WORK PLAN AND SCHEDULE FOR SUPPLEMENTAL CONTAMINANT INVESTIGATION REPORT FOR WHITE MESA MILL NITRATE INVESTIGATION

Blanding, Utah

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TABLE OF CONTENTS

LIST OF FIGURES ii
LIST OF TABLES ii
LIST OF APPENDICES ii
ACRONYMS AND ABBREVIATIONS iii
1.0 INTRODUCTION 1
1.1 Historical Land Use and Geomorphologic Study 3
1.2 Investigation of Potential Natural Nitrate Reservoir 3
1.3 Investigation of Potential Nitrate Source Locations 4
1.4 Stable Isotope Study 4
1.5 Mass Balance Calculations 6
2.0 GEOLOGY AND HYDROGEOLOGY 7
3.0 PROJECT MANAGEMENT 8
3.1 Field Documentation 8
3.2 Health and Safety 8
4.0 HISTORICAL LAND USE AND GEOMORPHOLOGIC STUDY 9
4.1 Initial Procedure 9
4.2 Initial Conclusions and Recommendations 10
5.0 INVESTIGATION OF NATURALLY OCCURRING NITRATE RESERVOIR IN SOIL 12
5.1 Geoprobe Nitrate and Chloride Investigation 13
5.2 Coring Study to Explore for Natural Nitrate Reservoir 15
6.0 INVESTIGATION OF POTENTIAL NITRATE SOURCE LOCATIONS 17
6.1 Geoprobe Investigation of Potential Nitrate Source Locations 17
6.2 Coring Study in Potential Nitrate Source Locations 19
7.0 STABLE ISOTOPES STUDY 20
7.1 Quality Assurance and Quality Control Procedures 23
8.0 MASS BALANCE CALCULATIONS 24
9.0 REFERENCES 26

LIST OF FIGURES

Figure 1 Flow Chart Depicting the Logical Progression of Additional Studies
Figure 2 $\delta^{15}N$ results from Sampling of Various Sources of Nitrate Contamination
Figure 3 $\delta^{15}N$ Results Normalized to N_2 in the Atmosphere from Sampling a Wider Range of Sources
Figure 4 A Plot of $\delta^{18}O$ versus $\delta^{15}N$
Figure 5 Location Map
Figure 6 Historical Aerial Imagery, 1937 Aerial Photo
Figure 7 Historical Aerial Imagery, 1955 Aerial Photo
Figure 8 Historical Aerial Imagery, June 30, 1985 Landsat
Figure 9 Historical Aerial Imagery, 1997 DOQQ
Figure 10 Historical Aerial Imagery, 2006 DOQQ
Figure 11 Historical Aerial Imagery, 2009 DOQQ
Figure 12 Pasture Coincident with Drainages
Figure 13 Outline of 1955 Pasture Overlain over the USGS Topographic Map
Figure 14 2006 Aerial Photograph Showing the Stock Pond
Figure 15 Pasture Areas Interpreted from 1955 Imagery
Figure 16 Location of Black Mesa Relative to White Mesa
Figure 17 Radar Site at White Mesa near Blanding, Utah, June 21, 1967
Figure 18 Bivouac Site at White Mesa near Blanding, Utah, June 21, 1967
Figure 19 Site Map with DUSA Property Boundary
Figure 20 Natural Nitrate Reservoir: Geoprobe Boring Locations
Figure 21 Nitrate Source Areas: Geoprobe Boring and Core Drilling Locations
Figure 22 Stable Isotope Sampling Wells

LIST OF TABLES

Table 1 Project Schedule
Table 2 Laboratory Analytical Parameters by Task and Media

LIST OF APPENDICES

Appendix A Nitrate Extraction and Field Test Procedure
Appendix B Analytical Methods List

ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
CCD	counter current decant circuit
CFC	chlorofluorocarbons
CIR	Contaminant Investigation Report
cm/sec	centimeters per second
δ	delta
DEQ	Department of Environmental Quality
DRC	Utah Division of Radiation Control
DUSA	Denison USA
ft/yr	feet per year
GPS	global positioning system
HASP	health and safety plan
i	average gradient
IAEA	International Atomic Energy Agency
k	hydraulic conductivity
m	meter
n	porosity
NIST	National Institute of Standards and Technology
Site	White Mesa Mill property
SMOW	Standard Mean Ocean Water
SPLP	synthetic precipitation leaching procedure
USCS	Unified Soil Classification System
USGS	United States Geological Survey

