

Environmental Report In Support of Construction  
Tailings Cell 4b  
White Mesa Uranium Mill  
Blanding, Utah

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## Introduction

Denison Mines (USA) Corp. is seeking an amendment to its' Radioactive Materials License, No. UT1900479 in order to obtain UDEQ's approval to construct, operate and (when operations are complete) reclaim a proposed new tailings impoundment at its White Mesa Uranium Mill, Cell 4b. The construction of the Cell 4b is an essential element of future operations at the White Mesa Mill as its construction is necessary in order to continue providing sufficient impoundment surface area for the evaporation of Mill processes water. This Cell also provides additional tailings capacity which is necessary to accommodate the tailing volume associated with routine ore processing operations. While the new cell has not yet been constructed, it was contemplated, described and assessed previously, being a critical component of the initial 1978 NRC-FEIS and attendant licensing of the facility. More specifically, the initial environmental analysis and license application for the facility contemplated six tailing cells; operating cells 1, 2 and 3, as well as 3 additional 80 acre cells, Cells 4, 5 and 6. With the construction of Cell 4a (40 acres), Cell 4b will consume the second 40 acres of the previously authorized 80 acre Cell 4.

The information required for an amendment to the Mill's Radioactive Materials License is found at R313-24-3. More specifically, the regulations state the following:

- (1) Each new license application, renewal, or major amendment shall contain an environmental report describing the proposed action, a statement of its purposes, and the environment affected. The environmental report shall present a discussion of the following:
  - (a) An assessment of the radiological and non-radiological impacts to the public health from the activities to be conducted pursuant to the license or amendment;
  - (b) An assessment of any impact on waterways and groundwater resulting from the activities conducted pursuant to the license or amendment;
  - (c) Consideration of alternatives, including alternative sites and engineering methods, to the activities to be conducted pursuant to the license or amendment;  
and
  - (d) Consideration of the long-term impacts including decommissioning, decontamination, and reclamation impacts, associated with activities to be conducted pursuant to the license or amendment.

In order to fulfill the requirements above, Denison considered and used the information topics and format cited by NRC in its guidance document NUREG 1359 for its recent

License Renewal Application. Because the Renewal Application provided current environmental information and assessments, the scope of this Environmental Report can be limited in some respects, focusing on pathways and assessments directly related to the construction of the new tailings cell. Accordingly, topical headings suggested by NUREG 1359 have been included in this document; however, where previously provided information is sufficient and unaffected by this amendment request, the prior information is incorporated by reference. Denison's assessment of the pathways to be considered for construction of cell 4b is principally focused on the examination of potential airborne releases from the pond and the groundwater considerations typically attendant to the design of a tailing cell. It is important to note that UDEQ has approved the design and construction of directly adjacent and nearly completed Cell 4a. The liner design and underlying ground conditions for Cell 4b are identical to those of Cell 4a.

**Table of Contents**

Introduction	i
Table of Contents	iii
Index of Figures	iv
1.0 Site Location and Layout.....	1
2.0 Climate and Meteorology.....	1
1.1 Regional Climate.....	1
1.2 Onsite Monitoring Program.....	4
3.0 Use of Adjacent Lands and Water.....	4
4.0 Population Distribution and Socioeconomic Profile.....	6
5.0 Topography.....	8
6.0 Geologic Setting.....	8
6.1 Regional Geology.....	8
6.2 Local Geology.....	9
6.3 Site-Specific Geologic Setting.....	9
7.0 Hydrologic Setting.....	12
7.1 Perched Zone Hydrogeology.....	12
7.2 Perched Groundwater Flow.....	15
7.3 Perched Hydrogeology (Down-gradient of Tailings Cells.....	15
7.4 Groundwater Quality.....	19
8.0 Ecological Resources and Biota.....	23
8.1 Terrestrial.....	23
8.2 Aquatic and Wetland Biota.....	26
9.0 Background Radiological and Non-Radiological Characteristics.....	26
10.0 Environmental Effects Related Directly to the Construction of Cell 4b	26
10.1 Groundwater Pathway Impact.....	27
10.2 Proposed Additional Groundwater Monitoring.....	27
10.3 Radiological Impact Related Directly to the Construction of Cell 4b	28
10.4 Radiological Monitoring Assessment.....	30
11.0 Alternatives.....	30
11.1 Issuance of Amendment for Cell 4b.....	31
11.2 No Action Alternative.....	31
11.3 Alternatives Considered But Eliminated.....	32
11.4 Cumulative Effects.....	33
11.5 Comparison of Predicted Environmental Impacts.....	33
11.6 Updates and Changes to Factors That May Cause Reconsideration of Alternatives.....	33
12.0 Costs and Benefits.....	34
13.0 Mitigation of Impacts.....	34
14.0 Long Term Impacts.....	35

**Appendix A**

Site Hydrogeology Estimation Of Groundwater Travel Times and Recommended  
Additional Monitoring Wells For Proposed Tailings Cell 4B White Mesa Uranium Mill  
Site Near Blanding, Utah

Appendix B

Dose Assessment Pertaining to the Proposed Development of New Tailings Cells For the White Mesa Uranium Mill, SENES Consultants, Hydro Geo Chem, Inc

Appendix C

Review of Environmental Monitoring Program, SENES Consultants

**Index of Figures**

<b><u>Figure</u></b>		<b><u>Page</u></b>
Figure 1	Location Map White Mesa Mill	2
Figure 2	White Mesa Mill Land Map	3
Figure 3	White Mesa Wind Rose	5
Figure 4	Population in the Project Vicinity	7
Figure 5	Local Topography	9
Figure 6	Generalized Stratigraphy of Whit Mesa Mill	10
Figure 7	Approximate Elevation Top of Brushy Basin	13
Figure 8	Kriged 4 <sup>th</sup> Quarter Water Levels	16
Figure 9	Approximate Location of Ruin Spring	17
Figure 10	Depth to Perched Water	18
Figure 11	Stock Watering Pond Locations	20
Figure 12	Reclamation Cover Grading Plan for Cell 4b	36

## **1.0 Site Location and Layout**

The Mill is regionally located in central San Juan County, Utah, approximately 6 miles (9.5 km) south of the city of Blanding. The Mill can be reached by taking a private road for approximately 0.5 miles west of Utah State Highway 191. See Figure 1.

Within San Juan County, the Mill is located on fee land and mill site claims, covering approximately 5,415 acres, encompassing all or part of Sections 21, 22, 27, 28, 29, 32, and 33 of T37S, R22E, and Sections 4, 5, 6, 8, 9, and 16 of T38S, R22E, Salt Lake Base and Meridian. See Figure 2.

All operations authorized by the License are conducted within the confines of the existing site boundary. The milling facility currently occupies approximately 50 acres and the current tailings disposal cells encompass another 250 acres. See Figure 2.

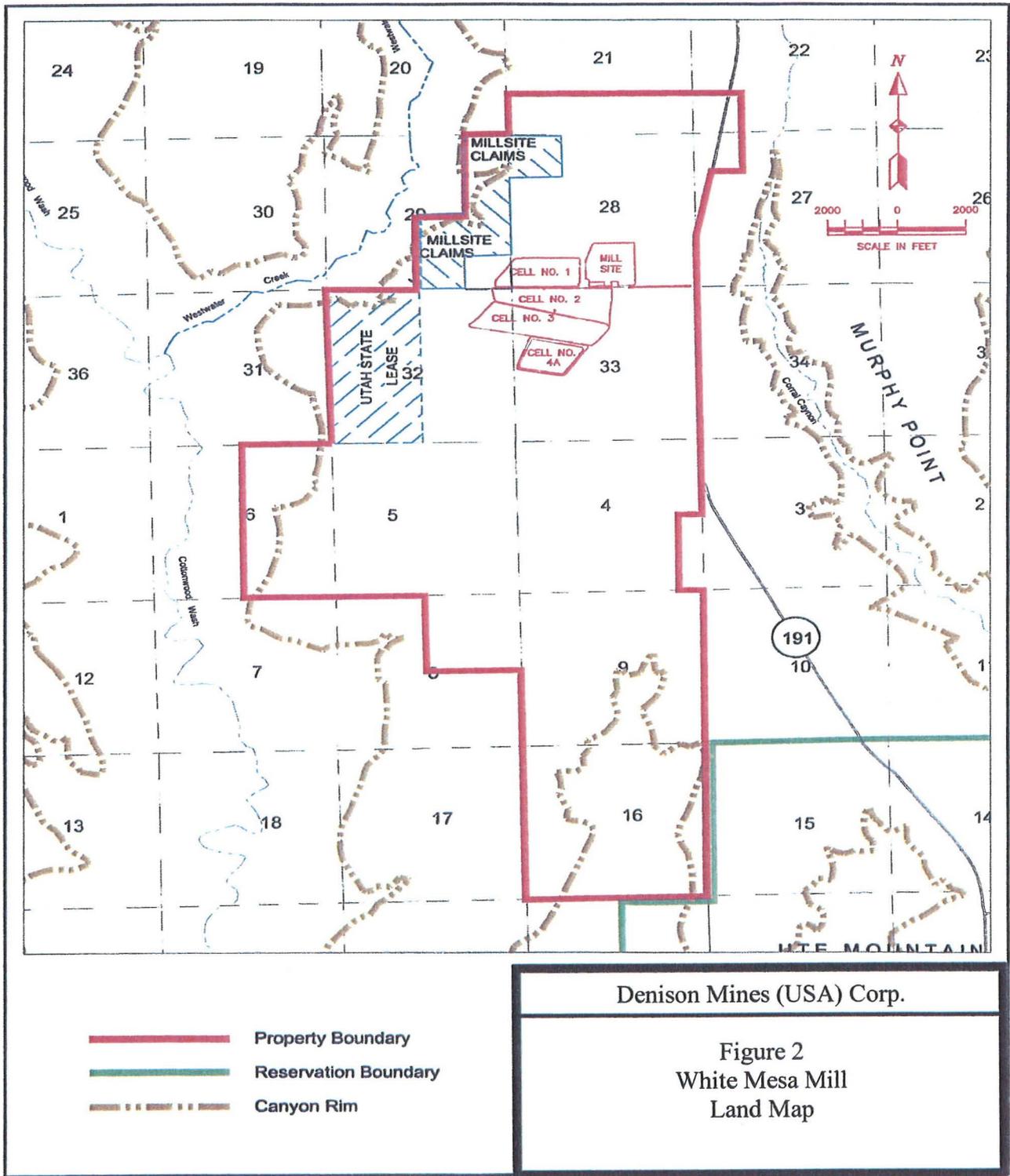
The resident currently nearest to the milling facility is located approximately 1.2 miles (1.9 km) north of the Mill site, just north of air sampling station BHV-1. See Figure 2.

## **2.0 Climate and Meteorology**

### **2.1 Regional Climate**

The climate of southeastern Utah is classified as dry to arid continental. Although varying somewhat with elevation and terrain, the climate in the vicinity of the Mill can be considered as semi-arid with normal annual precipitation of about 13.4 inches. Most precipitation is in the form of rain with snowfall accounting for about 29% of the annual total precipitation. There are two separate rainfall seasons in the region, the first in late summer and early autumn (August to October) and the second during the winter months (December to March). The mean annual relative humidity is about 44 percent and is normally highest in January and lowest in July. The average annual Class A pan evaporation rate is 68 inches (National Oceanic and Atmospheric Administration and U.S. Department of Commerce, 1977), with the largest evaporation rate typically occurring in July. This evaporation rate is not appropriate for determining water balance requirements for the tailings management system and must be reduced by the Class A pan coefficient to determine the later evaporation rate. Values of pan coefficients range from 60% to 81%. Denison assumes for a water balance calculations an average value of 70% to obtain an annual lake evaporation rate for the Mill area of 47.6 inches. Given the annual average precipitation rate of 13.4 inches, the net evaporation rate is 34.2 inches per year.





The weather in the Blanding area is typified by warm summers and cold winters. The mean annual temperature in Blanding is about 50° (F). January is usually the coldest month and July is usually the warmest month.

Winds are usually light to moderate in the area during all seasons, although occasional stronger winds may occur in the late winter and spring. The predominant winds are from the north through north-east (approximately 30 percent of the time) and from the south through south-west (about 25 percent of the time). Winds are generally less than 15 mph, with wind speeds faster than 25 mph occurring less than one percent of the time. The National Weather Service Station in Blanding, Utah is located about 6.25 miles north of the Mill. Data from the station is considered representative of the local weather conditions (1978 ER, Section 2.7.2). However, as an element of the pre-construction baseline study and ongoing monitoring programs, the Mill operates an onsite meteorological station, described in greater detail below. Further details about weather and climate conditions are provided in the 1978 ER (Section 2.7) and in the FES (Section 2.1). The 1978 ER and FEIS are resource documents, incorporated here by reference.

## 2.2 On Site Monitoring Program

On-site meteorological monitoring at the Mill was initiated in early 1977 and continues today. The original purpose of the meteorological monitoring program was to document the regional atmospheric baseline and to provide data to assist in assessing potential air quality and radiological impacts arising from operation of the Mill.

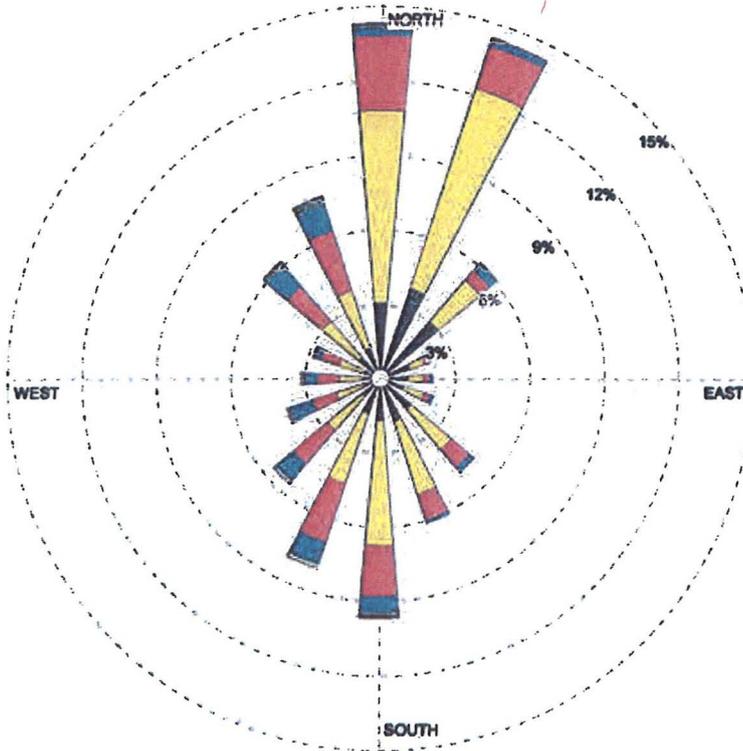
After the Mill construction was completed, the monitoring programs were modified to facilitate the assessment of Mill operations. The current meteorological monitoring program includes data collection for wind speed, wind direction, atmospheric stability according to the standard Pasquill scheme (via measurements of deviations in wind direction, referred to as sigma-theta), and precipitation as either rain or snow. The recorded on-site meteorological conditions are reported to Denison on a semi-annual basis and are described in semi-annual reports prepared for Denison and maintained at the Mill. Figure 3 shows the windrose for the Mill site during the period of January – December 2007, the most recent full year of compiled meteorological data.

## 3.0 **Use of Adjacent Lands and Water**

Approximately 65.8% of San Juan County is federally owned land administered by the U.S. Bureau of Land Management, the National Park Service, and the U.S. Forest Service. Primary land uses include livestock grazing, wildlife range, recreation, and exploration for minerals, oil, and gas. Approximately 22% of the county is Native American land owned either by the Navajo Nation or the Ute Mountain Ute Tribe. The area within 5 miles of the Mill site is predominantly range land owned by Blanding residents. The Mill site, including tailings cells, encompasses approximately 300 acres.

WIND ROSE PLOT:  
**White Mesa Mill**  
**Blanding, Utah**

DISPLAY:  
**Wind Speed**  
**Direction (blowing from)**



**WIND SPEED**  
**(m/s)**

- $\geq 11.1$
- 8.8 - 11.1
- 5.7 - 8.8
- 3.6 - 5.7
- 2.1 - 3.6
- 0.5 - 2.1

Calms: 0.65%

COMMENTS:

DATA PERIOD:  
**2007**  
**Jan 1 - Dec 31**  
**00:00 - 23:00**

COMPANY NAME:  
**Denison Mines (USA) Corporation**

MODELER:  
**McVehil-Monnett**  
**Associates**

Figure 3

CALM WINDS:

0.65%

TOTAL COUNT:  
**8753 hrs.**

AVG. WIND SPEED:

3.36 m/s

DATE:

2/4/2008

PROJECT NO.:

2018-06

A more detailed discussion of land use at the Mill site, in surrounding areas, and in southeastern Utah, is presented in the FES (Section 2.5). Results of archeological studies conducted at the site and in the surrounding areas as part of the 1978 ER are also documented in the FES (Section 2.5.2.3).

#### 4.0 Population Distribution and Socioeconomic Profile

Demographic information is generally derived from information obtained by the U.S. Census Bureau. These records are updated on a five year frequency for population centers which exceed 65,000 people and on a ten year frequency for lesser populations. As such, the local population update for the area of interest was last recorded in the year 2000, and it is that data base which was utilized to formulate the demographic information provided in the recent license renewal effort and this report. According to the 2000 census, the population density of San Juan County, in which the Mill is located, is 1.8 individuals per square mile. By comparison, the statewide density is greater than 27.2 persons per square mile. The town of Blanding, Utah, approximately 6 miles north of the Mill, is the largest population center near the Mill site, with 3,162 persons. Approximately 5 miles southeast of the Mill site is the White Mesa community, where approximately 277 Ute Mountain Ute tribal members reside. See Figure 4. The Navajo Reservation is located approximately 19 miles southeast of the Mill. The nearest community on the Navajo Reservation is Montezuma Creek, a community of approximately 507 individuals in Utah. The nearest resident to the Mill is located approximately 1.5 miles to the north of the Mill, near air monitoring station BHV-1.

Table 1 provides population centers located within 50 miles of the Mill site.

**Table 1-Population Centers Within 50 Miles of the Mill Site**

Population Center	2000 Population	Distance From Site <sup>2</sup> (miles)
Blanding, UT	3,162	6
White Mesa, UT	277	4
Bluff, UT	320	15
Montezuma Creek, UT	507	20
Aneth, UT	598	27
Mexican Hat, UT	88	30
Monticello, UT	1,958	27
Eastland/Ucolo, UT	249 <sup>3</sup>	32
Dove Creek, CO	698	37
Towaoc, CO	1,097	50

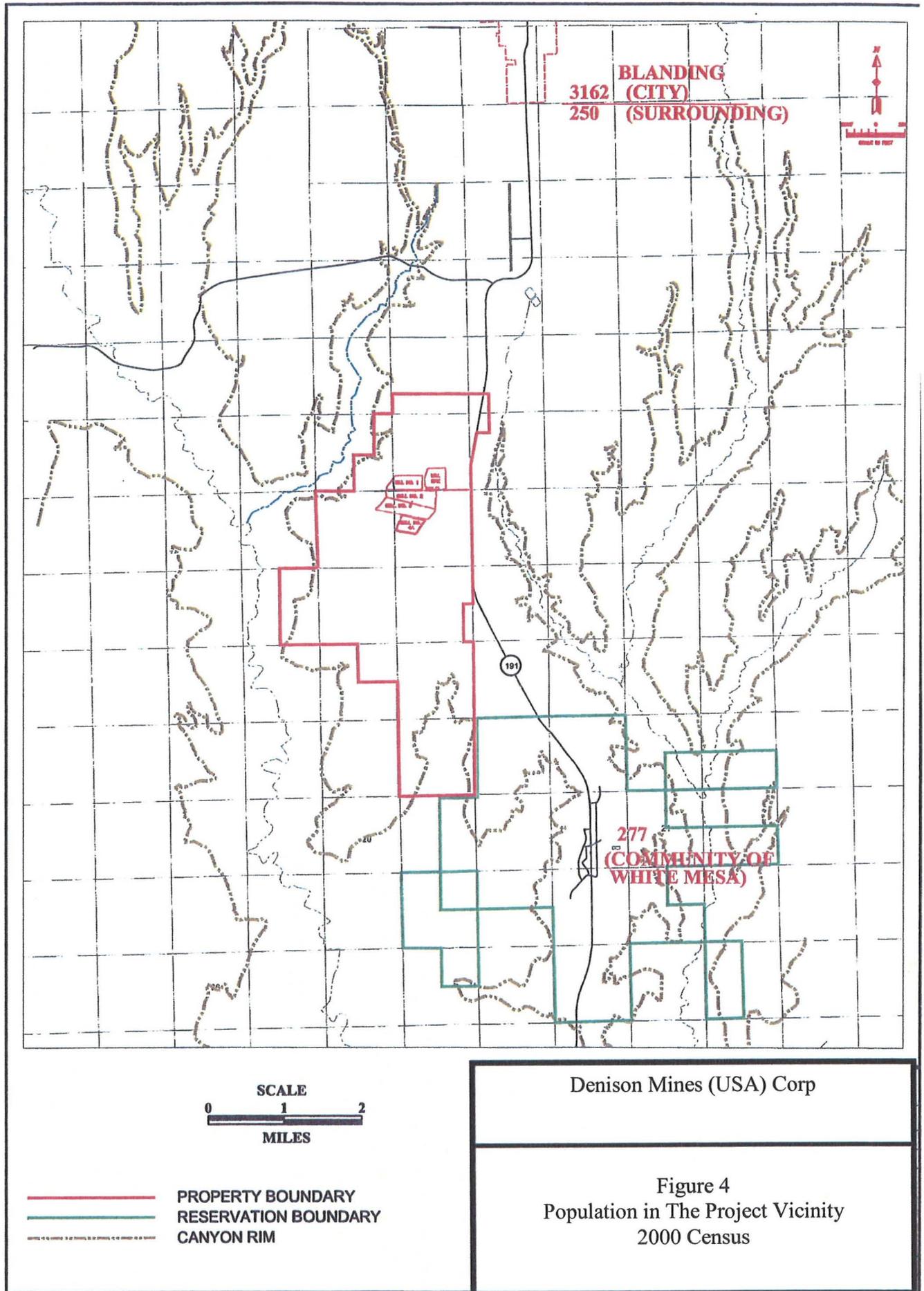
Source: <http://factfinder.census.gov>

<sup>1</sup> 2000 Census

<sup>2</sup> Approximate distance from Mill site by air

<sup>3</sup> Based on 1978 population estimate

San Juan County, Utah, is the largest and poorest county in Utah. As of December 2006, the unemployment rate in San Juan County was 4.9%, compared to 2.6% for Utah as a whole, and 4.5% for the nation as a whole. When operating, the Mill is one of the largest private employers in San Juan County, employing up to 60-140 full time employees. As



such, the Mills employees represent a significant economic base for the city of Blanding and rural residents of San Juan County. In addition, the Company pays local taxes to San Juan County, further supporting the development of the local economic base. The Mill also provides income to local minorities, typically employing a high percentage of minority workers ranging from 45-75% Native Americans.

Since its inception in 1980, the Mill has run on a campaign basis, in each case remaining on standby pending accumulation of sufficient ore stockpiles to justify a milling campaign. Currently, Mill employees are predominantly residents of San Juan County, or residents of neighboring counties who commute to the Mill on a daily basis. Historically, the Mill has drawn upon such residents of San Juan County and neighboring counties for each milling campaign, rather than relying upon an influx of workers to the area. As a result, Mill campaigns have not given rise to any unusual demands on public services or resulted in any cultural or socioeconomic issues for the surrounding areas.

## **5.0 Topography**

The Mill site is located on a gently sloping mesa that, from the air, appears similar to a peninsula, as it is surrounded by steep canyons and washes and is connected to the Abajo Mountains to the north by a narrow neck of land. On the mesa, the topography is relatively flat, sloping at less than one (1) percent to the south and nearly horizontal from east to west. See Figure 5.

## **6.0 Geologic Setting**

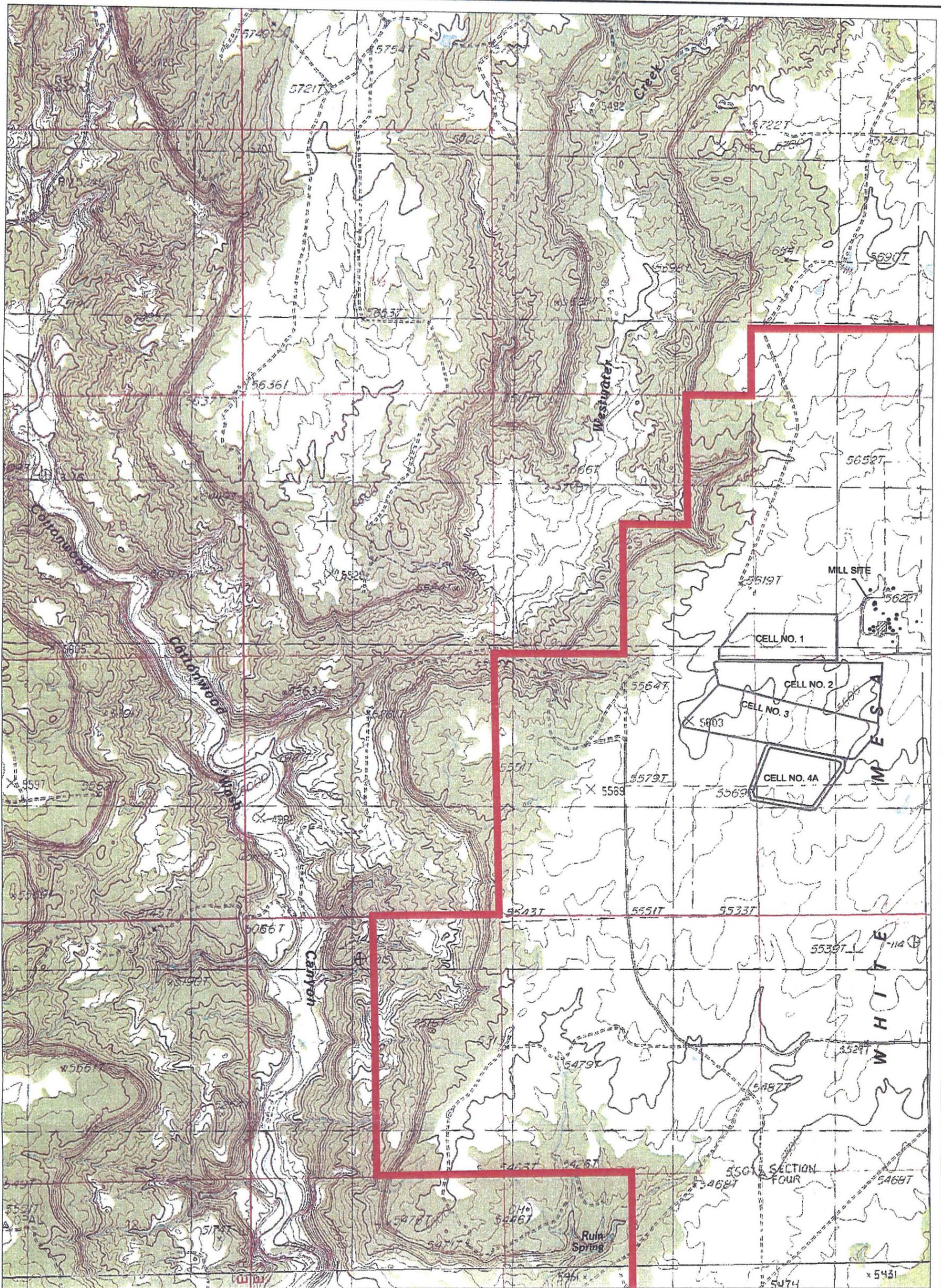
### **6.1 Regional Geology**

The Mill site lies within a region designated as the Canyon Lands section of the Colorado Plateau physiographic province. Elevations in the region range from approximately 3,000 feet in the bottom of canyons to over 11,000 feet among the peaks of the Henry, Abajo and La Sal Mountains. The average elevation for the area, excluding deeper canyons and isolated mountain peaks, is about 5,000 feet.

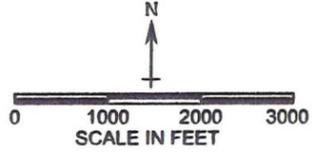
The sedimentary rocks exposed in southeastern Utah have a total thickness of approximately 6,000 to 7,000 feet. These sedimentary units range in age from Pennsylvanian to Late Cretaceous; older rock units which underlie those of Pennsylvanian age are not exposed in the Mill site area.

Structural features in the Mill site area have been divided into three main categories on the basis of origin or mechanism of the stress that created the structure. These categories are: (1) structures related to large-scale regional uplifting or downwarping directly related to movements in the basement complex (the Monument Uplift and the Blanding Basin); (2) structures due to diapiric deformation of thick sequences of evaporate deposits, salt plugs and salt anticlines (the Paradox Fold and Fault Belt); and (3) structures formed due to magmatic intrusions (the Abajo Mountains). A generalized stratigraphic column for the region is provided as Figure 6.

Fig. 5



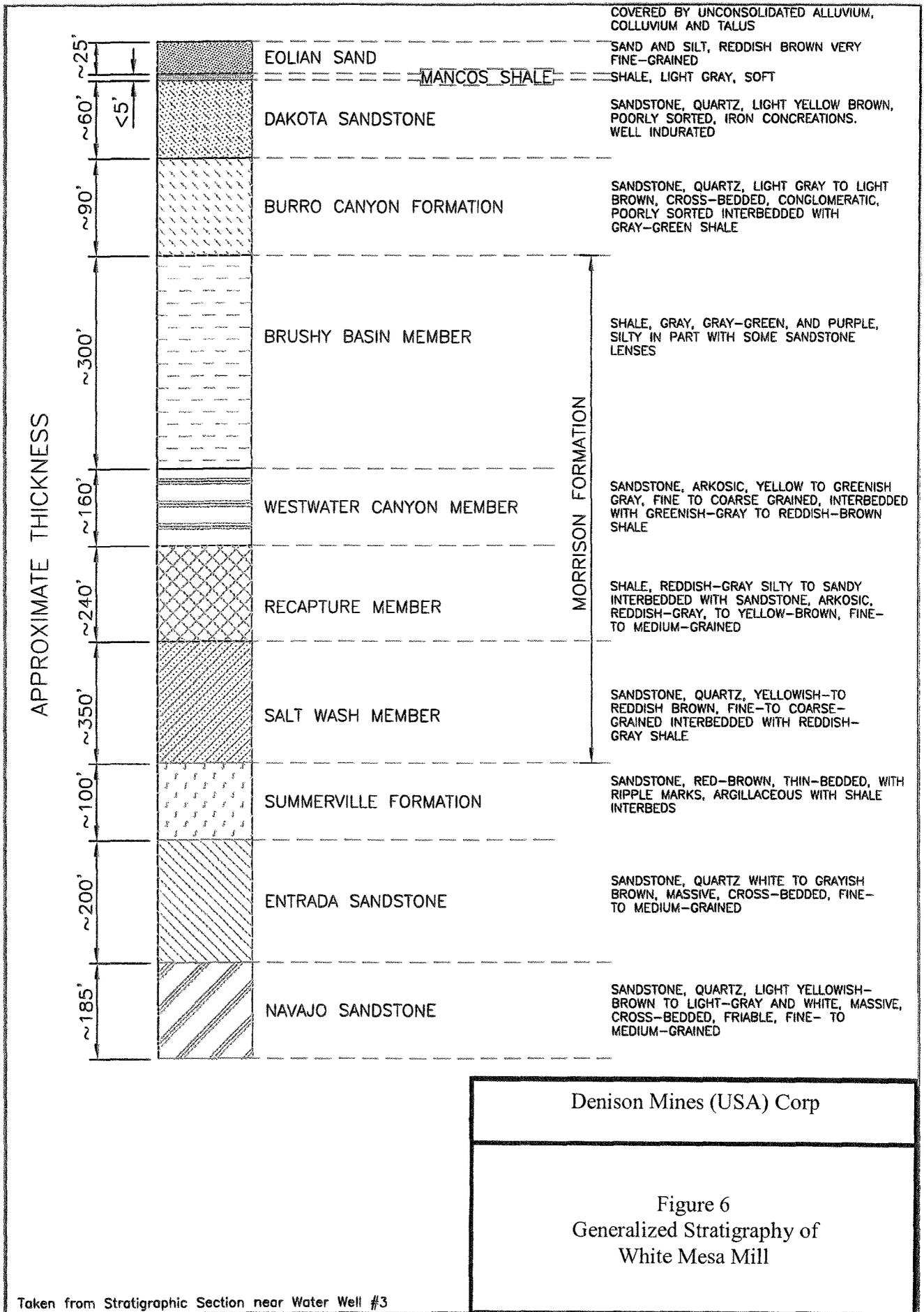
From USGS 7.5 minute quad sheet for Black Mesa



PROPERTY BOUNDARY

Denison Mines (USA) Corp

Figure 5  
Local Topography  
And Location of Ruin Spring



The Summerville Formation, Entrada Sandstone, and Navajo Sandstone are the deepest units of concern encountered at the site.

## 6.2 Local Geology

The Mill site is located on the western edge of the Blanding Basin, sometimes referred to as the Great Sage Plain, lying east of the north/south-trending Monument Uplift, south of the Abajo Mountains and adjacent to the northwest-trending Paradox Fold and Fault Belt. The Abajo Mountains are the most prominent topographic feature in the region, rising over 4,000 ft above the surface of the plain. The lithology of the immediate area is composed of thousands of feet of multi-colored pre-Tertiary age marine and non-marine sedimentary rocks. Erosion on the regionally-uplifted sedimentary strata has produced an array of eroded canyons and mesas.

The Mill is more specifically located on White Mesa and rests on alluvial windblown silt and sand which covers sandstones and shales of Jurassic and Cretaceous age. The surface of the mesa is nearly flat, with a surface relief of 98 ft. The maximum relief between White Mesa and the adjacent Cottonwood Canyon is about 750 ft.

## 6.3 Site-Specific Geologic Setting

The Mill is located within the Blanding Basin of the Colorado Plateau physiographic province. Typical of large portions of the Colorado Plateau province, the rocks underlying the site are relatively underformed. The average elevation of the site is approximately 5,600 ft (1,707 m) above mean sea level (amsl).

The site is underlain by unconsolidated alluvium and indurated sedimentary rocks consisting primarily of sandstone and shale. The indurated rocks are relatively flat lying with dips generally less than 3°. The alluvial materials consist mostly of aeolian silts and fine-grained aeolian sands with a thickness varying from a few feet to as much as 25 to 30 ft (7.6 to 9.1 m) across the site. The alluvium is underlain by the Dakota Sandstone and Burro Canyon Formation, which are sandstones having a total thickness ranging from approximately 100 to 140 ft (31 to 43 m). Beneath the Burro Canyon Formation lies the Morrison Formation, consisting, in descending order, of the Brushy Basin Member, the Westwater Canyon Member, the Recapture Member, and the Salt Wash Member. The Brushy Basin and Recapture Members of the Morrison Formation, classified as shales, are very fine-grained and have a very low permeability. The Westwater Canyon and Salt Wash Members also have a low average vertical permeability due to the presence of interbedded shales. See Figure 6 for a generalized stratigraphic column for the region.

Beneath the Morrison Formation lies the Summerville Formation, an argillaceous sandstone with interbedded shales, and the Entrada Sandstone. Beneath the Entrada lies the Navajo Sandstone. The Navajo and Entrada Sandstones constitute the primary aquifer in the area of the site. The Entrada and Navajo Sandstones are separated from the Burro Canyon Formation by approximately 1,000 to 1,100 ft (305 to 335 m) of materials having a low average vertical permeability. Groundwater within this system is under

artesian pressure in the vicinity of the site, and is used only as a secondary source of water at the site.

## 7.0 Hydrogeologic Setting

The site is located within a region that has a dry to arid continental climate, with average annual precipitation of approximately 13.4 in. Recharge to aquifers occurs primarily along the mountain fronts (for example, the Henry, Abajo, and La Sal Mountains), and along the flanks of folds such as Comb Ridge Monocline.

Although the water quality and productivity of the Navajo/Entrada aquifer are generally good, the depth of the aquifer (approximately 1,200 ft below land surface (bls)) makes access difficult. The Navajo/Entrada aquifer is capable of yielding significant quantities of water to wells (hundreds of gallons per minute (gpm)). Water in wells completed across these units at the site rises approximately 800 ft above the base of the overlying Summerville Formation.

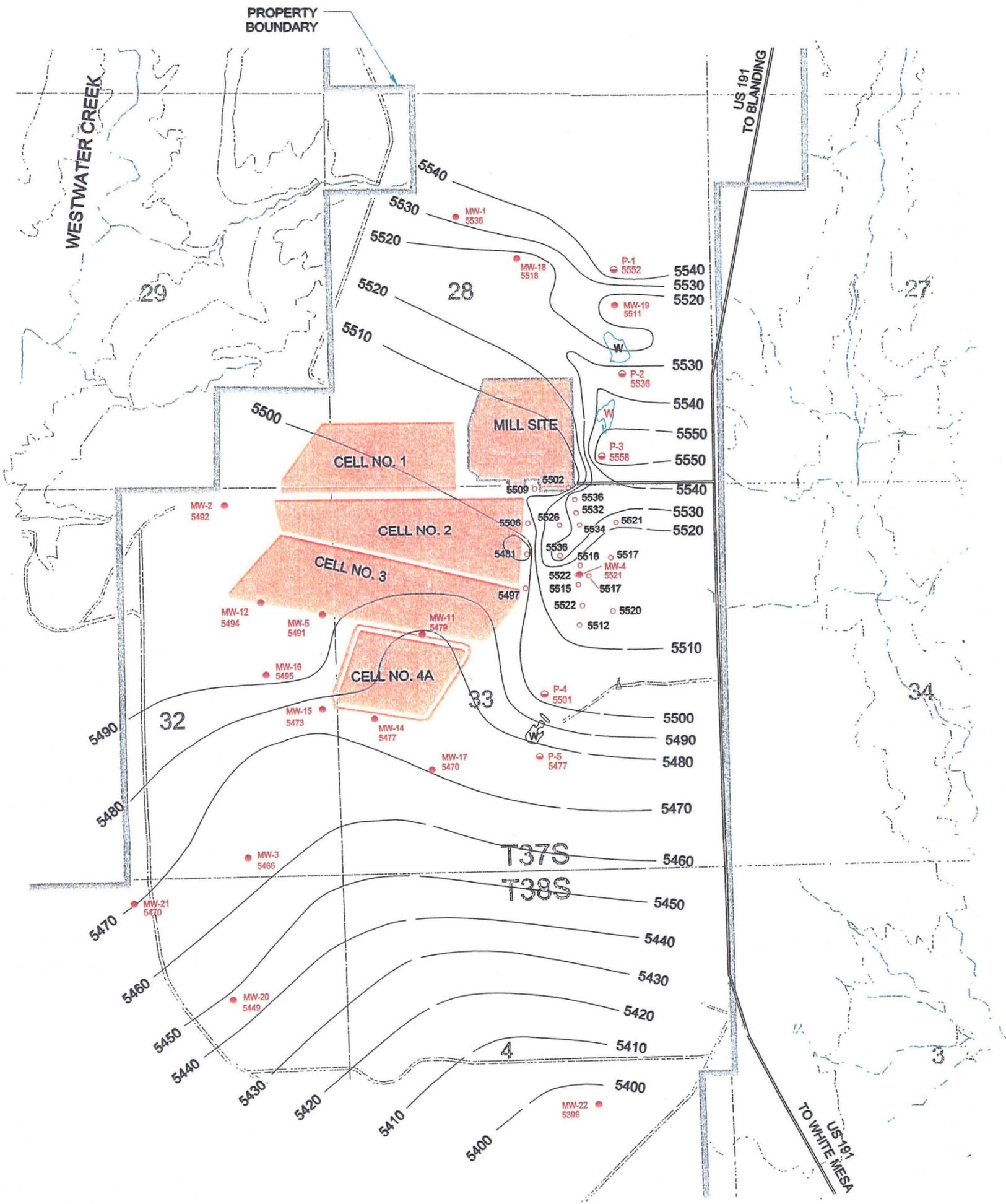
### 7.1 Perched Zone Hydrogeology

Perched groundwater beneath the site occurs primarily within the Burro Canyon Formation. Perched groundwater at the site has a generally low quality due to high total dissolved solids (TDS) in the range of 1,200 to 5,000 milligrams per liter (mg/L), and is used primarily for stock watering and irrigation in the areas upgradient (north) of the site. The saturated thickness of the perched water zone generally increases to the north of the site, increasing the yield of the perched zone to wells installed north of the site. Perched water is supported within the Burro Canyon Formation by the underlying, fine-grained Brushy Basin Member. Figure 7 is a contour map showing the approximate elevation of the contact of the Burro Canyon Formation with the Brushy Basin Member, which essentially forms the base of the perched water zone at the site. Contact elevations are based on monitoring well drilling and geophysical logs and surveyed land surface elevations. As indicated, the contact generally dips to the south/southwest beneath the site.

The permeability of the Dakota Sandstone and Burro Canyon Formation at the site is generally low. No significant joints or fractures within the Dakota Sandstone or Burro Canyon Formation have been documented in any wells or borings installed across the site (Knight Piésold, 1998). Any fractures observed in cores collected from site borings are typically cemented, showing no open space.

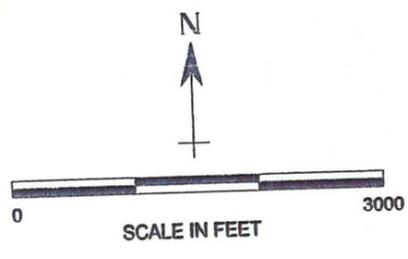
Based on samples collected during installation of wells MW-16 and MW-17 (the locations of the various monitoring wells are indicated on Figure 7), located immediately downgradient of the tailings cells at the site, porosities of the Dakota Sandstone range from 13.4% to 26%, averaging 20%, and water saturations range from 3.7% to 27.2%, averaging 13.5%. The average volumetric water content is approximately 3%. The permeability of the Dakota Sandstone based on packer tests in borings installed at the site ranges from 2.71E-06 centimeters per second (cm/s) to 9.12E-04 cm/s, with a geometric average of 3.89E-05 cm/s.

Fig. 7



**EXPLANATION**

- MW-11 5479 PERCHED MONITORING WELL SHOWING APPROXIMATE ELEVATION OF BRUSHY BASIN CONTACT IN FEET AMSL
- 5536 TEMPORARY PERCHED MONITORING WELL SHOWING APPROXIMATE ELEVATION OF BRUSHY BASIN CONTACT IN FEET AMSL
- ⊖ P-5 5552 PIEZOMETER SHOWING APPROXIMATE ELEVATION OF BRUSHY BASIN CONTACT IN FEET AMSL
- W WILDLIFE POND
- 5410 ——— CONTOUR LINE IN FEET AMSL, DASHED WHERE UNCERTAIN



Denison Mines (USA) Corp

Figure 7  
White Mesa Mill  
Approximate Elevation  
Top of Brushy Basin

The average porosity of the Burro Canyon Formation is similar to that of the Dakota Sandstone. Based on samples collected from the Burro Canyon Formation at MW-16, located immediately downgradient of the tailings cells at the site, porosity ranges from 2% to 29.1%, averaging 18.3%, and water saturations of unsaturated materials range from 0.6% to 77.2%, averaging 23.4%. Titan, 1994, reported that the hydraulic conductivity of the Burro Canyon Formation ranges from 1.9E-07 to 1.6E-03 cm/s, with a geometric mean of 1.1E-05 cm/s, based on the results of 12 pump/recovery tests performed in monitoring wells and 30 packer tests performed in borings prior to that time.

Hydraulic testing of wells MW-1, MW-3, MW-5, MW-17, MW-18, MW-19, MW-20, and MW-22 during the week of July 8, 2002, yielded average perched zone permeabilities ranging from approximately 4.0E-07 cm/s to 5.0E-04 cm/s, similar to the range reported by previous investigators at the site (HGC, 2002). Downgradient (south to southwest) of the tailings cells, average perched zone permeabilities based on tests at MW-3, MW-5, MW-17, MW-20, and MW-22 ranged from approximately 4.0E-07 to 4.0E-05 cm/s. Permeability estimates were based on pump/recovery and slug tests analyzed using several different methodologies.

A number of temporary monitoring wells have been installed at the site to investigate elevated concentrations of chloroform initially discovered at well MW-4 in 1999. Some of the conglomeratic zones encountered within the perched zone during installation of these wells are believed to be partly continuous or at least associated with a relatively continuous zone of higher permeability (IUSA and HGC, 2001). The higher permeability zone defined by these wells is generally located east to northeast of the tailings cells at the site, and is hydraulically cross-gradient to upgradient of the tailings cells with respect to perched groundwater flow. Relatively high permeabilities measured at MW-11, located on the southeastern margin of the downgradient edge of tailings Cell 3, and at MW-14, located on the downgradient edge of tailings Cell 4, of 1.4E-03 cm/s and 7.5E-04 cm/s, respectively (UMETCO, 1993), may indicate that this zone extends beneath the southeastern margin of the cells. This zone of higher permeability within the perched water zone does not appear to exist downgradient (south-southwest) of the tailings cells, however. At depths beneath the perched water table, the zone is not evident in lithologic logs of the southernmost temporary wells TW4-4 and TW4-6 (located east (cross-gradient) of Cell 3), nor is it evident in wells MW-3, MW-5, MW-12, MW-15, MW-16, MW-17, MW-20, MW-21, or MW-22, located south to southwest (downgradient) of the tailings cells, based on the lithologic logs or hydraulic testing of the wells.

Because of the generally low permeability of the perched zone beneath the site, well yields are typically low (less than 0.5 gpm), although yields of about 2 gpm may be possible in wells intercepting the higher permeability zones on the east side of the site. Sufficient productivity can, in general, only be obtained in areas where the saturated thickness is greater, which is the primary reason that the perched zone has been used on a limited basis as a water supply to the north (upgradient) of the site.

## 7.2 Perched Groundwater Flow

Perched groundwater flow at the site is generally to the south/southwest. Figure 8 displays the local perched groundwater elevation contours at the Mill. As indicated, the perched groundwater gradient changes from generally southwesterly in the western portion of the site to generally southerly in the eastern portion of the site.

