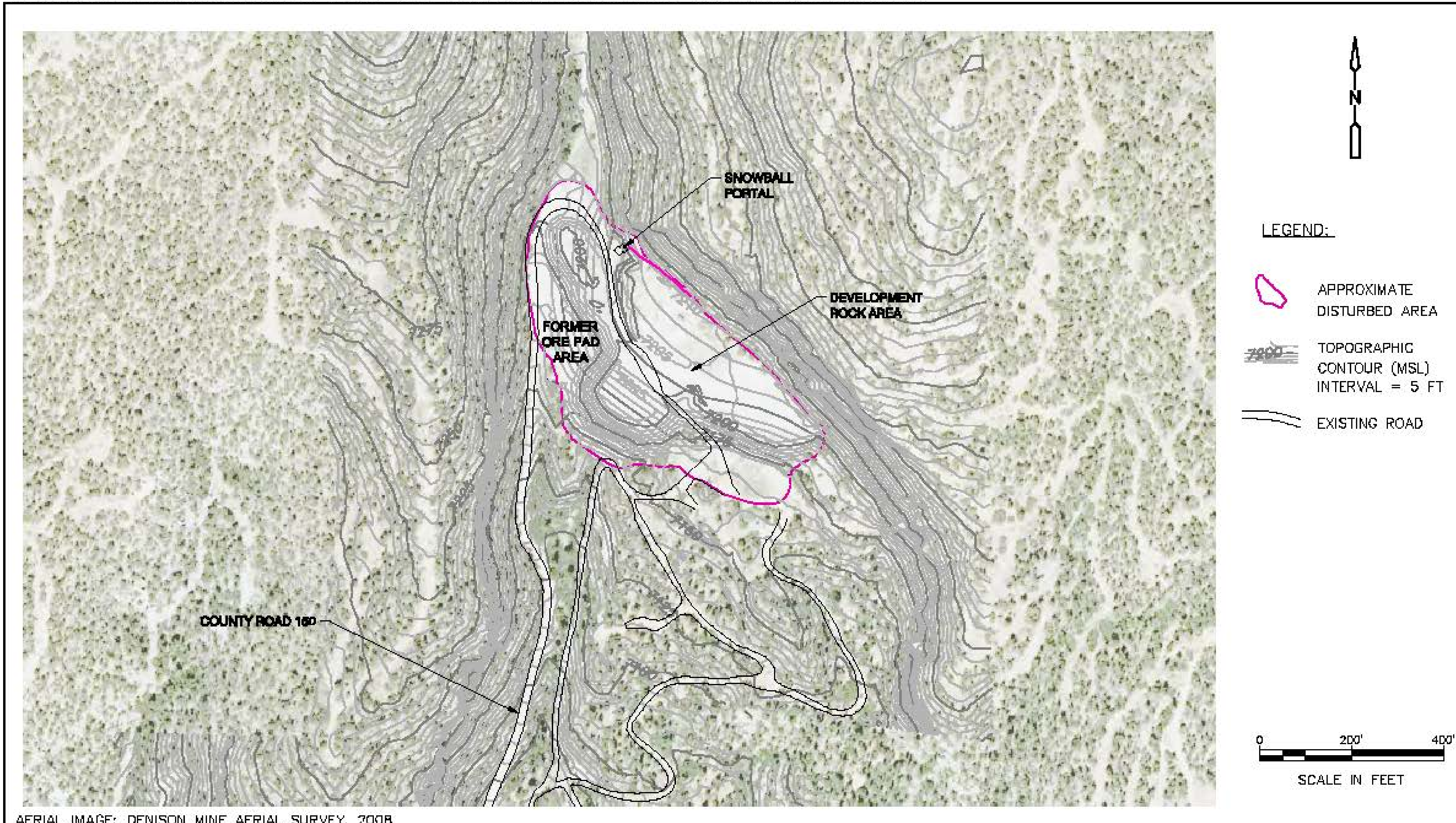

AERIAL IMAGE: DENISON MINE AERIAL SURVEY, 2008

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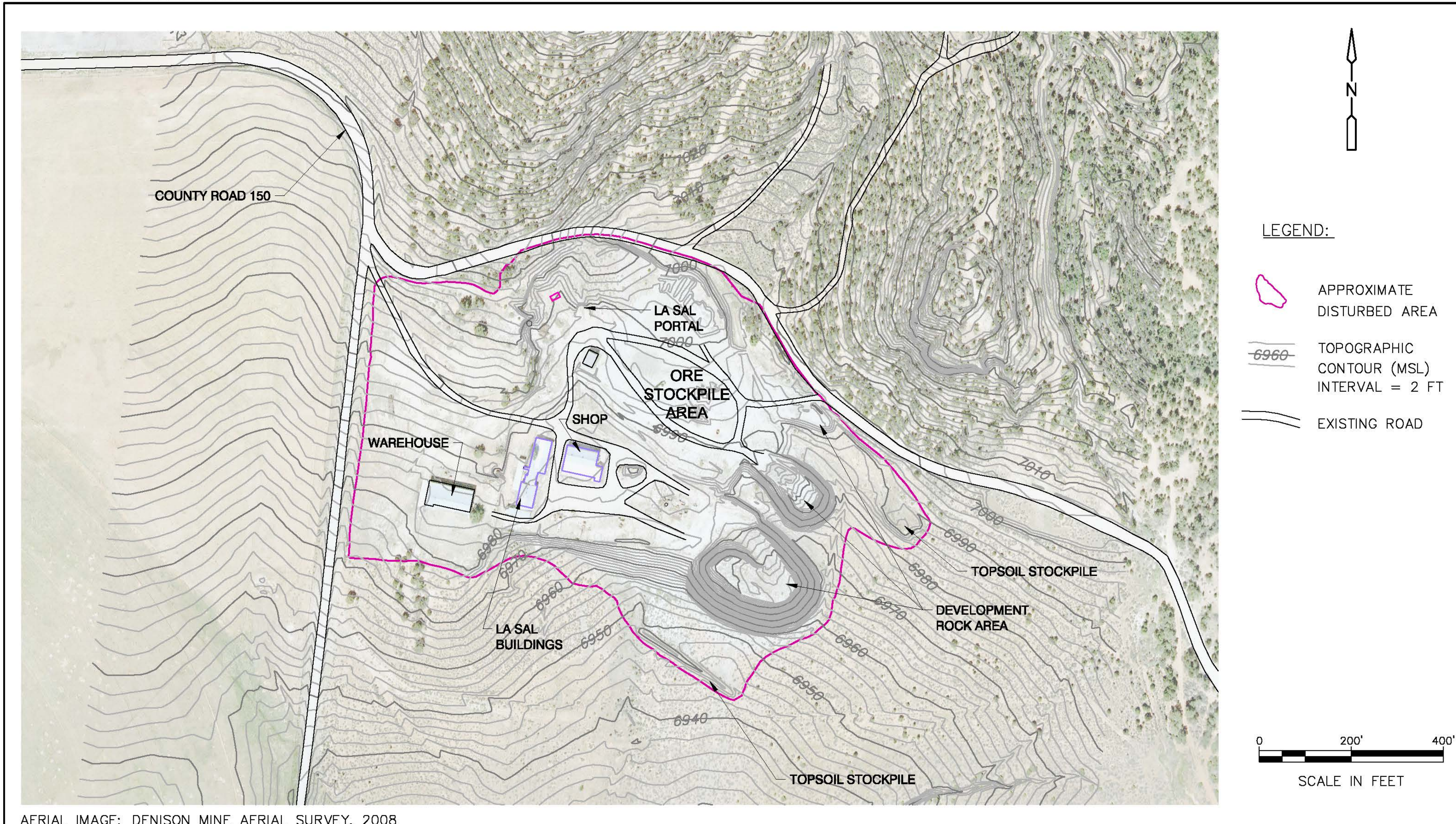
Figure 1-3
Snowball Mine Area
Site Map