1.0 INTRODUCTION

Denison Mines (USA) Corp. (DUSA) and the Co-Executive Secretary of the Utah Water Quality Board (Co-Executive Secretary) entered into a Stipulated Consent Agreement Docket No. UGW09-03 dated January 27, 2009 (Consent Agreement) related to nitrate contamination at DUSA's White Mesa Uranium Mill Site, Blanding Utah (Mill). Pursuant to Item 6.A of the Consent Agreement, DUSA submitted a Nitrate Contamination Investigation Report, White Mesa Uranium Mill Site, Blanding Utah, dated December 30, 2009 (CIR) to the Utah Division of Radiation Control (DRC). By a letter dated October 5, 2010 and hand delivered to DUSA on the same date, the Co-Executive Secretary notified DUSA of his determination that the CIR is incomplete (October 5, 2010 DRC Notice). As a result of this determination under Item 7.C of the Consent Agreement, DUSA is to remedy such omissions in the CIR on or before November 4, 2010.

By an email transmitted to the Co-Executive Secretary on October 20, 2010, and pursuant to Item 11 of the Consent Agreement, DUSA requested an amendment to the deadline stipulated in item 7.C of the Consent Agreement, which required that Denison must remedy any omissions in, content requirements of, or failure to meet any performance standards or objectives relating to the CIR mandated by Item 6.A of the Consent Agreement, within 30 calendar days of receipt of the October 5, 2010 DRC Notice (i.e., November 4, 2010). Instead, DUSA requested item 7.C be amended as follows: a. DUSA representatives would meet with the Co-Executive Secretary and his legal counsel within two weeks from the date of the email to discuss the legal responsibilities of DUSA with respect to the nitrate contamination; b. Once the legal responsibilities of DUSA with respect to the nitrate contamination have been determined, DUSA would, within 30 days after such a determination was made, submit to the Co-Executive Secretary for approval a plan and schedule to perform any further investigations that may be required in order to remedy any such omissions, content requirements or failures of performance standards, and to submit a revised CIR; and c. DUSA would perform such investigations and submit a revised CIR in accordance with the agreed upon plan and schedule.

On October 26, 2010, DUSA met with the Co-Executive Secretary, DRC staff and legal counsel (October 26, 2010 Meeting) to discuss DUSA's legal obligations with respect to the nitrate contamination. At the meeting, DUSA reported that it was premature to submit a schedule for submittal of performance standards and a Corrective Action Plan for the nitrate contamination. In turn, DUSA presented a new theory for a possible source of the nitrate and chloride contamination beneath the Mill, based on DUSA's review of the scientific literature (New Theory). Based on this New Theory, DUSA suggested that the nitrate contamination source is or could be caused by naturally occurring nitrate and chloride salt deposits located in the vadose

zone near or beneath the Mill site area, which have been mobilized by natural and/or artificial recharge. The parties agreed that this New Theory warranted additional investigation, along with certain of the other additional studies suggested in the October 5, 2010 DRC Notice. As agreed at the October 26, 2010 meeting, DUSA submitted via email on November 15, 2010, a letter setting out the additional studies to be considered that have been identified to date, including the additional studies suggested in the October 5, 2010 DRC Notice, proposed additional studies relating to the New Theory, and any other additional studies that DUSA believes may be relevant. In the November 15, 2010 letter, DUSA proposed that a meeting be held on November 30, 2010 between DRC Staff and DUSA technical and regulatory staff to discuss the foregoing studies and any associated matters, to agree on the studies to be performed and the manner of performing those studies, and to develop a plan and schedule for performing such studies and for submittal of a revised CIR

The meeting contemplated in DUSA's November 15, 2010 letter was held on November 30, 2010, among DRC Staff and DUSA technical and regulatory staff. At that meeting, DUSA presented a number of additional studies (herein "Additional Studies") to be performed by DUSA in order to complete the CIR. The Additional Studies were in addition to the New Theory. The Co-Executive Secretary and DUSA further agreed that DUSA would prepare a detailed plan and schedule (the "Plan and Schedule") for performing such studies and for submittal of a revised CIR that meets the requirements of all applicable regulations on or before February 15, 2011. The February 15, 2011 date for submittal of the Plan and Schedule is somewhat later than the original 30 days proposed by DUSA in its October 20, 2010 email to the Co-Executive Secretary, due to the complexity of certain of the Additional Studies to be performed. During the November 30, 2010 meeting, it was agreed that both the Plan and Schedule and the revised CIR will be subject to Co-Executive Secretary approval. DUSA's commitment to prepare and submit the Plan and Schedule is set out in a Tolling Agreement (the "Tolling Agreement") dated December 15, 2010 between DUSA and the Co-Executive Secretary.