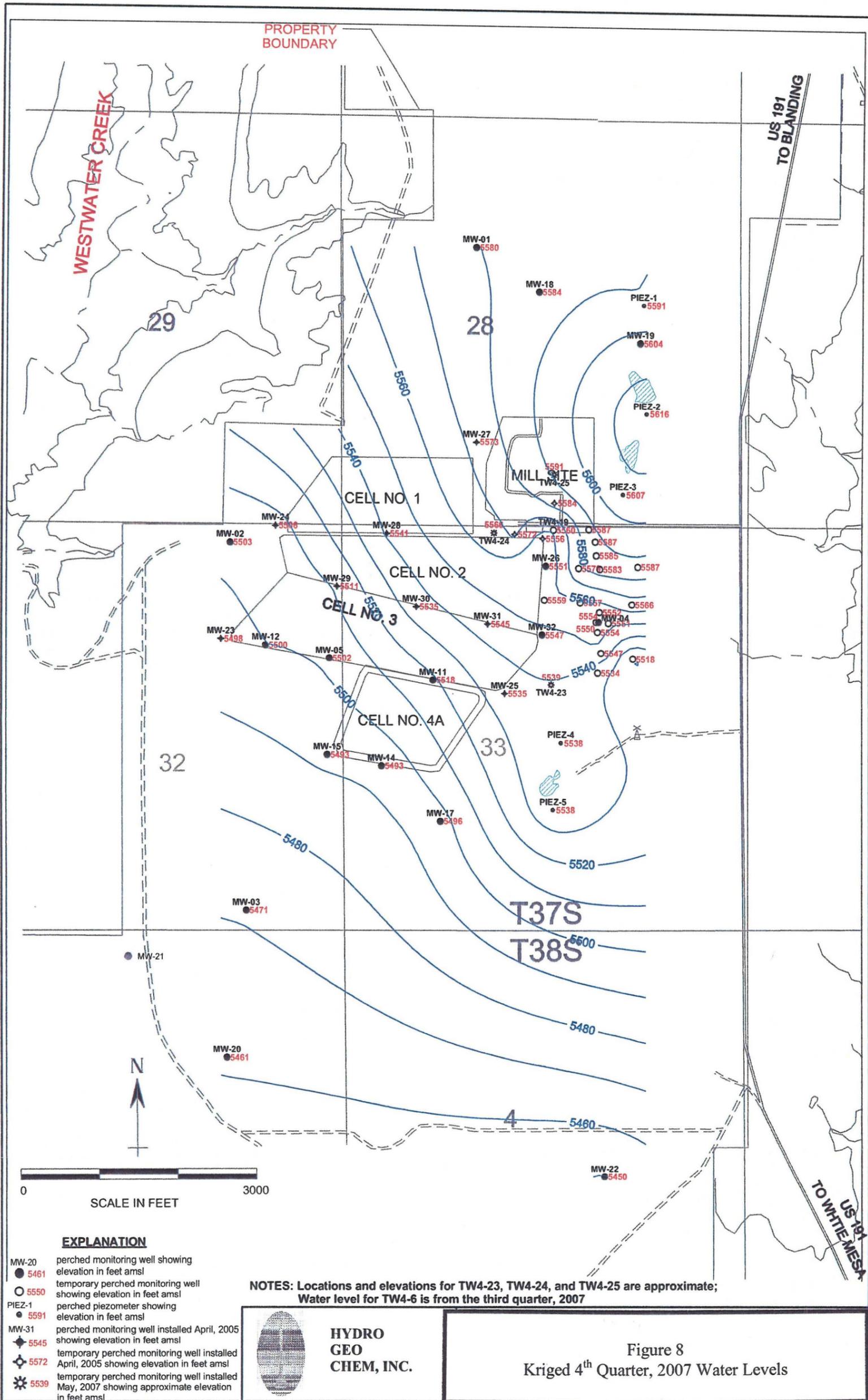
Perched water discharges in springs and seeps along Westwater Creek Canyon and Cottonwood Canyon to the west-southwest of the site, and along Corral Canyon to the east of the site, where the Burro Canyon Formation outcrops. Perched water flowing beneath the tailings cells eventually discharges in springs and seeps located in Westwater Canyon, to the south-southwest of the cells. The primary discharge point for perched water flowing beneath the tailings cells is believed to be Ruin Spring, located approximately 10,000 ft south-southwest of the Mill site, as shown in Figure 9.

## 7.3 Perched Zone Hydrogeology (Beneath and Down-gradient Of the Tailings Cells)

As of the 4th Quarter, 2006, perched water has been encountered at depths of approximately 50 to 115 ft bbs in the vicinity of the tailings cells at the site (Figure 10). Beneath tailings Cell 3, depths to water ranged from approximately 72 ft below top of casing (btoc) east of the cell (at MW-31), to approximately 115 ft btoc at the southwest margin of the cell (at MW-23). Assuming an average depth of the base of tailings Cell 3 of 25 ft below grade, this corresponds to perched water depths of approximately 47 to 90 ft below the base of the cell, or an average depth of approximately 70 feet beneath the base of the cell.

The saturated thickness of the perched zone as of the 4th Quarter, 2006 ranged from approximately 94 ft in the northeast portion of the site to less than 5 ft in the southwest portion of the site. Beneath tailings Cell 3, the saturated thickness varies from approximately 49 ft in the easternmost corner of the cell to approximately 6 ft in the westernmost corner of the cell. South-southwest of the tailings cells, the saturated thickness ranges from less than 1 ft at MW-21 to approximately 25 ft at MW-17. The average saturated thickness south-southwest of the tailings cells, based on measurements at MW-3, MW-5, MW-12, MW-14, MW-15, MW-17, and MW-20, is approximately 14 ft. The average saturated thickness based on measurements at MW-5, MW-15, MW-3, and MW-20, which lay close to a line between the center of tailings Cell 3 and Ruin Spring, is approximately 12 ft. By projecting conditions at these wells, the average saturated thickness is estimated to be approximately 10 to 15 ft between MW-20 and Ruin Spring.

Fig. 8



PROPERTY BOUNDARY

WESTWATER CREEK

US 191 TO BLANDING

US 191 TO WHITE MESA

T37S  
T38S

0 3000  
SCALE IN FEET

- EXPLANATION**
- MW-20 ● 5461 perched monitoring well showing elevation in feet amsl
  - 5550 temporary perched monitoring well showing elevation in feet amsl
  - PIEZ-1 ● 5591 perched piezometer showing elevation in feet amsl
  - MW-31 ● 5545 perched monitoring well installed April, 2005 showing elevation in feet amsl
  - ◆ 5572 temporary perched monitoring well installed April, 2005 showing elevation in feet amsl
  - ✱ 5539 temporary perched monitoring well installed May, 2007 showing approximate elevation in feet amsl

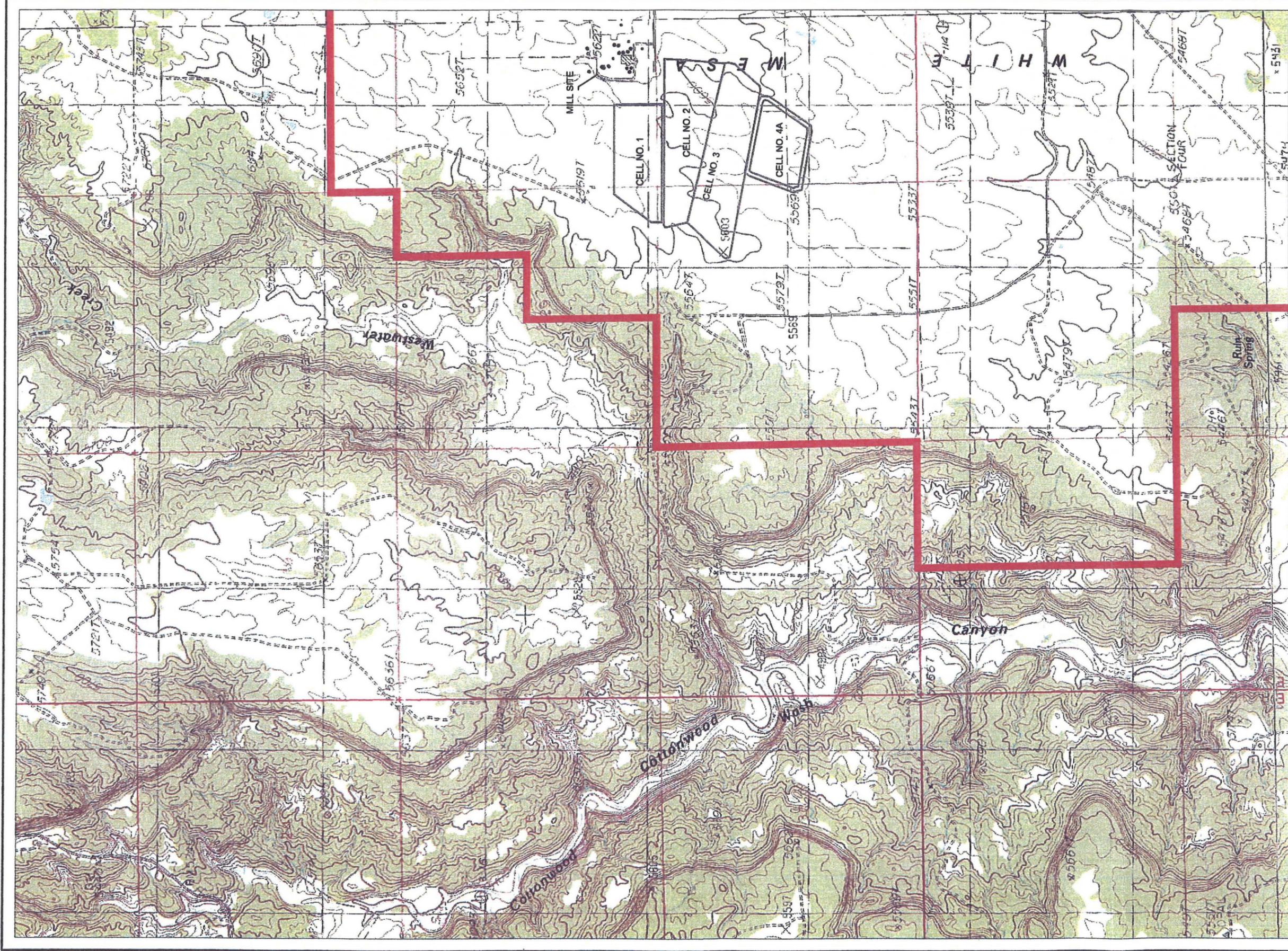
NOTES: Locations and elevations for TW4-23, TW4-24, and TW4-25 are approximate; Water level for TW4-6 is from the third quarter, 2007



HYDRO  
GEO  
CHEM, INC.

Figure 8  
Kriged 4<sup>th</sup> Quarter, 2007 Water Levels

Fig. 9



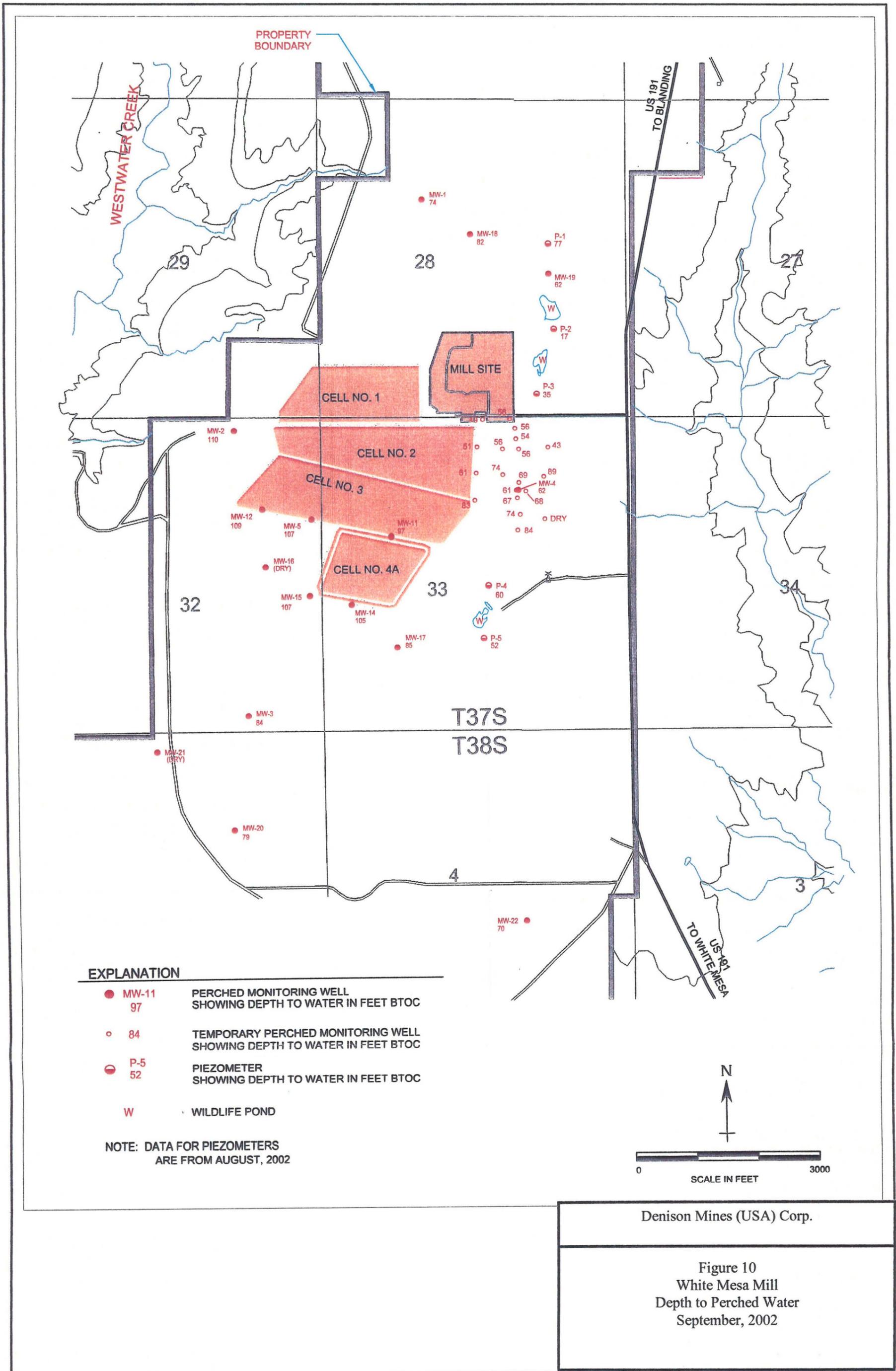
From USGS 7.5 minute quad sheet for Black Mesa

Denison Mines (USA) Corp

Figure 9  
White Mesa Mill  
Approximate Location  
Ruin Spring

PROPERTY BOUNDARY

Fig. 10



Perched zone hydraulic gradients currently range from a maximum of approximately 0.04 feet per foot (ft/ft) immediately northeast of tailings Cell 3 to less than 0.01 ft/ft downgradient of Cell 3, between Cell 3 and MW-20. The average hydraulic gradient between the downgradient edge of tailings Cell 3 and Ruin Spring was approximated by HGC to be approximately 0.012 ft/ft. HGC also estimated a hypothetical worst case average perched zone hydraulic gradient, assuming the perched water elevation to be coincident with the base of tailings Cell 3, to be approximately 0.019 ft/ft. See Section 3.2 of Appendix A.

HGC also estimated the average permeability of the perched zone downgradient of tailings Cell 3, based on pump/recovery test and slug test data obtained from perched zone wells located along the downgradient edge of and south of Cell 3, to be between 2.39E-05 cm/s and 4.3E-05 cm/s. See Section 3.3 of Appendix A to the February 28, 2007 Environmental Report incorporated here by reference.

#### 7.4 Groundwater Quality

##### 7.4.1 Entrada/Navajo Aquifer

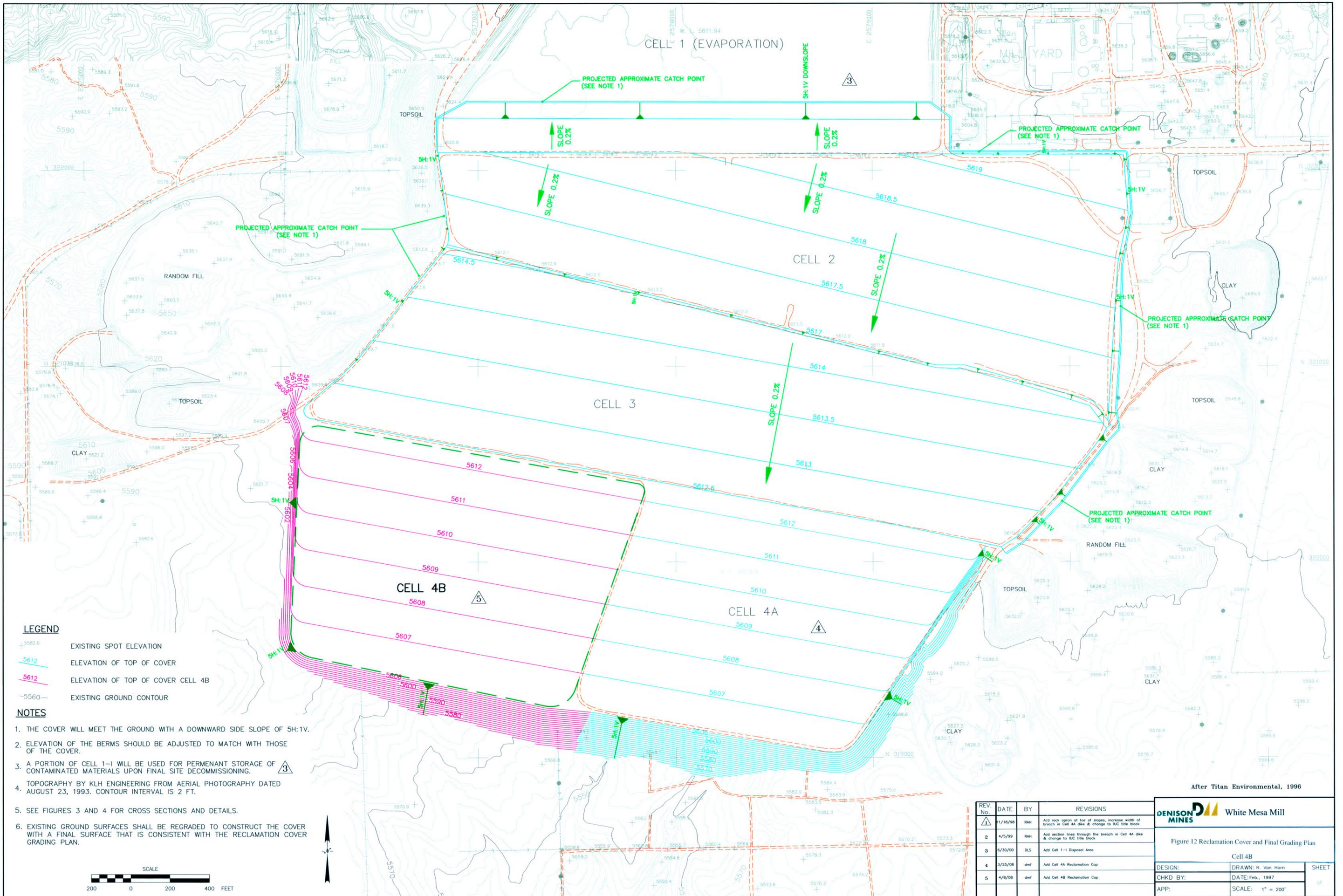
The Entrada and Navajo Sandstones are prolific aquifers beneath and in the vicinity of the site. Water wells at the site are screened in both of these units, and therefore, for the purposes of this discussion, they will be treated as a single aquifer. Water in the Entrada/Navajo Aquifer is under artesian pressure, rising 800 to 900 ft above the top of the Entrada's contact with the overlying Summerville Formation; static water levels are 390 to 500 ft below ground surface.

Within the region, this aquifer is capable of yielding domestic quality water at rates of 150 to 225 gpm, and for that reason, it serves as a secondary source of water for the Mill. Additionally, two domestic water supply wells drawing from the Entrada/Navajo Aquifer are located 4.5 miles southeast of the Mill site on the Ute Mountain Ute Reservation. Although the water quality and productivity of the Navajo/Entrada aquifer are generally good, the depth of the aquifer (>1,000 ft bls) makes access difficult.

Table 2 is a tabulation of groundwater quality of the Navajo Sandstone aquifer as reported in the FES and subsequent sampling. The total dissolved solids (TDS) range from 244 to 1,110 mg/liter in three samples taken over a period from January 27, 1977, to May 4, 1977. High iron (0.057 mg/liter) concentrations are found in the Navajo Sandstone. Because the Navajo Sandstone aquifer is isolated from the perched groundwater zone by approximately 1,000 to 1,100 ft of materials having a low average vertical permeability, sampling of the Navajo Sandstone is not required under the Mill's previous NRC Point of Compliance monitoring program or under the state's GWDP. However, samples were taken at two other deep aquifer wells (#2 and #5) on site (See Figure 11 for the locations of these wells), on June 1, 1999 and June 8, 1999, respectively, and the results are included in Table 2.

Fig. 11





**LEGEND**

- + 5582.6 EXISTING SPOT ELEVATION
- 5612 ELEVATION OF TOP OF COVER
- 5612 ELEVATION OF TOP OF COVER CELL 4B
- 5560 EXISTING GROUND CONTOUR

**NOTES**

1. THE COVER WILL MEET THE GROUND WITH A DOWNWARD SIDE SLOPE OF 5H:1V.
2. ELEVATION OF THE BERMS SHOULD BE ADJUSTED TO MATCH WITH THOSE OF THE COVER.
3. A PORTION OF CELL 1-1 WILL BE USED FOR PERMANENT STORAGE OF CONTAMINATED MATERIALS UPON FINAL SITE DECOMMISSIONING.
4. TOPOGRAPHY BY KLH ENGINEERING FROM AERIAL PHOTOGRAPHY DATED AUGUST 23, 1993. CONTOUR INTERVAL IS 2 FT.
5. SEE FIGURES 3 AND 4 FOR CROSS SECTIONS AND DETAILS.
6. EXISTING GROUND SURFACES SHALL BE REGRADED TO CONSTRUCT THE COVER WITH A FINAL SURFACE THAT IS CONSISTENT WITH THE RECLAMATION COVER GRADING PLAN.

After Titan Environmental, 1996



REV. No.	DATE	BY	REVISIONS
1	11/18/98	RAH	Add rock apron at toe of slopes, increase width of breach in Cell 4A dike & change to IUC title block
2	4/5/99	RAH	Add section lines through the breach in Cell 4A dike & change to IUC title block
3	6/30/00	DLS	Add Cell 1-1 Disposal Area
4	3/25/08	dmf	Add Cell 4A Reclamation Cap
5	4/8/08	dmf	Add Cell 4B Reclamation Cap

**White Mesa Mill**

Figure 12 Reclamation Cover and Final Grading Plan

Cell 4B

DESIGN:	DRAWN: R. Van Horn	SHEET
CHKD BY:	DATE: Feb., 1997	of
APP:	SCALE: 1" = 200'	

**Table 2**  
**Water Quality of Groundwater in the Mill Vicinity**

<b>Parameter</b>	<b>FES, Test Well (G2R) (1/27/77 - 3/23/78<sup>1</sup>)</b>	<b>Well #2 6/01/99<sup>1</sup></b>	<b>Well #5 6/08/99<sup>1</sup></b>
Field Specific Conductivity (umhos/cm)	310 to 400		
Field pH	6.9 to 7.6		
Temperature (°C)	11 to 22		
Estimated Flow m/hr (gpm)	109(20)		
pH	7.9 to 8.16		
<b>Determination, mg/liter</b>			
TDS (@180°C)	216 to 1110		
Redox Potential	211 to 220		
Alkalinity (as CaCO <sub>3</sub> )	180 to 224		
Hardness, total (as CaCO <sub>3</sub> )	177 to 208		
Bicarbonate		226	214
Carbonate (as CO <sub>3</sub> )	0.0	<1.0	<1.0
Aluminum		0.003	0.058
Aluminum, dissolved	<0.1		
Ammonia (as N)	0.0 to 0.16	<0.05	<0.05
Antimony		<0.001	<0.001
Arsenic, total	.007 to 0.014	0.018	<0.001
Barium, total	0.0 to 0.15	0.119	0.005
Beryllium		<0.001	<0.001
Boron, total	<0.1 to 0.11		
Cadmium, total	<0.005 to 0.0	<0.001	0.018
Calcium		50.6	39.8
Calcium, dissolved	51 to 112		
Chloride	0.0 to 50	<1.0	2.3
Sodium		7.3	9.8
Sodium, dissolved	5.3 to 23		
Silver		<0.001	<0.001
Silver, dissolved	<0.002 to 0.0		
Sulfate		28.8	23.6
Sulfate, dissolved (as SO <sub>4</sub> )	17 to 83		
Vanadium		0.003	0.003
Vanadium, dissolved	<.002 to 0.16		
Manganese		0.011	0.032
Manganese, dissolved	0.03 to 0.020		
Chromium, total	0.02 to 0.0	0.005	0.005
Copper, total	0.005 to 0.0	0.002	0.086
Fluoride		0.18	0.18
Fluoride, dissolved	0.1 to 0.22		
Iron, total	0.35 to 2.1	0.43	0.20
Iron, dissolved	0.30 to 2.3		

<sup>1</sup> Zero values (0.0) are below detection limits.

Parameter	FES, Test Well (G2R) (1/27/77 - 3/23/78 <sup>1</sup> )	Well #2 6/01/99 <sup>1</sup>	Well #5 6/08/99 <sup>1</sup>
Lead, total	0.02 - 0.0	<0.001	0.018
Magnesium		20.4	21.3
Magnesium, dissolved	15 to 21		
Mercury, total	<.00002 to 0.0	<0.001	<0.001
Molybdenum		0.001	<0.001
Molybdenum, dissolved	0.004 to 0.010		
Nickel		<0.001	0.004
Nitrate + Nitrate as N		<0.10	<0.10
Nitrate (as N)	<.05 to 0.12		
Phosphorus, total (as P)	<0.01 to 0.03		
Potassium		3.1	3.3
Potassium, dissolved	2.4 to 3.2		
Selenium		<0.001	<0.001
Selenium, dissolved	<.005 to 0.0		
Silica, dissolved (as SiO <sub>2</sub> )	5.8 to 12		
Strontium, total (as U)	0.5 to 0.67		
Thallium		<0.001	<0.001
Uranium, total (as U)	<.002 to 0.16	0.0007	0.0042
Uranium, dissolved (as U)	<.002 to 0.031		
Zinc		0.010	0.126
Zinc, dissolved	0.007 to 0.39		
Total Organic Carbon	1.1 to 16		
Chemical Oxygen Demand	<1 to 66		
Oil and Grease	1		
Total Suspended Solids	6 to 1940	<1.0	10.4
Turbidity		5.56	19.1
<b>Determination (pCi/liter)</b>			
Gross Alpha			<1.0
Gross Alpha ± precision	1.6±1.3 to 10.2±2.6		
Gross Beta			<2.0
Gross Beta ± precision	8±8 to 73±19		
Radium 226 ± precision			0.3±0.2
Radium 228			<1.0
Ra-226 ± precision	0.1±.3 to 0.6±0.4		
Th-230 ± precision	0.1±0.4 to 0.7±2.7		
Pb-210 ± precision	0.0±4.0 to 1.0±2.0		
Po-210 ± precision	0.0±0.3 to 0.0±0.8		

Source: Adapted from FES Table 2.25 with additional Mill sampling data

#### 7.4.2 Perched Groundwater Zone

Perched groundwater in the Dakota/Burro Canyon Formation is used on a limited basis to the north (upgradient) of the site because it is more easily accessible. The quality of the Burro Canyon perched water beneath and downgradient from the site is poor and extremely variable. The concentrations of total dissolved solids (TDS) measured in water sampled from upgradient and downgradient wells range between approximately 1,200 and 5,000 mg/l. Sulfate concentrations measured in three upgradient wells varied between 670 and 1,740 mg/l (Titan, 1994). The perched groundwater therefore is used primarily for stock watering and irrigation.

The saturated thickness of the perched water zone generally increases to the north of the site. See the Background Groundwater Quality Report: Existing Wells For Denison Mines (USA) Corp.'s White Mesa Mill Site, San Juan County, Utah dated December 2006 prepared by Intera, Inc., Appendix B.

At the time of renewal of the Mill license by the NRC in March, 1997 and up until issuance of the Mill's Groundwater Discharge Permit ("GWDP") in March 2005, the Mill implemented a groundwater detection monitoring program to ensure compliance to 10 CFR Part 40, Appendix A, in accordance with the provisions of Mill License condition 11.3A. The detection monitoring program was in accordance with the report entitled, "Points of Compliance, White Mesa Uranium Mill," submitted by letter to the NRC dated October 5, 1994. Under that program, the Mill sampled monitoring wells MW-5, MW-11, MW-12, MW-14, MW-15 and MW-17, on a quarterly basis. Samples were analyzed for chloride, potassium, nickel and uranium, and the results of such sampling were included in the Mill's Semi-Annual Effluent Monitoring Reports that were filed with the NRC up until August 2004 and with the DRC subsequent thereto.

Prior to 1997, commencing in 1979, the Mill monitored up to 20 constituents in up to 13 wells. That program was changed to the Points of Compliance Program in 1997 because:

- The Mill and tailings system had produced no impacts to the perched zone or deep aquifer; and
- The most dependable indicators of water quality and potential cell failure were considered to be chloride, nickel, potassium and natural uranium.

## **8.0 Ecological Resources and Biota**

### **8.1 Terrestrial**

#### **a) Flora**

The natural vegetation presently occurring within a 25-mile (40-km) radius of the Mill site is very similar to that of the region, being characterized by pinyon-juniper woodland intergrading with big sagebrush (*Artemisia tridentata*) communities. The pinyon-juniper community is dominated by Utah juniper (*Juniperus osteosperma*) with occurrences of pinyon pine (*Pinus edulis*) as a codominant or subdominant tree species. The understory of this community, which is usually quite open, is composed of grasses, forbs, and shrubs that are also found in the big sagebrush communities. Common associates include galleta grass (*Hilaria jamesii*), green ephedra (*Ephedra viridis*), and broom snakewood (*Gutierrezia sarothrae*). The big sagebrush communities occur in deep, well-drained soils on flat terrain, whereas the pinyon-juniper woodland is usually found on shallow rocky soil of exposed canyon ridges and slopes. See Section 2.9 of the 1978 ER.

Based on the work completed by Dames & Moore in the 1978 ER, no designated or proposed endangered plant species occur on or near the project site (1978 ER, Section 2.8.2.1). Of the 65 proposed endangered species in Utah at that time, six have documented distributions in San Juan

County. A careful review of the habitat requirements and known distributions of these species by Dames & Moore in the 1978 ER indicated that, because of the disturbed environment, these species would probably not occur on the project site. The Navajo Sedge has been added to the list as a threatened species since the Dames & Moore study.

In completing the 2002 EA, NRC staff contacted wildlife biologists from the BLM and the Utah Wildlife Service to gather local information on the occurrences of additional species surrounding the Mill. In the 2002 EA, NRC staff concluded that the Navajo Sedge has not been observed in the area surrounding Blanding, and is typically found in areas of moisture (2002 EA at 4).

#### b) Fauna

Wildlife data were collected by Dames & Moore through four seasons at several locations on the Mill site, prior to construction of the Mill. The presence of a species was based on direct observations, trappings and signs such as the occurrence of scat, tracks, or burrows. A total of 174 vertebrate species potentially occur within the vicinity of the Mill (1978 ER, Appendix D), 78 of which were confirmed (1978 ER, Section 2.8.2.2).

Although seven species of amphibians are thought to occur in the area, the scarcity of surface water limits the use of the site by amphibians. Eleven species of lizards and five snakes potentially occur in the area (1978 ER, Section 2.8.2.2).

Fifty-six species of birds were observed in the vicinity of the Mill site (1978 ER, Section 2.8.2.2).

The food habits of eagles vary depending on the season and the region in which they live. Fish, carrion and waterfowl such as mallard, are consumed by eagles when available to them. The FES indicates that mallards are both common and permanent in the vicinity of the Mill (FES, Table 2.28).

Raptors are prominent in the western United States. Five species were observed in the vicinity of the site. Although no nests of these species were located at the time of the FES, all (except the golden eagle, *Aquila chrysaetos*) have suitable nesting habitat in the vicinity of the site. The nest of a prairie falcon (*Falco mexicanus*) was found about 3/4 mile (1.2 km) east of the site. Although no sightings were made of this species, members tend to return to the same nests for several years if undisturbed (1978 ER, Section 2.8.2.2).

Of several mammals that occupy the site, mule deer (*Odocoileus hemionus*) is the largest species. The deer inhabit the project vicinity and adjacent canyons during winter to feed on the sagebrush and have been observed migrating through the site to Murphy Point (1978 ER, Section 2.8.2.2). Winter deer use of the project vicinity, as measured by browse utilization, is among the heaviest in southeastern Utah at 25 days of use per acre in the pinyon-juniper-sagebrush habitats in the vicinity of the project site. In addition, this area is heavily used as a migration route by deer traveling to Murphy Point to winter. Daily movement during winter periods by deer inhabiting the area has also been observed between Westwater Creek and Murphy Point. The present size of the local deer herd is not known.

Other mammals present at the site include the coyote (*Canis latrans*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), badger (*taxidea taxus*), longtail weasel (*Mustela frenata*), and bobcat (*Lynx rufus*). Nine species of rodents were trapped or observed on the site, the deer mouse (*Peromyscus maniculatus*) having the greatest distribution and abundance. Although desert cottontails (*Sylvilagus auduboni*) were uncommon in 1977, black-tailed jackrabbits (*Lepus californicus*) were seen during all seasons.

In the 2002 EA, NRC staff noted that, in the vicinity of the site, the U.S. Fish and Wildlife Service had provided the list set out in Table 3.12-1, of the endangered, threatened, and candidate species that may occur in the area around the site.

**Table 3 Endangered, Threatened and Candidate Species in the Mill Area**

Common Name	Scientific Name	Status
Navajo Sedge	<i>Carex specuicola</i>	Threatened
Bonytail Chub	<i>Gila elegans</i>	Endangered
Colorado Pikeminnow	<i>Ptychocheilus lucius</i>	Endangered
Humpback Chub	<i>Gila cypha</i>	Endangered
Razorback Sucker	<i>Xyrauchen texanus</i>	Endangered
Bald Eagle	<i>Haliaeetus leucocephalus</i>	Threatened
California Condor	<i>Gymnogyps californianus</i>	Endangered
Gunnison Sage Grouse	<i>Centrocercus minimus</i>	Candidate
Mexican Spotted Owl	<i>Strix occidentalis lucida</i>	Threatened
Southwestern Willow Flycatcher	<i>Empidonax traillii extimus</i>	Endangered
Western Yellow-billed Cuckoo	<i>Coccyzus americanus occidentalis</i>	Candidate
Black-footed Ferret	<i>Mustela nigripes</i>	Endangered

Source: 2002 EA

The 2002 EA also noted that, in addition, the species listed on Table 3.12-2 may occur within the Mill area that are managed under Conservation Agreements/Strategies

**Table 4  
Species Managed Under Conservation Agreements/Strategies at the Mill Area**

Common Name	Scientific Name
Colorado River Cutthroat Trout	<i>Oncorhynchus clarki pleuriticus</i>
Gunnison Sage Grouse	<i>Centrocercus minimus</i>

Source: 2002 EA

For the 2002 EA, NRC staff contacted wildlife biologists from the BLM and the Utah Wildlife Service to gather local information on the occurrences of these additional species surrounding the Mill. NRC staff made the following conclusions (2002 EA p. 4):

While the ranges of the bald eagle, peregrine falcon, and willow flycatcher encompass the project area, their likelihood of utilizing the site is extremely low. The black-footed ferret has not been seen in Utah since 1952, and is not expected to occur any longer in the area. The

California Condor has only rarely been spotted in the area of Moab, Utah, (70 miles north) and around Lake Powell (approximately 50 miles south). The Mexican Spotted Owl is only found in the mountains in Utah, and is not expected to be on the Mesa. The Southwestern Willow Flycatcher, Western Yellow-billed Cuckoo, and Gunnison Sage Grouse are also not expected to be found in the immediate area around the Mill site.

## 8.2 Aquatic and Wetlands Biota

Aquatic habitat at the Mill site ranges temporally from extremely limited to nonexistent due to the aridity, topography and soil characteristics of the region and consequent dearth of perennial surface water. Two small stockwatering ponds are located on the Mill site a few hundred yards from the ore pad area (See Figure 11). One additional small “wildlife pond”, east of Cell 4A, was completed in 1994 to serve as a diversionary feature for migrating waterfowl. Although more properly considered features of the terrestrial environment, these ponds essentially represent the total aquatic habitat on the Mill site. These ponds probably harbor algae, insects, other invertebrate forms, and amphibians. They also provide a water source for small mammals and birds. Similar ephemeral catch and seepage basins are typical and numerous to the northeast of the Mill site and south of Blanding.

Aquatic habitat in the Mill vicinity is similarly limited. The three adjacent streams (Corral Creek, Westwater Creek, and an unnamed arm of Cottonwood Wash) are only intermittently active, carrying water primarily in the spring during increased rainfall and snowmelt runoff, in the autumn, and briefly during localized but intense electrical storms. Intermittent water flow most typically occurs in April, August, and October in those streams. Again, due to the temporary nature of these streams, their contribution to the aquatic habitat of the region is probably limited to providing a water source for wildlife and a temporary habitat for insect and amphibian species.

In the 2002 EA, NRC staff concluded that (p. 4) no populations of fish are present on the project site, nor are any known to exist in the immediate area of the site. Four species of fish designated as endangered or threatened (the Bonytail Chub, Colorado Pikeminnow, Humpback Chub and Razorback Sucker) occur in the San Juan River 18 miles south of the site, which Dames & Moore noted in the 1978 ER (Section 2.8.2) is the closest habitat suitable for these species. NRC staff further concluded that there are no discharges of mill effluents to surface waters, and therefore, no impacts are expected for the San Juan River due to operations of the Mill.

## **9.0 Background Radiological and Non-Radiological Characteristics**

Background Radiological and Non-Radiological Effects have been evaluated, updated and reported extensively in Denison’s February 28, 2007 License Renewal Application and accompanying Environmental Report, incorporated here by reference.

## **10.0 Environmental Effects Related Directly to the Construction of Cell 4b**

The environmental effects of Cell 4b construction consist of those related to the release of airborne particulate (dusting), radon release from the operating cell, and the impact, if any, on

groundwater beneath the pond. In order to evaluate these environmental considerations two separate evaluations were completed, *Site Hydrogeology Estimation Of Groundwater Travel Times and Recommended Additional Monitoring Wells For Proposed Tailings Cell 4B White Mesa Uranium Mill Site Near Blanding, Utah, Hydro Geo Chem, Inc., 2008* and *Dose Assessment Pertaining to the Proposed Development of New Tailings Cells For the White Mesa Uranium Mill, SENES Consultants, Ltd, 2008.*

These evaluations are provided as Appendix A and Appendix B, respectively, and are discussed in summary in the pertinent subsections below.

#### 10.1 Groundwater Pathway Impact

The evaluation provided by Hydro Geo Chem Inc. finds that travel time for any water exiting the pond to the perched water zone and then to the point(s) of perched zone discharge is very long, far exceeding the time period of milling operations and closure of the tailings cells when little free liquid is available for infiltration through the cell liner system. More specifically, HGC found that the time for fluids that could be released from the cells to reach the points of seepage and spring formation at ruin spring and Cottonwood seep are on the order of several thousand years. However, this analysis is very conservative in that travel time through the pond liner was not considered, and because the liner system is robust state-of-the art construction, travel time through the liner is a significant protective factor. In fact, this aspect has been evaluated extensively by MWH Americas, Inc. in their report *Infiltration and Contaminant Transport Modeling Report, White Mesa Mill Site, Blanding Utah, November, 2007*, incorporated here by reference. The infiltration modeling effort revealed that the construction design for Cells 4a and 4b will meet the “Closed Cell Performance Requirements” of the Groundwater Discharge Permit at Part 1.D.6. More specifically, MWH concluded that the approved reclamation plan for the cells will meet the following regulatory requirements for a period of not less than 200 years:

- a) Minimize infiltration of precipitation or other surface water into the tailings, including but not limited to the radon barrier;
- b) Prevent the accumulation of leachate head within the tailings waste layer that could rise above or over-top the maximum FML liner elevation internal to any disposal cell, i.e. create a “bathtub” effect; and,
- c) Ensure that groundwater quality at the compliance monitoring wells does not exceed Ground Water Quality Standards or Ground Water Compliance Limits specified in Part 1.C.1 and Table 2 of the Permit.

#### 10.2 Proposed Additional Groundwater Monitoring

In order to monitor the performance of Cell 4b, and consistent with EPA Guidance, it was concluded by Hydro Geo Chem Inc. that an additional well or wells will be needed to monitor the Cell’s performance at the downgradient edge of the cell. This in addition to the many wells already incorporated into the Groundwater Discharge Permit for the facility. Accordingly, two additional wells are proposed, one at the southwest corner of proposed Cell 4b and one between the southwest corner well and existing well MW-15 (See Figure 10 of Appendix B. These

installations will conservatively maintain the approximate existing spacing as defined by the proximity of MW-14 to MW-15 along the downgradient edge of existing Cell 4a.

### 10.3 Radiological Impact

In February 2007, a dose assessment was prepared for DUSA by SENES Consultants, Ltd. in support of the license renewal application for the mill. MILDOS-AREA was used to estimate the dose commitments that could potentially be received by individuals and the general population within a 50 mile (80 km) radius for processing of conventional ores. The assessment was prepared for scenarios in which Colorado Plateau (0.25% U<sub>3</sub>O<sub>8</sub> and 1.5% V<sub>2</sub>O<sub>5</sub>) or Arizona Strip (0.637%) ores are processed at the mill.

In order to evaluate the radiological impact of Cell 4b's operation the prior dose assessment analyses was extended from the previous report of February 2007 to incorporate the dose from the proposed development of new tailings cells anticipated in the future. The results of this extended assessment are provided as Attachment B to this report (*Proposed Development of New Tailings cells For The White Mesa Uranium Mill, SENES, 2008*), and reveal that the addition of Cell 4b to the facility will not impact the ability of the facility to comply with regulatory requirements

The U.S. NRC approved MILDOS-AREA was used to estimate the dose commitments received by individuals and the general population within a 50 mile (80 km) radius of the site for the processing of either Colorado Plateau or Arizona Strip ore separately. In each scenario, the doses arising from emissions of dust and radon from the mill area and ore pads were assumed to be the same as the previous 2007 report since the scenarios both involve the processing of Colorado Plateau and Arizona Strip ores. Therefore, MILDOS-AREA runs from the previous report were revised to exclude the tailings cells. The doses from the tailings cells were estimated in separate MILDOS-AREA runs and added to the dose from the mill area and ore pads. Table 4 provides a summary of the source terms included in Phases 1 and 2 of the development of new tailings cells including Cells 4a and 4b.

**TABLE 4**  
**SOURCE TERMS INCLUDED IN PHASE 1 AND 2**

<b>Source Term</b>	<b>Phase 1</b>	<b>Phase 2</b>
Mill area	included	included
Ore Pads	included	included
Tailings Cell 2 with Interim Soil Cover	included	included
Tailings Cell 3	active	interim soil cover
Tailings Cell 4A	active	active
Tailings Cell 4B	excluded	active

The wind erosion and radon release rates from the tailings cells (active and with interim soil cover) were modeled by using a maximal worst case approach.

Each active tailings cell was modeled to have an active area of 10 acres (i.e., the maximum expected to be uncovered at any time since it is not possible to predict the distribution of uncovered tailings between the active cells at any given time. The release rate of wind-eroded tailings dust was estimated for 10 acres. The total annual radon release rate was estimated by assuming a radon release rate of 20 pCi/m<sup>2</sup>s (i.e., maximum radon-222 emissions to ambient air from an existing uranium mill pile) over the entire area of each cell consistent with NESHAPs.

Emissions from the tailings cells (2 and 3) with interim soil cover were assumed to occur over the entire area of each cell; however, only radon is released at a rate of 10 pCi/m<sup>2</sup>s after the application of the soil cover.

The calculated total annual effective dose commitments (including radon) calculated using MILDOS-AREA were compared to the Utah Administrative Code R313-15-301(1)(a) requirement that the dose to individual members of the public shall not exceed 100 mrem/yr (radon included). For proposed development of new tailings cells for the processing of Colorado Plateau ore, the maximum total annual effective dose commitments was calculated to be a maximum of 1.4 mrem/yr for an infant at the nearest potential resident, BHV-1 (Tables 6.1-1 and 6.1-3) (i.e., effective dose) and is about 1.4% of the R313-15-301(1)(a) limit of 100 mrem/yr (radon included) to an individual member of the public for Phases 1 and 2. For proposed development of new tailings cell for the processing of Arizona Strip ore, the total annual effective dose commitments were calculated to be a maximum of 3.1 mrem/yr for an infant at the nearest potential resident, BHV-1 (i.e., effective dose) and is about 3.1% of the 100 mrem/yr limit (radon included) to an individual member of the public for Phases 1 and 2. Overall, the predicted annual effective dose commitments for proposed development of new tailings cells during anticipated ore processing operations comply with R313-15.

In addition, our MILDOS-AREA calculated 40 CFR 190 annual dose commitments (excluding radon) were compared to the 40 CFR 190 criterion, which is 25 mrem/yr to the whole body (excluding the dose due to radon) and 25 mrem/yr to any other organ to any member of the public (U.S. EPA 2002). The 40 CFR 190 doses were also used to demonstrate compliance with R313-15-101(4) (10 CFR 20.1101(d)) (i.e., the licensee must demonstrate that total effective dose equivalent to the individual member of the public likely to receive the highest total effective dose equivalent will not exceed 10 mrem/yr (absent of the radon dose). For proposed development of new tailings cells for the processing of Colorado Plateau ore, the 40 CFR 190 annual dose commitments were

calculated to be a maximum of 4.8 mrem/yr for a teenage at the nearest potential resident, BHV-1 (i.e., dose to the bone) and is about 19% of the 40 CFR 190 dose criterion of 25 mrem/yr for Phases 1 and 2. Further, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) limit of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent. For Arizona Strip ore, the 40 CFR 190 annual dose commitments were at most 12 mrem/yr for a teenage at the nearest potential resident, BHV-1 (i.e., dose to the bone) and is well within the 40 CFR 190 dose criterion of 25 mrem/yr for Phases 1 and 2. Further, the annual effective dose commitments demonstrate compliance with R313-15-101(4) (10 CFR 20.1101(d)) limit of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent.

#### 10.4 Proposed Radiological Monitoring to Accommodate Cell 4b Operations

As an element of evaluating potential off-site doses related to the construction and operation of Cell 4b, Denison commissioned a review of its environmental monitoring programs in order to determine what, if any, additional monitoring would be needed to accommodate the operation of Cell 4b. The review was conducted by SENES Consultants, Ltd who concluded that the current environmental monitoring regime was sufficient and that added monitoring was not warranted due to the operation of Cell 4b. The results of the SENES review are attached here as Appendix C to this report.

### **11.0 Alternatives**

The action under consideration is the construction of an already contemplated tailings Cell (Cell 4b) in order accommodate continued operation of the Mill. The alternatives available to the Executive Secretary are to:

- a) Amend the License to include the construction of Cell 4b with its existing terms and conditions;
- b) Amend the License to include the construction of Cell 4b with such additional conditions as are considered necessary or appropriate to protect public health, safety and the environment; or
- c) Deny the addition of Cell 4b construction into the License.

As demonstrated in this ER, the environmental impacts associated with construction and operation of Cell 4b do not warrant either limiting the Mill's future operations or denying the Cell 4b construction approval request. As there are no significant public health, safety or environmental impacts associated with the construction of Cell 4b, Denison

asserts that alternatives with equal or greater impacts need not be evaluated, and alternative a) is the appropriate alternative for selection.

#### 11.1 Issuance of Amendment for Cell 4a

The Mill is one of only two operating uranium mills in the United States and the only uranium mill on the western slope of the Rocky Mountains. As a result, the Mill is the only currently available opportunity for production of uranium from conventionally mined ore in San Juan County and in the four corners area of the United States. The Mill therefore provides a benefit to the regional community and to the uranium industry as a whole in the United States. The construction of Cell 4b would allow the Mill to continue to provide these benefits for many more years and as contemplated in the original licensing effort.

As was demonstrated in Section 3 of the ER accompanying the 2007 License Renewal Application, the Mill's equipment, facilities and procedures are adequate to minimize impacts to public health, safety and the environment. More importantly, UDEQ has already approved the construction of Cell 4a which is identical to Cell 4b with regard to its robust and state-of-the-art protective design features. Also, the Mill has operated since its inception in compliance with all applicable regulatory standards and ALARA goals and is capable of continuing to operate in compliance with such standards and goals.