AERIAL IMAGE: DENISON MINE AERIAL SURVEY, 2008

CDM

Figure 1-4
LaSal Mine Area
Site Map

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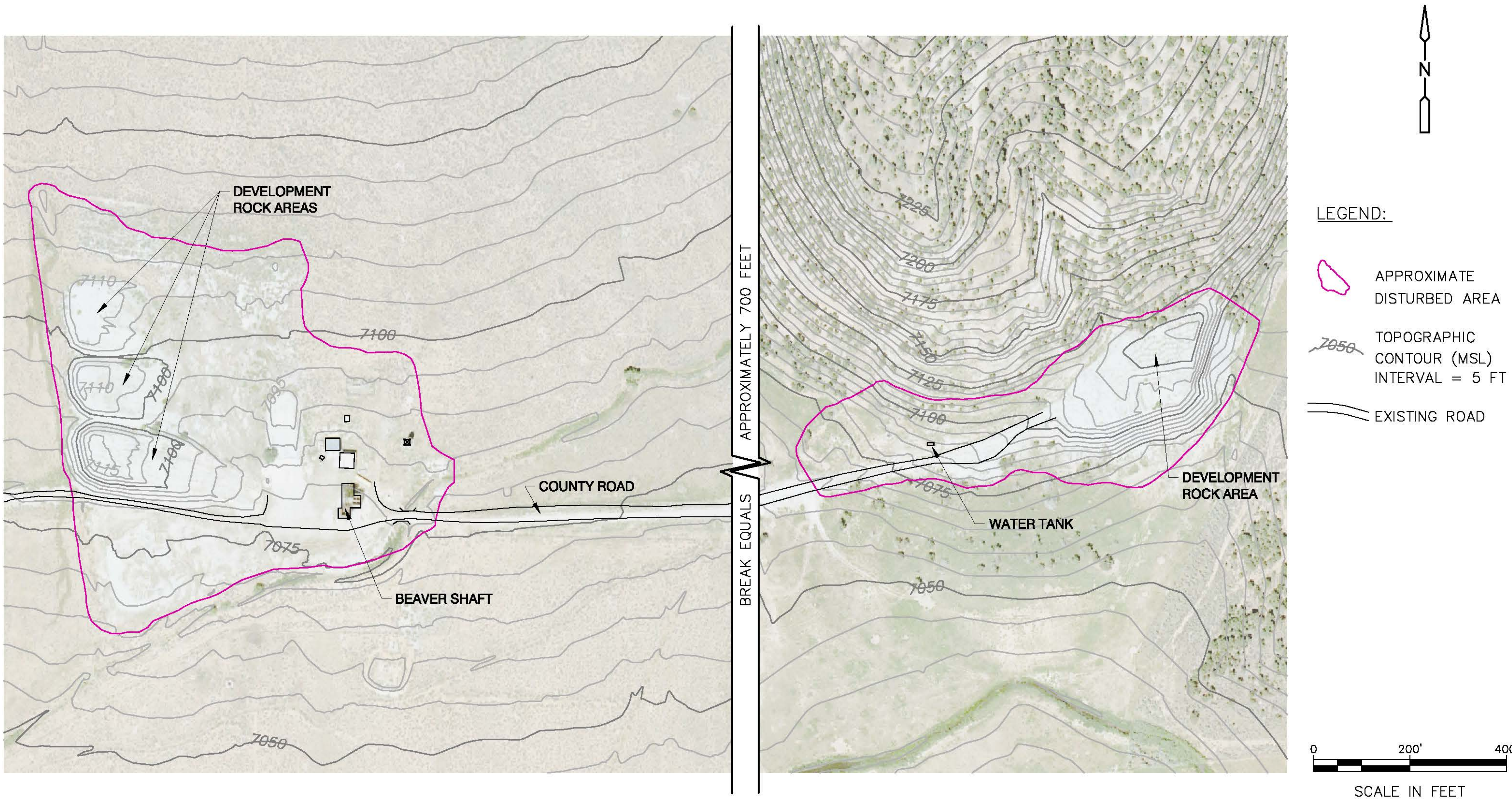