This document is the Plan and Schedule, which is being submitted in accordance with the Tolling Agreement. The purpose of this Plan and Schedule is to define the Additional Studies and to propose a plan and schedule to complete those studies and submit a revised CIR. DUSA proposes the Additional Studies described below. A flow chart depicting the logical progression of additional studies is presented as Figure 1 and a schedule chart showing the expected duration of each task and subtask is presented as Table1 and is organized by number of months after this document is approved. The plan and schedule presented here should be considered to be for Phase 1 of the investigation. Phase 2 would be initiated if Phase 1 encounters items or new information that requires additional study, such as any additional studies that may be needed to gain statistical power or to investigate any new findings. The schedule set out in Table 1

assumes that field work will commence in April 2011 and end in October 2011. This may allow for some iterations and additional field work if warranted from a review of initial results. Laboratory results for some of the isotopic analysis may take up to three months to receive, after the end of the field season. The final mass balance analysis will not commence until all laboratory data has been obtained. The final report will be prepared after the final mass balance analysis has been completed.

1.1 Historical Land Use and Geomorphologic Study

A further evaluation of historical land use in the vicinity of the White Mesa Mill property (site) will be performed in order to supplement the source evaluation (the "Source Review Report") that was included in the CIR. This further evaluation is currently under way and will (a) identify areas that have been subject to agricultural activities and (b) evaluate land-use practices that may have led to elevated levels of nitrate and other contaminants in groundwater. Objective (a) is also required to identify areas for sampling of buildup of atmospheric nitrogen, since we seek to sample areas that have not been subject to anthropomorphic activities. This analysis includes evaluation of historical aerial photography, historical Landsat satellite imagery, and an Internet-based search of historic military activities in the region. This study is expected to take up to four months to complete (Table 1), due to the time required to research and obtain imagery. It is described in more detail in Section 4.0 of this document.

1.2 Investigation of Potential Natural Nitrate Reservoir

Using the results of the historical land use study, undisturbed alluvial soils on DUSA property at locations that are close to site operations will be explored with a geoprobe for any potential natural subsurface reservoir of nitrogen and chloride, as has been described by Wolvaard et al., 2003) and to provide a background/baseline to the geoprobe study of potential sources identified in the Source Review Report. The geoprobe portion of this study would start approximately one month after this document is approved, and is expected to take approximately four months before laboratory analysis is complete (Table 1). The coring portion of this study will follow the geoprobing, starting approximately three months after approval of this document and taking four months until laboratory analysis is complete. The study is described in more detail in Section 5.0 of this document.

If alluvial soils do not yield positive results for nitrate and chloride, coring of the bedrock units would be performed in order to test the possibility that a reservoir of nitrate and chloride exists at some level in the bedrock geologic column above groundwater, due to lack of distributed recharge to groundwater over an extended period of time. If so, keeping a hydraulic head on the wildlife pond may have mobilized constituents within this reservoir. Note that irrigation of fields

north of the site or any action that caused new infiltration to groundwater could have had the same effect. It would be necessary to take core from an area that has not been affected by focused recharge such as the wildlife ponds or intermittent streams and drainage channels.

Samples of core would be taken at regular intervals, moisture content measured, and leached with specific amounts of double distilled water to determine the concentrations of nitrate and chloride present in soil moisture. Mass balance calculations could then integrate the mass of nitrate and chloride in soil moisture to determine if the total mass is sufficient to account for the observed concentrations in groundwater. The mass balance may or may not show that the nitrate in the spiked horizon is enough to account for the nitrate plume.