In addition to the License, the Mill has been issued a Groundwater Discharge Permit, which provides additional protection for public health and the environment, including a rigorous groundwater monitoring program to monitor and assess the performance of tailings cells associated with the facility. The Mill has demonstrated that it is capable of continuing to operate in a manner that satisfies all regulatory standards and ALARA goals under the existing terms and conditions of the License and GWDP, this amendment application has assessed and proposed additional monitoring necessary to accommodate newly constructed Cell 4b. Based upon these factors and considerations Denison asserts that there is no need to add any additional conditions to the License in order to protect public health, safety or the environment as a result of Cell 4b construction.

#### 11.2 No Action Alternative

A "no action" alternative would result in the amendment request being denied and the immediately available processing opportunities for mined uranium ore being lost in the short term, severely impacting independent uranium miners in the area and lessening the United States' capability to respond to the need for uranium for nuclear power generation.

Denying the request for construction of Cell 4b severely constrain the utilization of the Mill in the near term and eliminate its ability to operate over the longer term during a time when commodity prices for uranium are favorable, and the demand for uranium milling capacity is unprecedented. Permitting the Mill to continue processing

conventionally mined ore for the recovery of uranium and the construction of Cell 4b will provide the opportunity for regular employment in an economically depressed area of the United States. A large percentage of the workers at the Mill are Native American, and this employment opportunity has significant direct impact in the local Native American community. In addition to the direct hiring of employees at the Mill, local miners and other western United States mining companies require access to an operating uranium mill. The inability of these mining entities to gain access to local milling services will prevent the mining industry from responding to the current uranium supply shortage. Thus, secondary local economies will not enjoy the benefit of renewed mining income, and national demand for uranium will continue to be reliant primarily on foreign supplies of uranium for nuclear fuel. In order to respond to the current uranium market, conventional mining companies will be forced to license and construct new uranium milling facilities to engage in conventional ore processing, directly in opposition to the objective of non-proliferation of new uranium mill tailings disposal facilities embodied by 10 CFR Part 40 Appendix A, Criterion 2.

As has been demonstrated by the forgoing assessments, the impacts associated with the construction and operation of Cell 4b are well within the realm of impacts anticipated in the FES, the 1985 EA and the 1997 EA, and UDEQ's approval of Cell 4b construction will satisfy applicable criteria in R313-22-33 and R313-24. As a result, Denison asserts that the Executive Secretary should have no basis for denying the proposed action.

### 11.3 Alternatives Considered But Eliminated

#### a) Consideration of Alternative Sites

The Mill is already sited and in existence and has been operating for over 25 years. It is not feasible to consider moving the Mill to an alternative site or to construct additional tailing cells at a different location. Even if that were possible, it has been demonstrated in Section 3 of the February, 2007 ER accompanying the License Renewal Application that the Mill is sited in a good hydrogeologic setting and is otherwise well sited for its operations, including tailings cells contemplated at the time of the Mill's original licensure. This is evident from the fact that the Mill has operated since its inception in compliance with applicable regulatory standards and ALARA goals.

If the construction of Cell 4b is not approved as an element of continued milling operations, there can be no assurance that, as an alternative, an equally well-suited site for milling and tailings cell construction, that complies with the applicable siting requirements of 10 CFR Part 40 Appendix A, can be identified and obtained. Even if a suitable alternative site were to be identified and obtained, licensing and construction of a new mill and tailings cells could not be accomplished in a time frame that would ensure production could commence in a period of suitable market conditions. Furthermore, as the existing Mill tailings would have to be decommissioned in place, creation of a new mill site would result in unnecessary proliferation of mill tailings disposal facilities in contravention of 10 CFR Part 40 Appendix A, Criterion 2.

## b) Consideration of Alternative Engineering Methods

As will be demonstrated in Section 3, the existing Mill facilities, equipment, procedures and training of personnel have resulted in the Mill operating since inception in compliance with all applicable regulatory standards and ALARA goals. Current modeling demonstrates that the Mill is capable of continuing to operate under the existing terms and conditions of the License in a manner that will continue to comply with such standards and goals. Furthermore, the Mill's GWDP institutes additional protections and engineering controls, including the requirement that any new construction of tailings cells must meet current best available technology standards. Therefore, there is no need to consider alternative engineering methods. The existing equipment and facilities, together with the existing terms and conditions of the License and the GWDP are sufficient to ensure that all applicable requirements will continue to be satisfied.

### 11.4 Cumulative Effects

There are no past, present, or reasonably foreseeable future actions which could result in cumulative impacts that have not been contemplated and previously approved under the existing Mill License and the design of Cell 4b.

As stated throughout this License Amendment request, the Cell 4b construction will result in no activity with potential, significant, incremental impacts to public health, safety or the environment over and above the actions contemplated in the FES, the 1985 EA and the 1997 EA. The activities contemplated with regard to ore processing and disposal of tailings remain unchanged from those previously authorized under the License.

### 11.5 Comparison of the Predicted Environmental Impacts

There have been no observed significant impacts which were not previously quantified and addressed to public health, safety or the environment resulting from the proposed construction of Cell 4b. As there will be no significant changes in Mill operations if the License is amended to accommodate construction of Cell 4b, possible impacts to public health, safety or the environment will not exceed those predicted in the original License application and periodic renewals.

### 11.6 Updates & Changes to Factors That May Cause Reconsideration of Alternatives

As discussed in Section 12 below, Costs and Benefits, there have been no changes to factors that may cause reconsideration of alternatives. There have been no significant changes in the costs associated with operation of the Mill (including its impoundments), and the benefits associated with continued operation and construction of already contemplated tailing cells have become more evident over time as the number of uranium mills has dwindled and the demand for uranium milling service capacity from local miners and the industry as a whole has increased in recent years. Furthermore, no new

alternatives to the services provided by the Mill and its impoundments have been identified since the last License renewal in 1997.

## **12.0 Cost and Benefits**

Appendix A to NUREG 1569 requires that the applicant for a license renewal describe any updates and changes to the economic costs and benefits for the facility since the last application.

There have been no significant changes to the costs associated with the Mill since the last License renewal in 1997. While there will be a change to the currently disturbed area as a result of the Cell 4b construction, this additional Cell was contemplated, described and assessed, as a critical component of the initial 1978 NRC-FEIS and attendant licensing of the facility. As indicated in Section 3 of February, 2007 ER accompanying the renewal application, the Mill has operated in accordance with applicable regulatory standards and ALARA goals since its inception, and updated MILDOS AREA modeling indicates that the Mill is capable of continuing to operate well within those standards and goals. There have been no significant demographic changes that have impacted the ability of the Mill to operate in a manner that will result in no significant impacts to public health, safety or the environment. It is expected that continued Mill operations will continue to draw primarily upon the existing work force in the area with little impact on social services.

The Mill is one of only two operating uranium mills in the United States and is one of the largest private employers in San Juan County. The benefits of the Mill will continue to be the provision of well-paying jobs to workers in San Juan County and the support of the tax base in that County. Moreover, as the only operating uranium mill on the western slope of the Rocky Mountains, the Mill is relied upon by the large number of independent uranium miners in San Juan County and the Colorado Plateau as the only feasible uranium mill for their uranium ores. With the recent gap between the supply and demand for uranium and the increases in the price of uranium, the need for continued licensing of the Mill is crucial for such miners and for the uranium industry in the United States as a whole.

In sum, the costs associated with the operation of the Mill have not changed significantly, but the benefits have become more evident over time as the number of uranium mills has dwindled and the demand for uranium milling services from local miners and the industry as a whole has increased.

## **13.0 Mitigation of Impacts**

NUREG 1569 requires that the ER provide the “results of effectiveness of any mitigation proposed and implemented in the original license”. In the case of the White Mesa Mill, there have not been any mitigations proposed or implemented under the License.

## **14.0 Long Term Impacts**

The long term impacts, including decommissioning, decontamination, and reclamation impacts associated with activities conducted pursuant to the License have been considered in detail in the FES, the Mill's Reclamation Plan, and the 2000 EA prepared by the NRC in connection with the Reclamation Plan.

The Mill's Reclamation Plan and financial surety arrangements, as well as the provisions in the Mill's GWDP that relate to final reclamation of the site are described in detail in Section 8 of the February, 2007 License Renewal Application, and are incorporated here by reference. The construction of Cell 4b will not result in any changes to operations at the Mill that would impact decommissioning, decontamination or reclamation aspect associated with Mill activities, or the previous analyses of such aspects. The grading contours and other reclamation features related to closure of Cell 4b at site closure are shown in Figure 12. All design features for Cell 4b are included in the Cell 4b Design Report prepared by Geosyntec Consultants which was transmitted to UDEQ in January of 2008.

## Appendix A

**SITE HYDROGEOLOGY  
ESTIMATION OF GROUNDWATER TRAVEL TIMES  
AND RECOMMENDED ADDITIONAL MONITORING WELLS  
FOR PROPOSED TAILINGS CELL 4B  
WHITE MESA URANIUM MILL SITE  
NEAR BLANDING, UTAH**

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## TABLE OF CONTENTS

1.	INTRODUCTION .....	1
2.	SITE HYDROGEOLOGY.....	3
2.1	Geologic Setting.....	3
2.2	Hydrogeologic Setting .....	4
2.3	Perched Zone Hydrogeology .....	5
2.3.1	Lithologic and Hydraulic Properties.....	6
2.3.1.1	Dakota .....	7
2.3.1.2	Burro Canyon .....	7
2.3.2	Perched Groundwater Flow .....	9
3.	PERCHED ZONE HYDROGEOLOGY BENEATH AND DOWNGRAIENT OF THE TAILINGS CELLS .....	11
3.1	Saturated Thickness .....	11
3.2	Perched Water Flow.....	12
3.3	Permeability .....	13
4.	EVALUATION OF POTENTIAL FLOW PATHS AND TRAVEL TIMES FOR HYPOTHETICAL SEEPAGE ORIGINATING FROM CELL #3 .....	15
4.1	Estimated Travel Time from the Base of Cell #3 and Proposed Cell 4B to the Perched Zone .....	15
4.2	Estimated Travel Times from Tailings Cell #3 and Proposed Cell 4B to Ruin Spring.....	16
4.3	Estimated Total Travel Time from the Base of Tailings Cell #3 and Proposed Cell 4B to Ruin Spring .....	17
5.	RECOMMENDED ADDITIONAL PERCHED ZONE MONITORING WELLS DOWNGRAIENT OF PROPOSED CELL 4B .....	21
6.	REFERENCES .....	23
7.	LIMITATIONS STATEMENT .....	25

## TABLES

1	Peel Hydraulic Test Results
2	Results of July 2002 and June 2005 Hydraulic Tests

## TABLE OF CONTENTS (Continued)

### FIGURES

- 1 Site Plan and Perched Well Locations
- 2 Kriged Brushy Basin Contact Elevations
- 3 Perched Water Levels, August 1990
- 4 Perched Water Levels, August 1994
- 5 Perched Water Levels, September 2002
- 6 Kriged 3<sup>rd</sup> Quarter, 2007 Water Levels
- 7 Portion of USGS Black Mesa 7.5' Sheet Showing Approximate Location of Tailing Cells in Relation to Nearby Canyons and Ruin Spring
- 8 Depth to Water, 3<sup>rd</sup> Quarter 2007
- 9 Approximate Saturation Thickness, 3rd Quarter 2007
- 10 Site Plan Showing Existing and Proposed Perched Well Locations

## 1. INTRODUCTION

This report provides a brief description of the hydrogeology of the White Mesa Uranium Mill site (the “Mill” or the “site”), located south of Blanding, Utah, and focuses on the occurrence and flow of groundwater within the relatively shallow perched groundwater zone at the site. Based on available existing hydrogeologic information from the site, estimates of hydraulic gradients and intergranular rates of groundwater movement (interstitial or pore velocities) are provided. These estimates are used to calculate average travel times for a hypothetical conservative solute (assuming no dispersion) from existing tailings cell #3 and proposed cell 4B at the site to a downgradient discharge point. Recommendations for additional perched zone monitoring wells downgradient of proposed cell 4B are also provided. Figure 1 is a site plan showing the locations of perched monitoring wells and proposed cell 4B.

Tailings cell #3 has been in service for many years and a large quantity of groundwater monitoring and hydraulic test data exists for perched monitoring wells completed around the perimeter of the cell. Data from the vicinity of the cell are used in conjunction with data downgradient of the cell to calculate perched zone hydraulic properties and groundwater gradients between cell #3 and the discharge point. Cell 4B is proposed to be installed at the downgradient edge of cell #3. The data from the immediate vicinity and downgradient of cell #3 used to compute rates of movement and travel times for a hypothetical conservative solute will likewise be used to calculate travel times for the hypothetical solute from proposed cell 4B to the discharge point.



## 2. SITE HYDROGEOLOGY

Titan, 1994 provides a detailed description of site hydrogeology based on information available at that time. A brief summary of site hydrogeology that is based primarily on Titan, 1994, but includes the results of more recent site investigations, is provided below.

### 2.1 Geologic Setting

The White Mesa Uranium Mill site is located within the Blanding Basin of the Colorado Plateau physiographic province. Typical of large portions of the Colorado Plateau province, the rocks underlying the site are relatively undeformed. The average elevation of the site is approximately 5,600 feet above mean sea level (amsl).

The site is underlain by unconsolidated alluvium and indurated sedimentary rocks consisting primarily of sandstone and shale. The indurated rocks are relatively flat lying with dips generally less than 3°. The alluvial materials consist mostly of aeolian silts and fine-grained aeolian sands with a thickness varying from a few feet to as much as 25 to 30 feet across the site. The alluvium is underlain by the Dakota Sandstone and Burro Canyon Formation, which are sandstones having a total thickness ranging from approximately 100 to 140 feet. Beneath the Burro Canyon Formation lies the Morrison Formation, consisting, in descending order, of the Brushy Basin Member, the Westwater Canyon Member, the Recapture Member, and the Salt Wash Member. The Brushy Basin and Recapture Members of the Morrison Formation, classified as shales, are very fine-grained and have a very low permeability. The Brushy Basin

Member is primarily composed of bentonitic mudstones, siltstones, and claystones. The Westwater Canyon and Salt Wash Members also have a low average vertical permeability due to the presence of interbedded shales.

Beneath the Morrison Formation lie the Summerville Formation, an argillaceous sandstone with interbedded shales, and the Entrada Sandstone. Beneath the Entrada lies the Navajo Sandstone. The Navajo and Entrada Sandstones constitute the primary aquifer in the area of the site. The Entrada and Navajo Sandstones are separated from the Burro Canyon Formation by approximately 1,000 to 1,100 feet of materials having a low average vertical permeability. Groundwater within this system is under artesian pressure in the vicinity of the site, is of generally good quality, and is used as a secondary source of water at the site.

## **2.2 Hydrogeologic Setting**

The site is located within a region that has a dry to arid continental climate, with average annual precipitation of less than 11.8 inches, and average annual evapotranspiration of approximately 61.5 inches. Recharge to aquifers occurs primarily along the mountain fronts (for example, the Henry, Abajo, and La Sal Mountains), and along the flanks of folds such as Comb Ridge Monocline.

Although the water quality and productivity of the Navajo/Entrada aquifer are generally good, the depth of the aquifer (approximately 1,200 feet below land surface [bls]) makes access difficult. The Navajo/Entrada aquifer is capable of yielding significant quantities of water to

wells (hundreds of gallons per minute [gpm]). Water in wells completed across these units at the site rises approximately 800 feet above the base of the overlying Summerville Formation.

Perched groundwater in the Dakota Sandstone and Burro Canyon Formation is used on a limited basis to the north (upgradient) of the site because it is more easily accessible. Water quality of the Dakota Sandstone and Burro Canyon Formation is generally poor due to high total dissolved solids (TDS) and is used primarily for stock watering and irrigation. The saturated thickness of the perched water zone generally increases to the north of the site, increasing the yield of the perched zone to wells installed north of the site.

### **2.3 Perched Zone Hydrogeology**

Perched groundwater beneath the site occurs primarily within the Burro Canyon Formation. Perched groundwater at the site has a generally low quality due to high total dissolved solids (TDS) in the range of approximately 1,200 to 5,000 milligrams per liter (mg/L), and is used primarily for stock watering and irrigation in the areas upgradient (north) of the site. Perched water is supported within the Burro Canyon Formation by the underlying, fine-grained Brushy Basin Member. Figure 2 is a contour map showing the approximate elevation of the contact of the Burro Canyon Formation with the Brushy Basin Member, which essentially forms the base of the perched water zone at the site. Contact elevations are based on perched monitoring well drilling and geophysical logs and surveyed land surface elevations. As indicated, the contact generally dips to the south/southwest beneath the site.

Groundwater within the perched zone generally flows south to southwest beneath the site. Beneath the tailings cells, perched water flow is generally southwest to south-southwest.

### 2.3.1 Lithologic and Hydraulic Properties

Although the Dakota Sandstone and Burro Canyon Formations are often described as a single unit due to their similarity, previous investigators at the site have distinguished between them. The Dakota Sandstone is a relatively-hard to hard, generally fine-to-medium grained sandstone cemented by kaolinite clays. The Dakota Sandstone locally contains discontinuous interbeds of siltstone, shale, and conglomeratic materials. Porosity is primarily intergranular. The underlying Burro Canyon Formation hosts most of the perched groundwater at the site. The Burro Canyon Formation is similar to the Dakota Sandstone but is generally more poorly sorted, contains more conglomeratic materials, and becomes argillaceous near its contact with the underlying Brushy Basin Member. The permeability of the Dakota Sandstone and Burro Canyon Formation at the site is generally low.

No significant joints or fractures within the Dakota Sandstone or Burro Canyon Formation have been documented in any wells or borings installed across the site (Knight Piésold, 1998). Any fractures observed in cores collected from site borings are typically cemented, showing no open space.

### *2.3.1.1 Dakota*

Based on samples collected during installation of wells MW-16 (no longer in service) and MW-17, located immediately downgradient of the tailings cells at the site, porosities of the Dakota Sandstone range from 13.4 to 26 percent, averaging 20 percent, and water saturations range from 3.7 to 27.2 percent, averaging 13.5 percent. The average volumetric water content is approximately 3 percent. The permeability of the Dakota Sandstone based on packer tests in borings installed at the site ranges from  $2.71 \times 10^{-6}$  centimeters per second (cm/s) to  $9.12 \times 10^{-4}$  cm/s, with a geometric average of  $3.89 \times 10^{-5}$  cm/s.

### *2.3.1.2 Burro Canyon*

The average porosity of the Burro Canyon Formation is similar to that of the Dakota Sandstone. Based on samples collected from the Burro Canyon Formation at MW-16, located immediately downgradient of the tailings cells at the site (and no longer in service), porosity ranges from 2 to 29.1 percent, averaging 18.3 percent, and water saturations of unsaturated materials range from 0.6 to 77.2 percent, averaging 23.4 percent. Titan, 1994, reported that the hydraulic conductivity of the Burro Canyon Formation ranges from  $1.9 \times 10^{-7}$  to  $1.6 \times 10^{-3}$  cm/s, with a geometric mean of  $1.1 \times 10^{-5}$  cm/s, based on the results of 12 pumping/recovery tests performed in monitoring wells and 30 packer tests performed in borings prior to that time.

Hydraulic testing of wells MW-01, MW-03, MW-05, MW-17, MW-18, MW-19, MW-20, and MW-22 during the week of July 8, 2002, and newly installed wells MW-23, MW-25, MW-27, MW-28, MW-29, MW-30, MW-31, MW-32, TW4-20, TW4-21, and TW4-22 during

June, 2005, yielded average perched zone permeabilities ranging from approximately  $2 \times 10^{-7}$  cm/s to  $5 \times 10^{-4}$  cm/s, similar to the range reported by previous investigators at the site (Hydro Geo Chem, Inc [HGC], 2002; HGC, 2005). Downgradient (south to southwest) of the tailings cells, average perched zone permeabilities based on tests at MW-3, MW-5, MW-17, MW-20, MW-22, and MW-25 ranged from approximately  $4 \times 10^{-7}$  to  $1 \times 10^{-4}$  cm/s. Permeability estimates from these tests were based on pumping/recovery and slug tests analyzed using several different methodologies.

A number of temporary (TW4-series) perched zone monitoring wells have been installed at the site to investigate elevated concentrations of chloroform initially discovered at well MW-4 in 1999. Some of the conglomeratic zones encountered within the perched zone during installation of these wells are believed to be partly continuous or at least associated with a relatively continuous zone of higher permeability (International Uranium [USA] Corporation [IUSA] and HGC, 2001). The higher permeability zone defined by these wells is generally located east to northeast of the tailings cells at the site, and is hydraulically cross-gradient to upgradient of the tailings cells with respect to perched groundwater flow. Relatively high permeabilities measured at MW-11, located on the southeastern margin of the downgradient edge of tailings cell #3, and at MW-14, located on the downgradient edge of tailings cell #4, of  $1.4 \times 10^{-3}$  cm/s and  $7.5 \times 10^{-4}$  cm/s, respectively (UMETCO, 1993), may indicate that this zone extends beneath the southeastern margin of the cells. This zone of higher permeability within the perched water zone does not appear to exist downgradient (south-southwest) of the tailings cells, however. At depths beneath the perched water table, the zone is not evident in lithologic logs of the southernmost temporary wells TW4-4 and TW4-6 (located east [cross-gradient] of cell #3),

nor is it evident in wells MW-3, MW-5, MW-12, MW-15, MW-16, MW-17, MW-20, MW-21, or MW-22, located south to southwest (downgradient) of the tailings cells, based on the lithologic logs or hydraulic testing of the wells.

Because of the generally low permeability of the perched zone beneath the site, well yields are typically low (less than 0.5 gpm), although sustainable yields of as much as about 4 gpm may be possible in wells intercepting larger saturated thicknesses and higher permeability zones in the northeast portion of the site. Sufficient productivity can, in general, only be obtained in areas where the saturated thickness is greater, which is the primary reason that the perched zone has been used on a limited basis as a water supply to the north (upgradient) of the site.

### 2.3.2 Perched Groundwater Flow

Perched groundwater flow at the site has historically been to the south/southwest. Figures 3 through 6 are perched groundwater elevation contour maps for the years 1990, 1994, 2002, and 2007, respectively. The 1990, 1994, and 2002 maps were hand contoured because of sparse data. As groundwater elevations indicate, the perched groundwater gradient changes from generally southwesterly in the western portion of the site, to generally southerly in the eastern portion of the site. The most significant changes between the 2002 and 2007 water levels result from pumping of wells MW-4, TW4-19, TW4-20, and MW-26. These wells are pumped to reduce chloroform mass in the perched zone east and northeast of the tailings cells.

In general, perched groundwater elevations have not changed significantly at most of the site monitoring wells since installation, except in the vicinity of the wildlife ponds and the pumping wells. For example, relatively large increases in water levels occurred between 1994 and 2002 at MW-4 and MW-19, located in the east and northeast portions of the site, as shown by comparing Figures 4 and 5. These water level increases in the northeastern and eastern portions of the site are likely the result of seepage from wildlife ponds located near the piezometers shown in Figure 5, which were installed in 2001 for the purpose of investigating these changes. The increase in water levels in the northeastern portion of the site has resulted in a local steepening of groundwater gradients over portions of the site. Conversely, pumping of wells MW-4, TW4-19, TW4-20, and MW-26 has depressed the perched water table locally and reduced average hydraulic gradients to the south and southwest of these wells.

Perched water discharges in springs and seeps along Westwater Creek Canyon and Cottonwood Canyon to the west-southwest of the site, and along Corral Canyon to the east of the site, where the Burro Canyon Formation outcrops. The discharge point located most directly downgradient of the tailings cells is Ruin Spring. This feature is located approximately 10,000 feet south-southwest of tailings cell #3 and is depicted on the USGS 7.5-minute quad sheet for Black Mesa (Figure 7).

### **3. PERCHED ZONE HYDROGEOLOGY BENEATH AND DOWNGRAIENT OF THE TAILINGS CELLS**

Perched water as of the 3rd Quarter, 2007 was encountered at depths of approximately 57 to 115 feet bls in the vicinity of the tailings cells at the site (Figure 8). Beneath tailings cell #3, depths to water ranged from approximately 77 feet below top of casing (btoc) in the eastern portion of the cell (at MW-25), to approximately 114 feet btoc at the southwest margin of the cell (at MW-23). Assuming an average depth of the base of tailings cell #3 of 25 feet below grade, this corresponds to perched water depths of approximately 52 to 89 feet below the base of the cell, or an average depth of approximately 70 feet beneath the base of the cell. A similar assumption can be made for proposed cell 4B.

#### **3.1 Saturated Thickness**

The saturated thickness of the perched zone as of the 3rd Quarter, 2007 ranges from approximately 93 feet in the northeast portion of the site to less than 5 feet in the southwest portion of the site (Figure 9). Beneath tailings cell #3, the saturated thickness varies from approximately 49 feet in the easternmost corner of the cell to approximately 7 feet in the western portion of the cell. South-southwest of the tailings cells, the saturated thickness ranges from less than 1 foot at MW-21 to approximately 26 feet at MW-17. The average saturated thickness south-southwest of the tailings cells, based on measurements at MW-3, MW-5, MW-12, MW-14, MW-15, MW17, and MW-20, is approximately 14 feet. The average saturated thickness based on measurements at MW-5, MW-15, MW-3, and MW-20, which lay close to a line between the center of tailings cell #3 and Ruin Spring, is approximately 12 feet. By projecting conditions at

these wells, the average saturated thickness is estimated to be approximately 10 to 15 feet between MW-20 and Ruin Spring.

### **3.2 Perched Water Flow**

Perched groundwater flow beneath the tailings cells has historically been southwest, with the gradient steepening in recent years (since about 1994) and becoming more westerly as perched water levels in the northeastern portion of the site have risen. Perched water flowing beneath the tailings cells eventually discharges in springs and seeps located in Westwater Canyon, to the south-southwest of the cells. The primary discharge point for perched water flowing beneath the tailings cells is believed to be Ruin Spring, located approximately 10,000 feet south-southwest of the cells.

Perched zone hydraulic gradients currently range from a maximum of approximately 0.05 feet per foot (ft/ft) east of tailings cell #2 to approximately 0.01 ft/ft downgradient of cell #3, between cell #3 and MW-20. The average hydraulic gradient between the downgradient edge of tailings cell #3 and Ruin Spring can be approximated assuming the following:

- 1) The elevation of Ruin Spring, based on the USGS topographic map for Black Mesa, is approximately 5,390 feet amsl.
- 2) The distance between the downgradient edge of tailings cell #3 and Ruin Spring is approximately 10,000 feet.
- 3) The average groundwater elevation at the downgradient edge of tailings cell #3 is approximately 5,510 feet amsl.

Using these assumptions, the average perched zone hydraulic gradient between tailings cell #3 and Ruin Spring is approximately:

$$\frac{5510 - 5390}{10,000} = 0.012 \text{ ft / ft}$$

A hypothetical worst case average perched zone hydraulic gradient can also be estimated assuming the perched water elevation to be coincident with the base of tailings cell #3. The elevation of the base of tailings cell #3, which is also the approximate pre-existing land surface elevation near the center of the cell, is approximately 5,580 feet amsl. Under these conditions, for an unconfined perched zone, the maximum possible average perched zone hydraulic gradient between tailings cell #3 and Ruin Spring would be approximately:

$$\frac{5580 - 5390}{10,000} = 0.019 \text{ ft / ft}$$

Although the downgradient edge of proposed cell 4B is closer to Ruin Spring (approximately 9,000 feet from Ruin Spring rather than about 10,000 feet), the above hydraulic gradient calculations can also be applied to cell 4B.

### **3.3 Permeability**

The average permeability of the perched zone downgradient of tailings cell #3 can be approximated based on the pumping/recovery test and slug test data obtained from perched zone wells located along the downgradient edge of and south of cell #3. Peel conducted hydraulic tests at perched zone wells MW-11, MW-12, MW-14, and MW-15 in 1992 (UMETCO, 1993).

Results of these tests are provided in Table 1. HGC conducted slug tests at perched zone wells MW-3, MW-5, MW-17, MW-20, and MW-22 in July 2002 (HGC, 2002), and MW-25 in June, 2005 (HGC, 2005).

The HGC slug test results were analyzed using various solution methods including KGS (Hyder, 1994), and Bouwer-Rice (Bouwer and Rice, 1976). Each method yielded slightly different results as shown in Table 2, which is based on Table 1 of HGC, 2002, and Table 1 of HGC, 2005. A range of average permeabilities for the portion of the site south of the tailings cells can be obtained by taking the geometric mean of the Peel test results and the results obtained by the various solution methods used to analyze the HGC data. Averaging the Peel test results for wells MW-11, MW-12, MW-14, and MW-15 with the HGC KGS results for wells MW-3, MW-5, MW-17, MW-20, MW-22, and MW-25 yields a geometric average of  $2.3 \times 10^{-5}$  cm/s, and similarly averaging the Peel test results with the HGC Bouwer-Rice results yields a geometric average of  $4.3 \times 10^{-5}$  cm/s, as shown in Table 2. The “early time” results at MW-5 using the Bouwer-Rice solution (from Table 1 of HGC, 2002) were used in the computations to yield a conservatively high estimate of permeability.

#### **4. EVALUATION OF POTENTIAL FLOW PATHS AND TRAVEL TIMES FOR HYPOTHETICAL SEEPAGE ORIGINATING FROM CELL #3**

Although more than 25 years of groundwater monitoring at the site has shown no impact to perched water from the tailings cells, an evaluation of hypothetical transport of a conservative solute in seepage from existing cell #3 and proposed cell 4B is presented assuming a flow path from the base of the existing and proposed cells to the perched water, and thence to Ruin Spring. Average travel times for a conservative constituent moving from the base of tailings cell #3 and proposed cell 4B to the perched water, and then moving with the perched water to Ruin Spring, are computed assuming no dispersion.

The porosities and water saturations used in the calculations were based on measurements reported in Titan, 1994, for samples collected from the Dakota Sandstone during drilling of MW-16 and MW-17, and from the Burro Canyon Formation during drilling of MW-16.

##### **4.1 Estimated Travel Time from the Base of Cell #3 and Proposed Cell 4B to the Perched Zone**

Knight-Piésold estimated a maximum volumetric seepage rate for tailings cell #3 based on cell construction and liner characteristics, of approximately 80 cubic feet per day (ft/day) or 0.42 gpm over the entire cell (Knight-Piésold, 1998). Most of this seepage was estimated to be via diffusion through the liner. This rate was estimated to decrease over time as the cell desaturates once the final cover is emplaced. Assuming a cell footprint of  $3.38 \times 10^6 \text{ ft}^2$ , this rate is equivalent to  $2.37 \times 10^{-5} \text{ ft/day}$  or 0.0086 feet per year (ft/yr).

The average rate of downward movement of a conservative solute dissolved in the seepage, assuming 1) no dispersion, 2) an average water saturation of 0.20, 3) an average porosity of 0.18, and assuming that this rate of seepage would not significantly raise the average saturation of the underlying materials, can be approximated as:

$$\frac{0.0086 \text{ ft / yr}}{(.20)(.18)} = 0.24 \text{ ft / yr}$$

The average time to travel 70 feet to the perched water zone would then be approximately 290 years. This is a conservative estimate because the average water saturations would be likely to increase, thereby reducing the downward rate of travel, and increasing the travel time.

Assuming a similar travel time from the base of proposed cell 4B to the perched water would be even more conservative because the improved liner system to be used for that cell would result in less seepage than from cell #3. However, for purposes of calculation, potential seepage rates and downward rates of movement for a hypothetical conservative solute will be assumed to be the same for cell 4B as those calculated for cell #3.

#### **4.2 Estimated Travel Times from Tailings Cell #3 and Proposed Cell 4B to Ruin Spring**

Under current conditions, the average hydraulic gradient between the downgradient edge of tailings cell #3 to Ruin Spring is estimated to be 0.012, as discussed in Section 3.2. Assuming the following:

Average porosity	= 0.18
Average hydraulic gradient	= 0.012
Flow path length	= 10,000 feet
Average permeability range	= $2.3 \times 10^{-5}$ to $4.3 \times 10^{-5}$ cm/s (0.064 ft/day to 0.120 ft/day)

the average rate of intergranular movement of perched groundwater (interstitial or pore velocity) can be approximated to range from 0.0043 ft/day to 0.0080 ft/day (or 1.6 ft/yr to 2.9 ft/yr). The estimated average travel time for a conservative solute, assuming no dispersion, from tailings cell #3 to Ruin Spring would then be approximately 6,250 to 3,450 years over this range of permeabilities. Under conditions of the maximum possible average perched groundwater gradient of 0.019 ft/ft, as estimated in Section 3.2, and assuming the same permeabilities, porosity, and path length as above, the estimated average travel times would range from approximately 4,055 to 2,160 years.

For proposed cell 4B, which is about 9,000 feet from Ruin Spring, the estimated travel times would be approximately 5,625 to 3,100 years using the gradient of 0.012, and approximately 3,650 to 1,950 years using the gradient of 0.019.

#### **4.3 Estimated Total Travel Time from the Base of Tailings Cell #3 and Proposed Cell 4B to Ruin Spring**

The total average travel time for a conservative solute from the base of tailings cell #3 or proposed cell 4B to Ruin Spring under current conditions would be the sum of 1) the travel time from the base of either cell to the perched water table, and 2) the time to travel within the

perched zone to Ruin Spring. Based on the estimates provided in Sections 4.1 and 4.2, the total average travel time of a conservative solute (assuming no dispersion) over the range of average permeability estimates would be between 6,540 and 3,740 years for cell #3, and between 5,915 and 3,390 years for proposed cell 4B, assuming an average hydraulic gradient of 0.012 ft/ft. As discussed in Section 4.1, because the rate of movement of a conservative solute from the base of cell 4B would likely be slower than for cell #3 because seepage rates would lower, the total travel time would likely be higher than estimated above.

Conditions may hypothetically develop under which travel times may be reduced, such as an increase in average perched zone groundwater gradients between tailings cell #3 or cell 4B and Ruin Spring (as discussed in Section 3.2) or as a result of reduced vadose zone travel times due to development of a relatively large leak in either cell. Under hypothetical conditions in which a relatively large leak were to develop, potentially reducing vadose zone travel times to only a few years, the vadose zone travel time could be ignored, and the total average travel time (assuming no dispersion) would range from approximately 6,250 to 3,450 years for cell #3, and between 5,625 and 3,100 years for proposed cell 4B, assuming an average hydraulic gradient of 0.012 ft/ft. Under hypothetical conditions in which the average perched zone hydraulic gradient between either cell and Ruin Spring reached 0.019 ft/ft, which also implies a negligible vadose zone travel time, the total average travel time (assuming no dispersion) over the estimated range in permeability would be between approximately 4,055 and 2,160 years for cell #3, and between 3,650 and 1,950 years for cell 4B.

Estimates based on hypothetical assumptions of a relatively large leak in tailings cell #3 or an average hydraulic gradient as high as 0.019 ft/ft between either cell and Ruin Spring are considered very conservative because they assume conditions that are unlikely ever to develop. Furthermore the improved construction and leak detection system proposed for cell 4B would make this hypothetical scenario even less likely for cell 4B than for cell #3.



## **5. RECOMMENDED ADDITIONAL PERCHED ZONE MONITORING WELLS DOWNGRAIENT OF PROPOSED CELL 4B**

The current perched groundwater monitoring well network for the tailings cells includes wells that are upgradient, crossgradient, and downgradient of the cells as shown in Figure 10. Most of the wells are located along the margins of the cells and many that are between the cells function as both upgradient wells for the cell located immediately downgradient of the wells and as downgradient wells for the cell located immediately upgradient of the wells. For example, well MW-30 functions as a downgradient well for cell #2 and as an upgradient well for cell #3. Wells MW-5, MW-12, and MW-23 that currently function as downgradient wells for cell #3 would also serve as upgradient wells for proposed cell 4B. The current arrangement of tailings cell perched monitoring wells is conservative with respect to U.S. Environmental Protection Agency (US EPA) Draft Technical Guidance (US EPA, 1992) which generally recommends downgradient wells only along the downgradient margin of the facility which in this case would be the entire complex of tailings cells.

Once proposed cell 4B is installed, an additional well or wells would be needed at the downgradient edge of the cell to be consistent with EPA Draft Guidance (US EPA, 1992). As shown in Figure 10, two additional wells are proposed, one at the southwest corner of proposed cell 4B and one between the southwest corner well and existing well MW-15. These installations would conservatively maintain the approximate existing spacing as defined by the proximity of MW-14 to MW-15 along the downgradient edge of existing cell 4A. Existing wells MW-3, MW-20, and MW-21 would continue to function as distal downgradient wells for the entire cell

complex. Once installed, sampling frequencies for the new wells will be based on testing of the wells for perched zone hydraulic properties in the same fashion as for the existing wells.

## 6. REFERENCES

- Bouwer, H. and R.C. Rice. 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. *Water Resources Research*, Vo. 12:3. Pp. 423-428.
- Hyder, Z., J.J. Butler, C.D. McElwee, and W. Liu. 1994. Slug tests in partially penetrating wells. *Water Resources Research*. Vol. 30:11. Pp. 2945-2957.
- Hydro Geo Chem. 2001. Update to report "Investigation of Elevated Chloroform Concentrations in Perched Groundwater at the White Mesa Uranium Mill Near Blanding, Utah".
- Hydro Geo Chem. 2002. Hydraulic Testing at the White Mesa Uranium Mill Near Blanding, Utah During July, 2002. Submitted to International Uranium (USA) Corporation, Denver, Colorado.
- Hydro Geo Chem. 2005. Perched Monitoring Well Installation and Testing at the White Mesa Uranium Mill, April Through June, 2005. Submitted to International Uranium (USA) Corporation, Denver, Colorado.
- Knight-Piésold. 1998. Evaluation of Potential for Tailings Cell Discharge – White Mesa Mill. Attachment 5, Groundwater Information Report, White Mesa Uranium Mill, Blanding, Utah. Submitted to UDEQ.
- TITAN. 1994. Hydrogeological Evaluation of White Mesa Uranium Mill. Submitted to Energy Fuels Nuclear.
- UMETCO. 1993. Groundwater Study. White Mesa Facilities. Blanding, Utah. Prepared by UMETCO Minerals Corporation and Peel Environmental Services.
- US EPA. 1992. EPA RCRA Ground-Water Monitoring: Draft Technical Guidance, November 1992.



## 7. LIMITATIONS STATEMENT

The opinions and recommendations presented in this report are based upon the scope of services and information obtained through the performance of the services, as agreed upon by HGC and the party for whom this report was originally prepared. Results of any investigations, tests, or findings presented in this report apply solely to conditions existing at the time HGC's investigative work was performed and are inherently based on and limited to the available data and the extent of the investigation activities. No representation, warranty, or guarantee, express or implied, is intended or given. HGC makes no representation as to the accuracy or completeness of any information provided by other parties not under contract to HGC to the extent that HGC relied upon that information. This report is expressly for the sole and exclusive use of the party for whom this report was originally prepared and for the particular purpose that it was intended. Reuse of this report, or any portion thereof, for other than its intended purpose, or if modified, or if used by third parties, shall be at the sole risk of the user.



## **TABLES**

**TABLE 1**  
**Peel Hydraulic Test Results <sup>1</sup>**

Well	Hydraulic Conductivity (cm/s)
MW-11	$1.4 \times 10^{-3}$
MW-12	$2.2 \times 10^{-5}$
MW-14	$7.5 \times 10^{-4}$
MW-15	$1.9 \times 10^{-5}$

Notes:

<sup>1</sup> From UMETCO, 1993

**TABLE 2**  
**Results of July 2002 and June 2005 Hydraulic Tests <sup>2</sup>**

Well	Permeability in centimeters per second	
	KGS	Bouwer-Rice
MW-3	$4.0 \times 10^{-7}$	$1.5 \times 10^{-5}$
MW-5	$3.5 \times 10^{-6}$	$2.4 \times 10^{-5}$
MW-17	$2.6 \times 10^{-5}$	$2.7 \times 10^{-5}$
MW-20	--	$9.3 \times 10^{-6}$
MW-22	$1.0 \times 10^{-6}$	$7.9 \times 10^{-6}$
MW-25	$1.1 \times 10^{-4}$	$7.4 \times 10^{-5}$

*Geometric Average of above test results with Peel<sup>3</sup> test results for MW-11, MW-12, MW-14, and MW-15.*

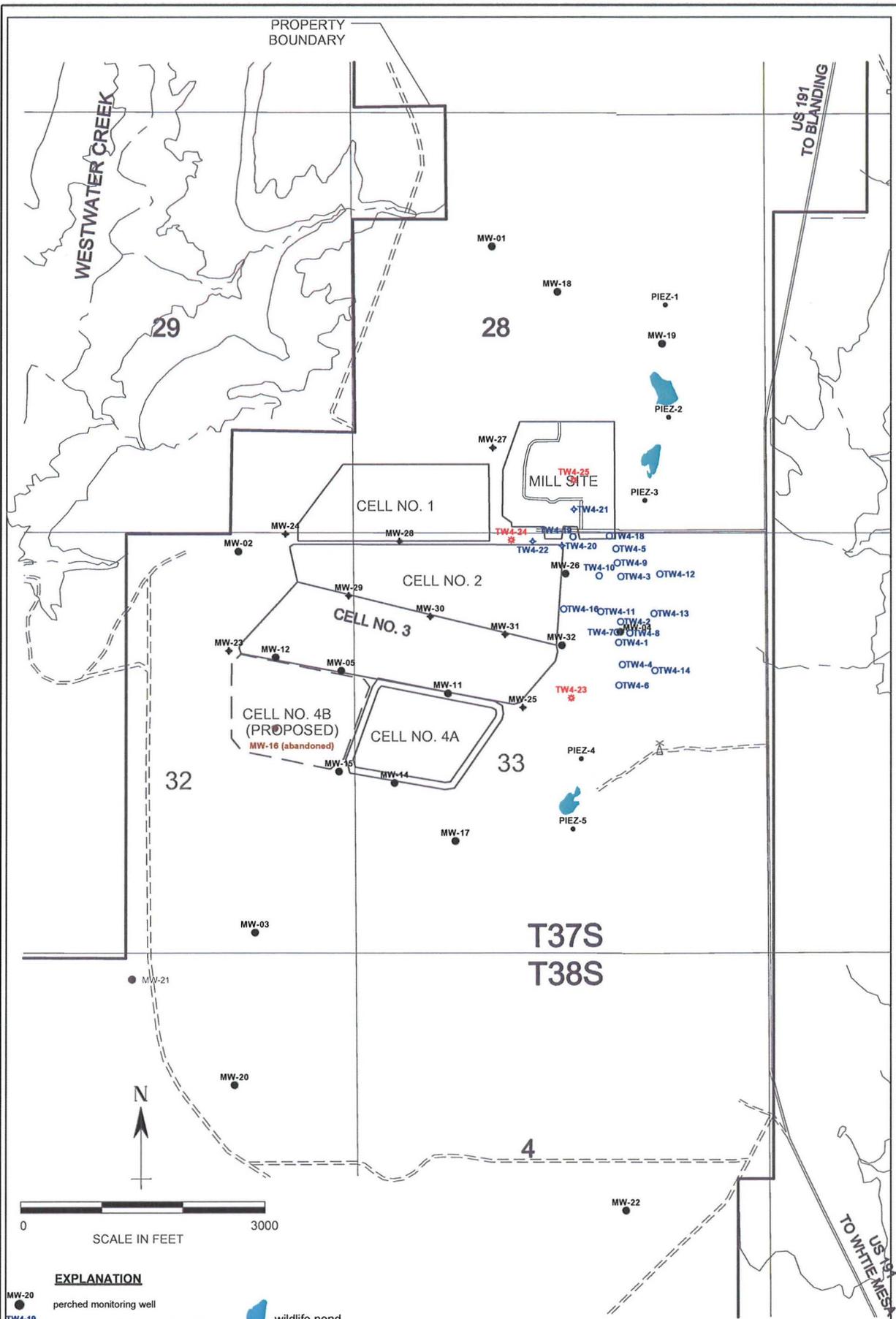
$2.3 \times 10^{-5}$	$4.3 \times 10^{-5}$
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Notes:

<sup>2</sup> From HGC, 2002; HGC, 2005

<sup>3</sup> From UMETCO, 1993

## FIGURES



**EXPLANATION**

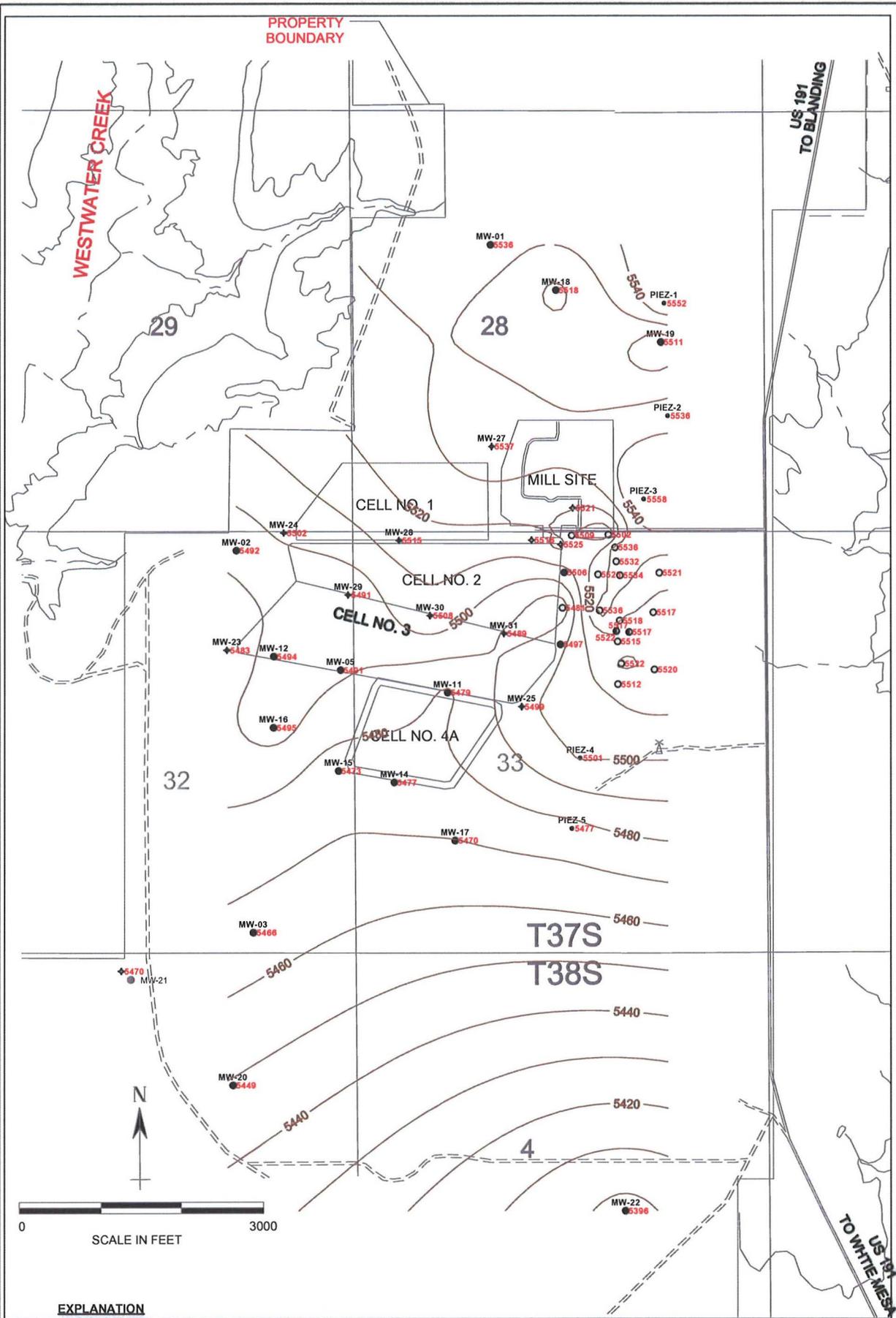
- MW-20 ● perched monitoring well
- TW4-19 ○ temporary perched monitoring well
- PIEZ-1 ● perched piezometer
- MW-31 ● perched monitoring well installed April, 2005
- TW4-20 ○ temporary perched monitoring well installed April, 2005
- TW4-23 ● new temporary perched monitoring well installed May, 2007 (locations approximate)