AERIAL IMAGE: DENISON MINE AERIAL SURVEY, 2008

CDM

Figure 1-5
Beaver Shaft Mine Area
Site Map

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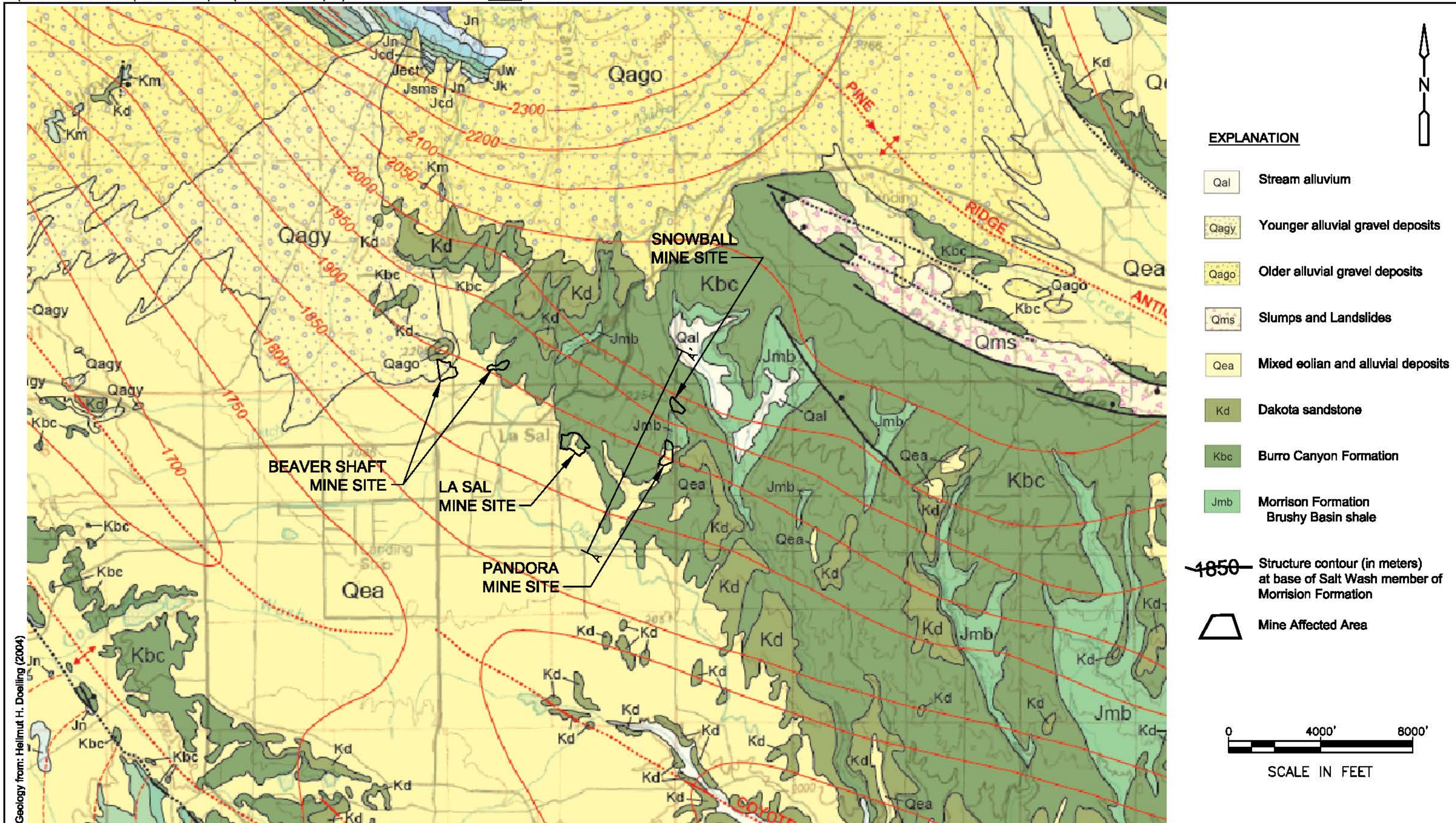

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Figure 3-1
La Sal Mines Complex Area
Geologic Map

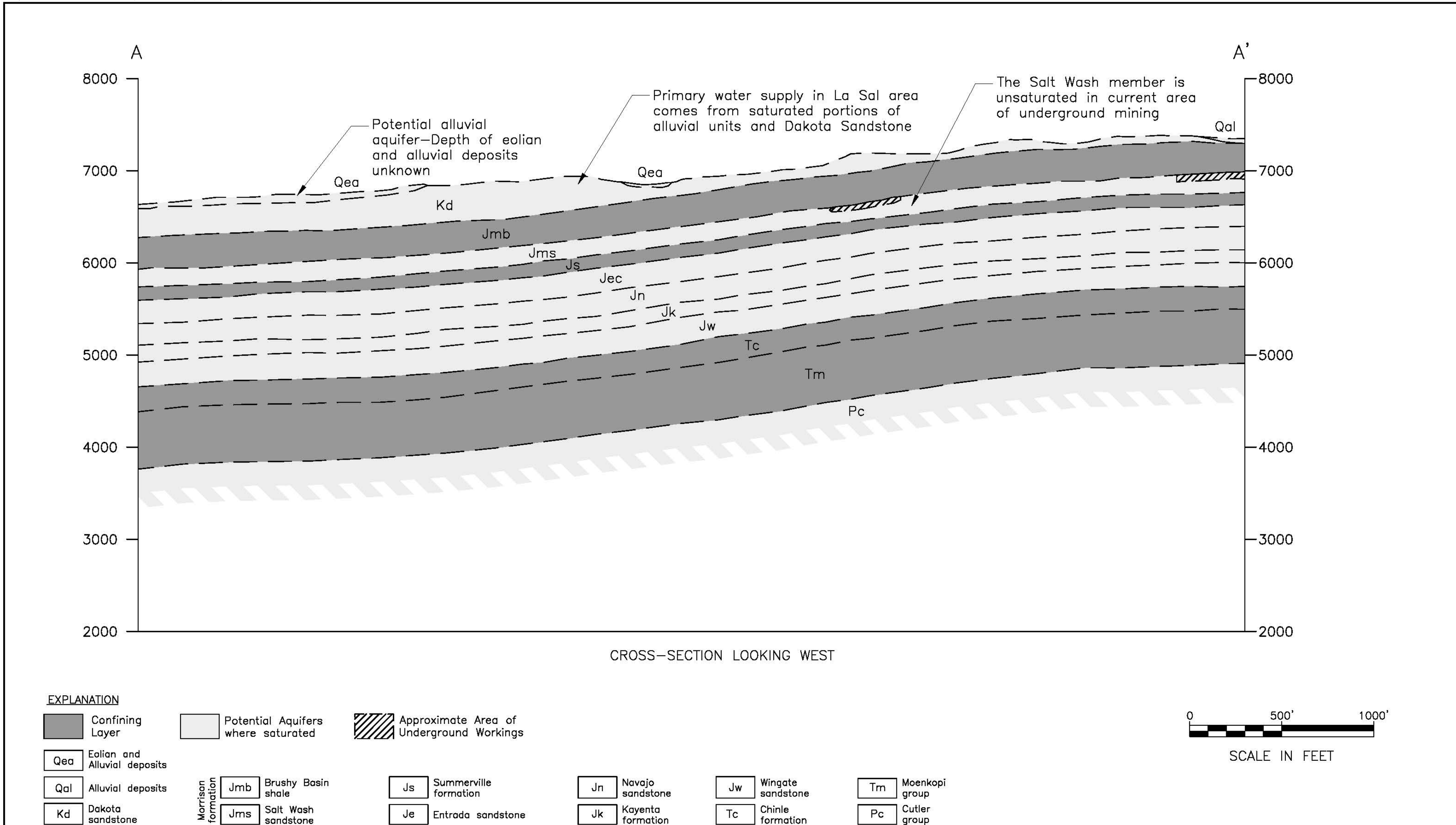

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Figure 3-2
LaSal Mine Area
Stratigraphy and Interpretive Hydrogeologic Framework