1.3 Investigation of Potential Nitrate Source Locations

Geoprobe samples will be collected from alluvial soils in or around specific potential sources identified in the Source Review Report and analyzed by Synthetic Precipitation Leaching Procedure ("SPLP") for nitrate and chloride. This work will only be useful in the unconsolidated soils at the site and would not be able to address the bedrock units. If results of the geoprobe work indicate the presence of elevated nitrate or chloride in alluvial soils a drill hole will be advanced through the alluvial material and a rock core of the geologic formation beneath the alluvium will be drilled, in any of the 15 potential nitrate source locations that are shown to contain elevated nitrate or chloride in the soil column within the geoprobe soil samples and that are not active leach fields as identified by DUSA. The geoprobe portion of this study would start approximately one month after this document is approved, and is expected to take approximately four months before laboratory analysis is complete (Table 1). The coring portion of this study will follow the geoprobing, starting approximately three months after approval of this document and taking four months until laboratory analysis is complete. This study is described in more detail in Section 6.0 of this document.

1.4 Stable Isotope Study

The stable isotope study is described in detail in Section 7.0 of this document, which contains specifics on analytes to be sampled and sampling locations. The groundwater sampling portion of this study would start approximately one month after this document is approved study and is expected to take approximately seven months before laboratory analysis is complete (Table 1) due to the non-standard laboratories that are required.

Stable (non-radioactive) isotopes of the same element differ by the number of neutrons in the atomic nucleus. A variety of physical and biological processes can affect the relative concentrations of light and heavy isotopes of the same element. This relative enrichment or

depletion of one stable isotope over another is called isotopic fractionation. During evaporation, for example, the heavier ^{18}O becomes enriched in the residual water as more of the lighter ^{16}O enters the vapor phase. Thus, meteoric water, derived largely from the evaporation of ocean water, is enriched with ^{16}O relative to ocean water.

For another example, nitrate in groundwater that has been denitrified by microbes, or originates from human or animal waste is enriched with ^{15}N. Measuring the relative proportions of stable isotopes in water or other media can lead to interpretation of the source or sources for those isotopes. Figure 2 shows $\delta^{15}N$ results from sampling of various sources of nitrate contamination, including a uranium mill, from McQuillan et al (1989), showing the potential to exclude mill tailings as a source of nitrate in groundwater, depending on the $\delta^{15}N$ signature in the groundwater. However, Figure 3 shows $\delta^{15}N$ results normalized to N2 in the atmosphere from sampling a different set of sources indicating the complexity that could potentially be encountered, raising the possibility that, while some sources can be readily distinguishable, results of any isotopic study could be inconclusive for distinguishing other sources. Finally, Figure 4 is a plot of $\delta^{18}O$ versus $\delta^{15}N$ from Roadcap et al (2001), also showing the overlapping nature of various sources but displaying the additional power of adding $\delta^{18}O$.

A Tritium study to sample groundwater with high nitrate concentrations to confirm whether groundwater with high nitrate is older or younger than the Mill was considered but rejected as a duplication of previously collected information. Hurst and Solomon (2008) found that MW-27 and MW-19 showed the influence of young water and commented that the outer margin of the groundwater mound must be between MW-27 and MW-30 and MW-31 which contain water that has no tritium and is therefore older than mid-sixties atomic testing (see Figure 22 for the locations of existing monitoring wells at the site). They state:

> *"Several samples have tritiogenic helium-3, indicative of young water, however these are only found in areas influenced by the wildlife ponds (MW-19, and MW-27). Tritiated water is introduced into the system by recharge from the wildlife ponds and appears in wells around the wildlife ponds. As recharge water from the wildlife ponds propagates through the system, evidence of tritiated water will appear in successive monitoring wells further from the ponds."*

And:

> *"Furthermore, stable isotope fingerprints of δD and $\delta^{18}O$ suggest mixing between wildlife pond recharge and older groundwater in MW-19 and MW-27. $\delta^{34}S$-SO4 and $\delta^{18}O$-SO4 fingerprints closely relate MW-27 to wildlife pond water, while the exceptionally low concentration of sulfate in MW-27, the only groundwater site to*

exhibit sulfate levels below 100 mg/L, suggest no leachate from the tailings cells has reached the well."

Thus, according to Hurst and Solomon (2008), tritium data from wells in the area of highest nitrate would contain younger water (the CFC dates for groundwater in MW-27 range from 1963 to 2001). However, they have already proven that groundwater in this area could not have come from the tailings impoundments.