**HYDRO  
GEO  
CHEM, INC.**

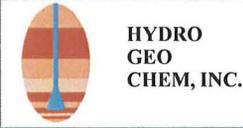
**SITE PLAN  
AND PERCHED WELL LOCATIONS  
WHITE MESA SITE**

APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/welloc.srf	1



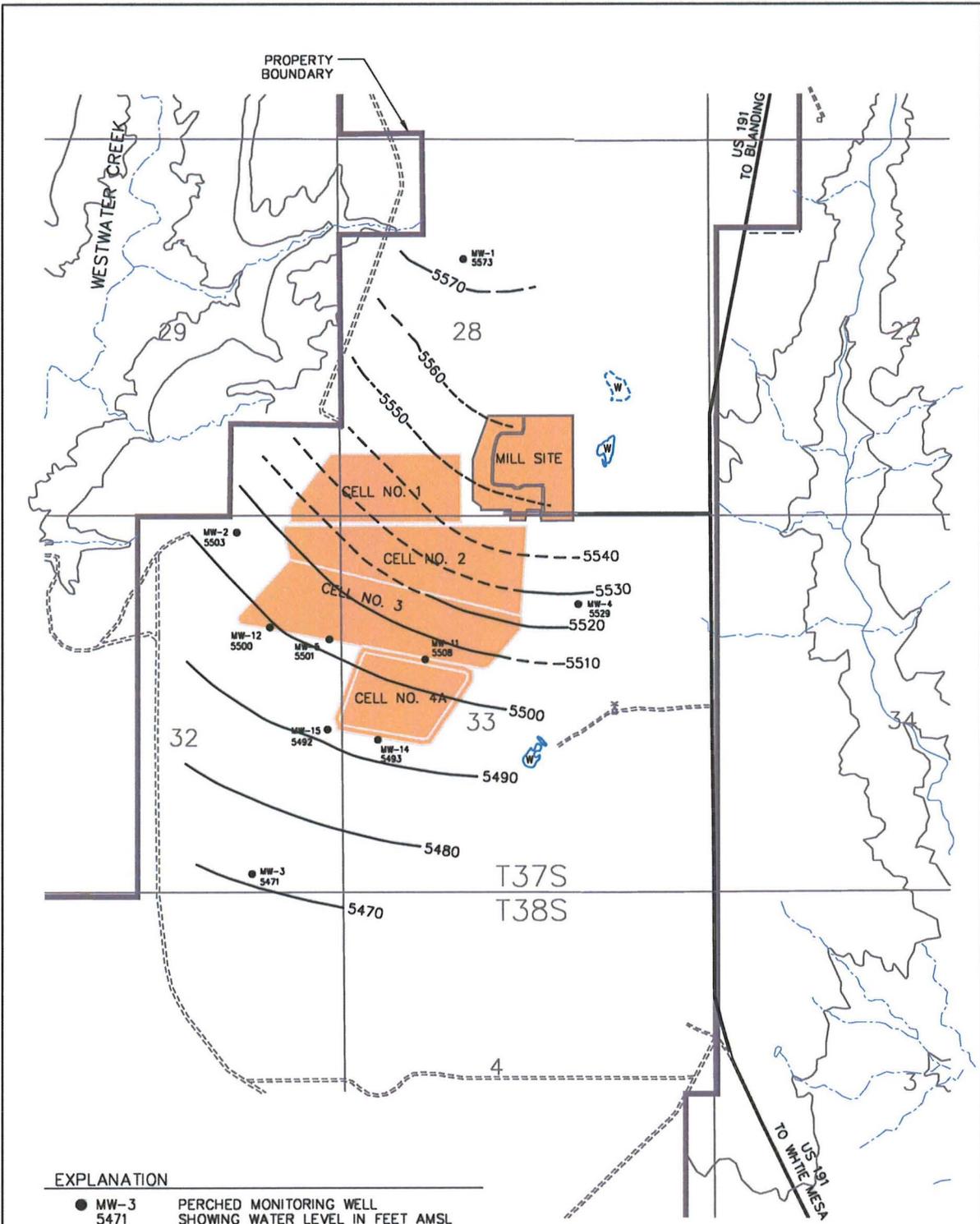
**EXPLANATION**

- MW-20 ● 5449 perched monitoring well showing elevation in feet amsl
- 5481 temporary perched monitoring well showing elevation in feet amsl
- PIEZ-1 ● 5552 perched piezometer showing elevation in feet amsl
- MW-31 ● 5489 perched monitoring well installed April, 2005 showing elevation in feet amsl
- ◆ 5525 temporary perched monitoring well installed April, 2005 showing elevation in feet amsl



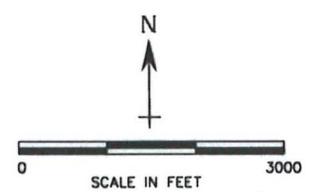
**KRIGED BRUSHY BASIN CONTACT ELEVATIONS  
WHITE MESA SITE**

APPROVED	DATE	REFERENCE	FIGURE
SJS	9/19/2007	H:/718000/cell4b/bbel0705.srf	2

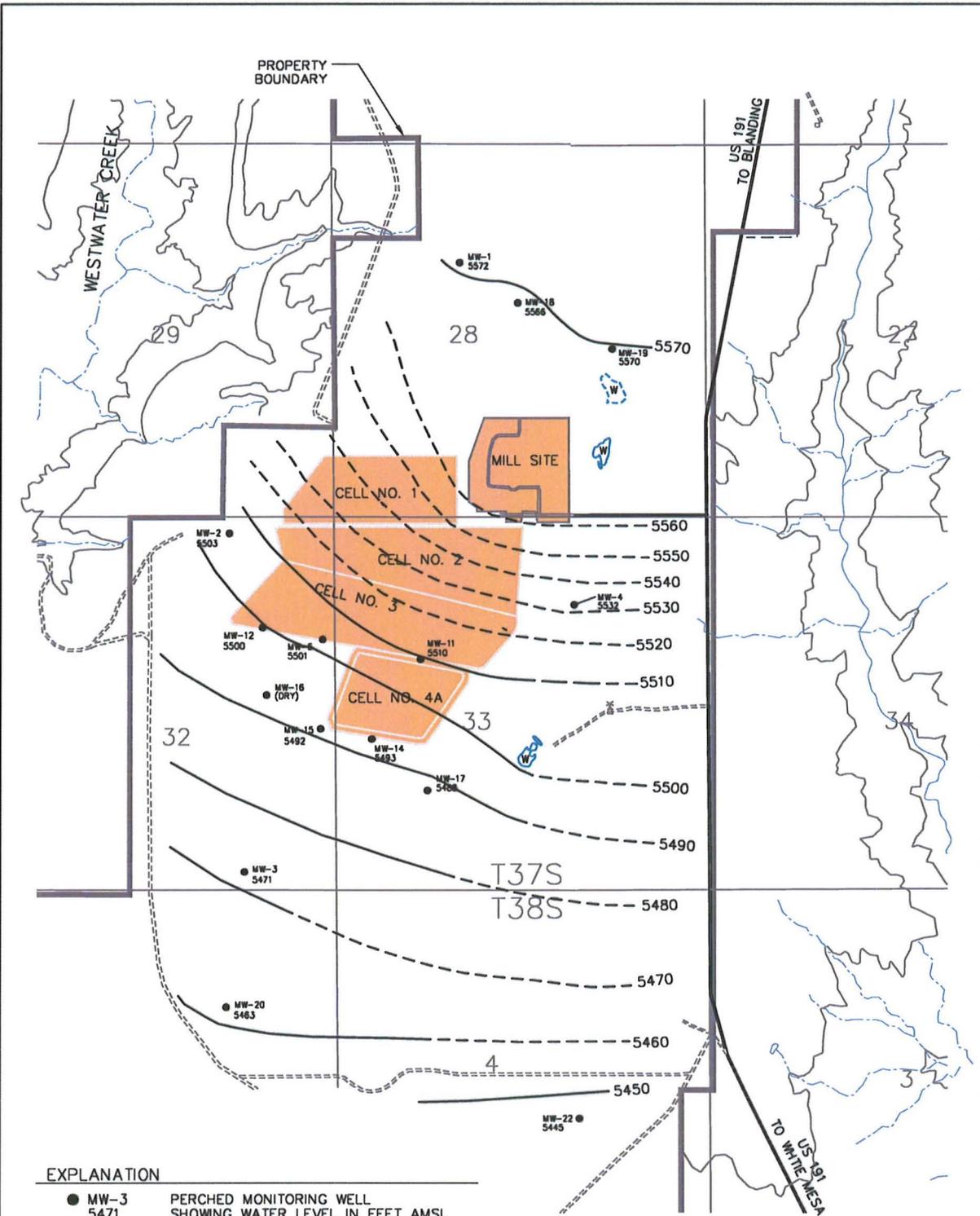


**EXPLANATION**

- MW-3 5471 PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL
- W WILDLIFE POND
- 5580 - - - WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN

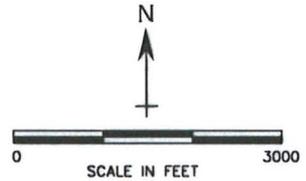


 <b>HYDRO GEO CHEM, INC.</b>	<b>PERCHED WATER LEVELS AUGUST 1990</b>					
	Approved SS	Date 01/30/03	Revised	Date	Reference: 71800101	FIG: 3

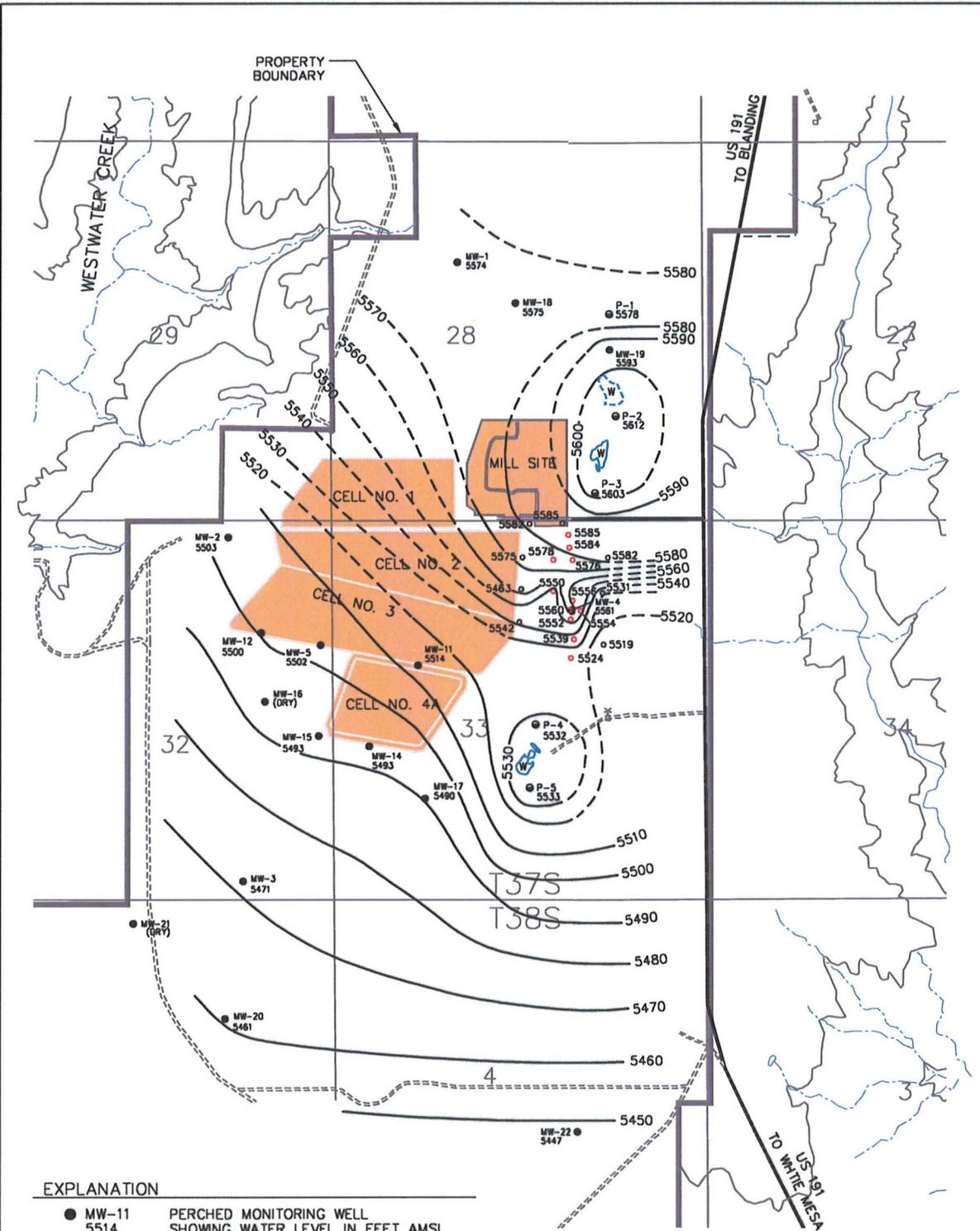


**EXPLANATION**

- MW-3 5471 PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL
- W WILDLIFE POND
- 5580 - - - WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN



 <b>HYDRO GEO CHEM, INC.</b>	<b>PERCHED WATER LEVELS AUGUST 1994</b>					
	Approved SS	Date 01/30/03	Revised	Date	Reference: 71800102	FIG: 4



**EXPLANATION**

- MW-11 5514 PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL
- 5524 TEMPORARY PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL
- P-5 5533 PIEZOMETER SHOWING WATER LEVEL IN FEET AMSL
- 5580 - - - WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN
- W WILDLIFE POND

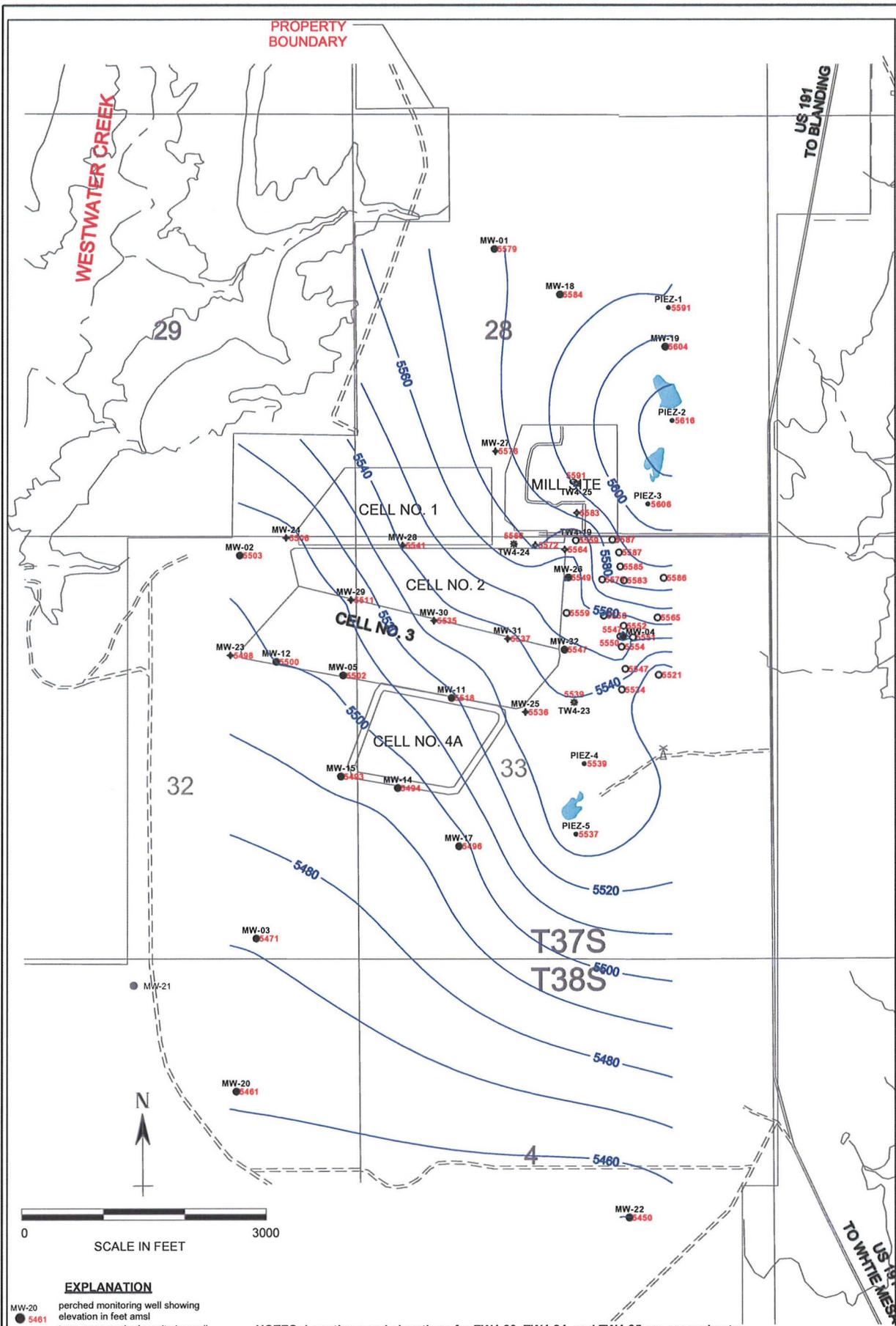
NOTE: WATER LEVELS FOR PIEZOMETERS ARE FROM AUGUST, 2002



**HYDRO  
GEO  
CHEM, INC.**

**PERCHED WATER LEVELS  
SEPTEMBER 2002**

Approved	Date	Revised	Date	Reference:	FIG:
SS	01/30/03			71800103	5



- EXPLANATION**
- MW-20 ● 5461 perched monitoring well showing elevation in feet amsl
  - 5550 temporary perched monitoring well showing elevation in feet amsl
  - PIEZ-1 ● 5591 perched piezometer showing elevation in feet amsl
  - MW-31 ◆ 5537 perched monitoring well installed April, 2005 showing elevation in feet amsl
  - ◆ 5571 temporary perched monitoring well installed April, 2005 showing elevation in feet amsl
  - ◆ 5539 temporary perched monitoring well installed May, 2007 showing approximate elevation in feet amsl

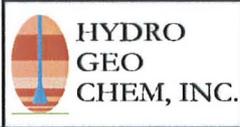
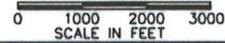
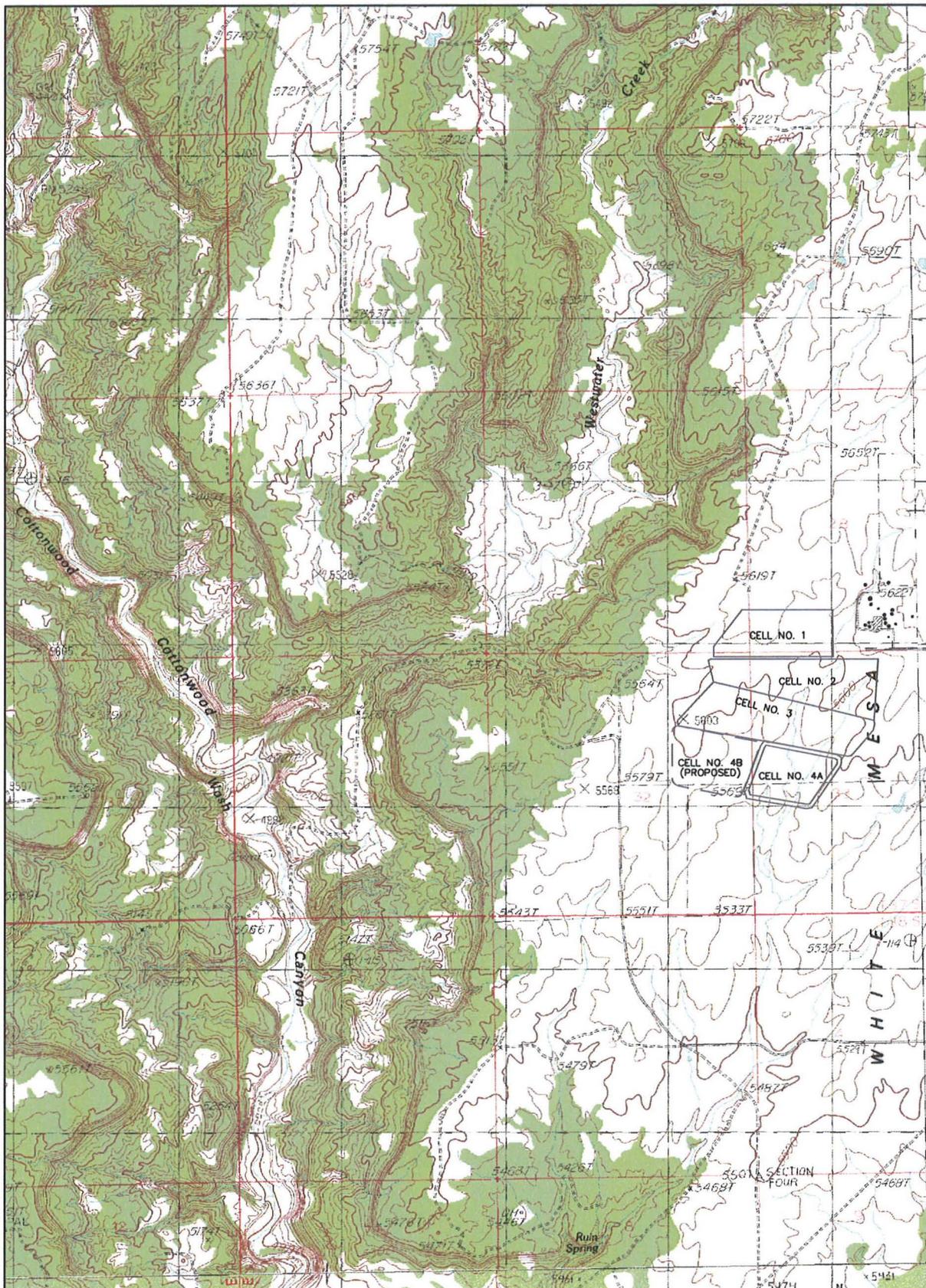
NOTES: Locations and elevations for TW4-23, TW4-24, and TW4-25 are approximate;  
Water level for MW-26 (TW4-15) is from the second quarter, 2007



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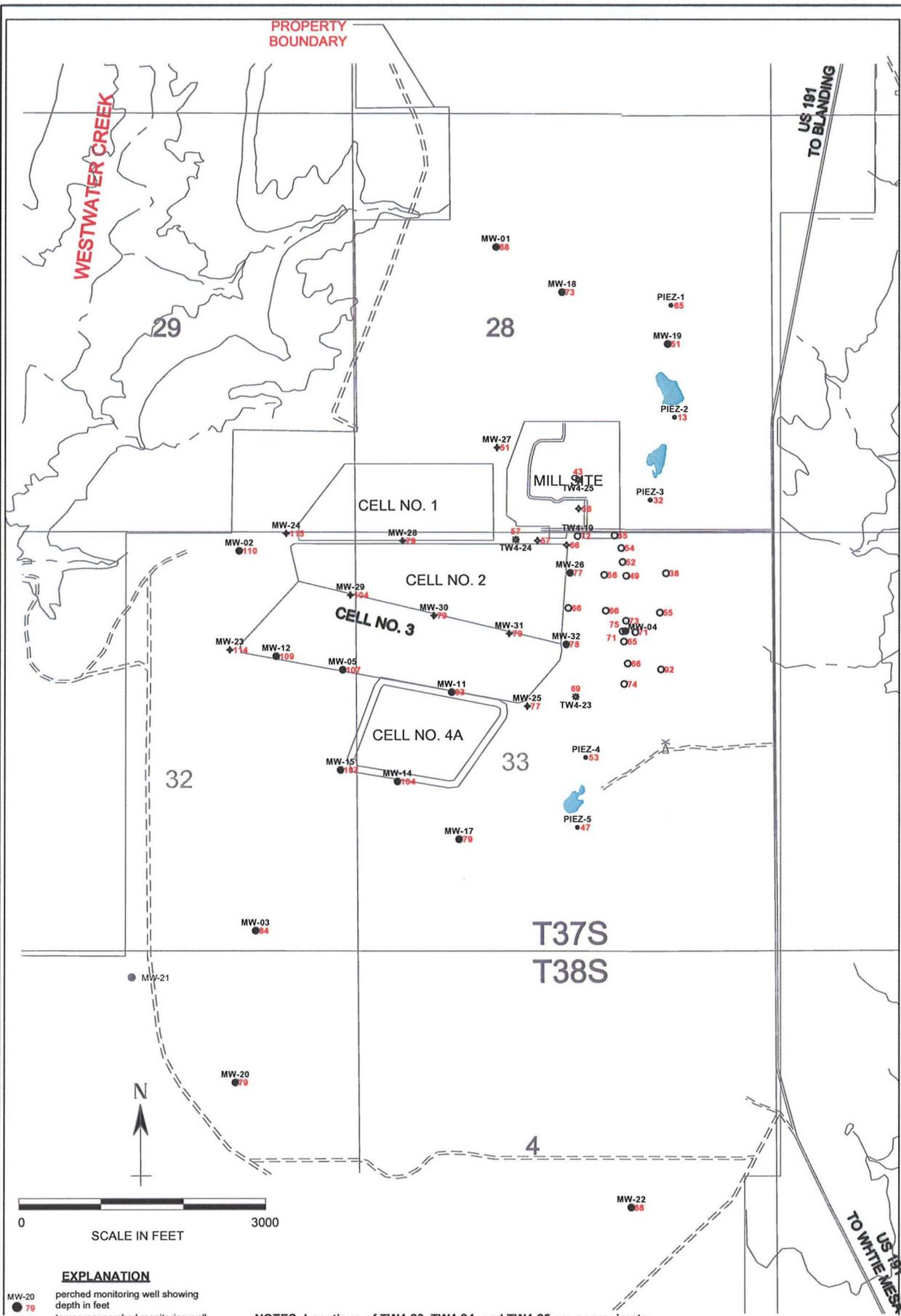
**KRIGED 3rd QUARTER, 2007 WATER LEVELS  
WHITE MESA SITE**

APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/wl0807.srf	6



PORTION OF USGS BLACK MESA 7.5' SHEET SHOWING  
APPROXIMATE LOCATION OF TAILING CELLS  
IN RELATION TO NEARBY CANYONS AND RUIN SPRING

Approved SS	Date 1/30/03	Revised	Date	Reference: 71800100	FIG: 7
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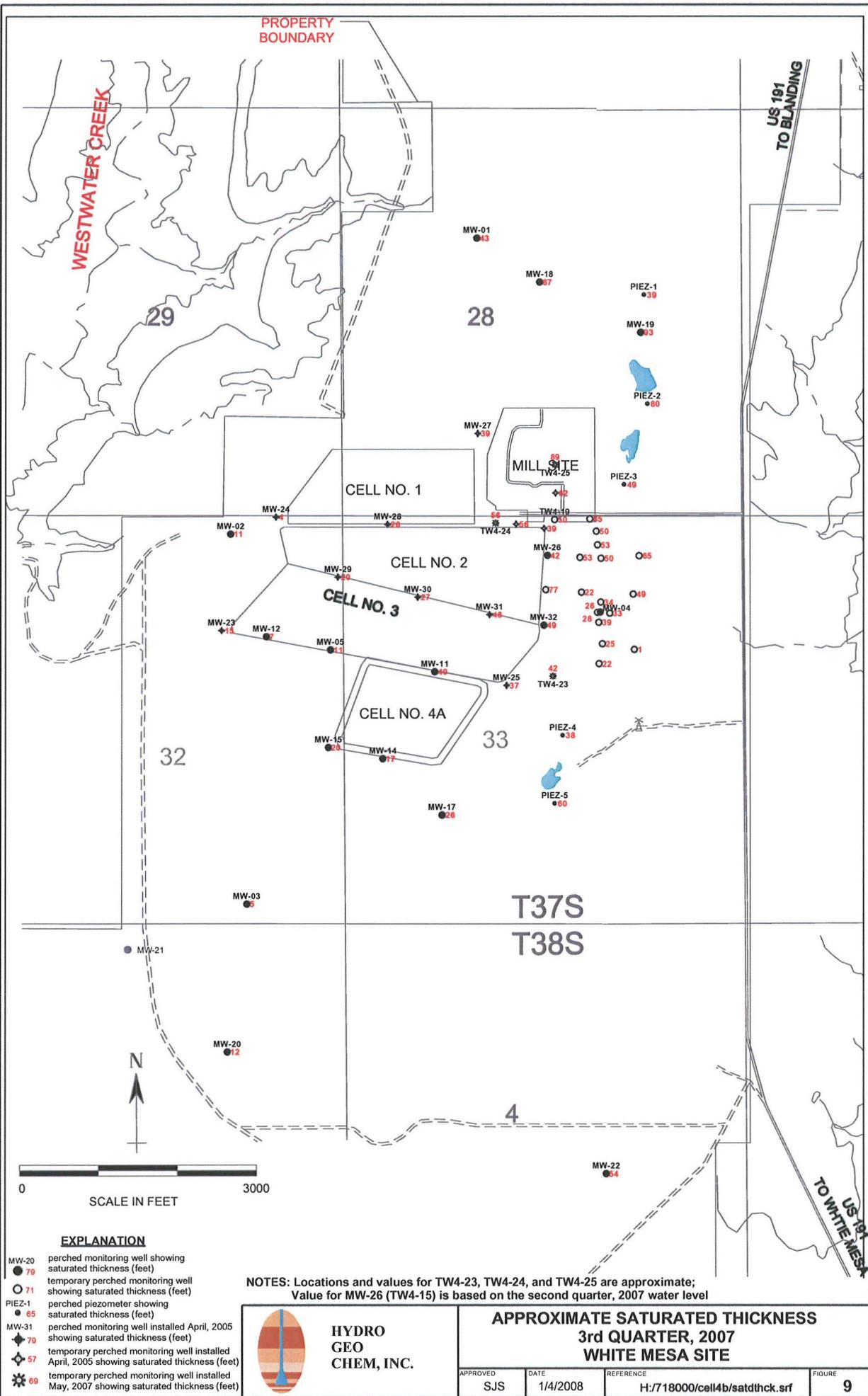
- EXPLANATION**
- MW-20 ● 79 perched monitoring well showing depth in feet
  - 71 temporary perched monitoring well showing depth in feet
  - PIEZ-1 ● 65 perched piezometer showing depth in feet
  - MW-31 ◆ 79 perched monitoring well installed April, 2005 showing depth in feet
  - ◆ 57 temporary perched monitoring well installed April, 2005 showing depth in feet
  - ◆ 69 temporary perched monitoring well installed May, 2007 showing depth in feet

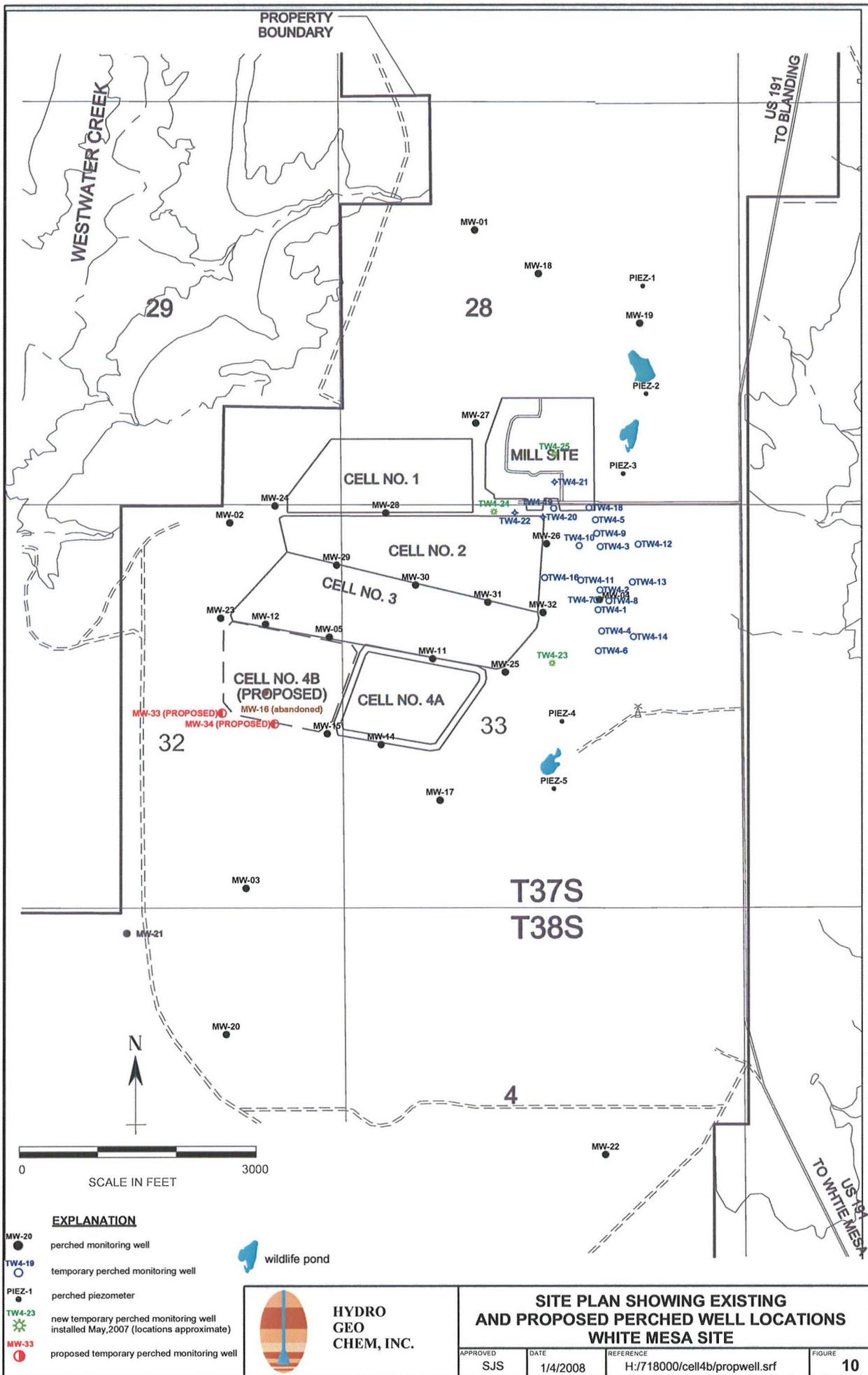
NOTES: Locations of TW4-23, TW4-24, and TW4-25 are approximate;  
Measurement for MW-26 (TW4-15) is from the second quarter, 2007



**HYDRO  
GEO  
CHEM, INC.**

<b>DEPTHS TO WATER 3rd QUARTER, 2007 WHITE MESA SITE</b>		APPROVED	DATE	REFERENCE	FIGURE
		SJS	1/4/2008	H:\718000\cell4b\dtw0807.srf	8





- EXPLANATION**
- MW-20 ● perched monitoring well
  - TW4-19 ○ temporary perched monitoring well
  - PIEZ-1 ● perched piezometer
  - TW4-23 ● new temporary perched monitoring well installed May, 2007 (locations approximate)
  - MW-33 ● proposed temporary perched monitoring well



**HYDRO  
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CHEM, INC.**

**SITE PLAN SHOWING EXISTING  
AND PROPOSED PERCHED WELL LOCATIONS  
WHITE MESA SITE**

APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/propwell.srf	10

## Appendix B

# **PROPOSED DEVELOPMENT OF NEW TAILINGS CELL 4B FOR THE WHITE MESA URANIUM MILL**

**Prepared for:**

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**Prepared by:**

**SENES Consultants Limited**  
121 Granton Drive, Unit 12  
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L4B 3N4

April 2008

Printed on Recycled Paper Containing Post-Consumer Fibre



## **EXECUTIVE SUMMARY**

Denison Mines (USA) Corp. (DUSA) operates the White Mesa Uranium Mill (hereafter referred to as the "mill") in San Juan County, Utah, approximately 6 miles (9.6 km) south of the city of Blanding. The mill is located on a parcel of land and mill site claims covering approximately 5,415 acres (2,191 ha). The mill is licensed by the State of Utah Division of Radiation Control (DRC) to process uranium ore and selected alternate feed materials.

In February 2007, SENES prepared a dose assessment for DUSA in support of the license renewal application for the mill (SENES 2007, also referred to as the previous report). MILDOS-AREA was used to estimate the dose commitments that could potentially be received by individuals and the general population within a 50 mile (80 km) radius for processing of conventional ores. The assessment was prepared for scenarios in which Colorado Plateau (0.25%  $U_3O_8$  and 1.5%  $V_2O_5$ ) or Arizona Strip (0.637%  $U_3O_8$  and no  $V_2O_5$ ) ores are processed at the mill.

This dose assessment extends the analyses of the previous report of February 2007 to incorporate the dose from the proposed development of new tailings Cell 4B, anticipated to be completed for use in 2009, in support of a license amendment application by DUSA for construction and operation of that cell. In doing the dose assessment for Cell 4B, we have updated the assumptions we used in February 2007 for modeling tailings Cells 1, 2, 3 and 4A to reflect the current operational status of the site, including the re-commissioning of Cell 4A for use in 2008. For purposes of modeling mill operations, we have separated operations into two phases. Phase 1 involves the continued use of Cell 1 for solution evaporation, the continued use of Cell 3 for solution evaporation and the disposal of tailings solids, and the use of Cell 4A for disposal of tailings solids and solution evaporation. Phase 2 occurs after Cell 3 is full and is no longer an active cell. During Phase 2, Cells 4A and 4B are used for disposal of tailings solids and solution evaporation, and Cell 1 is used for solution evaporation. In each Phase, Cell 2, with interim soil cover over the entire cell area, is included in the model, and in Phase 2, Cell 3, with interim soil cover over the entire cell area, is included in the model.

The United States Nuclear Regulatory Commission (NRC)-approved MILDOS-AREA was used to estimate the dose commitments received by individuals and the general population within a 50 mile (80 km) radius of the site for the processing of either Colorado Plateau or Arizona Strip ore separately. In each scenario, the doses arising from emissions of dust and radon from the mill area (excluding the tailings cells) and ore pads were assumed to be the same as the previous 2007 report since the scenarios both involve the processing of Colorado Plateau and Arizona Strip ores. Therefore, MILDOS-AREA runs from the previous report were revised to exclude the tailings cells. The doses from the tailings cells were estimated in separate MILDOS-AREA runs

and added to the dose from the mill area and ore pads. Table ES-1 provides a summary of the source terms included in Phases 1 and 2 of the development of new tailings cells.

**TABLE ES-1**  
**SOURCE TERMS INCLUDED IN PHASES 1 AND 2**

Source Term	Phase 1	Phase 2
Mill area	included	included
Ore Pads	included	included
Tailings Cell 2 with Interim Soil Cover	included	included
Tailings Cell 3	active	interim soil cover
Tailings Cell 4A	active	active
Tailings Cell 4B	excluded	active

The wind erosion and radon release rates from the tailings cells (active and with interim soil cover) were modelled by using a maximal worst case approach.

Each active tailings cell was modelled to have an active exposed (non-solution) tailings solids area of 10 acres (i.e., the maximum uncovered tailings solids area at any time allowed under NESHAPs Regulation 40 CFR 61.252(b), Subpart W) since it is not possible to predict the distribution of uncovered tailings between the active cells at any given time. As a result, the release rate of wind-eroded tailings dust was estimated at 10 acres at all times for each active cell. We understand that during the active life of each cell, the average exposed tailings solids will be less than 10 acres, so this assumption is considered to be conservative. The total annual radon release rate was estimated by assuming a radon release rate of 20 pCi/m<sup>2</sup>s (i.e., maximum radon-222 emissions to ambient air from an existing uranium mill pile) over the entire area of each cell consistent with NESHAPs. Actual radon emission rates from the tailings cells have historically been well below 20 pCi/m<sup>2</sup>s, so this assumption is also considered to be conservative.

Emissions from the tailings cells (2 and 3) with interim soil cover were assumed to occur over the entire area of each cell; however, only radon is released at a rate of 10 pCi/m<sup>2</sup>s after the application of the soil cover.

The calculated total annual effective dose commitments (including radon) calculated using MILDOS-AREA were compared to the Utah Administrative Code R313-15-301(1)(a) requirement that the dose to individual members of the public shall not exceed 100 mrem/yr (radon included). For the processing of Colorado Plateau ore, the maximum total annual effective dose commitments was calculated to be a maximum of 1.4 mrem/yr for an infant at the nearest potential resident, BHV-1 (Tables 6.1-1 and 6.1-3) (i.e., effective dose) and is about 1.4% of the R313-15-301(1)(a) limit of 100 mrem/yr (radon included) to an individual member

of the public, for Phases 1 and 2. For the processing of Arizona Strip ore, the total annual effective dose commitments were calculated to be a maximum of 3.1 mrem/yr for an infant at the nearest potential resident, BHV-1 (Tables 6.2-1 and 6.2-3) (i.e., effective dose) and is about 3.1% of the 100 mrem/yr limit (radon included) to an individual member of the public, for Phases 1 and 2. Overall, using conservative assumptions, the predicted annual effective dose commitments for Phases 1 and 2 comply with R313-15.

In addition, our MILDOS-AREA calculated 40 CFR 190 annual dose commitments (excluding radon) were compared to the 40 CFR 190 criterion, which is 25 mrem/yr to the whole body (excluding the dose due to radon) and 25 mrem/yr to any other organ to any member of the public (EPA 2002). The 40 CFR 190 doses were also used to demonstrate compliance with the ALARA (As Low As Reasonably Achievable) goal set out in R313-15-101(4) (10 CFR 20.1101(d)) (i.e., the ALARA goal is to demonstrate that total effective dose equivalent to the individual member of the public likely to receive the highest total effective dose equivalent will not exceed 10 mrem/yr (absent of the radon dose)). For the processing of Colorado Plateau ore, the 40 CFR 190 annual dose commitments were calculated to be a maximum of 4.8 mrem/yr for a teenager at the nearest potential resident, BHV-1 (Tables 6.1-5 and 6.1-8) (i.e., dose to the bone) and is about 19% of the 40 CFR 190 dose criterion of 25 mrem/yr, for Phases 1 and 2. Further, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) ALARA goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent (the maximum total effective dose equivalent (radon excluded) during Phases 1 and 2 was 0.545 mrem/yr for an infant at BHV-1.). For Arizona Strip ore, the 40 CFR 190 annual dose commitments were at most 12 mrem/yr for a teenager at the nearest potential resident, BHV-1 (Tables 6.2-5 and 6.2-8) (i.e., dose to the bone) and is about 49% of the 40 CFR 190 dose criterion of 25 mrem/yr for Phases 1 and 2. Further, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) ALARA goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent (the maximum total effective dose equivalent (radon excluded) during Phases 1 and 2 was 1.39 mrem/yr for an infant at BHV-1). Overall, using conservative assumptions, ore processing in Phases 1 and 2 comply with the requirements of 40 CFR 190 and the ALARA goal set out in R313 -15-101(4).