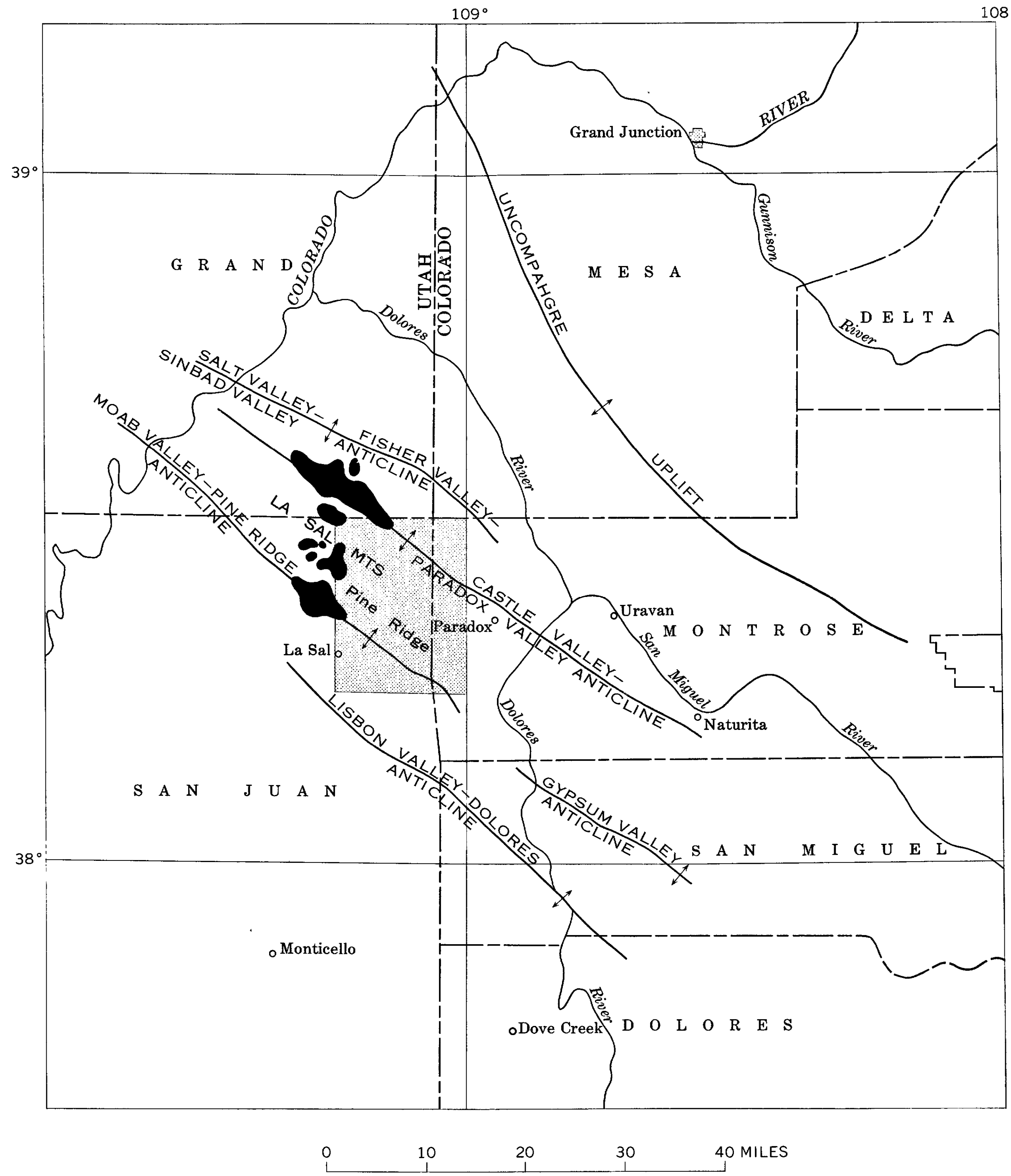

Figure 3-3. Generalized Structure of La Sal Area from Hunt (1958)