1.5 Mass Balance Calculations

It is possible to estimate the mass of nitrate and chloride in the groundwater beneath the mill site by assuming a saturated thickness of groundwater in the aquifer matrix, a porosity of the aquifer matrix, an average concentration of constituents in groundwater, and an area to which the average concentration applies. Any potential source of nitrate and chloride will be evaluated to determine if it has the potential to have caused the mass of nitrate and chloride observed in the groundwater plume beneath the mill site. First, the potential source must have a means to reach groundwater such as sufficient water or other fluid to travel through the vadose zone. Second there must have been sufficient nitrate and chloride in the source to account for the nitrate and chloride mass observed in the groundwater. Both conditions can be evaluated by mass balance calculations. This work will support a synthesis of all data collected in previous studies and will be instituted when all previous work is complete, approximately eight months after approval of this document (Table 1). This study is described in more detail in Section 8.0 of this document.

2.0 GEOLOGY AND HYDROGEOLOGY

The Site is located on White Mesa about 6 miles south of Blanding, Utah (Figure 5). Figure 22 shows the locations of existing monitoring wells at the site. The geologic layers beneath the Site consist of four main units. The surface and shallow alluvium consists of unconsolidated silt and sand to a depth of approximately 20 feet (22 ft in monitoring well MW-27). The alluvium is underlain by Cretaceous and Jurassic bedrock as follows, from youngest to oldest: the Upper Cretaceous Dakota Formation sandstone, siltstone, mudstone and shale, the Lower Cretaceous Burro Canyon sandstone, mudstone, and claystone, and the Upper Jurassic Brushy Basin Member of the Morrison Formation mudstone, claystone, shale, and sandstone. The top of the unconfined water table is located at a depth of 50 to 60 feet below ground surface (bgs) and the base of the aquifer is at the contact between the base of the Burro Canyon Formation and the top of the Brushy Basin Member, about 90 feet bgs. Thus the aquifer thickness is about 30 feet, with an average gradient (i) of about 0.011 from north to south across the Site (14,400 ft from wells TWN-12 to MW-20, water level elevations from May, 2008). The gradient increases to nearly 0.02 near the wildlife ponds where groundwater mounding occurs. According to Kirby (2008), the porosity (n) for undifferentiated Dakota and Burro Canyon Formation ranges from 2 to 22 percent, with a mean value of 10 percent. Hydraulic conductivity (K) of the aquifer based on laboratory measurement had a mean of 0.32 ft/day (1.14 x 10-4 cm/sec). Using the mean K, mean n, and site groundwater gradient i, the average groundwater velocity across the site is calculated as follows: V-average = iK/n = 0.035 ft/d x 360 = 13 ft/yr. Thus, based on the published regional aquifer parameters and local gradient, it would take approximately 1,100 years for water to travel 14,400 ft from wells TWN-12 to MW-20. On-site aquifer testing indicates a range of groundwater velocities from 0.55 ft/yr to 7 ft/yr in the northeast part of the site, to 23 ft/yr in the mill area (Hydro Geo Chem, Inc., 2009). Using the higher value of 23 ft/year, it would take approximately 626 years for groundwater to travel from well TWN-12 to well MW-20.

3.0 PROJECT MANAGEMENT

This project is managed by Dr. Dan Erskine of INTERA, Inc, Albuquerque, New Mexico. The field program will be conducted under the direction of Robert Sengebush of INTERA, utilizing INTERA field staff in cooperation with the DUSA White Mesa mill management and field personnel. Subcontractors, such as geoprobe operators and drillers, will be under contract to and under the supervision of INTERA.

3.1 Field Documentation

Field documentation will consist of, but not be limited to, detailed field note books, chain of custody forms, and digital photographs. In addition, the locations of geoprobe borings and other field activities will be recorded using a hand held global positioning system (GPS) instrument.

3.2 Health and Safety

An INTERA health and safety plan (HASP) will be prepared to address the health and safety requirements of all tasks outlined in this work plan. In addition, White Mesa mill health and safety and radiation protection procedures will be followed. Health and safety tail gate meetings will be held before starting field work and will address the specific requirements of the tasks scheduled to be conducted that day. All health and safety protocols and meetings will be under the supervision of and coordinated with the DUSA White Mesa mill Radiation Safety Officer and health and safety manager.

The following sections of this work plan describe the specific tasks to be conducted by INTERA on behalf of DUSA in an effort to identify the source of nitrate in groundwater beneath the site.