## **TABLE OF CONTENTS**

	<u>Page No.</u>
EXECUTIVE SUMMARY .....	ES-1
ACRONYMS & ABBREVIATIONS.....	AC-1
1.0 INTRODUCTION .....	1-1
1.1 Background .....	1-1
1.2 Objective.....	1-2
1.3 Approach.....	1-2
1.4 Contents Of This Report .....	1-3
2.0 REGULATORY COMPLIANCE .....	2-1
3.0 RADIATION DOSE ASSESSMENT .....	3-1
3.1 General Information About MILDOS-AREA .....	3-1
3.2 The Use of MILDOS-AREA In This Assessment.....	3-1
4.0 SOURCE TERMS .....	4-1
4.1 Point Sources .....	4-3
4.1.1 Grinder .....	4-3
4.1.2 Grizzly.....	4-3
4.1.3 Yellowcake Stacks .....	4-4
4.1.4 Vanadium Stack .....	4-4
4.2 Area Sources .....	4-5
4.2.1 Ore Pads .....	4-5
4.2.2 Tailings Cells .....	4-6
4.3 Meteorological Data.....	4-8
4.4 Population Data.....	4-8
4.5 Uranium Mill Source Emission Rates.....	4-9
4.5.1 Colorado Plateau Ore.....	4-9
4.5.2 Arizona Strip Ore.....	4-9
5.0 RECEPTORS.....	5-1
6.0 RADIATION DOSE ESTIMATES .....	6-1
6.1 MILDOS-AREA Results For Colorado Plateau Ore.....	6-2
6.1.1 R313-15-301(1)(a) Regulatory Compliance.....	6-2
6.1.2 40 CFR 190 Regulatory Compliance.....	6-9
6.2 MILDOS-AREA Results for Arizona Strip Ore.....	6-19
6.2.1 R313-15-301 (1)(a) Regulatory Compliance.....	6-19
6.2.2 40 CFR 190 Regulatory Compliance.....	6-26
7.0 KEY OBSERVATIONS.....	7-1
8.0 REFERENCES .....	8-1

## **LIST OF APPENDICES**

	<u>Page No.</u>
APPENDIX A HISTORY OF MILDOS .....	A-1
APPENDIX B EMISSION CALCULATIONS .....	B-1
B.1 Calculation of Annual Dust Loss .....	B-1
B.2 Emission Calculations.....	B-2
APPENDIX C MILDOS-AREA RESULTS.....	C-1
C.1 MILDOS-AREA Results for Colorado Plateau Ore.....	C-1
C.1.1 R313-15-301 (1)(a) Regulatory Compliance.....	C-1
C.2 MILDOS-AREA Results for Arizona Strip Ore.....	C-7
C.2.1 R313-15-301 (1)(a) Regulatory Compliance.....	C-7

**LIST OF TABLES**

	<u>Page No.</u>
ES-1 Source Terms Included in Phases 1 and 2 .....	ES-2
1.3-1 Source Terms Included in Phases 1 and 2 .....	1-3
4.2-1 Characteristics of Tailings Cells in Phase 1 .....	4-6
4.2-2 Characteristics of Tailings Cells in Phase 2 .....	4-6
4.5-1 Radioactive Particulate and Radon Emission Rates (Colorado Plateau Ore) .....	4-9
4.5-2 Radioactive Particulate and Radon Emission Rates (Arizona Strip Ore) .....	4-10
6.1-1 Phase 1-Comparison of Annual Dose Commitments with Applicable Radiation Protection Standards (Colorado Plateau Ore) .....	6-3
6.1-2 Phase 1-Total Annual Dose Commitments for Meat Ingestion Pathway (Colorado Plateau Ore) (mrem/yr) .....	6-6
6.1-3 Phase 2-Comparison of Annual Dose Commitments with Applicable Radiation Protection Standards (Colorado Plateau Ore) .....	6-6
6.1-4 Phase 2-Total Annual Dose Commitments for Meat Ingestion Pathway (Colorado Plateau Ore) (mrem/yr) .....	6-9
6.1-5 Phase 1-Comparison of 40 CFR190 Annual Dose Commitments with Applicable Radiation Protection Standards (Colorado Plateau Ore) .....	6-10
6.1-6 Phase 1-40 CFR190 Annual Dose Commitments for Meat Ingestion Pathway (Colorado Plateau Ore) (mrem/yr) .....	6-13
6.1-7 Phase 2-Annual Population Dose Commitments within 50 miles (80 km) of the Mill for Colorado Plateau Ore .....	6-13
6.1-8 Phase 2-Comparison of 40 CFR190 Annual Dose Commitments with Applicable Radiation Protection Standards (Colorado Plateau Ore) .....	6-15
6.1-9 Phase 2-40 CFR190 Annual Dose Commitments for Meat Ingestion Pathway (Colorado Plateau Ore) (mrem/yr) .....	6-18
6.1-10 Phase 2-Annual Population Dose Commitments within 50 miles (80 km) of the Mill for Colorado Plateau Ore .....	6-18
6.2-1 Phase 1-Comparison of Annual Dose Commitments with Applicable Radiation Protection Standards (Arizona Strip Ore) .....	6-20
6.2-2 Phase 1-Total Annual Dose Commitments for Meat Ingestion Pathway (Arizona Strip Ore) (mrem/yr) .....	6-23
6.2-3 Phase 2-Comparison of Annual Dose Commitments with Applicable Radiation Protection Standards (Arizona Strip Ore) .....	6-23
6.2-4 Phase 2-Total Annual Dose Commitments for Meat Ingestion Pathway (Arizona Strip Ore) (mrem/yr) .....	6-26
6.2-5 Phase 1-Comparison of 40 CFR190 Annual Dose Commitments with Applicable Radiation Protection Standards (Arizona Strip Ore) .....	6-27

## **LIST OF TABLES**

	<u>Page No.</u>
6.2-6 Phase 1-40 CFR190 Annual Dose Commitments for Meat Ingestion Pathway (Arizona Strip Ore) (mrem/yr) .....	6-30
6.2-7 Phase 1-Annual Population Dose Commitments within 50 miles (80 km) of the Mill for Arizona Strip Ore .....	6-30
6.2-8 Phase 2-Comparison of 40 CFR190 Annual Dose Commitments with Applicable Radiation Protection Standards (Arizona Strip Ore) .....	6-31
6.2-9 Phase 2-40 CFR190 Annual Dose Commitments for Meat Ingestion Pathway (Arizona Strip Ore) (mrem/yr) .....	6-34
6.2-10 Phase 2-Annual Population Dose Commitments within 50 miles (80 km) of the Mill for Arizona Strip Ore .....	6-34
7-1 Source Terms Included in Phases 1 and 2 .....	7-1
B.1 Parameter Values for Calculation of Annual Dusting Rate for Exposed Tailings .....	B-1
C.1-1 Annual Dose Commitments (Colorado Plateau Ore).....	C-1
C.1-2 40 CFR 190 Annual Dose Commitments (Colorado Plateau Ore).....	C-4
C.2-1 Annual Dose Commitments (Arizona Strip Ore).....	C-7
C.2-2 40 CFR 190 Annual Dose Commitments (Arizona Strip Ore).....	C-10

## **LIST OF FIGURES**

	<u>Page No.</u>
4.1 Source Locations.....	4-2
5.1 Receptor Locations .....	5-2

## **ACRONYMS & ABBREVIATIONS**

ALC	Allowable Concentration
ANL	Argonne National Laboratory
ALARA	As Low As Reasonably Achievable
Avg.	average
ASCII	American Standard Code for Information Interchange
Bi-210	bismuth-210
Bi-214	bismuth-214
CCD	Counter Current Decantation
CFR	Code of Federal Regulations
Ci	curie
DCF	Dose Conversion Factor
DRC	State of Utah Division of Radiation Control
DUSA	Denison Mines (USA) Corp.
EPA	United States Environmental Protection Agency
E <sub>w</sub>	Process Emission Factor
F	Radon Release Rate
FES	Final Environmental Statement
F <sub>s</sub>	annual frequency of occurrence of wind group S
ft	feet
ft <sup>3</sup>	cubic feet
g	grams
g ore	grams of ore
GPS	Global Positioning System
GUI	Graphical User Interface
ha	hectares
hr	hours
ICRP	International Commission on Radiological Protection
ID	Induced Draft
lbs	pounds
km	kilometers
kts	knots
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NRC	United States Nuclear Regulatory Commission
NUREG	Regulatory Guide
m	meters
m <sup>2</sup>	square meters
mrem	millirem
MPC	Maximum Permissible Concentration

Pb-210	lead-210
Pb-214	lead-214
pCi	picocurie
Po-210	polonium-210
Po-218	polonium-218
Ra-226	radium-226
Rn-222	radon-222
R <sub>s</sub>	Resuspension rate for wind group S
s	seconds
S	Radionuclide Emission Rate
SENES	Specialists in Energy, Nuclear and Environmental Sciences
TGLM	Task Group on Lung Dynamics Lung Model
Th-230	thorium-230
tpy	tons per year
U <sub>3</sub> O <sub>8</sub>	triuranium octoxide (“Yellowcake”)
Unat	natural uranium
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
V <sub>2</sub> O <sub>5</sub>	vanadium pentoxide
yd <sup>3</sup>	cubic yards
yr	year

## **1.0 INTRODUCTION**

### **1.1 BACKGROUND**

Denison Mines (USA) Corp. (DUSA) operates the White Mesa Uranium Mill (hereafter referred to as the “mill”) in San Juan County, Utah, approximately 6 miles (9.6 km) south of the city of Blanding. The mill is located on a parcel of land and mill site claims covering approximately 5,415 acres (2,191 ha). The mill was built in 1979 and licensed by the United States Nuclear Regulatory Commission (NRC) to process uranium ore and selected alternate feed materials. The mill began operations in July 1980. In August 2004, the State of Utah became an Agreement State for the regulation of uranium mills, and primary regulatory authority over the mill was assumed by the State of Utah Division of Radiation Control (DRC) at that time.

The mill is a standard design with both uranium and vanadium circuits and uses the acid leach-solvent extraction process for uranium recovery from uranium ores and uranium/vanadium ores. Vanadium in uranium/vanadium-bearing ores is partially solubilized during leaching, and the dissolved vanadium present in uranium raffinate is further processed for recovery of vanadium before recycling (NRC1979).

In the early 1990s, the mill began receiving “alternate feed material” (uranium-bearing materials other than conventionally mined ores) for processing. From 1999 to present, the mill has relied solely on alternate feed materials. The mill goes on standby for periods of time and then it processes the stockpiled alternate feeds for the recovery of uranium. The residual tailings from these processes are stored in the tailings cells on-site. DUSA has commenced mining activities in the Colorado Plateau district and conventional ores are being hauled and stockpiled at the mill. In addition, DUSA has mining assets in the Arizona Strip, and mining of those ores is expected to commence in 2008. Milling of conventional ore is scheduled for Spring 2008, when the milling of currently available alternate feed material is completed (DUSA 2007a).

In February 2007, SENES prepared a dose assessment for DUSA in support of the license renewal application for the mill (SENES 2007, also referred to as the previous report). MILDOS-AREA was used to estimate the dose commitments that could potentially be received by individuals and the general population within a 50 mile (80 km) radius for the processing of Colorado Plateau or Arizona Strip ores separately. (MILDOS-AREA is an NRC approved code designed as a tool to provide input on regulatory and compliance evaluations for various uranium recovery operations.) The following assumptions were used in the previous report:

- Colorado Plateau ore contains an average of 0.25%  $U_3O_8$  and 1.5%  $V_2O_5$  (NRC 1980). The vanadium content in the ore is further processed for recovery before recycling.
- Arizona Strip ore contains 0.637%  $U_3O_8$  and no vanadium (Landau 2007).

- The activity concentrations of U-238 in Colorado Plateau and Arizona Strip ore were 700 and 1783 pCi U-238/g ore, respectively.
- The proposed ore process rate was assumed to be 730,000 tons per year (tpy) (an average of 2,000 tons per day). Therefore, assuming that the average uranium recovery would be at the historical recovery yield of 94%, approximately 1,715 tons (3,431,000 lbs) of U<sub>3</sub>O<sub>8</sub> per year would be recovered from Colorado Plateau ore at the proposed ore process rate. Similarly, approximately 4,371 tons (8,742,000 lbs) of U<sub>3</sub>O<sub>8</sub> per year would be recovered from Arizona Strip ore at the proposed ore process rate.

## **1.2 OBJECTIVE**

The objective of this report is to extend the analyses of the previous report of February 2007 to incorporate the dose from the proposed development of new tailings Cell 4B, anticipated to be completed for use in 2009, in support of a license amendment application by DUSA for construction and operation of that cell. In doing the dose assessment for Cell 4B, we have updated the assumptions we used in February 2007 for modeling tailings Cells 1, 2, 3 and 4A to reflect the current operational status of the site, including the re-commissioning of Cell 4A for use in 2008. Otherwise, we have made as few changes to the 2007 calculations as possible. MILDOS-AREA was used to estimate the dose commitments that could potentially be received by individuals and the general population within a 50 mile (80 km) radius of the site for the processing of Colorado Plateau or Arizona Strip ores using the assumptions provided in Section 1.1.

## **1.3 APPROACH**

The approach used for this assessment was to extend the previous report to incorporate the dose from the proposed development of Cell 4B, with as few changes to the calculations as possible. For purposes of modeling mill operations, we have separated operations into two phases. Phase 1 involves the continued use of Cell 1 for solution evaporation, the continued use of Cell 3 for solution evaporation and the disposal of tailings solids and the use of Cell 4A for disposal of tailings solids and solution evaporation. Phase 2 occurs after Cell 3 is full and is no longer an active cell. Phase 2 involves the use of Cell 1 for solution evaporation and Cells 4A and 4B for disposal of tailings solids and solution evaporation. In each Phase, Cell 2, with interim soil cover over the entire cell area, is included in the model, and in Phase 2, Cell 3, with interim soil cover over the entire cell area, is included in the model.

Since there are two types of ore, MILDOS-AREA runs were created to assess the dose from processing of the Colorado Plateau and Arizona Strip ores separately (hereafter referred to as Scenario 1 and 2, respectively). Each scenario/ore was analyzed with the following separate MILDOS-AREA runs:

- Tailing Cell 2 with Interim Soil Cover;
- Tailings Cell 3 with Interim Soil Cover;
- Tailings Cell 3;
- Tailings Cell 4A;
- Tailings Cell 4B; and
- All source terms (at the mill including the ore pads) except for tailings cells (hereafter referred to as the mill area).

The dose from each tailings cell was calculated in separate MILDOS-AREA runs to allow for the flexibility of calculating the incremental doses from the different combination of tailings cells to the mill area and ore pads for the two anticipated development Phases. Table 1.3-1 provides a summary of the source terms included in Phases 1 and 2 of the development of new tailings cells.

**TABLE 1.3-1  
SOURCE TERMS INCLUDED IN PHASES 1 AND 2**

Source Term	Phase 1	Phase 2
Mill area	included	included
Ore Pads	included	included
Tailings Cell 2 with Interim Soil Cover	included	included
Tailings Cell 3	active	interim soil cover
Tailings Cell 4A	active	active
Tailings Cell 4B	excluded	active

#### **1.4 CONTENTS OF THIS REPORT**

The remainder of this report is arranged into seven sections.

Section 2.0, **Regulatory Compliance**, provides a description of the regulatory framework pertaining to the applicable dose limits to members of the public from licensed activities at the mill.

Section 3.0, **Radiation Dose Assessment**, describes the method used to estimate the radiation doses to members of the public and how MILDOS-AREA was used.

Section 4.0, **Source Terms**, describes the source terms and source emission rates related to the ore processing operations and other input parameters required (i.e., meteorological data and population data) for the MILDOS-AREA runs. The source emission rates were calculated for processing Colorado Plateau and Arizona Strip ores based on the ore grade, ore process rate and uranium recovery yield described in Section 1.1.

Section 5.0, **Receptors**, describes the receptors used in the MILDOS-AREA runs.

Section 6.0, **Radiation Dose Estimates**, provides the dose results from the MILDOS-AREA runs using the parameters described in Sections 4.0 and 5.0.

Section 7.0, **Overviews**, provides a summary of the dose estimates for the two Phases in each scenario.

Section 8.0, **References**, provides a list of reference material used to prepare this report.

Appendix A: **History of MILDOS-AREA**, describes how the MILDOS-AREA software has evolved, highlighting some of the key differences between the updated version, MILDOS-AREA (ANL 1998a), and the original version of MILDOS.

Appendix B: **Emissions Calculations**, describes the basis of the emission estimates for each source.

Appendix C: **MILDOS-AREA Results**, provides the dose estimates for MILDOS-AREA runs for the mill area (including the ore pads) and each tailings cell.

## **2.0 REGULATORY COMPLIANCE**

DRC has the regulatory authority over the license issued for the site. As required by Utah Administrative Code R313-15-101(2), the mill shall, to the extent practical, employ procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as reasonably achievable (ALARA). Under R313-15-301(1)(a), the licensee is required to demonstrate that the total dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (100 mrem) in a year (including radon), exclusive of the dose contribution from natural background and medical sources. Under 10 CFR 20.1301 (NRC 1991), NRC has adopted the provisions of the United States Environmental Protection Agency (EPA) environmental radiation standards in 40 CFR 190 (EPA 2002). This subpart requires that the licensee provide reasonable assurance that the radiation attributed to mill operations does not exceed the annual dose of 25 mrem/yr to the whole body, 75 mrem/yr to the thyroid and 25 mrem/yr to any other organ of any member of the public (radon and its daughters excepted). In addition, 10 CFR 20.1301 (d) (R313-15-101(4)) sets an ALARA goal on air emissions of radioactive material to the environment, excluding radon-222 and its daughters such that the individual member of the public likely to receive the highest total effective dose equivalent will not exceed 10 mrem/yr.

### **3.0 RADIATION DOSE ASSESSMENT**

#### **3.1 GENERAL INFORMATION ABOUT MILDOS-AREA**

MILDOS-AREA only considers airborne releases of radioactive materials; releases to surface water and groundwater are not addressed. The U-238 decay chain was assumed to be the only significant source of radiation from uranium milling operations (the radioactivity contribution from the U-235 chain is less than 5% of that from the U-238 chain). The particulate releases include U-238, Th-230, Ra-226 and Pb-210. The gaseous releases are defined for Rn-222 with in-growth of short-lived daughter products also considered. These Rn-222 daughters include Po-218, Pb-214, Bi-214, Pb-210 and Po-210. The model accounts for the releases and in-growth of other radionuclides using the assumption of secular equilibrium within the U-238 decay chain.

The transport of model radiological emissions from the point and area sources is predicted using a sector-averaged Gaussian plume dispersion model. The dispersion model uses the meteorological data provided by the user and also includes mechanisms of dry deposition of particulates, re-suspension, radioactive decay and progeny in-growth and plume reflection. Deposition build-up and in-growth of radioactive progeny are considered in estimating ground concentrations.

The impacts to humans through various pathways are estimated based on the calculated annual average air concentrations of radionuclides. The pathways considered in this analysis include: inhalation, external exposure from ground concentrations, external exposure from cloud immersion, and ingestion of meat and vegetables.

#### **3.2 THE USE OF MILDOS-AREA IN THIS ASSESSMENT**

As described in Section 1.3, the approach for this assessment was to extend the previous report (SENES 2007) to incorporate the dose from the proposed development of Cell 4B, with as few changes to the calculations as possible. MILDOS-AREA (version 2.20 $\beta$  (ANL 1998a)) was used to estimate potential radiation doses to members of the public estimated from the processing of Colorado Plateau or Arizona Strip ores, with separate runs for each scenario/ore. (Information about the history of MILDOS-AREA is provided in Appendix A). In Scenario 1, 1,715 tons (3,430,100 lbs) of U<sub>3</sub>O<sub>8</sub> per year of Colorado Plateau ore would be recovered at the proposed ore process rate of 730,000 tpy (assuming that the average uranium recovery is 94%). Similarly in Scenario 2, 4,371 tons (8,742,000 lbs) of U<sub>3</sub>O<sub>8</sub> per year of Arizona Strip ore would be recovered.

In order design a conceptual model of the mill, MILDOS-AREA requires the user to define source and receptor locations and source emissions. The locations of sources and receptors are defined in MILDOS-AREA by providing Cartesian coordinates of the source/receptor relative to

a reference point. The coordinates of a point source are entered directly while the user must enter vertex coordinates for an area source.

In this assessment, the location of all sources (except for the tailings cells) and receptors were taken from the previous report. The coordinates relative to the vanadium stack (i.e., the reference point for the site) were determined by plotting the GPS coordinates (provided by DUSA (Turk 2007a)) in Google Earth Pro (Google 2005). A description of the tailings cells is provided in Section 4.0. The source emissions were calculated using guidance from NRC Regulatory Guide 3.59 (NRC 1987) and NUREG-0706 (NRC 1980). Radionuclide emission for radioactive particulates and radon are entered directly for point sources. For area sources, MILDOS-AREA calculates the radionuclide emission for radioactive particulates and radon based on the release rates and source area.

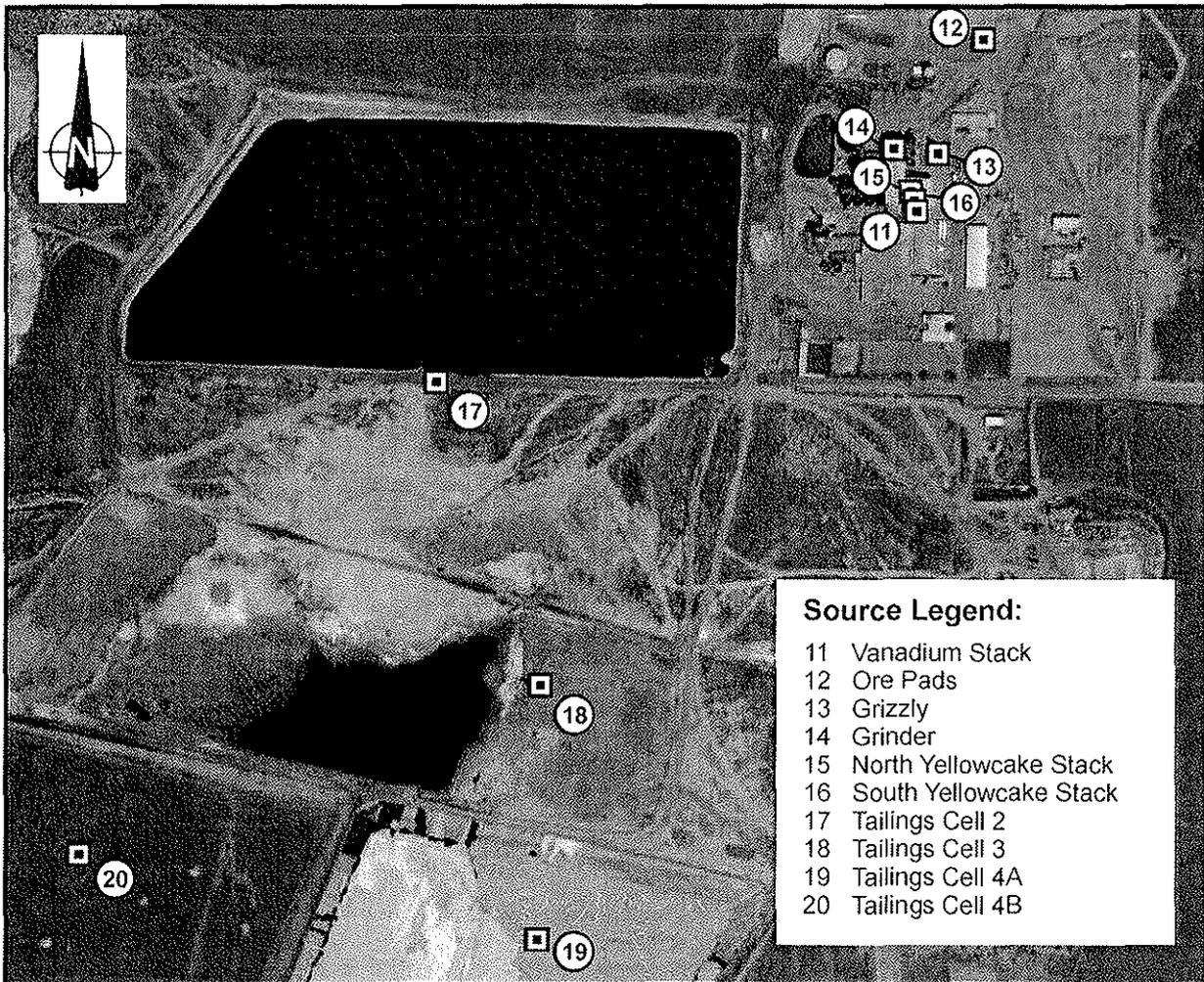
Since all source terms except for the tailings cells were taken from the previous report, the MILDOS-AREA run (from the previous report) for each scenario was revised to include all source terms except for the tailings cells. (Descriptions and emission rates for each source are provided in Section 4.0, and detailed emission estimates can be found in Appendix B.) The tailings cells were re-modelled individually in MILDOS-AREA as large area sources. Descriptions and emission rates for each cell are provided in Section 4.0, and detailed emission estimates are provided in Appendix B.

## **4.0 SOURCE TERMS**

The radionuclides of concern for the MILDOS-AREA model include: U-238 and its daughters Th-230, Ra-226, Pb-210 and Rn-222, which were assumed to be in secular equilibrium with the ore. The radioactive particulates and radon are emitted from airborne radioactive releases related to dust generation during ore handling (unloading ore from truck to ore pads and loading ore to the grizzly), point sources (grinder, yellowcake stacks and vanadium stack (only Scenario 1)) and area source dusting from ore pad stockpiles and the tailings cells. As mentioned in Section 3.2, all source terms except for the tailing cells were taken from the previous report. The locations of all point sources except for the grinder were determined by plotting the GPS coordinates (provided by DUSA (Turk 2007a)) in Google Earth Pro; and then using the measuring tool to measure the easting, northing and elevation of each source relative to a reference point at the mill (i.e., the vanadium stack).

The tailings cells were modelled as large area sources in MILDOS-AREA and located at the top centre of each cell. Figure 4.1 shows the locations (plotted in Google Earth) of all sources used in this assessment.

**FIGURE 4.1**  
**SOURCE LOCATIONS**



The doses to members of the public were estimated for the processing of Colorado Plateau or Arizona Strip ore in separate scenarios/runs. Therefore, the emission calculations are provided for each ore type based on the activity concentration of U-238 in the ore, expected ore grade, average uranium recovery and the proposed ore process rate. The MILDOS-AREA model for Colorado Plateau ore has an additional point source (i.e., vanadium stack) since the ore may contain vanadium (assumed at 1.5% V<sub>2</sub>O<sub>5</sub>). The approaches used to calculate the emissions from the point and area sources are described in Sections 4.1 and 4.2, respectively. Detailed source emissions calculations for all source terms are provided in Appendix B.

#### **4.1 POINT SOURCES**

Mill point sources used in this assessment include the grinder, loading ore to the grizzly and yellowcake stacks (north and south). The vanadium stack described in Section 4.1.4 is exclusive to the processing of Colorado Plateau ore. A description of the approach used to calculate the emissions from point sources is provided in this section.

##### **4.1.1 Grinder**

There is no on-site crushing of the ore, only a wet grinding operation. The ore dust emissions are controlled because the material is wet during the grinding operations. The particulate emission control from the grinding operation was assumed to be 99.9% (EnecoTech 1991a and 1991b). With these assumptions, U-238 and its decay daughters (assuming secular equilibrium) would be emitted at a rate of 9.27E-05 and 2.36E-04 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively. The emission rates for Rn-222 released during wet grinding was calculated assuming that only 20% of the radon is available for release or emanation from the mineral grains in which it is produced (NRC 1980). The Rn-222 concentration in the ore was assumed to be equal to the U-238 concentration. The Rn-222 released during wet grinding is 92.7 and 236 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively.

##### **4.1.2 Grizzly**

The emissions from trucks dumping ore onto the grizzly are highly controlled; the truck dump area is enclosed on three sides and has a negative pressure on it during dumping activities. The ore is delivered wet with an average moisture content of 10%. The exhaust from the induced draft (ID) fans used on the grizzly is ducted through a baghouse (EnecoTech 1991a and 1991b). The combined particulate dust control on this operation was assumed to be 99.9% (EnecoTech 1991a and 1991b). With these assumptions, U-238 and its decay daughters (assuming secular equilibrium) would be emitted at a rate of 9.27E-05 and 2.36E-04 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively.

### **4.1.3 Yellowcake Stacks**

The mill has two yellowcake dryers (north and south yellowcake dryers). From the EnecoTech analysis, stack tests on the yellowcake dryer yielded a yellowcake emission rate of 0.06 lbs/hr  $U_3O_8$  when the process rate was 1300 lbs/hr. This yields an emission rate of 0.092 lbs/hr of yellowcake per ton of feed (EnecoTech 1991a and 1991b). The emission rate is with all the particulate emissions controls. Since there are north and south yellowcake dryers, the stack emissions from U-238 and its decay daughters are assumed to be divided equally between the two (i.e., north and south yellowcake stacks). With these assumptions, U-238 would be emitted at a rate of 1.01E-02 and 2.36E-04 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively.

Based on field measurements, the decay daughters of U-238 (Th-230, Ra-226 and Pb-210) are processed along with yellowcake at 0.22%, 0.13% and 0.78% of U-238, respectively (EnecoTech 1991a and 1991b). Therefore, the decay daughters Th-230, Ra-226 and Pb-210 are emitted at a rate of 2.22E-05, 1.31E-05 and 7.88E-05 Ci/yr, respectively for Colorado Plateau ore. Similarly, the decay daughters Th-230, Ra-226 and Pb-210 are emitted at a rate of 5.67E-05, 3.35E-05 and 2.01E-04 Ci/yr, respectively for Arizona Strip ore.

Since the ore processing steps reject nearly all the radium to the tailings, very little radon is released during the production of yellowcake. No significant radon releases occur during yellowcake drying and packaging, since only about 0.1% of the original Ra-226 in the ore is found in yellowcake. Therefore, the amount of Rn-222 emitted from the yellowcake stack was assumed to be negligible.

### **4.1.4 Vanadium Stack**

The vanadium stack source term was only used in the MILDOS-AREA run for Colorado Plateau ore. The vanadium present in the Colorado Plateau ore is partially solubilized during leaching. The dissolved vanadium is present in uranium raffinate. Depending on its vanadium content, the uranium raffinate will either be recycled to the counter-current decantation step or further processed for recovery of vanadium before recycling. The product from the vanadium recovery contains less than 0.005%  $U_3O_8$  (NRC 1980). Therefore, the emission rate for the vanadium stack was calculated to be 0.005% of the total emission rate from the yellowcake stacks (north and south yellowcake stack) and U-238 was assumed to be emitted at a rate of 1.01E-06 Ci/yr.

Based on the EnecoTech (1991a and 1991b) measurements for the decay daughters of U-238 (Th-230, Ra-226 and Pb-210) processed along with yellowcake of 0.22%, 0.13% and 0.78% of U-238, respectively, the emissions from the remaining radionuclides were assumed to be negligible and in any event would likely be discharged to the tailings cells.

## **4.2 AREA SOURCES**

Mill area sources used in this assessment include the ore pads and the tailings cells. A description of the approach used to calculate the emissions from area sources is provided in this section.

### **4.2.1 Ore Pads**

The ore pad storage operation has two different sources of emissions, namely unloading ore from trucks to the ore pad and wind emissions. Approximately 300,000 tons of ore were assumed to be temporarily stockpiled at the mill's ore pads at any given time. Using a bulk ore density of 1.47 tons/yd<sup>3</sup> (DUSA, Feb. 6/07), the quantity of ore would create a pile 30 ft. (9.1 m) tall covering approximately 4 acres (17,000 m<sup>2</sup>) stockpile area.

With respect to the truck unloading emissions, a process emission factor of 0.04 lbs of ore is emitted per cubic yard handled (for a truck end and assuming no control (NRC 1987)) and a bulk ore density of 1.47 tons/yd<sup>3</sup> was used in the calculations. With these assumptions, U-238 and its decay daughters (assuming secular equilibrium) would be emitted at a rate of 1.58E-02 and 4.02E-02 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively.

Wind erosion from the ore pad was assumed to have a 50% control factor due to the active watering program in place (EnecoTech 1991a and 1991b). This is conservative, in that actual dust control on the ore pads may be better than this. The annual dust loss from the ore pad is 21.29 g/m<sup>2</sup>/yr; this was calculated using the method from NRC Regulatory Guide 3.59 (NRC 1987) on the basis of the meteorological data (provided by DUSA (Turk 2007b)) presented in Appendix B; the annual dust loss from the ore pads is 10% that of the tailings piles since the particulates in the ore pads are coarse material (1 to 6 inch) because the ore has not yet been ground. U-238 and its decay daughters (assuming secular equilibrium) were all assumed to be emitted at a rate of 3.17E-04 and 8.07E-04 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively. Therefore, the total emission rate of U-238 and its daughter from truck dumping and wind erosion is 1.61E-02 and 4.10E-02 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively.

Rn-222 will be produced in the ore pads from the decay of Ra-226. The estimated annual radon release rate from the ore pads is 375 and 956 Ci/yr for Colorado Plateau and Arizona Strip ore, respectively.

#### 4.2.2 Tailings Cells

The characteristics of each tailings cell included in Phases 1 and 2 of the proposed development of new tailings cell 4B are provided in Tables 4.2-1 and 4.2-2, respectively.

**TABLE 4.2-1  
CHARACTERISTICS OF TAILINGS CELLS IN PHASE 1**

Tailings Cell	Interim Soil Cover (Inactive)	Active
2	●	○
3	○	●
4A	○	●
4B	○	○

**TABLE 4.2-2  
CHARACTERISTICS OF TAILINGS CELLS IN PHASE 2**

Tailings Cell	Interim Soil Cover (Inactive)	Active
2	●	○
3	●	○
4A	○	●
4B	○	●

#### *Active Tailings Cells*

Wind erosion of tailings and radon release rates from the active tailings cell were estimated using a maximal worst cast approach. However, since it is not possible to predict the distribution of uncovered tailings between active cells at any given time, the active tailings cells were modelled by using a maximal worst case approach. The following assumptions were used for the active tailings cells:

- Each tailings cell was assumed to have a maximum area of 10 acres for uncovered tailings material (this assumptions is considered to be conservative, because the average area of uncovered tailings in a cell is expected to be less than 10 acres).
- Wind-eroded tailings dust would arise from the 10 acres of uncovered tailings.
- The total annual radon release rate for each tailings cell was calculated by assuming a radon release rate of 20 pCi/m<sup>2</sup>s (i.e., maximum radon-222 emissions to ambient air from an existing uranium mill pile that is allowed under the regulations) over the entire area of each cell. However, this total annual radon release rate was assumed to be released from the 10 acre area that was modelled. The area of tailings cell 3 was assumed to be 70 acres while tailing cells 4A and 4B were assumed to be 40 acres each.

Using the onsite wind data generated over the last three years (provided by DUSA (Turk 2007b)), the annual dust loss from the tailings cells was estimated to be approximately 213 g/m<sup>2</sup>/yr; this was calculated using the method from NRC Regulatory Guide 3.59 (NRC 1987). An average uranium recovery rate of 94% was assumed. In addition, a process emission control factor of 70% was assumed, based on 1) the active watering (tailings solutions spraying) program on exposed areas of tailings beaches in active areas; 2) solutions cover other tailings areas; and 3) crusting agents from the sprayed solutions act to minimize the erosion of the tailings beaches by wind (EnecoTech 1991a and 1991b).

With these assumptions and the particulate emission factor, U-238 would be emitted at a rate of 2.71E-04 Ci/yr and the decay daughters Th-230, Ra-226 and Pb-210 would be emitted at a rate of 4.52E-03 Ci/yr from each active cell for Colorado Plateau ore. These total annual emission rates assume operation at the proposed ore process rate of 730,000 tpy and an ore specific activity of 700 pCi/g. Similarly, for Arizona Strip ore, U-238 is emitted at a rate of 6.91E-04 Ci/yr and the decay daughters Th-230, Ra-226 and Pb-210 are emitted at a rate of 1.15E-02 Ci/yr from each active cell. These total annual emission rates assume the proposed ore process rate of 730,000 tpy and an ore specific activity of 1783 pCi/g.

In this assessment, the total annual radon release rates for active tailings cell 3 and 4A and 4B were estimated to be 179 Ci/yr for tailings cell 3 and 102 Ci/yr for each of tailings cells 4A and 4B. These estimates are extremely conservative because it was assumed that the radon release rate of 20 pCi/m<sup>2</sup>s (i.e., maximum radon-222 emissions to ambient air from an existing uranium mill tailings impoundment) occurred over the entire area of each cell. Actual measurements collected annually at the tailings cells to determine compliance with the NESHAPs radon emanation standard have confirmed that the 20 pCi/m<sup>2</sup>s release rate utilized for this assessment is a conservative estimate.

### ***Interim Soil Cover (Inactive Tailings Cells)***

The tailings cells (2 and 3) with interim soil cover were assumed to be the entire areas of each cell. The following assumptions were used for the tailings cells with interim soil covers:

- The area of tailings cell 2 with interim soil cover is 66.8 acres;
- The area of tailings cell 3 with interim soil cover is 70 acres;
- A nominal value of 10 pCi/m<sup>2</sup>s was used for radon flux based on historical values for the Mill's tailings cells; and,
- No tailings dust will be released.

Using the assumptions above, the total annual radon release from the tailings cells 2 and 3 with interim soil covers were 85.3 and 89.4 Ci/yr, respectively.

#### **4.3 METEOROLOGICAL DATA**

Meteorological conditions influence re-suspension and dispersion of radionuclides from point sources and area sources. The mill has an on-site weathering monitoring station that records wind speed, wind direction and stability class. This data is used to formulate a joint frequency distribution which is a required input for MILDOS-AREA. The joint frequency distribution used in this assessment was provided by DUSA (Turk 2007b) using the most recent three years (2004 to 2006) of recorded data.

#### **4.4 POPULATION DATA**

The population data was obtained from the year 2000 U.S. census and was used to complete demographic and population dose projections. Census data is only available in 10 year intervals for population centers of less than 65,000 residents, and local demographics have experienced little change since the 2000 census.

## 4.5 URANIUM MILL SOURCE EMISSION RATES

### 4.5.1 Colorado Plateau Ore

The calculated mill radioactive particulate and radon emission rates from point sources and area sources described in Sections 4.1 and 4.2, respectively for Colorado Plateau ore are provided in Table 4.5-1.

**TABLE 4.5-1  
RADIOACTIVE PARTICULATE AND RADON EMISSION RATES  
(COLORADO PLATEAU ORE)**

		Grinding	Ore Dump to Grizzly	Ore Pads	North YC Stack	South YC Stack	Interim Soil Cover		Active			Vanadium Stack <sup>b</sup>
							Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B	
Emission Rate (Ci/yr)	U-238	9.27E-05	9.27E-05	1.61E-02	1.01E-02	1.01E-02	0.00E+00	0.00E+00	2.71E-04	2.71E-04	2.71E-04	1.01E-06
	Th-230	9.27E-05	9.27E-05	1.61E-02	2.22E-05	2.22E-05	0.00E+00	0.00E+00	4.52E-03	4.52E-03	4.52E-03	2.22E-09
	Ra-226	9.27E-05	9.27E-05	1.61E-02	1.31E-05	1.31E-05	0.00E+00	0.00E+00	4.52E-03	4.52E-03	4.52E-03	1.31E-09
	Pb-210	9.27E-05	9.27E-05	1.61E-02	7.88E-05	7.88E-05	0.00E+00	0.00E+00	4.52E-03	4.52E-03	4.52E-03	7.88E-09
	Rn-222	9.27E+01	Note a	3.75E+02	Note a	Note a	8.53E+01	8.94E+01	1.79E+02	1.02E+02	1.02E+02	Note a

**Notes:**

- a) No significant release during this process.
- b) Source is exclusive to the processing of Colorado Plateau ore.

### 4.5.2 Arizona Strip Ore

The calculated mill radioactive particulate and radon emission rates from point sources and area sources described in Sections 4.1 and 4.2, respectively for Arizona Strip ore are provided in Table 4.5-2.

**TABLE 4.5-2  
RADIOACTIVE PARTICULATE AND RADON EMISSION RATES  
(ARIZONA STRIP ORE)**

		Grinding	Ore Dump to Grizzly	Ore Pads	North YC Stack	South YC Stack	Interim Soil Cover		Active		
							Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Emission Rate (Ci/yr)	U-238	2.36E-04	2.36E-04	4.10E-02	2.58E-02	2.58E-02	0.00E+00	0.00E+00	6.91E-04	6.91E-04	6.91E-04
	Th-230	2.36E-04	2.36E-04	4.10E-02	5.67E-05	5.67E-05	0.00E+00	0.00E+00	1.15E-02	1.15E-02	1.15E-02
	Ra-226	2.36E-04	2.36E-04	4.10E-02	3.35E-05	3.35E-05	0.00E+00	0.00E+00	1.15E-02	1.15E-02	1.15E-02
	Pb-210	2.36E-04	2.36E-04	4.10E-02	2.01E-04	2.01E-04	0.00E+00	0.00E+00	1.15E-02	1.15E-02	1.15E-02
	Rn-222	2.36E+02	Note a	9.56E+02	Note a	Note a	8.53E+01	8.94E+01	1.79E+02	1.02E+02	1.02E+02

Note:

a) No significant release during this process.

## **5.0 RECEPTORS**

The receptors used in this assessment were provided by DUSA. The receptors used in this assessment were as follows:

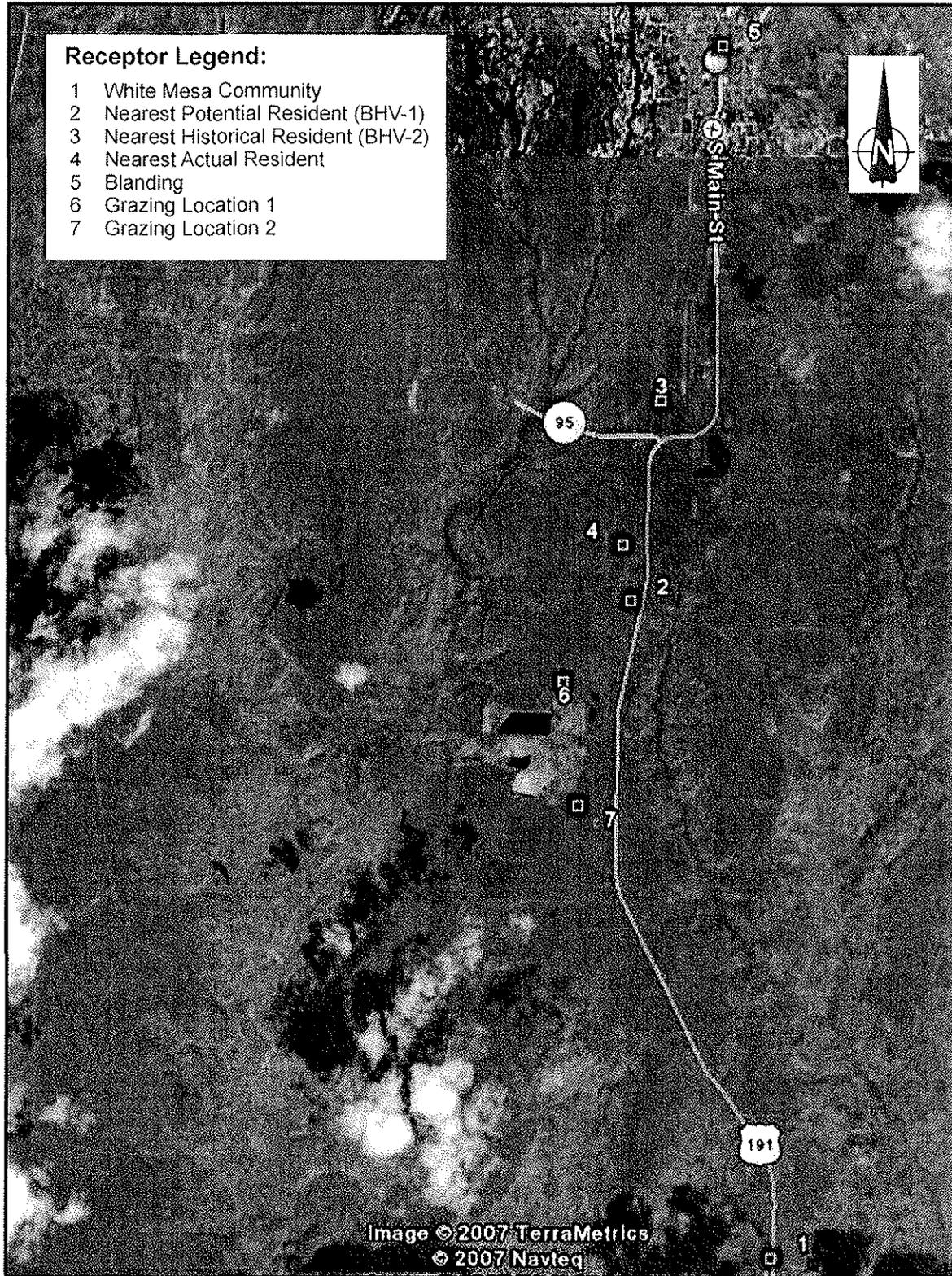
- Nearest Historical Resident (BHV-2);
- Nearest Actual Resident;
- Nearest Potential Resident (BHV-1);
- White Mesa Ute Community;
- Blanding, Utah.

In addition, two grazing locations 1 and 2 were considered as a possible source of meat.

As mentioned in Section 3.2, the receptor locations were determined using GPS coordinates provided by DUSA (Turk 2007a). The GPS coordinates were used for all the receptors except for Grazing locations 1 and 2 where the easting and northing for Grazing locations 1 and 2 were taken as nominal “mid-points” in Google Earth for these two receptor locations.

The receptor locations (plotted in Google Earth) with respect to the vanadium stack are shown in Figure 5.1.

**FIGURE 5.1**  
**RECEPTOR LOCATIONS**



At the time of the 1979 Final Environmental Statement (FES) (NRC 1979) for the mill, the nearest resident lived approximately 4.8 miles (4.5) km north-north east of the mill building, near the location of air monitoring station BHV-2 (also referred to as the historical nearest resident.) Currently, the nearest “potential” resident is approximately 1.2 miles (1.9 km) north of the Mill, near the location of air monitoring station BHV-1. The nearest actual resident is located approximately 1.6 miles (2.5 km) north of the mill. Nearby population groups include the community of White Mesa, about 8.5 km south east and the city of Blanding, approximately 6 miles (10 km) from the mill.

The area to the immediate north of the mill (Grazing location 1) is believed to be used only for grazing of meat animals (beef) (NRC 1979). A second location (Grazing location 2) to the east and south of the mill is also used for the grazing of meat animals (beef) as was assumed in the EnecoTech analysis (EnecoTech 1991a and 1991b). Although considered unlikely, in one worst case scenario, it is possible that the meat animals grazed at Grazing location 1 and 2 would be eaten by the residents near the mill. A scenario which supports dairy cattle grazing at Grazing locations 1 and 2 was not included because the prospect of supporting dairy cattle in those locations is not credible, given the arid climate and the much larger feed requirements of dairy cattle as opposed to beef cattle. DUSA has also indicated that there are no dairy cattle grazed in Grazing locations 1 and 2. It should be noted, however, that in all of the MILDOS-AREA model runs in this report, it was assumed, conservatively, that individuals at each receptor location drink all of their milk from cows and eat all of their beef from cattle that graze at the receptor locations (but not at Grazing locations 1 or 2). This is thought to be a very conservative assumption.

## **6.0 RADIATION DOSE ESTIMATES**

This section describes the MILDOS-AREA results of the mill's potential radiological impacts on the population in the vicinity of the Mill. This analysis was primarily based on the estimated annual releases of radioactive materials and assumptions discussed in Sections 4.0 and 5.0. All potential exposure pathways which are likely to impact individuals near the mill were included in the MILDOS-AREA model.

MILDOS-AREA calculates the total annual effective dose commitment (including radon). The calculated total annual effective dose commitments were compared to the 10 CFR 20 (R313-15) requirements that the dose to individual members of the public shall not exceed 100 mrem/yr (radon included). In addition, MILDOS-AREA calculates 40 CFR 190 doses (excludes radon). The 40 CFR 190 Criterion is 25 mrem/yr to the whole body (excluding the dose due to radon) and 25 mrem/yr to any other organ to any member of the public (EPA 2002). The 40 CFR 190 doses were also used to demonstrate compliance with 10 CFR 20.1101(d) (R313-15-101(4)). Under 10 CFR 20.1101(d) (R313-15-101(4)) the licensee must demonstrate as an ALARA goal that the total effective dose equivalent to the individual member of the public likely to receive the highest total effective dose equivalent will not exceed 10 mrem/yr (absent of the radon dose).

In this assessment, a worst-case scenario in which there is a possibility that individuals near the mill ingest meat from cattle grown at Grazing Location 1 or 2 was considered. It was assumed that the cattle will graze at Grazing location 1 or 2 for two months of the year (due to the arid nature of the region and the lack of forage). Therefore, the meat ingestion dose to individuals near the mill who might consume beef grazed at Grazing Location 1 or 2 was assumed to be one-sixth of the MILDOS-AREA calculated meat ingestion dose from these grazing locations.

As mentioned in Section 1.3, MILDOS-AREA was run separately for Colorado Plateau and Arizona Strip ore. Total annual dose commitments and 40 CFR 190 annual dose commitments were estimated for locations in which individual members of the public might reside (Nearest Potential Resident (BHV-1), Nearest Historical Resident (BHV-2), Nearest Actual Resident, White Mesa Ute Community and Blanding, Utah) for two development Phases of the new tailings cells. The total annual dose commitments and 40 CFR 190 annual dose commitments for Phases 1 and 2 are provided in Sections 6.1 and 6.2 for Colorado Plateau and Arizona Strip ore, respectively. In addition, total annual dose commitments and 40 CFR 190 annual dose commitments from the meat ingestion pathway that is estimated for Grazing location 1 and 2 are provided in Sections 6.1 and 6.2, respectively.

## **6.1 MILDOS-AREA RESULTS FOR COLORADO PLATEAU ORE**

The potential annual doses to the people living close to the mill and to the population living within 50 miles (80 km) as a result of processing Colorado Plateau ore was calculated using MILDOS-AREA.

The MILDOS-AREA-calculated total annual dose commitments (including radon) and 40 CFR 190 total annual dose commitment for processing of Colorado Plateau ore are provided in Sections 6.1.1 and 6.1.2, respectively

### **6.1.1 R313-15-301(1)(a) Regulatory Compliance**

The MILDOS-AREA calculated total annual dose commitments (including radon) for Phases 1 and 2 are provided in this section. These doses are regulated by R313-15-301(1)(a) which requires that the dose to an individual member of the public shall not exceed 100 mrem/yr (radon included).

#### ***Phase 1***

Table 6.1-1 presents a summary of the individual dose commitments for the residential receptors for the age group of infant, child, teenage and adult for Phase 1.