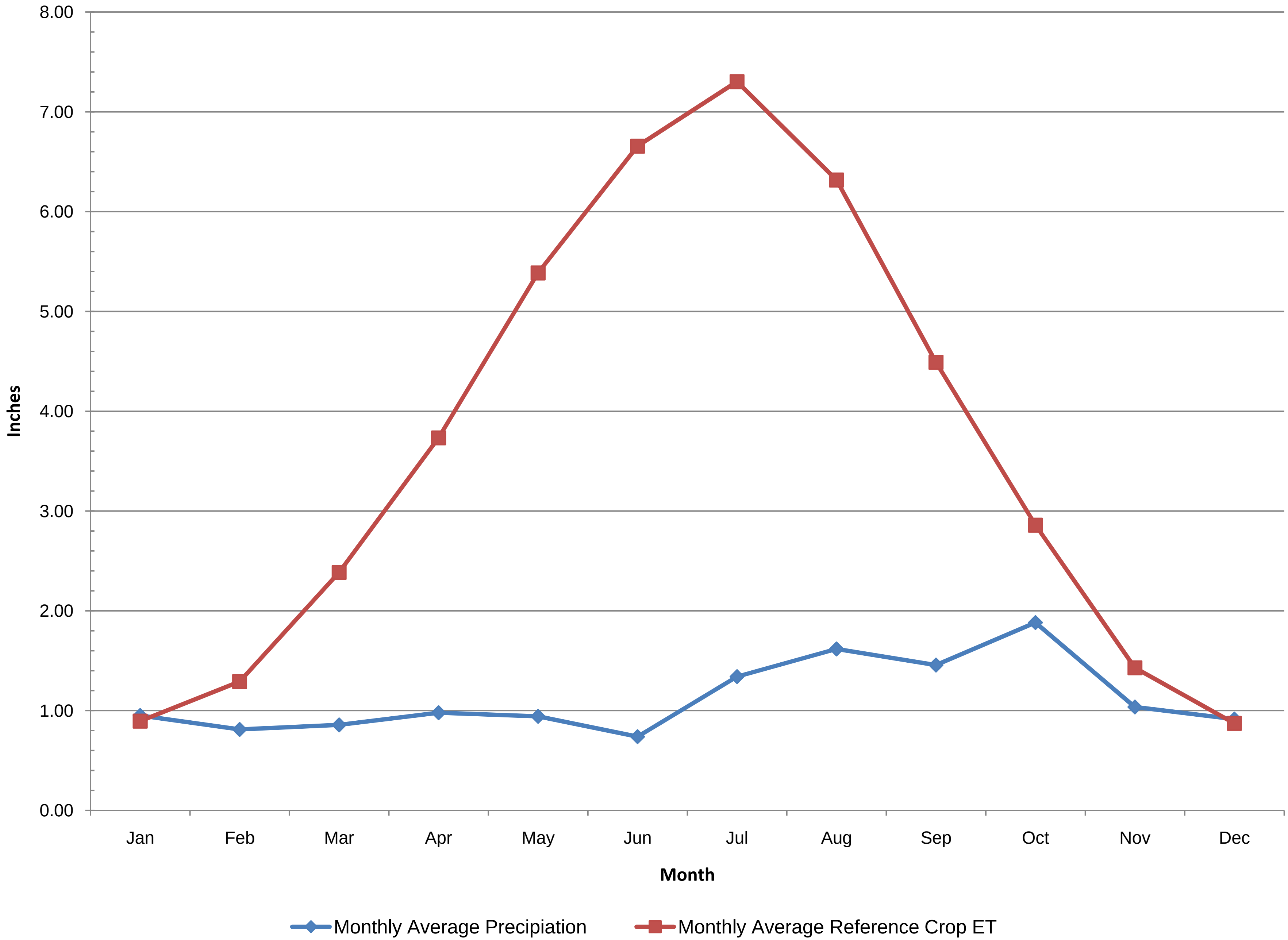

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Figure 4-1
Comparision of Monthly Precipitation to Reference Crop Evapotranspiration

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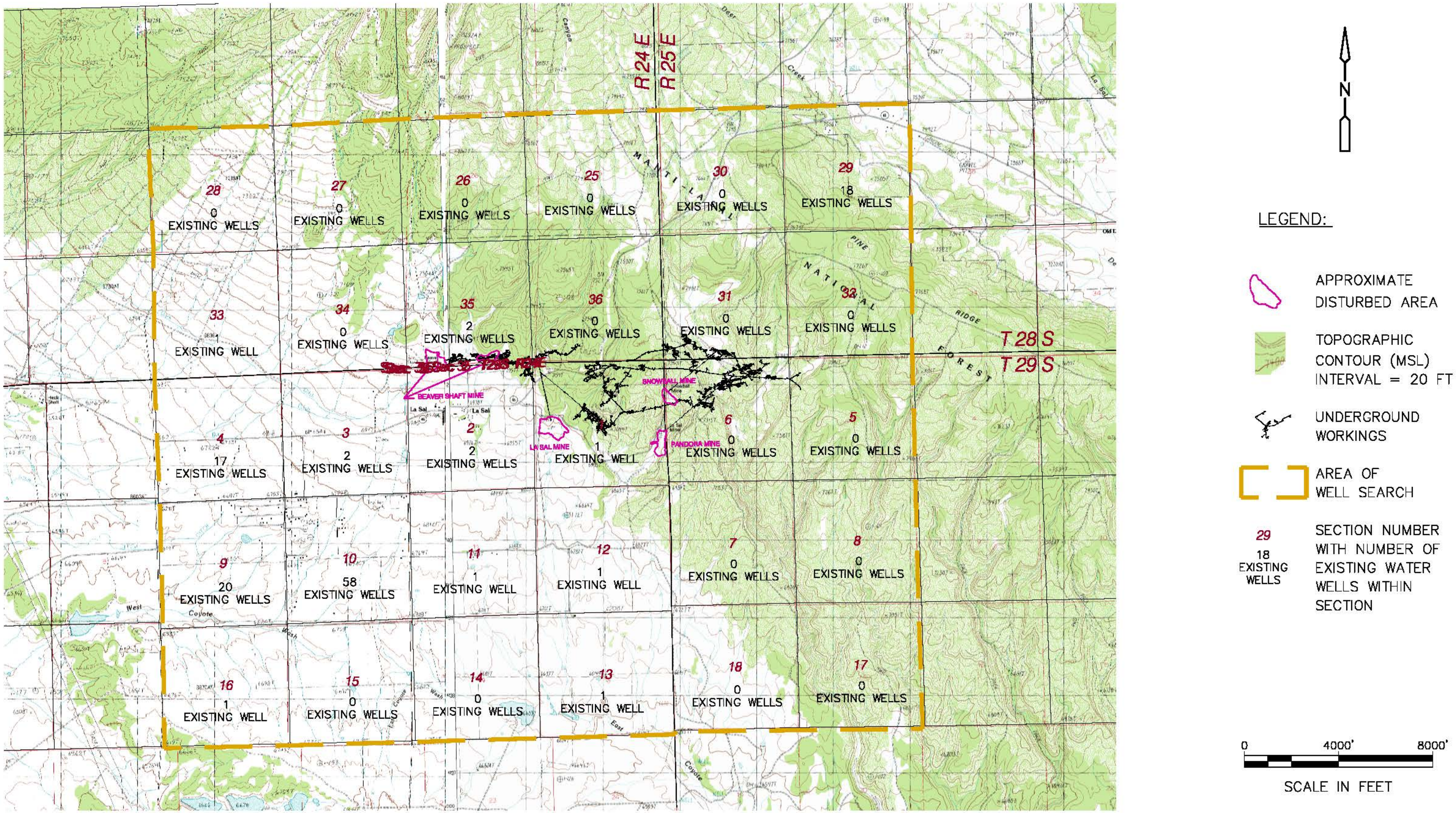

SOURCE: USGS TOPOGRAPHIC 7.5' PROVISIONAL QUADRANGLES, LA SAL EAST AND LA SAL WEST, (1987)

Figure 4-2
La Sal Mine Complex Area
Area of Well Search in Records of Utah Water Rights Division