4.0 HISTORICAL LAND USE AND GEOMORPHOLOGIC STUDY

Historic land uses at and in the vicinity of the site were evaluated in the Source Review Report, which was submitted with the CIR. INTERA Performed a preliminary evaluation of additional historical land uses in the vicinity of the White Mesa Mill property (site) to (1) identify areas that have been subject to agricultural activities and (2) evaluate land-use practices that may have led to elevated levels of nitrate and other contaminants in groundwater. Objective (1) is also required to identify areas for sampling of buildup of atmospheric nitrogen, since we seek to sample areas that have not been subject to anthropomorphic activities. For this analysis, we evaluated historical aerial photography, historical Landsat satellite imagery, and performed a brief Internet-based search of historic military activities in the region.

Further evaluation using additional imagery and further investigation of military uses of the site will be ongoing due to discovery during the preliminary evaluation that the mill site had been previously used as a part of the Pershing Missile Project, Blanding Launch Complex.

4.1 Initial Procedure

INTERA acquired historical aerial photography for the site from 1937, 1955, 1997, 2006, and 2009. We acquired Landsat imagery from 1985. These images are presented in Figures 6 through 11. Outlines of the primary White Mesa Mill features are provided on each image for reference. Note that the 1985 Landsat image is somewhat blurry due to the fact that Landsat images pixels are approximately 100 feet (30m) on a side. While the Landsat image does not provide significant detail, it does provide a useful tool for identifying areas of irrigated agriculture and riparian vegetation, which show quite clearly as areas that are much greener than the surrounding landscape.

These specific images were acquired because they were the most readily available and were available quickly for our analysis. More imagery is available and is being acquired, but will require some weeks to receive from various archives. However, the imagery that has been acquired to date allows us to make some preliminary conclusions with respect to historical land use, and may be supplemented with some additional analyses in the future.

The imagery was analyzed visually primarily for color and texture. Areas of pasture are clearly visible in the 1937 and 1955 photos as areas of relatively constant color and texture that stand out from surrounding areas not influenced by anthropomorphic activities. In the 1937 photo, the pasture areas generally appear as bright white patches. This is a common appearance for agricultural lands in early photography from the 1930s, because of the high contrast of the photography. The 1955 photo shows the pasture areas even more clearly, and the quality of the

photo allows for more detailed analysis. For example, close inspection reveals that the three-pronged pasture area present in the southwestern corner of Figure 7 is shaped the way that it is because the linear stretches of pasture are each coincident with a drainage that would be expected to provide slightly more water to the pasture grass (Figure 12). Figure 12 clearly shows a set of three drainages, each of which is coincident with a "finger" of pasture. Figure 13 shows the pasture outline overlain onto the United States Geological Survey (USGS) 7.5-minute quadrangle topographic map for the area, and the drainages are clearly visible on the map, as is the stock pond that they empty into in the central portion of the pasture. Figure 14, from 2006, indicates that the stock pond has been in use continually into recent times.

Using this same logic, and interpreting land use visually based on texture and color primarily from the 1955 photo (which provides the clearest view, based on present data, of historical agricultural activity in the vicinity of the site), we identified and digitized obvious pasture areas (Figure 15).

As discussed above, we also performed a brief Internet-based search of historic military activity in the vicinity of the site. The Blanding, Utah area was used by the United States Army from 1963 to 1970 as a launch site for Pershing missiles, which were flown to White Sands Missile Range in New Mexico (Encyclopedia Astronautica, 2011a). Black Mesa (just west of White Mesa, Figure 16) was one of numerous suborbital launch sites used to test the Pershing and other missile systems (Encyclopedia Astronautica, 2011b). While some of the historical information that we have discovered thus far indicates that primary launch operations were on Black Mesa, other information that we have discovered indicates that support operations such as radar tracking (Figure 17) and other substantial support activities, even perhaps launches themselves, occurred at and near the mill site on White Mesa (Figure 18). While these historical photographs provide only preliminary information, they certainly indicate the strong potential for military operations on White Mesa that may have led to some or all of the observed present-day groundwater contamination problems.

4.2 Initial Conclusions and Recommendations

INTERA evaluated historical aerial photography to identify areas that have been used in the past for grazing or other agricultural activities. These areas were identified for two reasons: (1) to evaluate areas that may have contributed to nitrate or other contaminants in groundwater due to agricultural operations and (2) to identify areas that have not been influenced by anthropomorphic activities during recent historical times, to allow identification of potential sampling areas for evaluation of natural atmospheric accumulation of nitrates.