**TABLE 6.1-1  
PHASE 1-COMPARISON OF ANNUAL DOSE COMMITMENTS TO APPLICABLE  
RADIATION PROTECTION STANDARDS (COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Potential Resident (BHV-1)	Infant	Effective	1.37E+00	100	1.37E-02
		Bone	1.92E+00	-	-
		Avg. Lung	5.31E-01	-	-
		Bronchi	1.30E+01	-	-
	Child	Effective	1.05E+00	100	1.05E-02
		Bone	1.37E+00	-	-
		Avg. Lung	7.10E-01	-	-
		Bronchi	1.30E+01	-	-
	Teenage	Effective	1.10E+00	100	1.10E-02
		Bone	4.84E+00	-	-
		Avg. Lung	5.68E-01	-	-
		Bronchi	1.30E+01	-	-
	Adult	Effective	9.84E-01	100	9.84E-03
		Bone	2.13E+00	-	-
		Avg. Lung	3.97E-01	-	-
		Bronchi	1.30E+01	-	-
Nearest Historical Resident (BHV-2)	Infant	Effective	3.10E-01	100	3.10E-03
		Bone	3.05E-01	-	-
		Avg. Lung	1.06E-01	-	-
		Bronchi	3.52E+00	-	-
	Child	Effective	2.66E-01	100	2.66E-03
		Bone	2.33E-01	-	-
		Avg. Lung	1.29E-01	-	-
		Bronchi	3.52E+00	-	-
	Teenage	Effective	2.72E-01	100	2.72E-03
		Bone	7.63E-01	-	-
		Avg. Lung	1.05E-01	-	-
		Bronchi	3.52E+00	-	-
	Adult	Effective	2.55E-01	100	2.55E-03
		Bone	3.53E-01	-	-
		Avg. Lung	7.69E-02	-	-
		Bronchi	3.52E+00	-	-

**TABLE 6.1-1 (Cont'd)**  
**PHASE 1-COMPARISON OF ANNUAL DOSE COMMITMENTS TO APPLICABLE RADIATION PROTECTION STANDARDS (COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Actual Resident	Infant	Effective	8.78E-01	100	8.78E-03
		Bone	1.13E+00	-	-
		Avg. Lung	3.17E-01	-	-
		Bronchi	8.78E+00	-	-
	Child	Effective	6.95E-01	100	6.95E-03
		Bone	8.12E-01	-	-
		Avg. Lung	4.21E-01	-	-
		Bronchi	8.78E+00	-	-
	Teenage	Effective	7.21E-01	100	7.21E-03
		Bone	2.83E+00	-	-
		Avg. Lung	3.39E-01	-	-
		Bronchi	8.78E+00	-	-
	Adult	Effective	6.55E-01	100	6.55E-03
		Bone	1.26E+00	-	-
		Avg. Lung	2.40E-01	-	-
		Bronchi	8.78E+00	-	-
White Mesa Community	Infant	Effective	2.45E-01	100	2.45E-03
		Bone	1.45E-01	-	-
		Avg. Lung	6.72E-02	-	-
		Bronchi	3.18E+00	-	-
	Child	Effective	2.25E-01	100	2.25E-03
		Bone	1.08E-01	-	-
		Avg. Lung	6.47E-02	-	-
		Bronchi	3.18E+00	-	-
	Teenage	Effective	2.26E-01	100	2.26E-03
		Bone	2.86E-01	-	-
		Avg. Lung	5.26E-02	-	-
		Bronchi	3.18E+00	-	-
	Adult	Effective	2.20E-01	100	2.20E-03
		Bone	1.48E-01	-	-
		Avg. Lung	4.27E-02	-	-
		Bronchi	3.18E+00	-	-

**TABLE 6.1-1 (Cont'd)**  
**PHASE 1-COMPARISON OF ANNUAL DOSE COMMITMENTS TO APPLICABLE RADIATION PROTECTION STANDARDS (COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Blanding	Infant	Effective	1.07E-01	100	1.07E-03
		Bone	8.94E-02	-	-
		Avg. Lung	3.36E-02	-	-
		Bronchi	1.25E+00	-	-
	Child	Effective	9.38E-02	100	9.38E-04
		Bone	6.78E-02	-	-
		Avg. Lung	3.91E-02	-	-
		Bronchi	1.25E+00	-	-
	Teenage	Effective	9.55E-02	100	9.55E-04
		Bone	2.10E-01	-	-
		Avg. Lung	3.23E-02	-	-
		Bronchi	1.25E+00	-	-
	Adult	Effective	9.08E-02	100	9.08E-04
		Bone	1.00E-01	-	-
		Avg. Lung	2.47E-02	-	-
		Bronchi	1.25E+00	-	-

From Table 6.1-1, the total annual effective dose commitments are at most 1.4% (effective dose for infant at BHV-1) of the R313-15-301(1)(a) limit of 100 mrem/yr (radon included) to an individual member of the public. Therefore, the predicted annual effective dose commitments comply with R313-15-301(1)(a).

In the worst case scenario in which there is a possibility that individuals near the mill ingest meat from cattle grown at Grazing Location 1 or 2. It was assumed that the cattle will graze at Grazing location 1 or 2 for 2 months of the year. The meat ingestion dose to individuals near the mill who might consume beef grazed at Grazing Location 1 or 2 was assumed to be one-sixth of the MILDOS-AREA calculated meat ingestion dose from these grazing locations. Table 6.1-2 presents a summary of the annual dose commitments from the meat ingestion pathway for Grazing location 1 and 2. Even in the very unlikely event that a resident were to consume meat from one of the grazing locations, the total dose would remain well below regulatory limits.

**TABLE 6.1-2**  
**PHASE 1-TOTAL ANNUAL DOSE COMMITMENTS FOR MEAT INGESTION**  
**PATHWAY (COLORADO PLATEAU ORE) (mrem/yr)**

Location	Age Group	Organ <sup>b</sup>		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.08E-02	5.40E-02	4.91E-02
	Teenage	1.70E-02	2.80E-01	4.30E-02
	Adult	1.23E-02	1.52E-01	3.55E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	7.35E-04	3.65E-03	3.12E-03
	Teenage	1.14E-03	1.92E-02	2.72E-03
	Adult	8.13E-04	1.01E-02	2.25E-03

Note:

a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.

**Phase 2**

Table 6.1-3 presents a summary of the individual dose commitments for the residential receptors for the age group of infant, child, teenage and adult for Phase 2.

**TABLE 6.1-3**  
**PHASE 2-COMPARISON OF ANNUAL DOSE COMMITMENTS TO APPLICABLE**  
**RADIATION PROTECTION STANDARDS (COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Potential Resident (BHV-1)	Infant	Effective	1.35E+00	100	1.35E-02
		Bone	1.90E+00	-	-
		Avg. Lung	5.20E-01	-	-
		Bronchi	1.28E+01	-	-
	Child	Effective	1.04E+00	100	1.04E-02
		Bone	1.35E+00	-	-
		Avg. Lung	6.93E-01	-	-
		Bronchi	1.28E+01	-	-
	Teenage	Effective	1.08E+00	100	1.08E-02
		Bone	4.75E+00	-	-
		Avg. Lung	5.54E-01	-	-
		Bronchi	1.28E+01	-	-
	Adult	Effective	9.68E-01	100	9.68E-03
		Bone	2.09E+00	-	-
		Avg. Lung	3.87E-01	-	-
		Bronchi	1.28E+01	-	-

**TABLE 6.1-3 (Cont'd)**  
**PHASE 2-COMPARISON OF ANNUAL DOSE COMMITMENTS TO APPLICABLE RADIATION PROTECTION STANDARDS (COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Historical Resident (BHV-2)	Infant	Effective	3.10E-01	100	3.10E-03
		Bone	3.03E-01	-	-
		Avg. Lung	1.05E-01	-	-
		Bronchi	3.52E+00	-	-
	Child	Effective	2.66E-01	100	2.66E-03
		Bone	2.31E-01	-	-
		Avg. Lung	1.28E-01	-	-
		Bronchi	3.52E+00	-	-
	Teenage	Effective	2.72E-01	100	2.72E-03
		Bone	7.57E-01	-	-
		Avg. Lung	1.04E-01	-	-
		Bronchi	3.52E+00	-	-
	Adult	Effective	2.55E-01	100	2.55E-03
		Bone	3.50E-01	-	-
		Avg. Lung	7.63E-02	-	-
		Bronchi	3.52E+00	-	-
Nearest Actual Resident	Infant	Effective	8.70E-01	100	8.70E-03
		Bone	1.12E+00	-	-
		Avg. Lung	3.11E-01	-	-
		Bronchi	8.69E+00	-	-
	Child	Effective	6.88E-01	100	6.88E-03
		Bone	7.98E-01	-	-
		Avg. Lung	4.13E-01	-	-
		Bronchi	8.69E+00	-	-
	Teenage	Effective	7.13E-01	100	7.13E-03
		Bone	2.78E+00	-	-
		Avg. Lung	3.32E-01	-	-
		Bronchi	8.69E+00	-	-
	Adult	Effective	6.48E-01	100	6.48E-03
		Bone	1.23E+00	-	-
		Avg. Lung	2.35E-01	-	-
		Bronchi	8.69E+00	-	-

**TABLE 6.1-3 (Cont'd)**  
**PHASE 2-COMPARISON OF ANNUAL DOSE COMMITMENTS TO APPLICABLE RADIATION PROTECTION STANDARDS (COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
White Mesa Community	Infant	Effective	2.47E-01	100	2.47E-03
		Bone	1.45E-01	-	-
		Avg. Lung	6.69E-02	-	-
		Bronchi	3.20E+00	-	-
	Child	Effective	2.26E-01	100	2.26E-03
		Bone	1.07E-01	-	-
		Avg. Lung	6.45E-02	-	-
		Bronchi	3.20E+00	-	-
	Teenage	Effective	2.28E-01	100	2.28E-03
		Bone	2.85E-01	-	-
		Avg. Lung	5.25E-02	-	-
		Bronchi	3.20E+00	-	-
	Adult	Effective	2.22E-01	100	2.22E-03
		Bone	1.48E-01	-	-
		Avg. Lung	4.27E-02	-	-
		Bronchi	3.20E+00	-	-
Blanding	Infant	Effective	1.08E-01	100	1.08E-03
		Bone	8.94E-02	-	-
		Avg. Lung	3.36E-02	-	-
		Bronchi	1.26E+00	-	-
	Child	Effective	9.46E-02	100	9.46E-04
		Bone	6.79E-02	-	-
		Avg. Lung	3.92E-02	-	-
		Bronchi	1.26E+00	-	-
	Teenage	Effective	9.62E-02	100	9.62E-04
		Bone	2.10E-01	-	-
		Avg. Lung	3.23E-02	-	-
		Bronchi	1.26E+00	-	-
	Adult	Effective	9.15E-02	100	9.15E-04
		Bone	1.00E-01	-	-
		Avg. Lung	2.48E-02	-	-
		Bronchi	1.26E+00	-	-

From Table 6.1-3, the total annual effective dose commitments are at most 1.4% (effective dose for infant at BHV-1) of the R313-15-301(1)(a) limit of 100 mrem/yr (radon included) to an individual member of the public. Therefore, the predicted annual effective dose commitments comply with R313-15-301(1)(a).

In addition, Table 6.1-4 presents a summary of the annual dose commitments from the meat ingestion pathway for Grazing location 1 and 2. As before, in the very unlikely event that a

resident were to consume meat from one of the grazing locations, the total dose would remain well below regulatory limits.

**TABLE 6.1-4  
PHASE 2-TOTAL ANNUAL DOSE COMMITMENTS FOR MEAT INGESTION  
PATHWAY (COLORADO PLATEAU ORE) (mrem/yr)**

Location	Age Group	Organ <sup>b</sup>		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.07E-02	5.35E-02	4.87E-02
	Teenage	1.68E-02	2.78E-01	4.26E-02
	Adult	1.22E-02	1.50E-01	3.51E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	6.73E-04	3.34E-03	2.82E-03
	Teenage	1.04E-03	1.76E-02	2.46E-03
	Adult	7.41E-04	9.22E-03	2.03E-03

Note:

a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.

### 6.1.2 40 CFR 190 Regulatory Compliance

MILDOS-AREA calculated 40 CFR 190 doses (excludes radon). These doses are regulated by the 40 CFR 190 criterion of 25 mrem/yr to the whole body (excluding the dose due to radon) (EPA 2002) or to any organ of the body. The 40 CFR 190 doses are also used to demonstrate compliance with R313-15-101(4) (10 CFR 20.1101(d)). The licensee must demonstrate as an ALARA goal, that total effective dose equivalent to the individual member of the public likely to receive the highest total effective dose equivalent will not exceed 10 mrem/yr (absent of the radon dose).

#### *Phase 1*

Table 6.1-5 presents a summary of the 40 CFR 190 individual dose commitments for residential receptors for the age group of infant, child, teenage and adult for Phase 1.

**TABLE 6.1-5**  
**PHASE 1-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Potential Resident (BHV-1)	Infant	Effective	5.45E-01	25	2.18E-02
		Bone	1.86E+00	25	7.45E-02
		Avg. Lung	4.85E-01	25	1.94E-02
		Bronchi	9.73E-04	no limit given	-
	Child	Effective	2.32E-01	25	9.28E-03
		Bone	1.33E+00	25	5.30E-02
		Avg. Lung	6.62E-01	25	2.65E-02
		Bronchi	9.73E-04	no limit given	-
	Teenage	Effective	2.76E-01	25	1.10E-02
		Bone	4.79E+00	25	1.92E-01
		Avg. Lung	5.22E-01	25	2.09E-02
		Bronchi	9.73E-04	no limit given	-
	Adult	Effective	1.63E-01	25	6.50E-03
		Bone	2.09E+00	25	8.35E-02
		Avg. Lung	3.51E-01	25	1.40E-02
		Bronchi	9.73E-04	no limit given	-
Nearest Historical Resident (BHV-2)	Infant	Effective	8.07E-02	25	3.23E-03
		Bone	2.82E-01	25	1.13E-02
		Avg. Lung	8.56E-02	25	3.42E-03
		Bronchi	1.39E-04	no limit given	-
	Child	Effective	3.61E-02	25	1.44E-03
		Bone	2.09E-01	25	8.37E-03
		Avg. Lung	1.07E-01	25	4.29E-03
		Bronchi	1.39E-04	no limit given	-
	Teenage	Effective	4.26E-02	25	1.71E-03
		Bone	7.30E-01	25	2.92E-02
		Avg. Lung	8.31E-02	25	3.32E-03
		Bronchi	1.39E-04	no limit given	-
	Adult	Effective	2.55E-02	25	1.02E-03
		Bone	3.26E-01	25	1.30E-02
		Avg. Lung	5.62E-02	25	2.25E-03
		Bronchi	1.39E-04	no limit given	-

**TABLE 6.1-5 (Cont'd)**  
**PHASE 1-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Actual Resident	Infant	Effective	3.17E-01	25	1.27E-02
		Bone	1.09E+00	25	4.37E-02
		Avg. Lung	2.81E-01	25	1.12E-02
		Bronchi	5.62E-04	no limit given	-
	Child	Effective	1.35E-01	25	5.40E-03
		Bone	7.73E-01	25	3.09E-02
		Avg. Lung	3.84E-01	25	1.54E-02
		Bronchi	5.62E-04	no limit given	-
	Teenage	Effective	1.60E-01	25	6.42E-03
		Bone	2.78E+00	25	1.11E-01
		Avg. Lung	3.02E-01	25	1.21E-02
		Bronchi	5.62E-04	no limit given	-
	Adult	Effective	9.46E-02	25	3.78E-03
		Bone	1.21E+00	25	4.86E-02
Avg. Lung		2.03E-01	25	8.12E-03	
Bronchi		5.62E-04	no limit given	-	
White Mesa Community	Infant	Effective	3.36E-02	25	1.35E-03
		Bone	1.19E-01	25	4.74E-03
		Avg. Lung	4.55E-02	25	1.82E-03
		Bronchi	4.25E-05	no limit given	-
	Child	Effective	1.31E-02	25	5.22E-04
		Bone	7.80E-02	25	3.12E-03
		Avg. Lung	3.85E-02	25	1.54E-03
		Bronchi	4.25E-05	no limit given	-
	Teenage	Effective	1.38E-02	25	5.51E-04
		Bone	2.31E-01	25	9.26E-03
		Avg. Lung	2.72E-02	25	1.09E-03
		Bronchi	4.25E-05	no limit given	-
	Adult	Effective	8.69E-03	25	3.48E-04
		Bone	1.11E-01	25	4.42E-03
Avg. Lung		1.91E-02	25	7.63E-04	
Bronchi		4.25E-05	no limit given	-	

**TABLE 6.1-5 (Cont'd)**  
**PHASE 1-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Blanding	Infant	Effective	2.21E-02	25	8.84E-04
		Bone	7.69E-02	25	3.08E-03
		Avg. Lung	2.39E-02	25	9.57E-04
		Bronchi	3.49E-05	no limit given	-
	Child	Effective	9.23E-03	25	3.69E-04
		Bone	5.38E-02	25	2.15E-03
		Avg. Lung	2.69E-02	25	1.08E-03
		Bronchi	3.49E-05	no limit given	-
	Teenage	Effective	1.06E-02	25	4.24E-04
		Bone	1.81E-01	25	7.25E-03
		Avg. Lung	2.05E-02	25	8.19E-04
		Bronchi	3.49E-05	no limit given	-
	Adult	Effective	6.38E-03	25	2.55E-04
		Bone	8.16E-02	25	3.27E-03
		Avg. Lung	1.39E-02	25	5.57E-04
		Bronchi	3.49E-05	no limit given	-

From Table 6.1-5, the 40 CFR 190 annual dose commitments are at most 19.2% (dose to the bone for the teenage at BHV-1) of the 40 CFR 190 dose criterion of 25 mrem/yr. In addition, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) ALARA goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent. The maximum total effective dose equivalent was 0.545 mrem/yr (infant at BHV-1), or 5.45% of the 10 mrem/yr goal.

In addition, Table 6.1-6 presents a summary of the 40 CFR 190 annual dose commitments from the meat ingestion pathway for Grazing Locations 1 and 2. As before, in the unlikely event a receptor were to eat meat from cattle grazing in areas 1 or 2, the total dose would remain well below regulatory limits.

**TABLE 6.1-6  
40 CFR 190 ANNUAL DOSE COMMITMENTS FOR MEAT INGESTION PATHWAY  
(COLORADO PLATEAU ORE)(mrem/yr)**

Location	Age Group	Organ <sup>b</sup>		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.08E-02	5.40E-02	4.91E-02
	Teenage	1.70E-02	2.80E-01	4.30E-02
	Adult	1.23E-02	1.52E-01	3.55E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	7.33E-04	3.63E-03	3.10E-03
	Teenage	1.13E-03	1.91E-02	2.72E-03
	Adult	8.10E-04	1.01E-02	2.24E-03

Note:

- a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.
- b) Exclusive of radon.

The annual doses to the population estimated within 50 miles (80 km) of the site are provided in Table 6.1-7.

**TABLE 6.1-7  
PHASE 1-ANNUAL POPULATION DOSE COMMITMENTS WITHIN 50 MILES  
(80 km) OF THE MILL FOR COLORADO PLATEAU ORE**

Organ	ANNUAL POPULATION DOSE COMMITMENTS, PERSON-REM PER YEAR
	Mill Operations
Effective	1.47E-01
Bone	1.12E+00
Avg. Lung	1.53E-01
Bronchi	8.60E+00

The population dose arising from processing Colorado Plateau ore during Phase 1 is estimated at 0.15 person-rem. This can be compared to the dose from natural background sources of radiation.

In the United States, nominal average levels of natural background radiation are as follows (NCRP 1987):

Cosmic and Cosmogenic	28 mrem/yr
Terrestrial	28 mrem/yr
Inhaled (Radon)	200 mrem/yr
Ingested	40 mrem/yr
<b>Total (Average)</b>	<b>296 mrem/yr (96 mrem/yr excluding radon)</b>

In the area of the White Mesa Mill, natural background radiation was measured at two sites in 1977: the project site (Blanding) and the Hanksville site. At the Blanding site, the average dose equivalent from external radiation was about 142 mrem/yr. Of this 142 mrem/yr, 68 mrem/yr came from cosmic radiation, while 74 mrem/yr came from terrestrial radiation. (Dames & Moore 1978). At the Hanksville site, the corresponding average dose equivalent was about 122 mrem/yr (68 mrem/yr from cosmic radiation and 54 mrem/yr from terrestrial radiation). (Dames & Moore 1978).

Ingested radionuclides would contribute (about) a further 18 mrem/yr (NRC 1979). This brings the total background dose from external radiation and ingested radioactivity, but exclusive of the dose from radon-222, to about 161 mrem/yr; which is higher than both the U.S. averages of 96 mrem/yr.

If the nominal U.S. dose from radon of about 200 mrem per year is added, then the total dose from natural background in the area of the mill is 360 mrem/yr (or more assuming the dose from radon would increase along with that from terrestrial source).

The current population of San Juan County is about 14,400 people. Assuming everyone living in San Juan County receives an annual dose of (about) 360 mrem/yr, then the total dose due to natural background is approximately 5184 person-rem. The theoretical incremental dose of 0.15 person-rem is clearly inconsequential by comparison.

## ***Phase 2***

Table 6.1-8 presents a summary of the 40 CFR 190 individual dose commitments for the residential receptors for the age group of infant, child, teenage and adult for Phase 2.

**TABLE 6.1-8**  
**PHASE 2-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Potential Resident (BHV-1)	Infant	Effective	5.40E-01	25	2.16E-02
		Bone	1.84E+00	25	7.36E-02
		Avg. Lung	4.75E-01	25	1.90E-02
		Bronchi	9.63E-04	no limit given	-
	Child	Effective	2.28E-01	25	9.11E-03
		Bone	1.30E+00	25	5.20E-02
		Avg. Lung	6.46E-01	25	2.58E-02
		Bronchi	9.63E-04	no limit given	-
	Teenage	Effective	2.70E-01	25	1.08E-02
		Bone	4.70E+00	25	1.88E-01
		Avg. Lung	5.09E-01	25	2.03E-02
		Bronchi	9.63E-04	no limit given	-
	Adult	Effective	1.59E-01	25	6.36E-03
		Bone	2.04E+00	25	8.17E-02
		Avg. Lung	3.42E-01	25	1.37E-02
		Bronchi	9.63E-04	no limit given	-
Nearest Historical Resident (BHV-2)	Infant	Effective	8.03E-02	25	3.21E-03
		Bone	2.81E-01	25	1.12E-02
		Avg. Lung	8.47E-02	25	3.39E-03
		Bronchi	1.38E-04	no limit given	-
	Child	Effective	3.58E-02	25	1.43E-03
		Bone	2.07E-01	25	8.29E-03
		Avg. Lung	1.06E-01	25	4.24E-03
		Bronchi	1.38E-04	no limit given	-
	Teenage	Effective	4.22E-02	25	1.69E-03
		Bone	7.23E-01	25	2.89E-02
		Avg. Lung	8.21E-02	25	3.29E-03
		Bronchi	1.38E-04	no limit given	-
	Adult	Effective	2.53E-02	25	1.01E-03
		Bone	3.23E-01	25	1.29E-02
		Avg. Lung	5.56E-02	25	2.22E-03
		Bronchi	1.38E-04	no limit given	-

**TABLE 6.1-8 (Cont'd)**  
**PHASE 2-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Actual Resident	Infant	Effective	3.15E-01	25	1.26E-02
		Bone	1.08E+00	25	4.32E-02
		Avg. Lung	2.75E-01	25	1.10E-02
		Bronchi	5.57E-04	no limit given	-
	Child	Effective	1.33E-01	25	5.31E-03
		Bone	7.59E-01	25	3.04E-02
		Avg. Lung	3.76E-01	25	1.50E-02
		Bronchi	5.57E-04	no limit given	-
	Teenage	Effective	1.58E-01	25	6.30E-03
		Bone	2.73E+00	25	1.09E-01
		Avg. Lung	2.95E-01	25	1.18E-02
		Bronchi	5.57E-04	no limit given	-
	Adult	Effective	9.28E-02	25	3.71E-03
		Bone	1.19E+00	25	4.77E-02
		Avg. Lung	1.99E-01	25	7.94E-03
		Bronchi	5.57E-04	no limit given	-
White Mesa Community	Infant	Effective	3.35E-02	25	1.34E-03
		Bone	1.18E-01	25	4.71E-03
		Avg. Lung	4.50E-02	25	1.80E-03
		Bronchi	4.23E-05	no limit given	-
	Child	Effective	1.29E-02	25	5.17E-04
		Bone	7.72E-02	25	3.09E-03
		Avg. Lung	3.80E-02	25	1.52E-03
		Bronchi	4.23E-05	no limit given	-
	Teenage	Effective	1.36E-02	25	5.46E-04
		Bone	2.29E-01	25	9.17E-03
		Avg. Lung	2.69E-02	25	1.08E-03
		Bronchi	4.23E-05	no limit given	-
	Adult	Effective	8.60E-03	25	3.44E-04
		Bone	1.09E-01	25	4.37E-03
		Avg. Lung	1.88E-02	25	7.54E-04
		Bronchi	4.23E-05	no limit given	-

**TABLE 6.1-8 (Cont'd)**  
**PHASE 2-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Blanding	Infant	Effective	2.21E-02	25	8.83E-04
		Bone	7.69E-02	25	3.07E-03
		Avg. Lung	2.39E-02	25	9.55E-04
		Bronchi	3.49E-05	no limit given	-
	Child	Effective	9.22E-03	25	3.69E-04
		Bone	5.37E-02	25	2.15E-03
		Avg. Lung	2.68E-02	25	1.07E-03
		Bronchi	3.49E-05	no limit given	-
	Teenage	Effective	1.06E-02	25	4.23E-04
		Bone	1.81E-01	25	7.24E-03
		Avg. Lung	2.04E-02	25	8.18E-04
		Bronchi	3.49E-05	no limit given	-
	Adult	Effective	6.37E-03	25	2.55E-04
		Bone	8.15E-02	25	3.26E-03
		Avg. Lung	1.39E-02	25	5.56E-04
		Bronchi	3.49E-05	no limit given	-

From Table 6.1-8, the 40 CFR 190 annual dose commitments are at most 18.8% (dose to the bone for the teenage at BHV-1) of the 40 CFR 190 dose criterion of 25 mrem/yr. In addition, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) ALARA goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent. The maximum total effective dose equivalent was 0.540 mrem/yr (infant at BHV-1), or 5.4% of the 10 mrem/yr goal.

In addition, Table 6.1-9 presents a summary of the 40 CFR 190 annual dose commitments from the meat ingestion pathway for Grazing Locations 1 and 2. As before, in the unlikely event a receptor were to eat meat from cattle grazing in areas 1 or 2, the total dose would remain well below regulatory limits.

**TABLE 6.1-9  
PHASE 2-40 CFR 190 ANNUAL DOSE COMMITMENTS) FOR MEAT INGESTION  
PATHWAY (COLORADO PLATEAU ORE) (mrem/yr)**

Location	Age Group	Organ <sup>b</sup>		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.07E-02	5.35E-02	4.87E-02
	Teenage	1.68E-02	2.78E-01	4.26E-02
	Adult	1.22E-02	1.50E-01	3.51E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	6.71E-04	3.32E-03	2.80E-03
	Teenage	1.03E-03	1.75E-02	2.46E-03
	Adult	7.39E-04	9.20E-03	2.03E-03

Note:

- a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.
- b) Exclusive of radon.

The annual doses to the population estimated within 50 miles (80 km) of the site are provided in Table 6.1-10.

**TABLE 6.1-10  
PHASE 2-ANNUAL POPULATION DOSE COMMITMENTS WITHIN 50 MILES  
(80 km) OF THE MILL FOR COLORADO PLATEAU ORE**

Organ	ANNUAL POPULATION DOSE COMMITMENTS, PERSON-REM PER YEAR
	Mill Operations
Effective	1.50E-01
Bone	1.15E+00
Avg. Lung	1.56E-01
Bronchi	8.66E+00

The population dose arising from processing Colorado Plateau ore during Phase 2 is estimated at 0.15 person-rem. This can be compared to the dose from natural background sources of radiation of about 360 mrem/yr as previously discussed in Phase 1.

The current population of San Juan County is about 14,400 people. Assuming everyone living in San Juan County receives an annual dose of (about) 360 mrem/yr, then the total dose due to natural background is approximately 5184 person-rem. The theoretical incremental dose of 0.15 person-rem is clearly inconsequential by comparison.

## **6.2 MILDOS-AREA RESULTS FOR ARIZONA STRIP ORE**

The potential annual doses to the people living close to the mill and to the population living within 50 miles (80 km) as a result of processing Arizona Strip ore was calculated using MILDOS-AREA.

The MILDOS-AREA calculated total annual dose commitments (including radon) and 40 CFR 190 total annual dose commitments for processing of Arizona Strip ore are provided in Sections 6.2.1 and 6.2.2, respectively.

### **6.2.1 R313-15-301 (1)(a) Regulatory Compliance**

The MILDOS-AREA calculated total annual dose commitments (including radon) for Phases 1 and 2 are provided in this section. These doses are regulated by R313-15-301(1)(a) which requires that the dose to an individual member of the public shall not exceed 100 mrem/yr (radon included).

#### ***Phase 1***

Table 6.2-1 presents a summary of the individual dose commitments for the residential receptors for the age group of infant, child, teenage and adult for Phase 1.

**TABLE 6.2-1**  
**PHASE 1-COMPARISON OF ANNUAL DOSE COMMITMENTS WITH APPLICABLE**  
**RADIATION PROTECTION STANDARDS (ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Potential Resident (BHV-1)	Infant	Effective	3.12E+00	100	3.12E-02
		Bone	4.86E+00	-	-
		Avg. Lung	1.34E+00	-	-
		Bronchi	2.72E+01	-	-
	Child	Effective	2.32E+00	100	2.32E-02
		Bone	3.48E+00	-	-
		Avg. Lung	1.79E+00	-	-
		Bronchi	2.72E+01	-	-
	Teenage	Effective	2.43E+00	100	2.43E-02
		Bone	1.23E+01	-	-
		Avg. Lung	1.43E+00	-	-
		Bronchi	2.72E+01	-	-
	Adult	Effective	2.14E+00	100	2.14E-02
		Bone	5.42E+00	-	-
		Avg. Lung	9.94E-01	-	-
		Bronchi	2.72E+01	-	-
Nearest Historical Resident (BHV-2)	Infant	Effective	6.60E-01	100	6.60E-03
		Bone	7.65E-01	-	-
		Avg. Lung	2.58E-01	-	-
		Bronchi	6.93E+00	-	-
	Child	Effective	5.46E-01	100	5.46E-03
		Bone	5.80E-01	-	-
		Avg. Lung	3.17E-01	-	-
		Bronchi	6.93E+00	-	-
	Teenage	Effective	5.63E-01	100	5.63E-03
		Bone	1.92E+00	-	-
		Avg. Lung	2.55E-01	-	-
		Bronchi	6.93E+00	-	-
	Adult	Effective	5.19E-01	100	5.19E-03
		Bone	8.85E-01	-	-
		Avg. Lung	1.85E-01	-	-
		Bronchi	6.93E+00	-	-

**TABLE 6.2-1 (Cont'd)**  
**PHASE 1-COMPARISON OF ANNUAL DOSE COMMITMENTS WITH APPLICABLE RADIATION PROTECTION STANDARDS (ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Actual Resident	Infant	Effective	1.96E+00	100	1.96E-02
		Bone	2.86E+00	-	-
		Avg. Lung	7.91E-01	-	-
		Bronchi	1.81E+01	-	-
	Child	Effective	1.50E+00	100	1.50E-02
		Bone	2.05E+00	-	-
		Avg. Lung	1.06E+00	-	-
		Bronchi	1.81E+01	-	-
	Teenage	Effective	1.56E+00	100	1.56E-02
		Bone	7.18E+00	-	-
		Avg. Lung	8.50E-01	-	-
		Bronchi	1.81E+01	-	-
	Adult	Effective	1.40E+00	100	1.40E-02
		Bone	3.18E+00	-	-
		Avg. Lung	5.96E-01	-	-
		Bronchi	1.81E+01	-	-
White Mesa Community	Infant	Effective	4.68E-01	100	4.68E-03
		Bone	3.51E-01	-	-
		Avg. Lung	1.56E-01	-	-
		Bronchi	5.72E+00	-	-
	Child	Effective	4.16E-01	100	4.16E-03
		Bone	2.53E-01	-	-
		Avg. Lung	1.46E-01	-	-
		Bronchi	5.72E+00	-	-
	Teenage	Effective	4.19E-01	100	4.19E-03
		Bone	6.90E-01	-	-
		Avg. Lung	1.16E-01	-	-
		Bronchi	5.72E+00	-	-
	Adult	Effective	4.04E-01	100	4.04E-03
		Bone	3.51E-01	-	-
		Avg. Lung	9.18E-02	-	-
		Bronchi	5.72E+00	-	-

**TABLE 6.2-1 (Cont'd)**  
**PHASE 1-COMPARISON OF ANNUAL DOSE COMMITMENTS WITH APPLICABLE RADIATION PROTECTION STANDARDS (ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Blanding	Infant	Effective	2.18E-01	100	2.18E-03
		Bone	2.20E-01	-	-
		Avg. Lung	7.98E-02	-	-
		Bronchi	2.39E+00	-	-
	Child	Effective	1.85E-01	100	1.85E-03
		Bone	1.64E-01	-	-
		Avg. Lung	9.22E-02	-	-
		Bronchi	2.39E+00	-	-
	Teenage	Effective	1.89E-01	100	1.89E-03
		Bone	5.16E-01	-	-
		Avg. Lung	7.49E-02	-	-
		Bronchi	2.39E+00	-	-
	Adult	Effective	1.78E-01	100	1.78E-03
		Bone	2.44E-01	-	-
		Avg. Lung	5.64E-02	-	-
		Bronchi	2.39E+00	-	-

From Table 6.2-1, the total annual effective dose commitments are at most 3.1% (effective dose for infant at BHV-1) of the R313-15-301(1)(a) limit of 100 mrem/yr (radon included) to an individual member of the public. Therefore, the predicted annual effective dose commitments comply with R313-15-101(1)(a).

In addition, Table 6.2-2 presents a summary of the annual dose commitments from the meat ingestion pathway for Grazing location 1 and 2. As before in the unlikely event that a receptor consumed beef from one of the grazing locations, the total dose would remain well below regulatory limits.

**TABLE 6.2-2  
PHASE 1-TOTAL ANNUAL DOSE COMMITMENTS FOR MEAT INGESTION  
PATHWAY (ARIZONA STRIP ORE) (mrem/yr)**

Location	Age Group	Organ <sup>b</sup>		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	2.75E-02	1.37E-01	1.25E-01
	Teenage	4.33E-02	7.16E-01	1.09E-01
	Adult	3.13E-02	3.87E-01	9.03E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.87E-03	9.29E-03	7.93E-03
	Teenage	2.90E-03	4.89E-02	6.94E-03
	Adult	2.07E-03	2.57E-02	5.73E-03

Note:

- a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.

**Phase 2**

Table 6.2-3 presents a summary of the individual dose commitments for the residential receptors for the age group of infant, child, teenage and adult for Phase 2.

**TABLE 6.2-3  
PHASE 2-COMPARISON OF ANNUAL DOSE COMMITMENTS WITH APPLICABLE  
RADIATION PROTECTION STANDARDS (ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit	
Nearest Potential Resident (BHV-1)	Infant	Effective	3.10E+00	100	3.10E-02	
		Bone	4.81E+00	-	-	
		Avg. Lung	1.31E+00	-	-	
	Child	Bronchi	Effective	2.30E+00	100	2.30E-02
			Bone	3.42E+00	-	-
			Avg. Lung	1.74E+00	-	-
			Bronchi	2.70E+01	-	-
	Teenage	Effective	Effective	2.40E+00	100	2.40E-02
			Bone	1.21E+01	-	-
			Avg. Lung	1.40E+00	-	-
			Bronchi	2.70E+01	-	-
	Adult	Effective	Effective	2.12E+00	100	2.12E-02
			Bone	5.31E+00	-	-
			Avg. Lung	9.71E-01	-	-
			Bronchi	2.70E+01	-	-

**TABLE 6.2-3 (Cont'd)**  
**PHASE 2-COMPARISON OF ANNUAL DOSE COMMITMENTS WITH APPLICABLE RADIATION PROTECTION STANDARDS (ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Historical Resident (BHV-2)	Infant	Effective	6.59E-01	100	6.59E-03
		Bone	7.60E-01	-	-
		Avg. Lung	2.56E-01	-	-
		Bronchi	6.93E+00	-	-
	Child	Effective	5.45E-01	100	5.45E-03
		Bone	5.75E-01	-	-
		Avg. Lung	3.14E-01	-	-
		Bronchi	6.93E+00	-	-
	Teenage	Effective	5.62E-01	100	5.62E-03
		Bone	1.91E+00	-	-
		Avg. Lung	2.52E-01	-	-
		Bronchi	6.93E+00	-	-
	Adult	Effective	5.18E-01	100	5.18E-03
		Bone	8.76E-01	-	-
		Avg. Lung	1.84E-01	-	-
		Bronchi	6.93E+00	-	-
Nearest Actual Resident	Infant	Effective	1.95E+00	100	1.95E-02
		Bone	2.83E+00	-	-
		Avg. Lung	7.77E-01	-	-
		Bronchi	1.80E+01	-	-
	Child	Effective	1.49E+00	100	1.49E-02
		Bone	2.02E+00	-	-
		Avg. Lung	1.03E+00	-	-
		Bronchi	1.80E+01	-	-
	Teenage	Effective	1.55E+00	100	1.55E-02
		Bone	7.06E+00	-	-
		Avg. Lung	8.32E-01	-	-
		Bronchi	1.80E+01	-	-
	Adult	Effective	1.39E+00	100	1.39E-02
		Bone	3.13E+00	-	-
		Avg. Lung	5.84E-01	-	-
		Bronchi	1.80E+01	-	-

**TABLE 6.2-3 (Cont'd)**  
**PHASE 2-COMPARISON OF ANNUAL DOSE COMMITMENTS WITH APPLICABLE RADIATION PROTECTION STANDARDS (ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
White Mesa Community	Infant	Effective	4.69E-01	100	4.69E-03
		Bone	3.49E-01	-	-
		Avg. Lung	1.55E-01	-	-
		Bronchi	5.75E+00	-	-
	Child	Effective	4.17E-01	100	4.17E-03
		Bone	2.52E-01	-	-
		Avg. Lung	1.45E-01	-	-
		Bronchi	5.75E+00	-	-
	Teenage	Effective	4.20E-01	100	4.20E-03
		Bone	6.85E-01	-	-
		Avg. Lung	1.15E-01	-	-
		Bronchi	5.75E+00	-	-
	Adult	Effective	4.05E-01	100	4.05E-03
		Bone	3.48E-01	-	-
		Avg. Lung	9.14E-02	-	-
		Bronchi	5.75E+00	-	-
Blanding	Infant	Effective	2.19E-01	100	2.19E-03
		Bone	2.20E-01	-	-
		Avg. Lung	7.98E-02	-	-
		Bronchi	2.40E+00	-	-
	Child	Effective	1.86E-01	100	1.86E-03
		Bone	1.64E-01	-	-
		Avg. Lung	9.22E-02	-	-
		Bronchi	2.40E+00	-	-
	Teenage	Effective	1.90E-01	100	1.90E-03
		Bone	5.15E-01	-	-
		Avg. Lung	7.49E-02	-	-
		Bronchi	2.40E+00	-	-
	Adult	Effective	1.79E-01	100	1.79E-03
		Bone	2.44E-01	-	-
		Avg. Lung	5.65E-02	-	-
		Bronchi	2.40E+00	-	-

From Table 6.2-3, the total annual effective dose commitments are at most 3.1% (effective dose for infant at BHV-1) of the R313-15-301(1)(a) limit of 100 mrem/yr (radon included) to an individual member of the public. Therefore, the predicted annual effective dose commitments comply with R313-15-101(1)(a).

In addition, Table 6.2-4 presents a summary of the annual dose commitments from the meat ingestion pathway for Grazing location 1 and 2. As before in the unlikely event that a receptor consumed beef from one of the grazing locations, the total dose would remain well below regulatory limits.

**TABLE 6.2-4  
PHASE 2-TOTAL ANNUAL DOSE COMMITMENTS FOR MEAT INGESTION  
PATHWAY (ARIZONA STRIP ORE) (mrem/yr)**

Location	Age Group	Organ <sup>b</sup>		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	2.73E-02	1.36E-01	1.24E-01
	Teenage	4.29E-02	7.10E-01	1.08E-01
	Adult	3.10E-02	3.83E-01	8.94E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.71E-03	8.50E-03	7.18E-03
	Teenage	2.65E-03	4.48E-02	6.28E-03
	Adult	1.89E-03	2.35E-02	5.18E-03

Note:

- a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.

### 6.2.2 40 CFR 190 Regulatory Compliance

MILDOS-AREA calculated 40 CFR 190 doses (excludes radon). These doses are regulated by the 40 CFR 190 criterion of 25 mrem/yr to the whole body (excluding the dose due to radon) (EPA 2002) or to any organ of the body. The 40 CFR 190 doses are also used to demonstrate compliance with R313-15-101(4) (10 CFR 20.1101(d)). The licensee must demonstrate as an ALARA goal, that total effective dose equivalent to the individual member of the public likely to receive the highest total effective dose equivalent will not exceed 10 mrem/yr (absent of the radon dose).

#### *Phase 1*

Table 6.2-5 presents a summary of the 40 CFR 190 individual dose commitments for residential receptors for the age group of infant, child, teenage and adult for Phase 1.

**TABLE 6.2-5  
PHASE 1-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH  
APPLICABLE RADIATION PROTECTION STANDARDS  
(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Potential Resident (BHV-1)	Infant	Effective	1.39E+00	25	5.55E-02
		Bone	4.76E+00	25	1.90E-01
		Avg. Lung	1.24E+00	25	4.95E-02
		Bronchi	2.48E-03	no limit given	-
	Child	Effective	5.92E-01	25	2.37E-02
		Bone	3.37E+00	25	1.35E-01
		Avg. Lung	1.69E+00	25	6.74E-02
		Bronchi	2.48E-03	no limit given	-
	Teenage	Effective	7.03E-01	25	2.81E-02
		Bone	1.22E+01	25	4.88E-01
		Avg. Lung	1.33E+00	25	5.31E-02
		Bronchi	2.48E-03	no limit given	-
	Adult	Effective	4.14E-01	25	1.66E-02
		Bone	5.32E+00	25	2.13E-01
Avg. Lung		8.93E-01	25	3.57E-02	
Bronchi		2.48E-03	no limit given	-	
Nearest Historical Resident (BHV-2)	Infant	Effective	2.06E-01	25	8.24E-03
		Bone	7.20E-01	25	2.88E-02
		Avg. Lung	2.18E-01	25	8.73E-03
		Bronchi	3.54E-04	no limit given	-
	Child	Effective	9.19E-02	25	3.68E-03
		Bone	5.32E-01	25	2.13E-02
		Avg. Lung	2.73E-01	25	1.09E-02
		Bronchi	3.54E-04	no limit given	-
	Teenage	Effective	1.09E-01	25	4.34E-03
		Bone	1.86E+00	25	7.44E-02
		Avg. Lung	2.11E-01	25	8.44E-03
		Bronchi	3.54E-04	no limit given	-
	Adult	Effective	6.49E-02	25	2.60E-03
		Bone	8.30E-01	25	3.32E-02
Avg. Lung		1.43E-01	25	5.73E-03	
Bronchi		3.54E-04	no limit given	-	

**TABLE 6.2-5 (Cont'd)**  
**PHASE 1-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Actual Resident	Infant	Effective	8.11E-01	25	3.24E-02
		Bone	2.79E+00	25	1.11E-01
		Avg. Lung	7.16E-01	25	2.86E-02
		Bronchi	1.44E-03	no limit given	-
	Child	Effective	3.44E-01	25	1.38E-02
		Bone	1.97E+00	25	7.88E-02
		Avg. Lung	9.78E-01	25	3.91E-02
		Bronchi	1.44E-03	no limit given	-
	Teenage	Effective	4.09E-01	25	1.64E-02
		Bone	7.09E+00	25	2.83E-01
		Avg. Lung	7.71E-01	25	3.08E-02
		Bronchi	1.44E-03	no limit given	-
	Adult	Effective	2.41E-01	25	9.64E-03
		Bone	3.09E+00	25	1.24E-01
		Avg. Lung	5.17E-01	25	2.07E-02
		Bronchi	1.44E-03	no limit given	-
White Mesa Community	Infant	Effective	8.58E-02	25	3.43E-03
		Bone	3.02E-01	25	1.21E-02
		Avg. Lung	1.16E-01	25	4.64E-03
		Bronchi	1.08E-04	no limit given	-
	Child	Effective	3.33E-02	25	1.33E-03
		Bone	1.99E-01	25	7.95E-03
		Avg. Lung	9.80E-02	25	3.92E-03
		Bronchi	1.08E-04	no limit given	-
	Teenage	Effective	3.51E-02	25	1.41E-03
		Bone	5.90E-01	25	2.36E-02
		Avg. Lung	6.92E-02	25	2.77E-03
		Bronchi	1.08E-04	no limit given	-
	Adult	Effective	2.21E-02	25	8.85E-04
		Bone	2.82E-01	25	1.13E-02
		Avg. Lung	4.87E-02	25	1.95E-03
		Bronchi	1.08E-04	no limit given	-

**TABLE 6.2-5 (Cont'd)**  
**PHASE 1-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Blanding	Infant	Effective	5.64E-02	25	2.26E-03
		Bone	1.96E-01	25	7.83E-03
		Avg. Lung	6.08E-02	25	2.43E-03
		Bronchi	8.89E-05	no limit given	-
	Child	Effective	2.35E-02	25	9.41E-04
		Bone	1.37E-01	25	5.48E-03
		Avg. Lung	6.86E-02	25	2.74E-03
		Bronchi	8.89E-05	no limit given	-
	Teenage	Effective	2.70E-02	25	1.08E-03
		Bone	4.62E-01	25	1.85E-02
		Avg. Lung	5.20E-02	25	2.08E-03
		Bronchi	8.89E-05	no limit given	-
	Adult	Effective	1.63E-02	25	6.50E-04
		Bone	2.08E-01	25	8.32E-03
		Avg. Lung	3.55E-02	25	1.42E-03
		Bronchi	8.89E-05	no limit given	-

From Table 6.5-2, the 40 CFR 190 annual dose commitments are at most 48.8% (dose to the bone for the teenage at BHV-1) of the 40 CFR 190 dose criterion of 25 mrem/yr. In addition, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) ALARA goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent. The maximum total effective dose equivalent was 1.39 mrem/yr (infant at BHV-1), or 13.9% of the 10 mrem/yr goal.

In addition, Table 6.2-6 presents a summary of the 40 CFR 190 annual dose commitments from the meat ingestion pathway for Grazing location 1 and 2. As before in the unlikely event that someone was to consume beef from grazing area 1 or 2, the total dose would be small and well below regulatory limits.

**TABLE 6.2-6**  
**PHASE 1-40 CFR 190 ANNUAL DOSE COMMITMENTS FOR MEAT INGESTION**  
**PATHWAY (ARIZONA STRIP ORE) (mrem/yr)**

Location	Age Group	Organ		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	2.75E-02	1.37E-01	1.25E-01
	Teenage	4.33E-02	7.16E-01	1.09E-01
	Adult	3.13E-02	3.87E-01	9.03E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.87E-03	9.27E-03	7.90E-03
	Teenage	2.88E-03	4.87E-02	6.92E-03
	Adult	2.06E-03	2.57E-02	5.71E-03

Note:

- a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.
- b) Exclusive of radon.

The annual doses to the population estimated within 50 miles (80 km) of the site are provided in Table 6.2-7.

**TABLE 6.2-7**  
**PHASE 1-ANNUAL POPULATION DOSE COMMITMENTS WITHIN 50 MILES**  
**(80 km) OF THE MILL FOR ARIZONA STRIP ORE**

Organ	ANNUAL POPULATION DOSE COMMITMENTS, PERSON-REM PER YEAR
	Mill Operations
Effective	3.08E-01
Bone	2.48E+00
Avg. Lung	3.28E-01
Bronchi	1.64E+01

The population dose arising from processing Arizona Strip ore during Phase 1 is estimated at 0.31 person-rem. This can be compared to the dose from natural background sources of radiation of about 360 mrem/yr as previously discussed.

The current population of San Juan County is about 14,400 people. Assuming everyone living in San Juan County receives an annual dose of (about) 360 mrem/yr, then the total dose due to natural background is approximately 5184 person-rem. The theoretical incremental dose of 0.31 person-rem is clearly inconsequential by comparison.

**Phase 2**

Table 6.2-8 presents a summary of the 40 CFR 190 individual dose commitments for residential receptors for the age group of infant, child, teenage and adult for Phase 2.