CDM

Tables

Table 4-1
Average Monthly Precipitation
La Sal, Utah

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.02	0.01	0.05	0.03	0.03	0.03	0.03	0.07	0.06	0.03	0.03	0.06
2	0.01	0.03	0.06	0.06	0.04	0.04	0.02	0.06	0.01	0.05	0.04	0.03
3	0.01	0.02	0.04	0.04	0.02	0.03	0.01	0.05	0.02	0.11	0.04	0.03
4	0.05	0.01	0.03	0.03	0.02	0.02	0.04	0.03	0.04	0.09	0.00	0.03
5	0.05	0.03	0.02	0.04	0.06	0.05	0.03	0.03	0.04	0.05	0.02	0.03
6	0.02	0.01	0.04	0.04	0.03	0.01	0.02	0.05	0.10	0.06	0.06	0.02
7	0.02	0.02	0.04	0.01	0.06	0.04	0.01	0.06	0.06	0.07	0.02	0.06
8	0.06	0.04	0.02	0.01	0.06	0.04	0.04	0.01	0.05	0.08	0.04	0.04
9	0.01	0.03	0.03	0.05	0.03	0.02	0.06	0.03	0.06	0.05	0.04	0.00
10	0.03	0.01	0.02	0.04	0.03	0.04	0.04	0.05	0.04	0.05	0.03	0.05
11	0.02	0.02	0.04	0.04	0.02	0.04	0.03	0.05	0.06	0.09	0.03	0.05
12	0.03	0.02	0.04	0.02	0.04	0.03	0.05	0.04	0.09	0.07	0.06	0.01
13	0.03	0.04	0.01	0.03	0.05	0.01	0.05	0.07	0.06	0.06	0.03	0.03
14	0.04	0.05	0.01	0.01	0.02	0.03	0.02	0.06	0.05	0.04	0.02	0.02
15	0.04	0.03	0.01	0.03	0.01	0.01	0.02	0.06	0.07	0.04	0.06	0.04
16	0.07	0.03	0.02	0.01	0.03	0.03	0.03	0.03	0.04	0.16	0.07	0.03
17	0.03	0.05	0.02	0.03	0.04	0.05	0.09	0.04	0.03	0.05	0.02	0.02
18	0.03	0.03	0.01	0.04	0.03	0.01	0.06	0.03	0.05	0.04	0.04	0.06
19	0.03	0.03	0.01	0.02	0.02	0.03	0.08	0.03	0.07	0.07	0.03	0.04
20	0.03	0.02	0.03	0.05	0.01	0.02	0.09	0.03	0.05	0.07	0.02	0.03
21	0.00	0.04	0.02	0.04	0.07	0.01	0.03	0.06	0.04	0.04	0.02	0.03
22	0.01	0.03	0.02	0.04	0.04	0.01	0.05	0.09	0.03	0.07	0.02	0.02
23	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.06	0.05	0.05	0.04	0.03
24	0.01	0.01	0.01	0.04	0.03	0.03	0.07	0.14	0.03	0.05	0.02	0.01
25	0.06	0.04	0.03	0.03	0.03	0.01	0.06	0.04	0.03	0.04	0.03	0.03
26	0.04	0.03	0.04	0.01	0.03	0.02	0.05	0.06	0.05	0.03	0.05	0.01
27	0.03	0.02	0.03	0.02	0.01	0.01	0.05	0.04	0.03	0.06	0.04	0.02
28	0.04	0.04	0.03	0.05	0.04	0.01	0.04	0.04	0.04	0.05	0.04	0.01
29	0.02	0.04	0.06	0.03	0.01	0.01	0.05	0.12	0.05	0.07	0.05	0.03
30	0.01		0.04	0.06	0.01	0.03	0.04	0.05	0.06	0.04	0.03	0.05
31	0.08		0.02		0.00		0.05	0.05		0.04		0.01
Monthly Average	**0.95**	**0.81**	**0.86**	**0.98**	**0.94**	**0.74**	**1.34**	**1.62**	**1.46**	**1.88**	**1.04**	**0.91**

Notes:
All values in inches

CDM

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Table 4-2
Average Monthly Reference Crop Evapotranspiration
La Sal, Utah

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.02	0.03	0.06	0.10	0.15	0.20	0.24	0.22	0.18	0.12	0.06	0.03
2	0.02	0.03	0.06	0.10	0.15	0.20	0.24	0.22	0.18	0.12	0.06	0.03
3	0.02	0.03	0.06	0.10	0.15	0.20	0.24	0.22	0.18	0.11	0.06	0.03
4	0.02	0.04	0.06	0.11	0.16	0.20	0.24	0.22	0.18	0.11	0.06	0.03
5	0.02	0.04	0.06	0.11	0.16	0.21	0.24	0.22	0.17	0.11	0.06	0.03
6	0.03	0.04	0.06	0.11	0.16	0.21	0.24	0.22	0.17	0.11	0.06	0.03
7	0.03	0.04	0.06	0.11	0.16	0.21	0.25	0.22	0.17	0.11	0.06	0.03
8	0.03	0.04	0.07	0.11	0.16	0.21	0.24	0.22	0.16	0.11	0.06	0.03
9	0.03	0.04	0.07	0.11	0.16	0.20	0.24	0.22	0.16	0.10	0.06	0.03
10	0.03	0.04	0.07	0.12	0.16	0.21	0.24	0.21	0.16	0.10	0.06	0.03
11	0.03	0.04	0.07	0.11	0.16	0.21	0.24	0.21	0.16	0.10	0.05	0.03
12	0.03	0.04	0.07	0.12	0.17	0.22	0.24	0.21	0.15	0.10	0.05	0.03
13	0.03	0.04	0.07	0.12	0.17	0.22	0.24	0.21	0.15	0.10	0.05	0.03
14	0.03	0.04	0.07	0.12	0.17	0.22	0.24	0.20	0.15	0.09	0.05	0.03
15	0.03	0.04	0.07	0.13	0.18	0.22	0.24	0.20	0.15	0.09	0.05	0.03
16	0.03	0.04	0.08	0.13	0.17	0.22	0.24	0.20	0.15	0.09	0.04	0.03
17	0.03	0.05	0.08	0.13	0.17	0.22	0.23	0.20	0.15	0.09	0.04	0.03
18	0.03	0.05	0.08	0.13	0.18	0.23	0.23	0.21	0.15	0.09	0.04	0.03
19	0.03	0.05	0.08	0.13	0.18	0.23	0.23	0.20	0.14	0.09	0.04	0.03
20	0.03	0.05	0.08	0.13	0.18	0.23	0.23	0.20	0.14	0.08	0.04	0.03
21	0.03	0.05	0.09	0.13	0.18	0.24	0.23	0.19	0.14	0.08	0.04	0.03
22	0.03	0.05	0.09	0.14	0.18	0.24	0.23	0.19	0.14	0.08	0.04	0.03
23	0.03	0.05	0.09	0.14	0.18	0.24	0.23	0.19	0.14	0.08	0.04	0.02
24	0.03	0.05	0.09	0.14	0.18	0.24	0.23	0.19	0.13	0.08	0.04	0.03
25	0.03	0.05	0.09	0.14	0.19	0.24	0.23	0.19	0.13	0.08	0.04	0.03
26	0.03	0.05	0.09	0.14	0.19	0.24	0.23	0.19	0.13	0.07	0.04	0.02
27	0.03	0.05	0.09	0.14	0.19	0.24	0.23	0.19	0.13	0.07	0.04	0.02
28	0.03	0.06	0.09	0.14	0.20	0.24	0.23	0.18	0.13	0.07	0.03	0.03
29	0.03	0.06	0.09	0.14	0.20	0.24	0.23	0.18	0.12	0.07	0.03	0.03
30	0.03	0.00	0.09	0.14	0.20	0.24	0.23	0.18	0.12	0.07	0.03	0.03
31	0.03	0.00	0.10	0.00	0.20	0.00	0.22	0.18	0.00	0.07	0.00	0.03
Total	**0.89**	**1.29**	**2.38**	**3.73**	**5.39**	**6.66**	**7.30**	**6.32**	**4.49**	**2.86**	**1.43**	**0.87**

Notes:
All values in inches

Table 4-3
Hydrogeologic Characteristics of Rock Units

Aquifer	Hydrogeologic Unit	Thickness (ft.)	Physical Characteristics	Hydrogeologic Characteristics
Unconsolidated Aquifers	Alluvial	0-200 (average less than 50)	Alluvial sands and gravels, loess, colluviums, eolian sands	Source of water in vicinity of town of La Sal, yields water for springs and wells, stock and domestic
D Aquifer	Dakota Sandstone	Approx. 200	Fine to coarse grained cross-bedded sandstone	Source of water in vicinity of the town of La Sal, common target for water-well drillers in San Juan County because of shallow depth
	Burro Canyon Formation	260	Conglomerate, sandstone and shale	
	Brushy Basin Member of Morrison Formation	345	Bentonitic shale interbedded with minor sandstone	Confining Unit
M Aquifer	Bluff Sandstone, Salt Wash, Recapture, and Westwater Canyon Members of Morrison Formation	Approx. 350	Medium grained sandstone interbedded with shale	Yields small quantities, stock and domestic
	Summerville Formation	60-140	Shales interbedded with minor sandstone	Confining unit
N Aquifer	Entrada Sandstone	260	Medium to large grained cross-bedded sandstone	Main source of domestic water in San Juan County
	Navajo Sandstone	0-240	Fine grained cross-bedded sandstone	
	Kayenta Formation	160	Sandstone interbeded with siltstone and thin bedded shale	
	Wingate Sandstone	150-280	Medium grained, poorly cemented, cross-bedded sandstone	
	Chinle Formation	150-280	Shale, siltstones intebedded with minor fine grained sandstone	Yields small quantities where fractured, stock and domestic
	Moenkopi Group	Up to 600	Shale interbedded with minor sandstone	Yields small quantities, stock and domestic
P and C Aquifers	Cutler Group	390-2690	Fine grained sandstone interbedded with minor conglomerate and shale	Yields small quantities, stock and domestic
	Hermosa Formation	0-3,900	Shales, limestones, salt, and gypsum, includes Paradox Member of Hermosa Formation	Confining unit

Notes: Data from Huffman et al. (1996), Weir et al. (1983), and Hanna and Gandera (2000)

Table 4-4
Well Data for Wells within Approximately 3 Miles of La Sal Mines Complex

Well Application Number	Section	Township	Range	Finished Well Depth (feet)	Well Intake Depth (feet)	Static Water Level Depth (feet)	Lithology or Formation Name at Well Intake
0605023M00	1	29S	24E	460	460	385	White Sandstone
289029	2	29S	24E	248	228	112	Morrison Formation
0405014M00	2	29S	24E	380	200	212	Dakota Formation
392393	3	29S	24E	417	245	105.4	Gray Mancos Shale
05-1786	3	29S	24E	110	110	65	Blue/Black Mudstone
218903	4	29S	24E	260	165	100	White Dakota and Sandstone
261270	4	29S	24E	285	225	92	White Dakota Sandstone
258714	4	29S	24E	337	277	100	NA
238991	4	29S	24E	280	240	NA	Yellow and Tan Sandstone
05-1565	4	29S	24E	265	240	120	Dakota Sandstone
05-1480	4	29S	24E	260	260	68	White and Brown Sandstone
05-1402	4	29S	24E	240	108	57	White Sandstone
230956	4	29S	24E	280	220	105	White Sandstone
348929	4	29S	24E	310	290	154	Yellow Sandstone
0305002P00	4	29S	24E	320	260	134	White, Gray, Yellow Sandstone
285742	4	29S	24E	270	210	110	White Sandstone
393124	4	29S	24E	320	260	NA	Dakota Formation
05-1879	4	29S	24E	252	NA	170	NA
05-1444	4	29S	24E	275	215	132	Conglomerate Bedrock
0605015M00	4	29S	24E	146	126	51	Blue and White Shale and Clay
0705015M00	4	29S	24E	320	266	122	Gray and Tan Sandstone
0805013M00	4	29S	24E	315	225	118	Dakota Rim Tan Sandstone
183474	9	29S	24E	195	175	62	High Permeability Sand
272228	9	29S	24E	270	190	63	Dakota Silt
259809	9	29S	24E	320	270	82.4	White/Yellow Sandstone
260540	9	29S	24E	180	180	135	Brown Sandstone
254332	9	29S	24E	140	60	32	NA