**TABLE 6.2-8  
PHASE 2-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH  
APPLICABLE RADIATION PROTECTION STANDARDS (ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Potential Resident (BHV-1)	Infant	Effective	1.38E+00	25	5.50E-02
		Bone	4.71E+00	25	1.88E-01
		Avg. Lung	1.21E+00	25	4.84E-02
		Bronchi	2.45E-03	no limit given	-
	Child	Effective	5.81E-01	25	2.32E-02
		Bone	3.31E+00	25	1.32E-01
		Avg. Lung	1.64E+00	25	6.58E-02
		Bronchi	2.45E-03	no limit given	-
	Teenage	Effective	6.89E-01	25	2.76E-02
		Bone	1.20E+01	25	4.79E-01
		Avg. Lung	1.29E+00	25	5.18E-02
		Bronchi	2.45E-03	no limit given	-
	Adult	Effective	4.05E-01	25	1.62E-02
		Bone	5.21E+00	25	2.08E-01
		Avg. Lung	8.71E-01	25	3.48E-02
		Bronchi	2.45E-03	no limit given	-

**TABLE 6.2-8 (Cont'd)**  
**PHASE 2-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
Nearest Historical Resident (BHV-2)	Infant	Effective	2.05E-01	25	8.20E-03
		Bone	7.16E-01	25	2.86E-02
		Avg. Lung	2.16E-01	25	8.64E-03
		Bronchi	3.53E-04	no limit given	-
	Child	Effective	9.11E-02	25	3.64E-03
		Bone	5.27E-01	25	2.11E-02
		Avg. Lung	2.70E-01	25	1.08E-02
		Bronchi	3.53E-04	no limit given	-
	Teenage	Effective	1.07E-01	25	4.30E-03
		Bone	1.84E+00	25	7.38E-02
		Avg. Lung	2.09E-01	25	8.35E-03
		Bronchi	3.53E-04	no limit given	-
	Adult	Effective	6.42E-02	25	2.57E-03
		Bone	8.22E-01	25	3.29E-02
		Avg. Lung	1.42E-01	25	5.66E-03
		Bronchi	3.53E-04	no limit given	-
Nearest Actual Resident	Infant	Effective	8.04E-01	25	3.22E-02
		Bone	2.76E+00	25	1.10E-01
		Avg. Lung	7.02E-01	25	2.81E-02
		Bronchi	1.42E-03	not limited	-
	Child	Effective	3.39E-01	25	1.35E-02
		Bone	1.94E+00	25	7.74E-02
		Avg. Lung	9.57E-01	25	3.83E-02
		Bronchi	1.42E-03	not limited	-
	Teenage	Effective	4.02E-01	25	1.61E-02
		Bone	6.97E+00	25	2.79E-01
		Avg. Lung	7.54E-01	25	3.02E-02
		Bronchi	1.42E-03	not limited	-
	Adult	Effective	2.36E-01	25	9.46E-03
		Bone	3.03E+00	25	1.21E-01
		Avg. Lung	5.06E-01	25	2.02E-02
		Bronchi	1.42E-03	not limited	-

**TABLE 6.2-8 (Cont'd)**  
**PHASE 2-COMPARISON OF 40 CFR 190 ANNUAL DOSE COMMITMENTS WITH**  
**APPLICABLE RADIATION PROTECTION STANDARDS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)	Applicable Limit (mrem/yr)	Fraction of Limit
White Mesa Community	Infant	Effective	8.53E-02	25	3.41E-03
		Bone	3.00E-01	25	1.20E-02
		Avg. Lung	1.15E-01	25	4.59E-03
		Bronchi	1.08E-04	not limited	-
	Child	Effective	3.30E-02	25	1.32E-03
		Bone	1.97E-01	25	7.87E-03
		Avg. Lung	9.68E-02	25	3.87E-03
		Bronchi	1.08E-04	not limited	-
	Teenage	Effective	3.48E-02	25	1.39E-03
		Bone	5.85E-01	25	2.34E-02
		Avg. Lung	6.83E-02	25	2.73E-03
		Bronchi	1.08E-04	not limited	-
	Adult	Effective	2.19E-02	25	8.75E-04
		Bone	2.79E-01	25	1.12E-02
Avg. Lung		4.81E-02	25	1.92E-03	
Bronchi		1.08E-04	not limited	-	
Blanding	Infant	Effective	5.64E-02	25	2.26E-03
		Bone	1.96E-01	25	7.82E-03
		Avg. Lung	6.07E-02	25	2.43E-03
		Bronchi	8.88E-05	not limited	-
	Child	Effective	2.35E-02	25	9.40E-04
		Bone	1.37E-01	25	5.47E-03
		Avg. Lung	6.84E-02	25	2.74E-03
		Bronchi	8.88E-05	not limited	-
	Teenage	Effective	2.70E-02	25	1.08E-03
		Bone	4.61E-01	25	1.85E-02
		Avg. Lung	5.19E-02	25	2.08E-03
		Bronchi	8.88E-05	not limited	-
	Adult	Effective	1.62E-02	25	6.49E-04
		Bone	2.08E-01	25	8.31E-03
Avg. Lung		3.55E-02	25	1.42E-03	
Bronchi		8.88E-05	not limited	-	

From Table 6.2-8, the 40 CFR 190 annual dose commitments are at most 48% (dose to the bone for the teenage at BHV-1) of the 40 CFR 190 dose criterion of 25 mrem/yr. In addition, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) ALARA goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent. The maximum total effective dose equivalent was 1.38 mrem/yr (infant at BHV-1), or 13.8% of the 10 mrem/yr goal.

In addition, Table 6.2-9 presents a summary of the 40 CFR 190 annual dose commitments from the meat ingestion pathway for Grazing location 1 and 2. As before in the unlikely event that someone was to consume beef from grazing area 1 or 2, the total dose would be small and well below regulatory limits.

**TABLE 6.2-9  
PHASE 2-40 CFR 190 ANNUAL DOSE COMMITMENTS FOR MEAT INGESTION  
PATHWAY (ARIZONA STRIP ORE) (mrem/yr)**

Location	Age Group	Organ		
		Effective <sup>a</sup>	Bone <sup>a</sup>	Avg. Lung <sup>a</sup>
Grazing Location 1	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	2.73E-02	1.36E-01	1.24E-01
	Teenage	4.29E-02	7.10E-01	1.08E-01
	Adult	3.10E-02	3.83E-01	8.94E-02
Grazing Location 2	Infant	0.00E+00	0.00E+00	0.00E+00
	Child	1.71E-03	8.48E-03	7.14E-03
	Teenage	2.63E-03	4.46E-02	6.25E-03
	Adult	1.88E-03	2.35E-02	5.17E-03

Note:

- a) Assumes cattle will graze at the particular Grazing location for 2 months of the year.
- b) Exclusive of radon.

The annual doses to the population estimated within 50 miles (80 km) of the site are provided in Table 6.2-10.

**TABLE 6.2-10  
PHASE 2-ANNUAL POPULATION DOSE COMMITMENTS WITHIN 50 MILES  
(80 km) OF THE MILL FOR ARIZONA STRIP ORE**

Organ	ANNUAL POPULATION DOSE COMMITMENTS, PERSON-REM PER YEAR
	Mill Operations
Effective	3.15E-01
Bone	2.55E+00
Avg. Lung	3.34E-01
Bronchi	1.65E+01

The population dose arising from processing Arizona Strip ore during Phase 2 is estimated at 0.32 person-rem. This can be compared to the dose from natural background sources of radiation in the Colorado Plateau of about 360 mrem/yr as previously discussed.

The current population of San Juan County is about 14,400 people. Assuming everyone living in San Juan County receives an annual dose of (about) 360 mrem/yr, then the total dose due to natural background is approximately 5184 person-rem. The theoretical incremental dose of 0.32 person-rem is clearly inconsequential by comparison.

## **7.0 KEY OBSERVATIONS**

As described in Section 1.0, milling of conventional ore is scheduled for the Spring of 2008 when the milling of currently available alternate feed materials is completed (DUSA 2007a). The objective of this dose assessment was to extend the previous report (SENES 2007) to incorporate the dose from the proposed development of new tailings cell 4B, in support of a license amendment application for the construction and operation of that cell.

The NRC-approved MILDOS-AREA was used to estimate the dose commitments received by individuals and the general population within a 50 mile (80 km) radius of the site for the processing of Colorado Plateau or Arizona Strip ore separately. In each scenario, the doses arising from the emissions of dust and radon from the mill area and ore pads were assumed to be the same as in the previous 2007 report since the scenarios both involve the processing of Colorado Plateau and Arizona Strip ores. Therefore, MILDOS-AREA runs from the previous report were revised to exclude the tailings cells. The doses from the tailings cells were estimated in separate MILDOS-AREA runs and added to the dose from the mill area and ore pads. Table 7-1 provides a summary of the source terms included in Phases 1 and 2.

**TABLE 7-1  
SOURCE TERMS INCLUDED IN PHASES 1 AND 2**

<b>Source Term</b>	<b>Phase 1</b>	<b>Phase 2</b>
Mill area	included	included
Ore Pads	included	included
Tailings Cell 2 with Interim Soil Cover	included	included
Tailings Cell 3	active	interim soil cover
Tailings Cell 4A	active	active
Tailings Cell 4B	excluded	active

The wind erosion and radon release rates from the tailings cells (active and with interim soil cover) were modelled by using a maximal worst case approach.

Each active tailings cell was modelled to have an active exposed (non-solution) tailings solids area of 10 acres (i.e., the maximum uncovered tailings solids area at any time allowed under NESHAPs Regulation 40 CFR 61.252(b), Subpart W) since it is not possible to predict the distribution of uncovered tailings between the active cells at any given time. As a result, the release rate of wind-eroded tailings dust was estimated at 10 acres at all times for each active cell. The total annual radon release rate was estimated by assuming a radon release rate of 20 pCi/m<sup>2</sup>s (i.e., maximum radon-222 emissions to ambient air from an existing uranium mill pile) over the entire area of each cell consistent with NESHAPs.

The tailings cells (2 and 3) with interim soil cover were assumed to be the entire areas of each cell; however, only radon is released at a rate of 10 pCi/m<sup>2</sup>s after the application of the soil cover.

The calculated total annual effective dose commitments (including radon) calculated using MILDOS-AREA were compared to the Utah Administrative Code R313-15-301(1)(a) requirement that the dose to individual members of the public shall not exceed 100 mrem/yr (radon included). For processing of Colorado Plateau ore, the maximum total annual effective dose commitments was calculated to be a maximum of 1.4 mrem/yr for an infant at the nearest potential resident, BHV-1 (Tables 6.1-1 and 6.1-3) (i.e., effective dose) and is about 1.4% of the R313-15-301(1)(a) limit of 100 mrem/yr (radon included) to an individual member of the public for Phases 1 and 2. For processing of Arizona Strip ore, the total annual effective dose commitments were calculated to be a maximum of 3.1 mrem/yr for an infant at the nearest potential resident, BHV-1 (Tables 6.2-1 and 6.2-3) (i.e., effective dose) and is about 3.1% of the 100 mrem/yr limit (radon included) to an individual member of the public for Phases 1 and 2. Overall, using conservative assumptions, the predicted annual effective dose commitments for Phases 1 and 2 comply with R313-15.

In addition, our MILDOS-AREA calculated 40 CFR 190 annual dose commitments (excluding radon) were compared to the 40 CFR 190 criterion, which is 25 mrem/yr to the whole body (excluding the dose due to radon) and 25 mrem/yr to any other organ to any member of the public (EPA 2002). The 40 CFR 190 doses were also used to demonstrate compliance with the ALARA goal set out in R313-15-101(4) (10 CFR 20.1101(d)) (i.e., the ALARA goal is to demonstrate that total effective dose equivalent to the individual member of the public likely to receive the highest total effective dose equivalent will not exceed 10 mrem/yr (absent of the radon dose)). For processing of Colorado Plateau ore, the 40 CFR 190 annual dose commitments were calculated to be a maximum of 4.8 mrem/yr for a teenager at the nearest potential resident, BHV-1 (Tables 6.1-5 and 6.1-8) (i.e., dose to the bone) and is about 19% of the 40 CFR 190 dose criterion of 25 mrem/yr, for Phases 1 and 2. Further, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) ALARA goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent (the maximum total effective dose equivalent (radon excluded) during Phases 1 and 2 was 0.545 mrem/yr for an infant at BHV-1). For Arizona Strip ore, the 40 CFR 190 annual dose commitments were at most 12 mrem/yr for a teenage at the nearest potential resident, BHV-1 (Tables 6.2-5 and 6.2-8) (i.e., dose to the bone) and is about 49% of the 40 CFR 190 dose criterion of 25 mrem/yr for Phases 1 and 2. Further, the 40 CFR 190 annual effective dose commitments demonstrate compliance with the R313-15-101(4) (10 CFR 20.1101(d)) goal of 10 mrem/yr to the individual member of the public likely to receive the highest total effective dose equivalent (the maximum total effective dose equivalent (radon excluded) during Phases 1 and 2 was 1.39 mrem/yr for an infant at BHV-1). Overall, using conservative assumptions, ore processing in Phases 1 and 2 comply with the requirements of 40 CFR 190 and the ALARA goal set out in R313 -15-101(4).

## **8.0 REFERENCES**

- Argonne National Laboratory (ANL) 1998a. *MILDOS-AREA, Version 2.20β*, Developed at the Environmental Assessment Division
- Argonne National Laboratory (ANL) 1998b. *MILDOS-AREA User's Guide (Draft)*, Environmental Assessment Division
- Code of Federal Regulations (CFR) Title 10 Part 20 *Standards for Protection Against Radiation*. May.
- Dames & Moore 1978. *Environmental Report: White Mesa Uranium Project San Juan County, Utah for Energy Fuels Nuclear, Inc.* January.
- Denison Mines (USA) Corp. (DUSA) 2007a. *Press Release: Denison Announces Operations Update*. January 30.
- Denison Mines (USA) Corp. (DUSA) 2007b. *2006 ALARA Report*. May 10.
- EnecoTech Environmental Consultants 1991a. *MILDOS Modeling Results (Letter)*, Prepared for Umetco Minerals. October 31.
- EnecoTech Environmental Consultants 1991b. *MILDOS Modeling Correction (Letter)*, Prepared for Umetco Minerals. November 27.
- United States Environmental Protection Agency (EPA) 1989. Code of Federal (CFR) Regulations Title 40 Part 61 *National Emission Standards for Hazardous Air Pollutants (NESHAPs), Subpart W*. December.
- United States Environmental Protection Agency (EPA) 2002. Code of Federal (CFR) Regulations Title 40 Part 190 *Environmental Radiation Protection for Nuclear Power Operations*. February.
- Google 2005. *Google Earth Pro 3.0.0762*, November.
- International Commission on Radiological Protection (ICRP) 1959. *Report of ICRP Committee II on Permissible Dose for Internal Radiation*, Health Physics 3:1-380, 1960.
- International Commission on Radiological Protection (ICRP) 1966. *Deposition and retention models for internal dosimetry of the human respiratory tract*. Health Physics 12; 173-207.

- International Commission on Radiological Protection (ICRP) 1971. *Recommendations of the International Commission on Radiological Protection*. ICRP Publication 10A. Pergamon Press, New York.
- International Commission on Radiological Protection (ICRP) 1972. *The Metabolism of Compounds of Plutonium and Other Actinides*. ICRP Publication 19, Pergamon Press.
- International Commission on Radiological Protection (ICRP) 1979. *Limits for Intakes of Radionuclides by Workers (adopted from July 1978)*. ICRP Publication 30.
- Landau, S. 2007. Email: RE: 34489- Preliminary Mildos Results and Emissions Calculations. Received Feb. 13/07.
- National Council on Radiation Protection and Measurements (NCRP) 1987. Report No. 94. *Exposure of Population in the United States and Canada from Natural Background Radiation*
- United States Nuclear Regulatory Commission (NRC) 1979. *Final Environmental Statement Related to the Energy Fuels Nuclear, Inc*, NUREG-0556. Docket No. 40-8681. May.
- United States Nuclear Regulatory Commission (NRC) 1980. *Final Generic Environmental Impact Statement on Uranium Milling Project M-25*, NUREG-0706 Vol. 3. September.
- United States Nuclear Regulatory Commission (NRC) 1987. *Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations*, March.
- SENES Consultants Limited (SENES) 2007. *Dose Assessment in Support of the License Renewal Application & Environmental Report for the White Mesa Mill*. Prepared for Denison Mines (USA) Corp. February.
- Streng, D.L. and Bander, T.J. 1981. *MILDOS- A Computer Program for Calculating Environmental Radiation Doses from Uranium Recovery Operations*, NUREG/CR-2011. Prepared for U.S. Nuclear Regulatory Commission.
- Turk, D. 2007a. Email to A. Ho: RE: Receptor GPS. Received February 14-15.
- Turk, D. 2007b. Email to D. Chambers: FW: Additional Weather Information. Received Feb 7.
- Yu, C. 1992. *Calculation of Radiation Dose from Uranium Recovery Operations for Large Area-Sources*, Argonne National Laboratory.

**APPENDIX A**  
**HISTORY OF MILDOS**

## **APPENDIX A HISTORY OF MILDOS**

The MILDOS computer code was developed from the version IV for Argonne National Laboratory's (ANL's) Uranium Dispersion and Dosimetry (UDAD) computer program 1981. The MILDOS program was based on the models and assumptions from NRC Draft Regulatory Guide RH802-4 (Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Material Resulting from Uranium Milling Operation) and portions of the UDAD document (Streng and Bender 1981).

In 1989, ANL developed the MILDOS-AREA code by modifying the MILDOS code developed in 1981. The MILDOS-AREA code was designed for use on IBM or IBM compatible computers; the changes made were intended to enhance capabilities for calculating dose from large area-sources and updated dosimetry calculations. The major revision from the original MILDOS code is the treatment of atmospheric dispersion from area sources; MILDOS-AREA substituted a finite-element approach for the virtual-point source method (the algorithm used in the original MILDOS code) when specified by the user. The new approach subsequently led to a reduction in the number of sources from 20 to 10 in MILDOS-AREA due to the fact that a large area can be considered as a single source rather than two or more point sources.

The internal dosimetry calculations were also updated in MILDOS-AREA. In the original version of MILDOS, the dose to exposed individual is calculated for comparison with requirements of both 40 CFR 190 and 10 CFR 20 (R313-15). The calculations of ingestion DCFs were based on ICRP Publication 2 and 10A's ingestion models (ICRP 1966). The inhalation DCFs are calculated by the ANL computer program UDAD in accordance with Task Group on Lung Dynamics Lung Model (TGLM) of the International Commission on Radiological Protection (ICRP 1966, ICRP 1972). ICRP Publication 19 (ICRP 1972) gives dose commitments to adult members of the public at age 20 that are assumed to live another 50 years. DCFs are provided as a function of particle size and organ for the radionuclides U-238, U-234, Th-230, Ra-226, Pb-210, Po-210 and Bi-210. The inhalation dose factors incorporated into MILDOS-AREA are calculated using the dosimetric model from ICRP Publication 30 (ICRP 1979) (Yu 1992); the inhalation dose factors are provided for the age groups of infant, child, teenager and adult. However, these factors are fixed internally in the code, and are not part of the input options. The annual average air concentrations were computed to the maximum permissible concentrations (MPCs) in 10 CFR 20. The MPCs in 10 CFR 20 (incorporated by reference in R313-15) were revised in 1994 to incorporate the updated dosimetry to the ICRP 1978 recommendations.

In 1997, the MILDOS-AREA code was updated to meet the requirements of the revised 10 CFR 20. The dose limit to the general public also changed; which led to a revised calculation

of the allowable concentrations (ALCs) for unrestricted areas, with MPC replaced with the term “effluent concentrations”.

In 1998, ANL again updated the MILDOS-AREA code in an attempt to improve the “user friendliness” of the software. In the past, the user must develop an input file in an American Standard Code for Information Interchange (ASCII) file containing values that are required by the code. The code executes this file to produce the output. The latest version of MILDOS-AREA, has a graphical user interface (GUI) which provides an interface for the user to input each parameter needed for the calculations in the Windows operating system. The GUI allows the results of the MILDOS-AREA calculations to be viewed. The 1998 update was the last time ANL made changes to the MILDOS-AREA code. The most up-to-date version of MILDOS-AREA was used in this assessment.

MILDOS-AREA calculates the impacts based on annual average air concentrations of nuclides considered. The human pathways considered in MILDOS-AREA for individual and population impacts are: inhalation, external exposure from ground concentrations, external exposure from cloud immersion, ingestion of vegetables, ingestion of meat and ingestion of milk.

**APPENDIX B**  
**EMISSION CALCULATIONS**

## APPENDIX B EMISSION CALCULATIONS

Supplemental Information which describes the model and assumptions used to calculate the source emissions for the sources described in Section 4.0 are provided below.

### B.1 CALCULATION OF ANNUAL DUST LOSS

The calculation of the annual dust loss from the ore pads and the tailings cells was required to calculate an emission factor. This dusting rate for the tailings impoundments is calculated according to the emission factor ( $E_w$ ) equation from NRC Regulatory Guide 3.59 (NRC 1987). The equation of for the dusting rate is calculated as follows:

$$E_w = \frac{3.156 \times 10^7}{0.5} \times \sum_s R_s F_s \quad (B.1)$$

where,

$E_w$ = annual dust loss per unit area in  $g/m^2$ yr;

$F_s$ = annual average frequency of occurrence of wind speed group S (dimensionless) obtained from the joint relative frequency distribution for the mill (provided by DUSA (Turk 2007b));

$R_s$ = resuspension rate for the tailings pond at the average wind speed for wind group S, for particles  $\leq 20 \mu m$  in diameter in  $g/m^2s$ ;

$3.156 \times 10^7$ = number of seconds per year; and,

$0.5$ = fraction of the total dust lost constituted by particle  $\leq 20 \mu m$  in diameter.

**TABLE B.1  
PARAMETER VALUES FOR CALCULATION OF ANNUAL DUSTING RATE FOR  
EXPOSED TAILINGS**

Wind Speed (kts)	Average Wind Speed	Resuspension Rate ( $R_s$ ) ( $g/m^2s$ ) <sup>a</sup>	Frequency of Occurrence, ( $F_s$ ) <sup>b</sup>	$R_s \times F_s$
0 to 3	1.5	0	0.165	0.00E+00
4 to 6	5.5	0	0.427	0.00E+00
7 to 10	10.0	3.92E-07	0.276	1.08E-07
11 to 16	15.5	9.68E-06	0.106	1.03E-06
17 to 21	21.5	5.71E-05	0.021	1.20E-06
21+	28.0	2.08E-04	0.005	1.04E-06
			$\sum_s$	3.37E-06

Notes:

a) Resuspension rate of a function of wind speed is computed by the MILDOS code.

b) Wind speed frequency obtained from joint frequency distribution data provided by DUSA (Turk 2007b).

Using equation B.1 and the parameters in Table B-1, the annual dust loss from the tailings cells is approximately 213 g/m<sup>2</sup>yr. As mentioned in Section 4.2.1, the annual dust lost for ore pads is 10% of that of the tailings cells since the particulates on the ore pad are coarse material (1 to 6 inch) because the ore has not yet been ground; therefore the annual dust loss from the ore pad is 21.29 g/m<sup>2</sup>yr.

## **B.2 EMISSION CALCULATIONS**

The equations and assumptions used to calculate the radioactive particulate (U-238) and its daughters thorium (Th-230), radium (Ra-226) and lead (Pb-210) and radon emission rates from the grizzly, grinding, ore pads, vanadium stack (exclusively for processing Colorado Plateau ore), yellowcake stacks (north and south yellowcake stacks) and the tailings cells were taken from NRC Regulatory Guide 3.59 (NRC 1987), NUREG-0706 (NRC 1980) and the EnecoTech analysis (EnecoTech 1991a and 1991b).

### **B.2.1 Wet Grinding**

#### ***Radioactive Particulate Emission Rates***

	<b>Colorado Plateau Ore</b>	<b>Arizona Strip Ore</b>
Process Rate (tpy)	730,000	730,000
Contaminant Concentration (pCi/g U-238)	700	1783
Process Emission Factor (lbs/ton) <sup>a</sup>	0.16	0.16
Activity Enrichment Ratio	2.5	2.5
Control Factor (%) <sup>b</sup>	99.90	99.90

Notes:

- a) For moisture <8% (NRC 1987).
- b) Particulate emission control from the wet grinding operations was assumed to be 99.9% (EnecoTech 1991a and 1999b)

The U-238 Emission Rate (S) is calculated as follows:

$$S = (\text{Process Rate (tons/yr)}) * (\text{Process Emission Factor (lbs/ton)}) * (453.6 \text{ g/lb}) * (\text{Contaminant Concentration (pCi/g)}) * (\text{Activity Enrichment Ratio}) * (1 - \text{Control Factor}) * (10^{-12} \text{ Ci/pCi}) \quad (\text{B.2-1})$$

Using equation B.2-1, the U-238 Emission Rate from wet grinding operations of Colorado Plateau ore is approximately 9.27E-05 Ci/yr. U-238 decay daughters (Th-230, Ra-226 and Pb-210) are assumed to be in secular equilibrium; therefore the decay daughters are also emitted at a rate of 9.27E-05 Ci/yr. Similarly, the U-238 Emission Rate from the wet grinding operations

of Arizona Strip ore is approximately 2.36E-04 Ci/yr and the decay daughters (Th-230, Ra-226 and Pb-210) are also emitted at a rate of 2.36E-04 Ci/yr.

***Radon Emission Rates***

	<b>Colorado Plateau ore</b>	<b>Arizona Strip ore</b>
Process Rate (tpy)	730,000	730,000
Contaminant Concentration (pCi/g Ra-226)	700	1783
Activity Factor(%) <sup>a</sup>	20	20

Note:

- a) It was assumed that only 20% of the radon is available for release or emanation from the mineral grains in which it is produced (i.e. the emanating fraction or power is 0.20) (NRC 1980).

Radon Release (F):

$$F = (\text{Process Rate (tons/yr)}) * (2000 \text{ lbs/ton}) * (453.6 \text{ g/lb}) * (\text{Contaminant Concentration pCi/g Ra-226}) * (10^{-12} \text{ Ci/pCi}) * (\text{Activity Factor}) \quad (\text{B.2-2})$$

Using equation B.2-2, the radon release from the wet grinding operations of Colorado Plateau ore is approximately 92.7 Ci/yr. Similarly, the radon release from the wet grinding operations of Arizona Strip ore is approximately 236 Ci/yr.

**B.2.2 Ore Dump to Grizzly**

***Radioactive Particulate Emission Rates***

	<b>Colorado Plateau Ore</b>	<b>Arizona Strip Ore</b>
Process Rate (tpy)	730,000	730,000
Contaminant Concentration (pCi/g U-238)	700	1783
Process Emission Factor (lbs/ton) <sup>a</sup>	0.16	0.16
Activity Enrichment Ratio	2.5	2.5
Control Factor (%)	99.90	99.90

Notes:

- a) For moisture <8% (NRC 1987).
- b) Grizzly Dump is enclosed on three sides. Trucks dump inside enclosure under negative pressure. The ID fans are ducted through a baghouse. Ore moisture content is 10 % (EnecoTech 1991a and 1999b).

The U-238 Emission Rate (S) is calculated as follows:

$$S = (\text{Process Rate (tons/yr)}) * (\text{Process Emission Factor (lbs/ton)}) * (453.6 \text{ g/lb}) * (\text{Contaminant Concentration (pCi/g)}) * (\text{Activity Enrichment Ratio}) * (1 - \text{Control Factor}) * (10^{-12} \text{ Ci/pCi}) \quad (\text{B.2-3})$$

Using equation B.2-3, the U-238 Emission Rate due to the trucks dumping Colorado Plateau ore on the grizzly is approximately 9.27E-05 Ci/yr. U-238 decay daughters (Th-230, Ra-226 and Pb-210) are assumed to be in secular equilibrium; therefore the decay daughters are also emitted at a rate of 9.27E-05 Ci/yr. Similarly, the U-238 Emission Rate due to the trucks dumping Arizona Strip ore on the grizzly is approximately 2.36E-04 Ci/yr and the decay daughters (Th-230, Ra-226 and Pb-210) are also emitted at a rate of 2.36E-04 Ci/yr.

***Radon Emission Rates***

No radon is released from the trucks dumping ore onto the grizzly.

**B.2.3 Yellowcake Stacks**

As mentioned in Section 4.1.3, the mill has two yellowcake dryers (north and south yellowcake stack dryers); therefore the total emissions were assumed to be divided equally between the two stacks (i.e., north and south yellowcake stacks).

***Radioactive Particulate Emission Rates***

	<b>Colorado Plateau Ore</b>	<b>Arizona Strip Ore</b>
Process Rate (tpy U <sub>3</sub> O <sub>8</sub> )	1716	4371
Contaminant Concentration (Ci/g of U-238)	3.33E-07	3.33E-07
Process Emission Factor (g U-238/g U <sub>3</sub> O <sub>8</sub> )	0.848	0.848
Emission Rate (lbs/ton) <sup>a</sup>	0.092	0.092

Note:

- a) Based stack tests that showed an emission rate of 0.06 lbs/hr U<sub>3</sub>O<sub>8</sub> per 1300 lbs/hr process rate which translates to 0.092 lb/ton including controls (EnecoTech 1991a and 1999b).

The U-238 Emission Rate (S) for one yellowcake stack is calculated as follows:

$$S = [(\text{Process Rate (tons/yr U}_3\text{O}_8)] * (\text{Emission Rate (lbs/ton)}) * (\text{Process Emission Factor}) * (453.6 \text{ g/lb}) * (\text{Contaminant Concentration (Ci/g)})] / 2 \quad (\text{B.2-4})$$

Based on field measurements, the decay daughters Th-230, Ra-226 and Pb-210 are processed along with yellowcake at 0.22%, 0.13% and 0.78%, respectively.

Using equation B.2-4, the U-238 Emission Rate from each yellowcake stack (north and south yellowcake stacks) is approximately 1.01E-02 Ci/yr for the processing of Colorado Plateau ore. The emission rate for the decay daughters Th-230, Ra-226 and Pb-210 is 2.22E-05, 1.31E-05 and 7.88E-05 Ci/yr, respectively from each yellowcake stack (north and south yellowcake stacks). Similarly, the U-238 Emission Rate from each yellowcake stack (north and south yellowcake stacks) is approximately 2.58E-02 Ci/yr for the processing of Arizona Strip ore. The emission rate for the decay daughters Th-230, Ra-226 and Pb-210 is 5.67E-05, 3.35E-05 and 2.01E-04 Ci/yr, respectively from each yellowcake stack (north and south yellowcake stacks).

***Radon Emission Rates***

There is no significant radon releases during this process.

**B.2.4 Vanadium Stack**

***Radioactive Particulate Emission Rates***

As mentioned in Section 4.1.4, the vanadium source was only used in the MILDOS-AREA model for Colorado Plateau ore. The product from the vanadium recovery contains less than 0.005% U<sub>3</sub>O<sub>8</sub> (NRC 1980). Therefore, the emission rates of U-238 and its decay daughters from the vanadium stack were assumed to be 0.005% of the total emission rate from the yellowcake stacks (north and south yellowcake stacks).

Radioactive Particulate	Emission Rate (S) (Ci/yr)	
	Total from Yellowcake Stacks	Vanadium Stack <sup>a</sup>
U-238	2.02E-02	1.01E-06
Th-230	4.45E-05	2.22E-09
Ra-226	2.63E-05	1.31E-09
Pb-210	1.58E-04	7.88E-09

Note:

- a) Total from yellowcake stacks (north and south yellowcake stacks)\*0.005%.

***Radon Emission Rates***

There are no significant radon releases during this process.

### **B.2.5 Ore Pads**

The ore pad storage operation has two different sources of emissions - namely unloading from the truck to the ore pad and wind emissions. For the wind emissions calculated, it was assumed that approximately 300,000 tons of ore are temporarily stockpiled with a height of 30 ft (9.1 m), and bulk density of ore of 120 lbs/ft<sup>3</sup> (1.47 tons/yd<sup>3</sup>). Using these assumptions, the area of the ore pad is approximately 17,000 m<sup>2</sup>.

#### ***Radioactive Particulate Emission Rates***

Source Description: Truck Unloading

	<b>Colorado Plateau Ore</b>	<b>Arizona Strip Ore</b>
Process Rate (tpy)	730,000	730,000
Contaminant Concentration (pCi/g U-238)	700	1783
Process Emission Factor (lbs/yd <sup>3</sup> ) <sup>a</sup>	0.04	0.04
Activity Emission Ratio	2.5	2.5
Control Factor	None	None
Bulk Density of Ore (tons/yd <sup>3</sup> )	1.47	1.47

Note:

a) Process emission factor for Truck end dump (NRC 1987).

The U-238 Emission Rate (S) is calculated as follows:

$$S = \text{Process Rate (tons/yr)} * (1 \text{ yd}^3 / 1.47 \text{ tons}) * (\text{Process Emission Factor (lbs/yd}^3\text{)}) * (453.6 \text{ g/lb}) * (\text{Contaminant Concentration (pCi/g)}) * (\text{Activity Enrichment Ratio}) * (10^{-12} \text{ Ci/pCi}) \quad (\text{B.2-5})$$

Using equation B.2-5, the U-238 Emission Rate from truck unloading Colorado Plateau ore is approximately 1.58E-02 Ci/yr. U-238 decay daughters (Th-230, Ra-226 and Pb-210) were assumed to be in secular equilibrium; therefore the decay daughters are also emitted at a rate of 1.58E-02 Ci/yr. Similarly, the U-238 Emission Rate from truck unloading of Arizona Strip ore is approximately 4.02E-02 Ci/yr and the decay daughters (Th-230, Ra-226 and Pb-210) are also emitted at a rate of 4.02E-02 Ci/yr.

Source Description: Wind Erosion

	<b>Colorado Plateau Ore</b>	<b>Arizona Strip Ore</b>
Area (m <sup>2</sup> ) <sup>a</sup>	17000	17000
Contaminant Concentration (pCi/g U-238)	700	1783
Process Emission Factor, E <sub>w</sub> (g/m <sup>2</sup> yr) <sup>b</sup>	21.29	21.29
Activity Enrichment Ratio	2.5	2.5
Control Factor (%) <sup>c</sup>	50	50

Notes:

- a) Calculated assuming a stockpile of 300,000 tons of ore with a height of 30 ft. and bulk ore density of 1.47 tons/yard<sup>3</sup>.
- b) The process emission factor for the ore pad was derived in Section B.1.
- c) The control factor of 50% is based on the assumption that an active watering program will be in place during operations (EnecoTech 1991a and 1999b).

The U-238 Emission Rate (S) is calculated as follows:

$$S = (\text{Process Emission Factor (g/m}^2\text{yr)}) * (\text{Area (m}^2\text{)}) * (\text{Contaminant Concentration (pCi/g)}) * (\text{Activity Enrichment Ratio}) * (1 - \text{Control Factor}) * (10^{-12} \text{ Ci/pCi}) \quad (\text{B.2-6})$$

Using equation B.2-6, the U-238 Emission Rate from trucks unloading Colorado Plateau ore is approximately 3.17E-04 Ci/yr. U-238 decay daughters (Th-230, Ra-226 and Pb-210) were assumed to be in secular equilibrium; therefore the decay daughters are also emitted at a rate of 3.17E-04 Ci/yr. Similarly, the U-238 Emission Rate from truck unloading of Arizona Strip ore is approximately 8.07E-04 Ci/yr and the decay daughters (Th-230, Ra-226 and Pb-210) are also emitted at a rate of 8.07E-04 Ci/yr.

The total radioactive particulate emission rates from the ore pad are obtained by adding the results of truck unloading and wind erosion and are as follows:

<b>Radioactive Particulate</b>	<b>Emission Rate (S) (Ci/yr)</b>	
	<b>Colorado Plateau Ore</b>	<b>Arizona Strip Ore</b>
U-238	1.61E-02	4.10E-02
Th-230	1.61E-02	4.10E-02
Ra-226	1.61E-02	4.10E-02
Pb-210	1.61E-02	4.10E-02

**Radon Emission Rates**

	<b>Colorado Plateau ore</b>	<b>Arizona Strip ore</b>
Area (m <sup>2</sup> )	17000	17000
Contaminant Concentration (pCi/g Ra-226)	700	1783
Specific Radon Flux Factor (pCi Rn-222/m <sup>2</sup> s)/(pCi/g Ra-226)	1	1

Radon Release (F):

$$F = (\text{Specific Radon Flux Factor (pCi Rn-222/m}^2\text{s)} / (\text{pCi/g Ra-226})) * (\text{Contaminant Concentration (pCi/g Ra-226)}) * (\text{Area (m}^2\text{)}) * (3.156 \times 10^7 \text{ s/yr}) * (10^{-12} \text{ Ci/pCi}) \quad (\text{B.2-7})$$

Using equation B.2-7, the radon release from storage of Colorado Plateau ore is approximately 375 Ci/yr. Similarly, the radon release from storage of Arizona Strip ore is approximately 956 Ci/yr.

**B.2-6 Tailings Cells**

*Factors used to Calculate Radioactive Particulate Emission Rates*

	<b>Colorado Plateau Ore</b>		<b>Arizona Strip Ore</b>	
	<b>Active</b>		<b>Active</b>	
	<b>Cell 3</b>	<b>Cell 4A/4B</b>	<b>Cell 3</b>	<b>Cell 4A/4B</b>
Area (acres)	10	10	10	10
Contaminant Concentration (pCi/g U-238) <sup>a</sup>	42	42	107	107
Contaminant Concentration of all other isotopes (pCi/g)	700	700	1783	1783
Process Emission Factor, E <sub>w</sub> (g/m <sup>2</sup> yr) <sup>b</sup>	213	213	213	213
Activity Enrichment Ratio	2.5	2.5	2.5	2.5
Control Factor (%) <sup>c</sup>	70	70	70	70

Notes:

- a) Assumes 94% recovery.
- b) The process emission factor for the tailings cells was derived in Section B.1.
- c) The control factor of 70% is based on the assumption that active watering programs as well as crusting agents are used to minimize the erosion of the tailings by wind (EnecoTech 1991a and 1991b).

The Emission Rate (S) for U-238 and its decay daughters were calculated as follows:

$$S = (\text{Process Emission Factor (g/m}^2\text{yr)}) * (\text{Area (acres)}) * (4047 \text{ m}^2\text{/acre}) * (\text{Contaminant Concentration (pCi/g)}) * (\text{Activity Enrichment Ratio}) * (1 - \text{Control Factor}) * (10^{-12} \text{ Ci/pCi}) \quad (\text{B.2-8})$$

Using equation B.2-8, the U-238 Emission Rate from the active tailings cells 3, 4A and 4B from the processing of Colorado Plateau ore is approximately 2.71E-04 Ci/yr. The decay daughters (Th-230, Ra-226 and Pb-210) are emitted at a rate of 4.52E-03 Ci/yr.

Similarly, the U-238 Emission Rate from the active tailings cells 3, 4A and 4B from the processing of Arizona Strip ore is approximately 6.91E-04 Ci/yr. The decay daughters (Th-230, Ra-226 and Pb-210) are emitted at a rate of 1.15E-02 Ci/yr.

There is no dust released from tailings cells 2 and 3 with interim covers.

***Factors Used to Calculate Radon Emission Rates***

	<b>Colorado Plateau/ Arizona Strip Ore</b>			
	<b>Interim Soil Cover</b>		<b>Active</b>	
	<b>Cell 2</b>	<b>Cell 3</b>	<b>Cell 3</b>	<b>Cell 4A/4B</b>
Area (acres)	66.8	70	70	40
Contaminant Concentration (pCi/m <sup>2</sup> s)	10	10	20	20

Radon Release (F):

$$F = (\text{Contaminant Concentration (pCi/m}^2\text{s)}) * (\text{Area (acres)}) * (4047 \text{ m}^2\text{/acre}) * (3.156 \times 10^7 \text{ s/yr}) * (10^{-12} \text{ Ci/pCi}) \quad (\text{B.2-9})$$

Using equation B.2-9, the radon release from the active tailings cells 3, 4A and 4B are approximately 179 and 102 Ci/yr, respectively. The radon release for tailings cells 2 and 3 with interim cover are approximately 85.3 and 89.4 Ci/yr, respectively.

**APPENDIX C**  
**MILDOS-AREA RESULTS**

## APPENDIX C MILDOS-AREA RESULTS

This Appendix provides the dose estimates for MILDOS-AREA runs for the mill area (including the ore pads) and each tailings cell for the processing of Colorado Plateau or Arizona Strip ore. The total annual dose commitments and 40 CFR 190 annual dose commitments for Phases 1 and 2 are provided in Sections C.1 and C.2 for Colorado Plateau ore and Arizona Strip ore, respectively.

### C.1 MILDOS-AREA RESULTS FOR COLORADO PLATEAU ORE

The MILDOS-AREA calculated total annual dose commitments (including radon) and 40 CFR 190 annual dose commitments for the mill area (including the ore pads) and each tailings cell for processing of Colorado Plateau ore are provided in Sections C.1.1 and C.1.2, respectively.