Well Application Number	Section	Township	Range	Finished Well Depth (feet)	Well Intake Depth (feet)	Static Water Level Depth (feet)	Lithology or Formation Name at Well Intake
05-204	9	29S	24E	127	127	NA	White Dakota Sand
05-1424	9	29S	24E	125	95	50	Dark Brown Clay
05-623	9	29S	24E	107	107	60	Grey Sandstone
05-1802	9	29S	24E	95	95	90	Blue and Black Clay
341990	9	29S	24E	300	240	80	Yellow Sandstone
05-1406	9	29S	24E	297	297	120	Burro Canyon Red Yellow Sandstone
317518	9	29S	24E	305	245	110	Lime and Gray Sandstone
259079	9	29S	24E	350	260	NA	White and light yellow Sandstone
05-1435	9	29S	24E	200	40	40	Brown Clay
05-1512	9	29S	24E	140	60	60	Soft Sandstone
05-1451	9	29S	24E	287	60	60	Silt
05-1650	9	29S	24E	275	275	60	Brown Sandstone
05-1460	9	29S	24E	127	100	40	Light Gray Clay, Sand and Gravel
525341	9	29S	24E	306	266	100	White Sandstone with Green and Brown Shale Layers
0805024M00	9	29S	24E	320	280	89	Dakota Rim White, Tan and Brown Sandstone
72076	10	29S	24E	40	40	8	Light Brown Sandstone
261636	10	29S	24E	370	310	120	White Sandstone
249218	10	29S	24E	235	195	NA	Green and White Sandstone
257983	10	29S	24E	280	118	38	Brown Sandstone
05-869	10	29S	24E	80	60	39	Conglomerate
141106	10	29S	24E	295	235	43	White Sandstone
268941	10	29S	24E	225	165	20	Yellow Sandstone
245566	10	29S	24E	225	165	NA	White Sandstone
251410	10	29S	24E	250	190	40	Red Sand
316787	10	29S	24E	325	245	80	White Sandstone
325188	10	29S	24E	195	155	35	White Sandstone
22767	10	29S	24E	180	150	52	Sandstone
05-1205	10	29S	24E	130	130	NA	White Dakota Sand Rock
05-1450	10	29S	24E	121	118	17	Bedrock
05-1844	10	29S	24E	92	92	10	Yellow Clay
05-1609	10	29S	24E	96	96	20	Blue Hardpan/Shale

Well Application Number	Section	Township	Range	Finished Well Depth (feet)	Well Intake Depth (feet)	Static Water Level Depth (feet)	Lithology or Formation Name at Well Intake
05-1226	10	29S	24E	173	173	NA	White Dakota Sandstone
05-1828	10	29S	24E	113	113	45	Dark gray Clay
28976	10	29S	24E	60	60	42	Blue Shale
05-968	10	29S	24E	430	250	40	White Sand
05-968	10	29S	24E	250	200	40	White Sandstone
05-105	10	29S	24E	90	40	30	Sand and Gravel
05-1586	10	29S	24E	75	40	30	Clay and Sand
05-1696	10	29S	24E	87	87	20	Brown Sandstone with Boulders
05-1767	10	29S	24E	104	104	3	Dark Blue Clay
50526	10	29S	24E	282	262	39	Red Brown Shale
279898	10	29S	24E	365	205	37.5	White Brown Sandstone
268210	10	29S	24E	520	260	70	White Sandstone
347103	10	29S	24E	260	200	56	Green/White Sandstone
258348	10	29S	24E	200	140	55	Yellow Sandstone
285377	10	29S	24E	320	260	72	White Sandstone
308752	10	29S	24E	277	257	NA	Yellow Sandstone
0405002M00	10	29S	24E	145	105	NA	White Sandstone
0405006M00	10	29S	24E	340	300	NA	Yellow Sandstone
404080	10	29S	24E	320	280	NA	White Sandstone
400429	10	29S	24E	340	300	NA	NA
05-1584	10	29S	24E	170	NA	15	NA
05-1585	10	29S	24E	165	NA	6	NA
0405010M00	10	29S	24E	310	270	NA	White Sandstone with Purple Streaks
408463	10	29S	24E	310	270	NA	White Sandstone with Purple Streaks
05-1587	10	29S	24E	137	117	30	Yellow Clay
0505006M00	10	29S	24E	285	245	70	Yellow Sandstone
0505007M00	10	29S	24E	300	260	70	Yellow Sandstone
0505030M00	10	29S	24E	220	180	50	Yellow Sandstone
05-1417	10	29S	24E	65	55	45	Yellow Clay and Gravel
24228	10	29S	24E	95	60	30	Lt. Brown Sandstone
05-1496	10	29S	24E	300	NA	NA	Dakota Formation
05-1497	10	29S	24E	300	NA	NA	Dakota Formation

Well Application Number	Section	Township	Range	Finished Well Depth (feet)	Well Intake Depth (feet)	Static Water Level Depth (feet)	Lithology or Formation Name at Well Intake
05-1499	10	29S	24E	240	NA	NA	Dakota Formation
05-1502	10	29S	24E	310	NA	NA	Dakota Formation
05-1503	10	29S	24E	290	NA	NA	Dakota Formation
05-1643	10	29S	24E	168	168	10	Light Gray Sandstone
05-1701	10	29S	24E	120	120	7	Brown and Gray Sandstone
83032	10	29S	24E	150	140	52	Trace Clay and Sandstone
05-1846	10	29S	24E	67	67	18	Yellow to Brown Sandstone
0705002M00	10	29S	24E	180	180	37	Dakota Sandstone
0705011M00	10	29S	24E	220	180	180	White Sand
05-779	10	29S	24E	176	136	10.2	Mancos Shale
05-873	11	29S	24E	335	255	28	Blue Green Clay
0905002M00	12	29S	24E	260	220	15	White Sand
05-780	13	29S	24E	200	160	NA	Yellow Sandstone
0605005M00	16	29S	24E	230	200	140	Yellow Sandstone
05-1694	33	28S	24E	410	300	238	Gray, Brown and Red Clay
05-1721	35	28S	24E	168	40	38	Brown Bedrock
05-1620	35	28S	24E	210	140	146	Dakota Formation
05-514	29	28S	25E	250	190	120	Red sandstone
49796	29	28S	25E	181	172	75	Gravel
231321	29	28S	25E	100	85	55	Gravel
83763	29	28S	25E	120	75	NA	Sand and Gravel
05-1467	29	28S	25E	140	NA	NA	NA
05-1822	29	28S	25E	123	103	93	Fine Sand and Gravel
05-1697	29	28S	25E	100	NA	40	NA
05-1712	29	28S	25E	125	107	85	Brown Clay
05-1723	29	28S	25E	175	NA	NA	NA
05-1661	29	28S	25E	123	94	73	Clayey and Sandy Silt
05-1515	29	28S	25E	100	60	60	Sand
05-1265	29	28S	25E	160	127	50	Coarse Sand and Gravel
05-1547	29	28S	25E	100	80	75	Light Brown Gravel
05-764	29	28S	25E	128	128	NA	Gravel
05-354	29	28S	25E	70	50	50	Sand and Gravel

Well Application Number	Section	Township	Range	Finished Well Depth (feet)	Well Intake Depth (feet)	Static Water Level Depth (feet)	Lithology or Formation Name at Well Intake
05-533	29	28S	25E	150	138	NA	Gray Sandstone
441335	29	28S	25E	180	120	98.2	Tan Unconsolidated Silt, Sand, Gravel and Cobbles
428187	29	28S	25E	170	170	105	Tan Gravel