#### C.1.1 R313-15-301 (1)(a) Regulatory Compliance

**TABLE C.1-1  
ANNUAL DOSE COMMITMENTS  
(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Potential Resident (BHV-1)	Infant	Effective	1.11E+00	6.03E-02	5.84E-02	1.30E-01	6.88E-02	5.55E-02
		Bone	1.81E+00	2.57E-03	2.70E-03	6.09E-02	4.94E-02	3.74E-02
		Avg. Lung	4.66E-01	2.45E-03	2.55E-03	3.46E-02	2.77E-02	2.14E-02
		Bronchi	9.22E+00	9.67E-01	9.34E-01	1.87E+00	9.14E-01	7.44E-01
	Child	Effective	7.96E-01	6.03E-02	5.84E-02	1.29E-01	6.77E-02	5.46E-02
		Bone	1.24E+00	2.65E-03	2.79E-03	7.48E-02	6.06E-02	4.54E-02
		Avg. Lung	6.20E-01	2.56E-03	2.69E-03	4.86E-02	3.88E-02	2.92E-02
		Bronchi	9.22E+00	9.67E-01	9.34E-01	1.87E+00	9.14E-01	7.44E-01
	Teenage	Effective	8.34E-01	6.04E-02	5.85E-02	1.32E-01	7.05E-02	5.66E-02
		Bone	4.40E+00	3.28E-03	3.53E-03	2.42E-01	1.98E-01	1.46E-01
		Avg. Lung	4.94E-01	2.54E-03	2.66E-03	3.99E-02	3.15E-02	2.38E-02
		Bronchi	9.22E+00	9.67E-01	9.34E-01	1.87E+00	9.14E-01	7.44E-01
	Adult	Effective	7.30E-01	6.03E-02	5.84E-02	1.27E-01	6.59E-02	5.32E-02
		Bone	1.91E+00	2.85E-03	3.03E-03	1.20E-01	9.80E-02	7.29E-02
		Avg. Lung	3.43E-01	2.50E-03	2.61E-03	2.88E-02	2.25E-02	1.70E-02
		Bronchi	9.22E+00	9.67E-01	9.34E-01	1.87E+00	9.14E-01	7.44E-01

**TABLE C.1-1 (Cont'd)**  
**ANNUAL DOSE COMMITMENTS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Historical Resident (BHV-2)	Infant	Effective	2.18E-01	2.14E-02	2.09E-02	4.54E-02	2.53E-02	2.42E-02
		Bone	2.69E-01	1.84E-03	1.90E-03	1.88E-02	1.55E-02	1.53E-02
		Avg. Lung	8.29E-02	1.61E-03	1.65E-03	1.17E-02	9.36E-03	9.18E-03
		Bronchi	2.20E+00	3.31E-01	3.22E-01	6.43E-01	3.39E-01	3.23E-01
	Child	Effective	1.75E-01	2.14E-02	2.08E-02	4.48E-02	2.49E-02	2.37E-02
		Bone	1.91E-01	1.97E-03	2.04E-03	2.20E-02	1.82E-02	1.80E-02
		Avg. Lung	1.01E-01	1.82E-03	1.87E-03	1.48E-02	1.19E-02	1.17E-02
		Bronchi	2.20E+00	3.31E-01	3.22E-01	6.43E-01	3.39E-01	3.23E-01
	Teenage	Effective	1.80E-01	2.14E-02	2.09E-02	4.57E-02	2.57E-02	2.44E-02
		Bone	6.40E-01	3.10E-03	3.28E-03	6.48E-02	5.52E-02	5.52E-02
		Avg. Lung	8.09E-02	1.78E-03	1.83E-03	1.23E-02	9.71E-03	9.60E-03
		Bronchi	2.20E+00	3.31E-01	3.22E-01	6.43E-01	3.39E-01	3.23E-01
	Adult	Effective	1.65E-01	2.14E-02	2.08E-02	4.43E-02	2.44E-02	2.33E-02
		Bone	2.89E-01	2.34E-03	2.45E-03	3.38E-02	2.84E-02	2.82E-02
		Avg. Lung	5.86E-02	1.70E-03	1.74E-03	9.44E-03	7.21E-03	7.10E-03
		Bronchi	2.20E+00	3.31E-01	3.22E-01	6.43E-01	3.39E-01	3.23E-01
Nearest Actual Resident	Infant	Effective	6.83E-01	4.54E-02	4.33E-02	9.67E-02	5.23E-02	4.57E-02
		Bone	1.05E+00	2.46E-03	2.54E-03	4.45E-02	3.61E-02	3.10E-02
		Avg. Lung	2.68E-01	2.30E-03	2.36E-03	2.59E-02	2.07E-02	1.79E-02
		Bronchi	5.98E+00	7.20E-01	6.84E-01	1.38E+00	6.95E-01	6.09E-01
	Child	Effective	5.03E-01	4.54E-02	4.33E-02	9.57E-02	5.14E-02	4.49E-02
		Bone	7.12E-01	2.55E-03	2.65E-03	5.38E-02	4.37E-02	3.74E-02
		Avg. Lung	3.56E-01	2.44E-03	2.53E-03	3.52E-02	2.81E-02	2.41E-02
		Bronchi	5.98E+00	7.20E-01	6.84E-01	1.38E+00	6.95E-01	6.09E-01
	Teenage	Effective	5.24E-01	4.54E-02	4.34E-02	9.81E-02	5.34E-02	4.66E-02
		Bone	2.52E+00	3.36E-03	3.58E-03	1.70E-01	1.40E-01	1.19E-01
		Avg. Lung	2.85E-01	2.41E-03	2.50E-03	2.90E-02	2.29E-02	1.96E-02
		Bronchi	5.98E+00	7.20E-01	6.84E-01	1.38E+00	6.95E-01	6.09E-01
	Adult	Effective	4.65E-01	4.54E-02	4.33E-02	9.41E-02	5.01E-02	4.38E-02
		Bone	1.10E+00	2.81E-03	2.95E-03	8.54E-02	6.99E-02	5.96E-02
		Avg. Lung	2.00E-01	2.36E-03	2.43E-03	2.13E-02	1.65E-02	1.41E-02
		Bronchi	5.98E+00	7.20E-01	6.84E-01	1.38E+00	6.95E-01	6.09E-01

**TABLE C.1-1 (Cont'd)**  
**ANNUAL DOSE COMMITMENTS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
White Mesa Community	Infant	Effective	1.40E-01	2.23E-02	2.48E-02	5.17E-02	3.15E-02	2.82E-02
		Bone	1.16E-01	2.81E-03	3.05E-03	1.44E-02	1.22E-02	1.08E-02
		Avg. Lung	4.60E-02	2.26E-03	2.47E-03	1.04E-02	8.61E-03	7.61E-03
		Bronchi	1.65E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
	Child	Effective	1.21E-01	2.23E-02	2.48E-02	5.11E-02	3.09E-02	2.77E-02
		Bone	7.67E-02	3.14E-03	3.38E-03	1.51E-02	1.27E-02	1.12E-02
		Avg. Lung	4.24E-02	2.76E-03	2.99E-03	1.09E-02	8.64E-03	7.69E-03
		Bronchi	1.65E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
	Teenage	Effective	1.21E-01	2.24E-02	2.49E-02	5.13E-02	3.10E-02	2.79E-02
		Bone	2.15E-01	5.93E-03	6.28E-03	3.51E-02	3.09E-02	2.72E-02
		Avg. Lung	3.35E-02	2.67E-03	2.90E-03	9.33E-03	7.10E-03	6.34E-03
		Bronchi	1.65E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
	Adult	Effective	1.17E-01	2.23E-02	2.48E-02	5.07E-02	3.05E-02	2.73E-02
		Bone	1.06E-01	4.04E-03	4.33E-03	2.08E-02	1.78E-02	1.57E-02
		Avg. Lung	2.66E-02	2.47E-03	2.69E-03	7.88E-03	5.77E-03	5.18E-03
		Bronchi	1.65E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
Blanding	Infant	Effective	6.98E-02	8.36E-03	8.50E-03	1.82E-02	1.05E-02	1.04E-02
		Bone	7.53E-02	1.17E-03	1.22E-03	7.12E-03	5.86E-03	5.93E-03
		Avg. Lung	2.45E-02	8.95E-04	9.22E-04	4.57E-03	3.64E-03	3.67E-03
		Bronchi	7.34E-01	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01
	Child	Effective	5.72E-02	8.34E-03	8.49E-03	1.79E-02	1.03E-02	1.02E-02
		Bone	5.16E-02	1.34E-03	1.39E-03	8.18E-03	6.75E-03	6.83E-03
		Avg. Lung	2.78E-02	1.15E-03	1.19E-03	5.69E-03	4.51E-03	4.55E-03
		Bronchi	7.34E-01	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01
	Teenage	Effective	5.84E-02	8.37E-03	8.52E-03	1.82E-02	1.06E-02	1.04E-02
		Bone	1.65E-01	2.74E-03	2.88E-03	2.28E-02	1.96E-02	1.99E-02
		Avg. Lung	2.26E-02	1.10E-03	1.14E-03	4.84E-03	3.74E-03	3.76E-03
		Bronchi	7.34E-01	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01
	Adult	Effective	5.46E-02	8.33E-03	8.47E-03	1.77E-02	1.01E-02	9.99E-03
		Bone	7.58E-02	1.79E-03	1.87E-03	1.23E-02	1.03E-02	1.05E-02
		Avg. Lung	1.70E-02	9.99E-04	1.03E-03	3.84E-03	2.86E-03	2.87E-03
		Bronchi	7.34E-01	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01

C.2.2 40 CFR 190 Regulatory Compliance

**TABLE C.1-2  
40 CFR 190 ANNUAL DOSE COMMITMENTS  
(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Potential Resident (BHV-1)	Infant	Effective	5.22E-01	0.00E+00	0.00E+00	1.24E-02	1.03E-02	7.72E-03
		Bone	1.76E+00	0.00E+00	0.00E+00	5.43E-02	4.54E-02	3.39E-02
		Avg. Lung	4.33E-01	0.00E+00	0.00E+00	2.83E-02	2.38E-02	1.80E-02
		Bronchi	9.30E-04	0.00E+00	0.00E+00	2.34E-05	1.93E-05	1.41E-05
	Child	Effective	2.12E-01	0.00E+00	0.00E+00	1.11E-02	9.23E-03	6.83E-03
		Bone	1.20E+00	0.00E+00	0.00E+00	6.80E-02	5.65E-02	4.18E-02
		Avg. Lung	5.85E-01	0.00E+00	0.00E+00	4.19E-02	3.48E-02	2.57E-02
		Bronchi	9.30E-04	0.00E+00	0.00E+00	2.34E-05	1.93E-05	1.41E-05
	Teenage	Effective	2.49E-01	0.00E+00	0.00E+00	1.46E-02	1.20E-02	8.86E-03
		Bone	4.37E+00	0.00E+00	0.00E+00	2.34E-01	1.93E-01	1.41E-01
		Avg. Lung	4.61E-01	0.00E+00	0.00E+00	3.33E-02	2.75E-02	2.03E-02
		Bronchi	9.30E-04	0.00E+00	0.00E+00	2.34E-05	1.93E-05	1.41E-05
	Adult	Effective	1.46E-01	0.00E+00	0.00E+00	8.99E-03	7.44E-03	5.49E-03
		Bone	1.88E+00	0.00E+00	0.00E+00	1.13E-01	9.35E-02	6.90E-02
		Avg. Lung	3.10E-01	0.00E+00	0.00E+00	2.24E-02	1.85E-02	1.36E-02
		Bronchi	9.30E-04	0.00E+00	0.00E+00	2.34E-05	1.93E-05	1.41E-05
Nearest Historical Resident (BHV-2)	Infant	Effective	7.43E-02	0.00E+00	0.00E+00	3.36E-03	2.99E-03	2.98E-03
		Bone	2.54E-01	0.00E+00	0.00E+00	1.47E-02	1.31E-02	1.30E-02
		Avg. Lung	7.02E-02	0.00E+00	0.00E+00	8.10E-03	7.28E-03	7.22E-03
		Bronchi	1.28E-04	0.00E+00	0.00E+00	5.68E-06	5.02E-06	5.04E-06
	Child	Effective	3.07E-02	0.00E+00	0.00E+00	2.86E-03	2.53E-03	2.53E-03
		Bone	1.76E-01	0.00E+00	0.00E+00	1.76E-02	1.56E-02	1.56E-02
		Avg. Lung	8.70E-02	0.00E+00	0.00E+00	1.07E-02	9.54E-03	9.53E-03
		Bronchi	1.28E-04	0.00E+00	0.00E+00	5.68E-06	5.02E-06	5.04E-06
	Teenage	Effective	3.58E-02	0.00E+00	0.00E+00	3.63E-03	3.22E-03	3.23E-03
		Bone	6.21E-01	0.00E+00	0.00E+00	5.79E-02	5.12E-02	5.14E-02
		Avg. Lung	6.73E-02	0.00E+00	0.00E+00	8.37E-03	7.42E-03	7.43E-03
		Bronchi	1.28E-04	0.00E+00	0.00E+00	5.68E-06	5.02E-06	5.04E-06
	Adult	Effective	2.12E-02	0.00E+00	0.00E+00	2.27E-03	2.01E-03	2.02E-03
		Bone	2.72E-01	0.00E+00	0.00E+00	2.85E-02	2.53E-02	2.53E-02
		Avg. Lung	4.55E-02	0.00E+00	0.00E+00	5.66E-03	5.01E-03	5.02E-03
		Bronchi	1.28E-04	0.00E+00	0.00E+00	5.68E-06	5.02E-06	5.04E-06

**TABLE C.1-2 (Cont'd)**  
**40 CFR 190 ANNUAL DOSE COMMITMENTS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Actual Resident	Infant	Effective	3.01E-01	0.00E+00	0.00E+00	8.77E-03	7.42E-03	6.32E-03
		Bone	1.02E+00	0.00E+00	0.00E+00	3.85E-02	3.25E-02	2.77E-02
		Avg. Lung	2.43E-01	0.00E+00	0.00E+00	2.04E-02	1.74E-02	1.48E-02
		Bronchi	5.32E-04	0.00E+00	0.00E+00	1.61E-05	1.35E-05	1.14E-05
	Child	Effective	1.21E-01	0.00E+00	0.00E+00	7.79E-03	6.54E-03	5.55E-03
		Bone	6.85E-01	0.00E+00	0.00E+00	4.77E-02	4.01E-02	3.41E-02
		Avg. Lung	3.30E-01	0.00E+00	0.00E+00	2.93E-02	2.46E-02	2.09E-02
		Bronchi	5.32E-04	0.00E+00	0.00E+00	1.61E-05	1.35E-05	1.14E-05
	Teenage	Effective	1.42E-01	0.00E+00	0.00E+00	1.01E-02	8.46E-03	7.16E-03
		Bone	2.48E+00	0.00E+00	0.00E+00	1.62E-01	1.35E-01	1.14E-01
		Avg. Lung	2.59E-01	0.00E+00	0.00E+00	2.32E-02	1.94E-02	1.64E-02
		Bronchi	5.32E-04	0.00E+00	0.00E+00	1.61E-05	1.35E-05	1.14E-05
	Adult	Effective	8.31E-02	0.00E+00	0.00E+00	6.27E-03	5.26E-03	4.45E-03
		Bone	1.07E+00	0.00E+00	0.00E+00	7.88E-02	6.60E-02	5.60E-02
		Avg. Lung	1.74E-01	0.00E+00	0.00E+00	1.56E-02	1.31E-02	1.11E-02
		Bronchi	5.32E-04	0.00E+00	0.00E+00	1.61E-05	1.35E-05	1.14E-05
White Mesa Community	Infant	Effective	2.98E-02	0.00E+00	0.00E+00	1.90E-03	1.98E-03	1.72E-03
		Bone	1.02E-01	0.00E+00	0.00E+00	8.21E-03	8.59E-03	7.41E-03
		Avg. Lung	3.45E-02	0.00E+00	0.00E+00	5.38E-03	5.61E-03	4.85E-03
		Bronchi	3.85E-05	0.00E+00	0.00E+00	1.94E-06	2.05E-06	1.76E-06
	Child	Effective	1.04E-02	0.00E+00	0.00E+00	1.29E-03	1.36E-03	1.17E-03
		Bone	6.11E-02	0.00E+00	0.00E+00	8.25E-03	8.66E-03	7.45E-03
		Avg. Lung	2.86E-02	0.00E+00	0.00E+00	4.82E-03	5.07E-03	4.36E-03
		Bronchi	3.85E-05	0.00E+00	0.00E+00	1.94E-06	2.05E-06	1.76E-06
	Teenage	Effective	1.08E-02	0.00E+00	0.00E+00	1.46E-03	1.53E-03	1.32E-03
		Bone	1.85E-01	0.00E+00	0.00E+00	2.24E-02	2.36E-02	2.03E-02
		Avg. Lung	2.01E-02	0.00E+00	0.00E+00	3.45E-03	3.63E-03	3.12E-03
		Bronchi	3.85E-05	0.00E+00	0.00E+00	1.94E-06	2.05E-06	1.76E-06
	Adult	Effective	6.70E-03	0.00E+00	0.00E+00	9.71E-04	1.02E-03	8.78E-04
		Bone	8.57E-02	0.00E+00	0.00E+00	1.21E-02	1.27E-02	1.09E-02
		Avg. Lung	1.41E-02	0.00E+00	0.00E+00	2.42E-03	2.54E-03	2.18E-03
		Bronchi	3.85E-05	0.00E+00	0.00E+00	1.94E-06	2.05E-06	1.76E-06

**TABLE C.1-2 (Cont'd)**  
**40 CFR 190 ANNUAL DOSE COMMITMENTS**  
**(COLORADO PLATEAU ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Blanding	Infant	Effective	2.00E-02	0.00E+00	0.00E+00	1.05E-03	1.01E-03	1.03E-03
		Bone	6.79E-02	0.00E+00	0.00E+00	4.59E-03	4.42E-03	4.52E-03
		Avg. Lung	1.88E-02	0.00E+00	0.00E+00	2.63E-03	2.54E-03	2.58E-03
		Bronchi	3.17E-05	0.00E+00	0.00E+00	1.63E-06	1.56E-06	1.61E-06
	Child	Effective	7.55E-03	0.00E+00	0.00E+00	8.57E-04	8.23E-04	8.44E-04
		Bone	4.34E-02	0.00E+00	0.00E+00	5.31E-03	5.09E-03	5.23E-03
		Avg. Lung	2.06E-02	0.00E+00	0.00E+00	3.22E-03	3.09E-03	3.17E-03
		Bronchi	3.17E-05	0.00E+00	0.00E+00	1.63E-06	1.56E-06	1.61E-06
	Teenage	Effective	8.49E-03	0.00E+00	0.00E+00	1.07E-03	1.03E-03	1.05E-03
		Bone	1.48E-01	0.00E+00	0.00E+00	1.69E-02	1.62E-02	1.67E-02
		Avg. Lung	1.56E-02	0.00E+00	0.00E+00	2.47E-03	2.38E-03	2.44E-03
		Bronchi	3.17E-05	0.00E+00	0.00E+00	1.63E-06	1.56E-06	1.61E-06
	Adult	Effective	5.05E-03	0.00E+00	0.00E+00	6.77E-04	6.49E-04	6.67E-04
		Bone	6.50E-02	0.00E+00	0.00E+00	8.47E-03	8.13E-03	8.35E-03
		Avg. Lung	1.06E-02	0.00E+00	0.00E+00	1.68E-03	1.62E-03	1.66E-03
		Bronchi	3.17E-05	0.00E+00	0.00E+00	1.63E-06	1.56E-06	1.61E-06

**C.2 MILDOS-AREA RESULTS FOR ARIZONA STRIP ORE**

The MILDOS-AREA calculated total annual dose commitments (including radon) and 40 CFR 190 annual dose commitments for the mill area (including the ore pads) and each tailings cell for processing of Arizona Strip ore are provided in Sections C.2.1 and C.2.2, respectively.

**C.2.1 R313-15-301 (1)(a) Regulatory Compliance**

**TABLE C.2-1  
ANNUAL DOSE COMMITMENTS  
(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Potential Resident (BHV-1)	Infant	Effective	2.82E+00	6.03E-02	5.84E-02	1.52E-01	8.64E-02	6.86E-02
		Bone	4.59E+00	2.57E-03	2.70E-03	1.47E-01	1.21E-01	9.11E-02
		Avg. Lung	1.19E+00	2.45E-03	2.55E-03	8.04E-02	6.62E-02	5.04E-02
		Bronchi	2.35E+01	9.67E-01	9.34E-01	1.87E+00	9.15E-01	7.45E-01
	Child	Effective	2.03E+00	6.03E-02	5.84E-02	1.48E-01	8.36E-02	6.63E-02
		Bone	3.15E+00	2.65E-03	2.79E-03	1.82E-01	1.50E-01	1.11E-01
		Avg. Lung	1.57E+00	2.56E-03	2.69E-03	1.16E-01	9.42E-02	7.02E-02
		Bronchi	2.35E+01	9.67E-01	9.34E-01	1.87E+00	9.15E-01	7.45E-01
	Teenage	Effective	2.12E+00	6.04E-02	5.85E-02	1.57E-01	9.07E-02	7.15E-02
		Bone	1.12E+01	3.28E-03	3.53E-03	6.05E-01	4.97E-01	3.67E-01
		Avg. Lung	1.26E+00	2.54E-03	2.66E-03	9.34E-02	7.57E-02	5.63E-02
		Bronchi	2.35E+01	9.67E-01	9.34E-01	1.87E+00	9.15E-01	7.45E-01
	Adult	Effective	1.86E+00	6.03E-02	5.84E-02	1.43E-01	7.90E-02	6.29E-02
		Bone	4.88E+00	2.85E-03	3.03E-03	2.97E-01	2.44E-01	1.81E-01
		Avg. Lung	8.74E-01	2.50E-03	2.61E-03	6.54E-02	5.27E-02	3.94E-02
		Bronchi	2.35E+01	9.67E-01	9.34E-01	1.87E+00	9.15E-01	7.45E-01

**TABLE C.2-1 (Cont'd)**  
**ANNUAL DOSE COMMITMENTS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Historical Resident (BHV-2)	Infant	Effective	5.57E-01	2.14E-02	2.09E-02	5.10E-02	3.04E-02	2.93E-02
		Bone	6.85E-01	1.84E-03	1.90E-03	4.19E-02	3.62E-02	3.59E-02
		Avg. Lung	2.11E-01	1.61E-03	1.65E-03	2.47E-02	2.10E-02	2.07E-02
		Bronchi	5.61E+00	3.31E-01	3.22E-01	6.44E-01	3.39E-01	3.23E-01
	Child	Effective	4.45E-01	2.14E-02	2.08E-02	4.98E-02	2.92E-02	2.81E-02
		Bone	4.85E-01	1.97E-03	2.04E-03	4.96E-02	4.28E-02	4.25E-02
		Avg. Lung	2.56E-01	1.82E-03	1.87E-03	3.18E-02	2.71E-02	2.69E-02
		Bronchi	5.61E+00	3.31E-01	3.22E-01	6.44E-01	3.39E-01	3.23E-01
	Teenage	Effective	4.59E-01	2.14E-02	2.09E-02	5.18E-02	3.10E-02	2.99E-02
		Bone	1.63E+00	3.10E-03	3.28E-03	1.54E-01	1.35E-01	1.35E-01
		Avg. Lung	2.05E-01	1.78E-03	1.83E-03	2.58E-02	2.16E-02	2.15E-02
		Bronchi	5.61E+00	3.31E-01	3.22E-01	6.44E-01	3.39E-01	3.23E-01
	Adult	Effective	4.21E-01	2.14E-02	2.08E-02	4.83E-02	2.79E-02	2.68E-02
		Bone	7.36E-01	2.34E-03	2.45E-03	7.84E-02	6.79E-02	6.78E-02
		Avg. Lung	1.49E-01	1.70E-03	1.74E-03	1.87E-02	1.54E-02	1.53E-02
		Bronchi	5.61E+00	3.31E-01	3.22E-01	6.44E-01	3.39E-01	3.23E-01
Nearest Actual Resident	Infant	Effective	1.74E+00	4.54E-02	4.33E-02	1.12E-01	6.49E-02	5.64E-02
		Bone	2.67E+00	2.46E-03	2.54E-03	1.05E-01	8.77E-02	7.48E-02
		Avg. Lung	6.82E-01	2.30E-03	2.36E-03	5.88E-02	4.87E-02	4.18E-02
		Bronchi	1.53E+01	7.20E-01	6.84E-01	1.38E+00	6.96E-01	6.10E-01
	Child	Effective	1.28E+00	4.54E-02	4.33E-02	1.09E-01	6.26E-02	5.44E-02
		Bone	1.81E+00	2.55E-03	2.65E-03	1.29E-01	1.07E-01	9.09E-02
		Avg. Lung	9.05E-01	2.44E-03	2.53E-03	8.18E-02	6.73E-02	5.73E-02
		Bronchi	1.53E+01	7.20E-01	6.84E-01	1.38E+00	6.96E-01	6.10E-01
	Teenage	Effective	1.34E+00	4.54E-02	4.34E-02	1.15E-01	6.77E-02	5.86E-02
		Bone	6.40E+00	3.36E-03	3.58E-03	4.21E-01	3.50E-01	2.97E-01
		Avg. Lung	7.27E-01	2.41E-03	2.50E-03	6.62E-02	5.40E-02	4.60E-02
		Bronchi	1.53E+01	7.20E-01	6.84E-01	1.38E+00	6.96E-01	6.10E-01
	Adult	Effective	1.19E+00	4.54E-02	4.33E-02	1.05E-01	5.94E-02	5.17E-02
		Bone	2.80E+00	2.81E-03	2.95E-03	2.08E-01	1.73E-01	1.47E-01
		Avg. Lung	5.09E-01	2.36E-03	2.43E-03	4.67E-02	3.78E-02	3.23E-02
		Bronchi	1.53E+01	7.20E-01	6.84E-01	1.38E+00	6.96E-01	6.10E-01

**TABLE C.2-1 (Cont'd)**  
**ANNUAL DOSE COMMITMENTS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
White Mesa Community	Infant	Effective	3.56E-01	2.23E-02	2.48E-02	5.47E-02	3.47E-02	3.10E-02
		Bone	2.95E-01	2.81E-03	3.05E-03	2.73E-02	2.57E-02	2.24E-02
		Avg. Lung	1.17E-01	2.26E-03	2.47E-03	1.89E-02	1.74E-02	1.53E-02
		Bronchi	4.20E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
	Child	Effective	3.07E-01	2.23E-02	2.48E-02	5.32E-02	3.32E-02	2.96E-02
		Bone	1.96E-01	3.14E-03	3.38E-03	2.80E-02	2.63E-02	2.29E-02
		Avg. Lung	1.08E-01	2.76E-03	2.99E-03	1.85E-02	1.66E-02	1.46E-02
		Bronchi	4.20E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
	Teenage	Effective	3.09E-01	2.24E-02	2.49E-02	5.37E-02	3.36E-02	3.00E-02
		Bone	5.46E-01	5.93E-03	6.28E-03	6.98E-02	6.76E-02	5.87E-02
		Avg. Lung	8.54E-02	2.67E-03	2.90E-03	1.48E-02	1.29E-02	1.13E-02
		Bronchi	4.20E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
	Adult	Effective	2.97E-01	2.23E-02	2.48E-02	5.23E-02	3.22E-02	2.88E-02
		Bone	2.70E-01	4.04E-03	4.33E-03	3.96E-02	3.76E-02	3.27E-02
		Avg. Lung	6.77E-02	2.47E-03	2.69E-03	1.18E-02	9.87E-03	8.70E-03
		Bronchi	4.20E+00	3.36E-01	3.74E-01	7.48E-01	4.43E-01	3.97E-01
Blanding	Infant	Effective	1.78E-01	8.36E-03	8.50E-03	1.99E-02	1.22E-02	1.21E-02
		Bone	1.92E-01	1.17E-03	1.22E-03	1.43E-02	1.28E-02	1.30E-02
		Avg. Lung	6.25E-02	8.95E-04	9.22E-04	8.79E-03	7.70E-03	7.80E-03
		Bronchi	1.87E+00	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01
	Child	Effective	1.46E-01	8.34E-03	8.49E-03	1.94E-02	1.17E-02	1.16E-02
		Bone	1.31E-01	1.34E-03	1.39E-03	1.65E-02	1.48E-02	1.51E-02
		Avg. Lung	7.09E-02	1.15E-03	1.19E-03	1.08E-02	9.42E-03	9.59E-03
		Bronchi	1.87E+00	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01
	Teenage	Effective	1.49E-01	8.37E-03	8.52E-03	2.00E-02	1.23E-02	1.22E-02
		Bone	4.19E-01	2.74E-03	2.88E-03	4.92E-02	4.49E-02	4.60E-02
		Avg. Lung	5.74E-02	1.10E-03	1.14E-03	8.81E-03	7.54E-03	7.67E-03
		Bronchi	1.87E+00	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01
	Adult	Effective	1.40E-01	8.33E-03	8.47E-03	1.89E-02	1.13E-02	1.12E-02
		Bone	1.93E-01	1.79E-03	1.87E-03	2.56E-02	2.31E-02	2.35E-02
		Avg. Lung	4.34E-02	9.99E-04	1.03E-03	6.58E-03	5.48E-03	5.56E-03
		Bronchi	1.87E+00	1.25E-01	1.27E-01	2.53E-01	1.40E-01	1.38E-01

C.2.2 40 CFR 190 Regulatory Compliance

**TABLE C.2-2  
40 CFR 190 ANNUAL DOSE COMMITMENTS  
(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Potential Resident (BHV-1)	Infant	Effective	1.33E+00	0.00E+00	0.00E+00	3.15E-02	2.63E-02	1.97E-02
		Bone	4.51E+00	0.00E+00	0.00E+00	1.38E-01	1.16E-01	8.63E-02
		Avg. Lung	1.10E+00	0.00E+00	0.00E+00	7.22E-02	6.07E-02	4.59E-02
		Bronchi	2.37E-03	0.00E+00	0.00E+00	5.96E-05	4.90E-05	3.59E-05
	Child	Effective	5.40E-01	0.00E+00	0.00E+00	2.84E-02	2.35E-02	1.74E-02
		Bone	3.06E+00	0.00E+00	0.00E+00	1.73E-01	1.44E-01	1.07E-01
		Avg. Lung	1.49E+00	0.00E+00	0.00E+00	1.07E-01	8.86E-02	6.55E-02
		Bronchi	2.37E-03	0.00E+00	0.00E+00	5.96E-05	4.90E-05	3.59E-05
	Teenage	Effective	6.36E-01	0.00E+00	0.00E+00	3.71E-02	3.07E-02	2.26E-02
		Bone	1.11E+01	0.00E+00	0.00E+00	5.95E-01	4.91E-01	3.61E-01
		Avg. Lung	1.17E+00	0.00E+00	0.00E+00	8.48E-02	7.01E-02	5.16E-02
		Bronchi	2.37E-03	0.00E+00	0.00E+00	5.96E-05	4.90E-05	3.59E-05
	Adult	Effective	3.72E-01	0.00E+00	0.00E+00	2.29E-02	1.89E-02	1.40E-02
		Bone	4.80E+00	0.00E+00	0.00E+00	2.88E-01	2.38E-01	1.76E-01
		Avg. Lung	7.89E-01	0.00E+00	0.00E+00	5.70E-02	4.72E-02	3.48E-02
		Bronchi	2.37E-03	0.00E+00	0.00E+00	5.96E-05	4.90E-05	3.59E-05
Nearest Historical Resident (BHV-2)	Infant	Effective	1.90E-01	0.00E+00	0.00E+00	8.54E-03	7.63E-03	7.59E-03
		Bone	6.49E-01	0.00E+00	0.00E+00	3.74E-02	3.34E-02	3.33E-02
		Avg. Lung	1.79E-01	0.00E+00	0.00E+00	2.07E-02	1.86E-02	1.84E-02
		Bronchi	3.27E-04	0.00E+00	0.00E+00	1.45E-05	1.28E-05	1.28E-05
	Child	Effective	7.82E-02	0.00E+00	0.00E+00	7.27E-03	6.46E-03	6.46E-03
		Bone	4.48E-01	0.00E+00	0.00E+00	4.48E-02	3.98E-02	3.98E-02
		Avg. Lung	2.21E-01	0.00E+00	0.00E+00	2.73E-02	2.42E-02	2.43E-02
		Bronchi	3.27E-04	0.00E+00	0.00E+00	1.45E-05	1.28E-05	1.28E-05
	Teenage	Effective	9.11E-02	0.00E+00	0.00E+00	9.26E-03	8.21E-03	8.22E-03
		Bone	1.58E+00	0.00E+00	0.00E+00	1.47E-01	1.30E-01	1.31E-01
		Avg. Lung	1.71E-01	0.00E+00	0.00E+00	2.13E-02	1.89E-02	1.90E-02
		Bronchi	3.27E-04	0.00E+00	0.00E+00	1.45E-05	1.28E-05	1.28E-05
	Adult	Effective	5.39E-02	0.00E+00	0.00E+00	5.80E-03	5.15E-03	5.14E-03
		Bone	6.93E-01	0.00E+00	0.00E+00	7.27E-02	6.45E-02	6.45E-02
		Avg. Lung	1.16E-01	0.00E+00	0.00E+00	1.44E-02	1.28E-02	1.28E-02
		Bronchi	3.27E-04	0.00E+00	0.00E+00	1.45E-05	1.28E-05	1.28E-05

**TABLE C.2-2 (Cont'd)**  
**40 CFR 190 ANNUAL DOSE COMMITMENTS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Nearest Actual Resident	Infant	Effective	7.69E-01	0.00E+00	0.00E+00	2.23E-02	1.89E-02	1.61E-02
		Bone	2.60E+00	0.00E+00	0.00E+00	9.79E-02	8.29E-02	7.06E-02
		Avg. Lung	6.19E-01	0.00E+00	0.00E+00	5.19E-02	4.43E-02	3.79E-02
		Bronchi	1.36E-03	0.00E+00	0.00E+00	4.11E-05	3.43E-05	2.90E-05
	Child	Effective	3.08E-01	0.00E+00	0.00E+00	1.98E-02	1.67E-02	1.41E-02
		Bone	1.75E+00	0.00E+00	0.00E+00	1.21E-01	1.02E-01	8.66E-02
		Avg. Lung	8.41E-01	0.00E+00	0.00E+00	7.47E-02	6.27E-02	5.32E-02
		Bronchi	1.36E-03	0.00E+00	0.00E+00	4.11E-05	3.43E-05	2.90E-05
	Teenage	Effective	3.62E-01	0.00E+00	0.00E+00	2.57E-02	2.16E-02	1.83E-02
		Bone	6.33E+00	0.00E+00	0.00E+00	4.13E-01	3.44E-01	2.91E-01
		Avg. Lung	6.63E-01	0.00E+00	0.00E+00	5.90E-02	4.94E-02	4.19E-02
		Bronchi	1.36E-03	0.00E+00	0.00E+00	4.11E-05	3.43E-05	2.90E-05
	Adult	Effective	2.12E-01	0.00E+00	0.00E+00	1.60E-02	1.34E-02	1.13E-02
		Bone	2.72E+00	0.00E+00	0.00E+00	2.01E-01	1.68E-01	1.42E-01
		Avg. Lung	4.44E-01	0.00E+00	0.00E+00	3.97E-02	3.32E-02	2.82E-02
		Bronchi	1.36E-03	0.00E+00	0.00E+00	4.11E-05	3.43E-05	2.90E-05
White Mesa Community	Infant	Effective	7.59E-02	0.00E+00	0.00E+00	4.83E-03	5.06E-03	4.36E-03
		Bone	2.59E-01	0.00E+00	0.00E+00	2.09E-02	2.19E-02	1.89E-02
		Avg. Lung	8.79E-02	0.00E+00	0.00E+00	1.37E-02	1.44E-02	1.24E-02
		Bronchi	9.81E-05	0.00E+00	0.00E+00	4.94E-06	5.23E-06	4.48E-06
	Child	Effective	2.66E-02	0.00E+00	0.00E+00	3.29E-03	3.45E-03	2.96E-03
		Bone	1.56E-01	0.00E+00	0.00E+00	2.10E-02	2.21E-02	1.90E-02
		Avg. Lung	7.28E-02	0.00E+00	0.00E+00	1.23E-02	1.29E-02	1.11E-02
		Bronchi	9.81E-05	0.00E+00	0.00E+00	4.94E-06	5.23E-06	4.48E-06
	Teenage	Effective	2.75E-02	0.00E+00	0.00E+00	3.71E-03	3.91E-03	3.36E-03
		Bone	4.73E-01	0.00E+00	0.00E+00	5.70E-02	6.00E-02	5.16E-02
		Avg. Lung	5.11E-02	0.00E+00	0.00E+00	8.78E-03	9.24E-03	7.95E-03
		Bronchi	9.81E-05	0.00E+00	0.00E+00	4.94E-06	5.23E-06	4.48E-06
	Adult	Effective	1.70E-02	0.00E+00	0.00E+00	2.47E-03	2.60E-03	2.24E-03
		Bone	2.19E-01	0.00E+00	0.00E+00	3.07E-02	3.23E-02	2.79E-02
		Avg. Lung	3.60E-02	0.00E+00	0.00E+00	6.15E-03	6.47E-03	5.56E-03
		Bronchi	9.81E-05	0.00E+00	0.00E+00	4.94E-06	5.23E-06	4.48E-06

**TABLE C.2-2 (Cont'd)**  
**40 CFR 190 ANNUAL DOSE COMMITMENTS**  
**(ARIZONA STRIP ORE)**

Location	Age Group	Organ	Estimated Dose (mrem/yr)					
			Mill Area (including ore pads)	Interim Soil Cover		Active		
				Tailings Cell 2	Tailings Cell 3	Tailings Cell 3	Tailings Cell 4A	Tailings Cell 4B
Blanding	Infant	Effective	5.12E-02	0.00E+00	0.00E+00	2.68E-03	2.57E-03	2.63E-03
		Bone	1.73E-01	0.00E+00	0.00E+00	1.17E-02	1.12E-02	1.15E-02
		Avg. Lung	4.77E-02	0.00E+00	0.00E+00	6.71E-03	6.45E-03	6.58E-03
		Bronchi	8.07E-05	0.00E+00	0.00E+00	4.16E-06	3.99E-06	4.11E-06
	Child	Effective	1.93E-02	0.00E+00	0.00E+00	2.19E-03	2.10E-03	2.15E-03
		Bone	1.10E-01	0.00E+00	0.00E+00	1.35E-02	1.30E-02	1.33E-02
		Avg. Lung	5.25E-02	0.00E+00	0.00E+00	8.21E-03	7.87E-03	8.07E-03
		Bronchi	8.07E-05	0.00E+00	0.00E+00	4.16E-06	3.99E-06	4.11E-06
	Teenage	Effective	2.17E-02	0.00E+00	0.00E+00	2.73E-03	2.61E-03	2.69E-03
		Bone	3.77E-01	0.00E+00	0.00E+00	4.32E-02	4.14E-02	4.25E-02
		Avg. Lung	3.97E-02	0.00E+00	0.00E+00	6.31E-03	6.04E-03	6.21E-03
		Bronchi	8.07E-05	0.00E+00	0.00E+00	4.16E-06	3.99E-06	4.11E-06
	Adult	Effective	1.29E-02	0.00E+00	0.00E+00	1.72E-03	1.66E-03	1.70E-03
		Bone	1.66E-01	0.00E+00	0.00E+00	2.16E-02	2.07E-02	2.13E-02
		Avg. Lung	2.71E-02	0.00E+00	0.00E+00	4.29E-03	4.11E-03	4.23E-03
		Bronchi	8.07E-05	0.00E+00	0.00E+00	4.16E-06	3.99E-06	4.11E-06

## Appendix C



34489-10

28 April 2008

Mr. Steven D. Landau  
Manager, Environmental Affairs  
Denison Mines (USA) Corp.  
1050 17th Street, Suite 950  
Denver, CO 80265

**Subject: Review of Environmental Radiological Monitoring Program  
for the White Mesa Uranium Mill**

Dear Mr. Landau:

This letter report provides a review of the environmental radiological monitoring program at Denison's White Mesa Uranium Mill (the "Mill") in San Juan County, Utah, in support of an application by Denison Mines (USA) Corp. (DUSA) to develop new tailings cell 4B... Specifically, this report addresses the question of whether or not any changes to the current environmental radiation monitoring program at the Mill site are warranted by the addition of tailings Cell 4B

In preparing this report, we directly reference and use information in Mill's 2007 Semi-Annual Effluent Monitoring Reports (DUSA 2007 and 2008), and other information provided to us by DUSA.

## **1.0 CURRENT ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM**

Annual meteorological data collected from the Mill's meteorological station show that the predominant wind directions during the past four years (2004-2007) were blowing from the north-north-easterly and northerly directions (Turk 2007 and Landau 2008b). The 2007 annual frequency distribution is presented graphically in Figure 1. The wind blows from the north-north-easterly (at an average speed of 2.8 m/s, 14.9% of the time) and northerly (at an average speed of 3.1 m/s, 14.0% of the time) (Landau 2008b). The locations of the air monitoring stations are also shown on Figure 1. These data are considered to represent long term wind patterns at the Mill. Air monitoring stations BHV-1 and BHV-2 will detect radiological

characteristics of winds from the south and station BHV-4 and BHV-6 will detect radiological characteristics of winds from the north.

The current radiological monitoring program at the Mill has the following environmental media and conditions (DUSA 2007 and 2008):

1. Air particulate radionuclide concentrations from the following sampling stations (see Figure 2):
  - North, East, and South of the Mill site: BHV-1 & BHV-2 (north), BHV-5 (east), BHV-4 (south);
  - BHV-3 (a background station west of the Mill) used to monitor airborne particulate until November 1995 and subsequently decommissioned with the approval of the United States Nuclear Regulatory Commission (NRC);
  - BHV-6 (station specifically requested by the White Mesa Ute Community south of the Mill site).
2. External (direct) gamma radiation measurements at air monitoring stations BHV-1, BHV-2, BHV-3, BHV-4, aBHV-5 and BHV-6.
3. Radon-222 is measured at air monitoring stations BHV-1, BHV-2, BHV-4, BHV-5 and BHV-6.
4. Vegetative uptake of radionuclides at three periphery locations.
5. Stack releases from the facility's air emissions sources.
6. Annual Surface water samples from within Cottonwood Creek and, when flowing, the Westwater Creek drainage, both located west of the Mill.
7. Annual Soil radionuclide activity obtained near the air monitoring station.
8. Groundwater at the Mill facility, as well as up gradient and down gradient).

## **2.0 REVIEW OF ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM**

In order to review the adequacy of the environmental radiological monitoring program in light of the addition of Cell 4B, some general observations from the semi-annual effluent reports for 2007 (DUSA 2007 and 2008) and meteorological data are provided:

- The current BHV stations cover the predominant wind directions: BHV-1 and BHV-2 cover winds that flow predominantly from the south, and BHV-4 and BHV-6 cover the winds predominantly flowing from the north of the Mill.
- The annual mean wind speed was 3.4 m/s;

- The measured activity of airborne particulate (U-nat, Th-230, Ra-226 and Pb-210) at all monitoring stations shown in Figure 2 were well below regulatory Effluent Concentration Limits (ECLs) and the Mill's "As Low As Reasonably Achievable" (ALARA) goals (i.e., 25% of the ECL);
- Previously, radon monitoring had been carried out but was discontinued with the agreement of the NRC in 1995. However, over time, radon detection has improved and alpha track monitoring for radon was implemented at the environmental monitoring stations in the 1<sup>st</sup> quarter of 2007. The measured radon-222 concentration values are compared to derived ECLs which serve an ALARA goal. It is noted that the annual average radon-222 concentrations were less than the evaluation values for 2007.
- Results of thermoluminescent (TLD) measurement for external gamma radiation indicate gamma levels generally consistent with the local background, which although variable due to local geology and variation in altitude, is about 120 mrem per year (30 mrem per quarter), except for BHV-1 (which is adjacent to the front gate) and BHV-5 (near the site boundary).
- 2007 data compared to previous years indicate no increase in uptake of Ra-226 or Pb-210 in vegetation and are well within the range of previous sampling episodes. Moreover, the droughts in recent years have affected the availability of vegetative species at the three sampling locations.
- Stack releases were reported but these are direct stack measurements and are not comparable to ECLs which for regulatory compliance purposes are site boundary standards.
- Soil samples collected for fall 2007 showed that Ra-226 and U-nat concentrations were near background.
- Surface water samples were collected at Cottonwood Creek but radionuclide data did not indicate trending over time nor influences from the Mill operations. Westwater Creek was not able to be sampled because it was dry for the sampling events.

The results from DUSA (2007) did not show any anomalies from the historical data, which indicates the Mill's ALARA practices are adequately protecting the people and the environment. The measured radon-222 concentration were less than the derived ECLs; however, it is understood that monitoring will be continued to identify trends over time. .

### 3.0 EVALUATION

In our opinion, the current environmental radiological monitoring program is quite comprehensive and provides adequate measurements to provide assurance that the current activities at the Mill are not adversely affecting the local environment and to confirm the MILDOS modelling.

MILDOS modelling has shown that the introduction of tailings cell 4B will have no material effect on the exposures and doses to people living nearby the Mill. In part, this is due to the nature of local winds that predominantly blow from the north-north-easterly and northerly

directions based on the meteorological data from the last four years. As a result, any dust or radon from activities at the site will tend to disperse towards the valley to the west of the cell away from nearby residents. Thus, existing monitoring is adequate for ensuring protection of people who live near the Mill.

Given our understanding of the existing monitoring data and the low doses to people who live or undertake recreational activities such as hiking or hunting near the Mill, in our opinion the current environmental radiological monitoring is adequate and consistent with the objectives set out in the NRC's Regulatory Guide 4.14, *Radiological Effluent and Environmental Monitoring at Uranium Mills* (NRC 1980).

In closing, the current radiological monitoring program at the Mill adequately monitors the release of radioactive materials to the local environment associated with current Mill activities.

Should you have any questions or comments on this letter, please contact us at your convenience.

Yours very truly,

**SENES Consultants Limited**

Douglas B. Chambers, Ph.D.  
Vice-President, Director of  
Radioactivity and Risk Studies

**REFERENCES**

- Denison Mines (USA) Corp. (DUSA) 2007. *White Mesa Uranium Mill Radioactive Materials License UT900479 Semi-Annual Effluent Monitoring Report (January through June, 2007)*. December.
- Denison Mines (USA) Corp. (DUSA) 2008. *White Mesa Uranium Mill Radioactive Materials License UT900479 Semi-Annual Effluent Monitoring Report (July through Decemeber, 2007)*. March.
- Landau, S. 2008a. E-mail to D. Chambers: FW: 34489 Environmental Rad Monitoring at White Mesa Mill
- Landau, S. 2008b. E-mail to D. Chambers: 2007 Windrose
- Turk, D. 2007. E-mail to D. Chambers: FW: Additional Weather Information.
- United States Nuclear Regulatory Commission (NRC) 1980. Regulatory Guide 4.14, *Radiological Effluent and Environmental Monitoring at Uranium Mills-Rev. 1*.

FIGURE 2  
LOCATION OF AIR MONITORING STATIONS

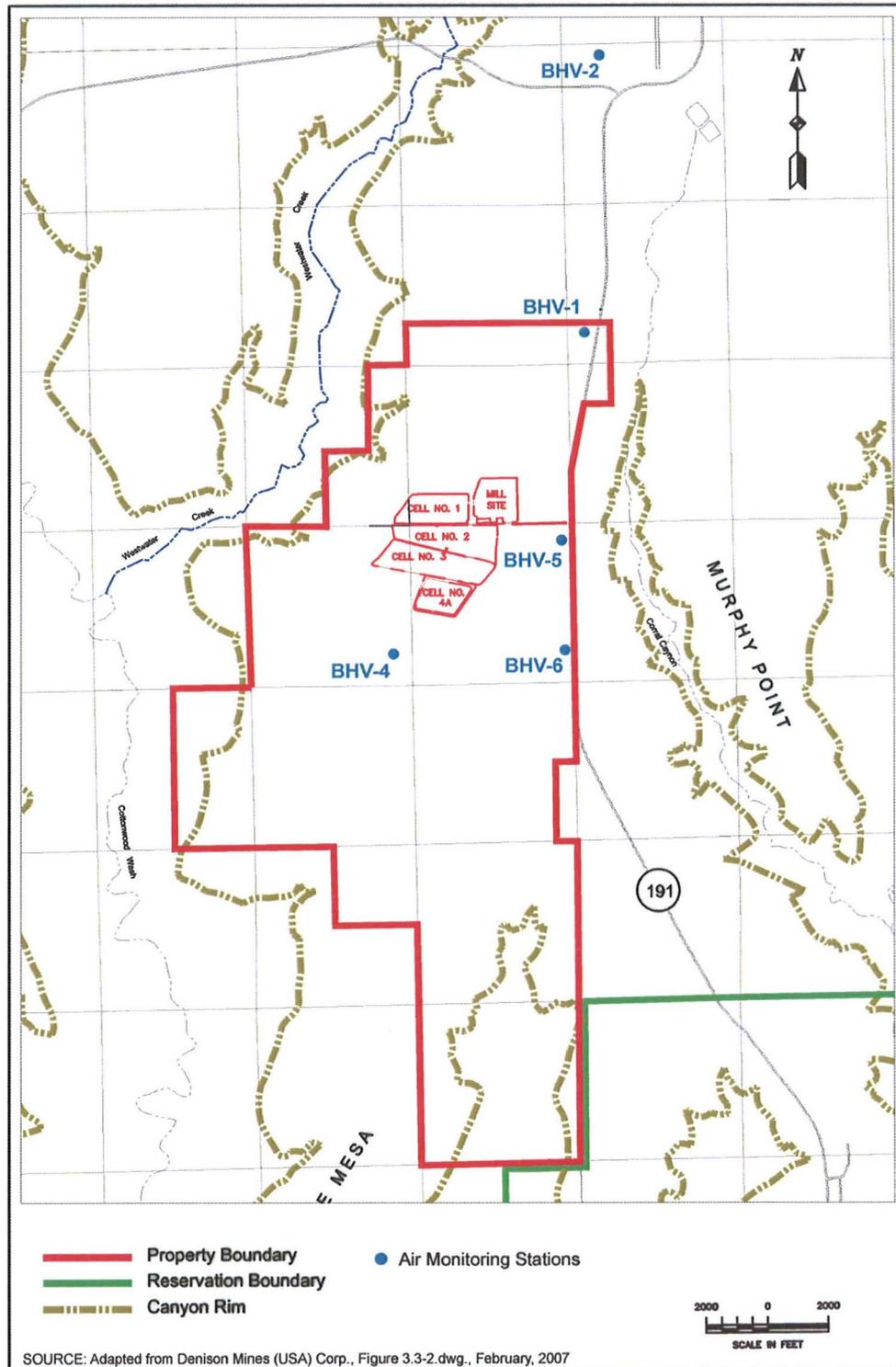


FIGURE 1  
 2007 WIND ROSE PLOT

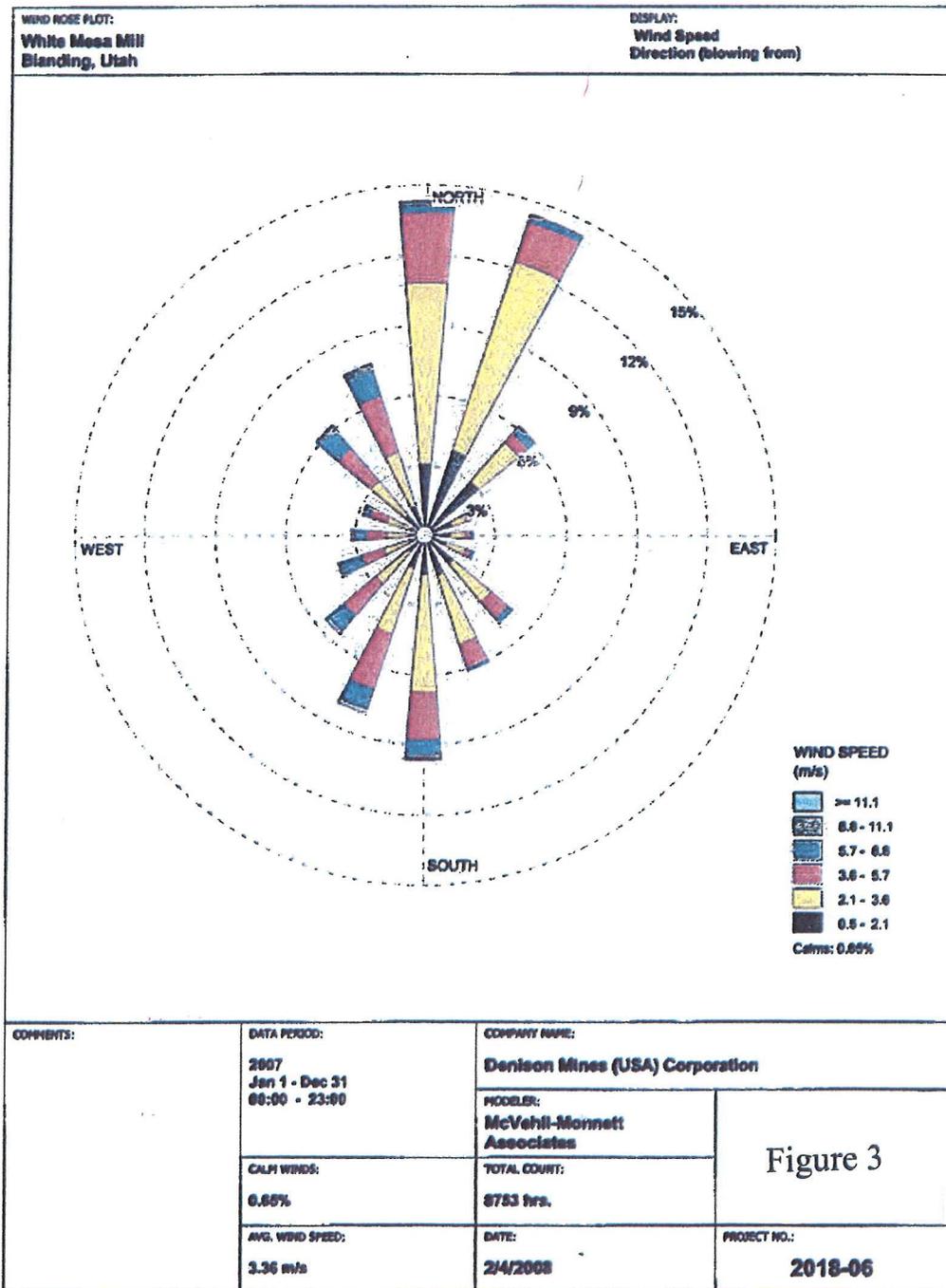


FIGURE 2  
LOCATION OF AIR MONITORING STATIONS