The results from a preliminary analysis of readily-available aerial photography allowed us to clearly delineate areas in the vicinity of the White Mesa Mill that have been used as pasture in the past. These areas were digitized and the resulting polygons can be overlain over present-day aerial photography and mapping data to evaluate them as potential sources of groundwater contamination as well as identify sampling locations for the atmospheric nitrogen study. Additional historical aerial imagery is being acquired, and review of this additional information is being conducted.

With respect to researching historical military operations in the vicinity of the White Mesa Mill, we have completed a very preliminary search which indicates that the US Army had operations on White Mesa associated with launch testing of the Pershing missile dating from the early 1960s through about 1970. These activities certainly deserve additional analysis as they have significant potential to have had soil and groundwater contamination associated with them. Additional research is underway to more fully evaluate these activities.

5.0 INVESTIGATION OF NATURALLY OCCURRING NITRATE RESERVOIR IN SOIL

The purpose of this investigation is to test for the presence or absence of a nitrate and chloride concentration in the alluvial soil column in selected locations at the Site. The Site and the DUSA property boundary are shown on Figure 19. Such concentrations or "reservoirs" have been identified in the scientific literature (Walvoord, et al., 2003, Scanlon, et al., 2005 and others). "Unsaturated-zone chloride and nitrate profiles archive changes in recharge related to recent conversion of rangeland to agricultural ecosystems. Increased recharge associated with dryland as well as irrigated agriculture can lead to degradation of groundwater quality because of leaching of salts that have been accumulating in the unsaturated zone for thousands of years prior to cultivation, because of application of fertilizers, and, in irrigated areas, because of evapo-concentration of applied groundwater. In the SHP (southern high plains), median groundwater nitrate-N concentrations increased by 221% beneath irrigated areas and 163% beneath dryland areas, reflecting LU/LC-induced (land use/land cover) contamination of groundwater." (Scanlon, et al., 2005).

This investigation will involve geoprobe borings to test nitrate and chloride concentrations in the alluvial soil, and drilling rock core in several locations.

Based on the results of the historical land use and geomorphologic study, the boring locations have been chosen to represent areas which have not undergone irrigation or other forms of culturally-induced surface water recharge. These locations are based on interpretation of aerial photographic imagery. Actual locations will be selected in the field by the field team leader in consultation with DUSA management and field personnel. This selection process is designed to maximize the opportunity of finding soil chemistry that reflects only natural cycles of wetting and drying from precipitation and evapotranspiration. The presence of such a nitrate and chloride reservoir would suggest that these concentrations could be present throughout the White Mesa alluvial soil column and could be mobilized to groundwater as the result of increased surface water recharge due to irrigation, surface water impoundment, canal leakage, or other recharge processes.

Scanlon (2005) shows nitrate concentrations in soil on Texas high plains rangeland on the order of 200 mg/L at depths between approximately 9 and 19 ft bgs, and up to over 300 mg/L in irrigated high plains soil at approximately 3 ft and a nitrate spike of about 190 mg/L in high plains dry land farming soil. The thickness of the elevated nitrate mound or spike is on the order of 6 ft. The non-elevated nitrate and chloride concentrations are on the order of 10 mg/L or less.

5.1 Geoprobe Nitrate and Chloride Investigation

The purpose of the geoprobe investigation is to determine the presence or absence of a soil nitrate and/or chloride reservoir in the alluvial soil. The following procedure is written to apply to both nitrate and chloride, although only nitrate procedures are described from this point forward. The investigation will consist of 20 selected locations spread across the entire DUSA mill property. At each location, an initial boring (with no sampling) may be conducted to test subsurface conditions and one probe boring will be conducted for sample collection. Based on a log of monitoring well MW-27, the thickness of the alluvial cover near the center of the mill site is approximately 22 feet. The field team will be prepared to test the entire interval from ground surface to the top of bedrock or geoprobe refusal (whichever is first) in one foot increments. The location latitude and longitude of these geoprobe borings will have been recorded prior to conducting the field work.

The geoprobe boring locations are shown on Figure 20. These locations are approximate and may be changed based on judgment of the field team leader in consultation with DUSA personnel. The actual "as built" location of each boring will be recorded in the field with a hand held GPS instrument.

The geoprobe boring naming protocol is as follows:

GP-XX, where GP stands for geoprobe and XX is the number of the location, as 01, 02, 12, etc. The geoprobe boring locations will be recorded in the field note book as follows:

Boring ID	Latitude	Longitude

The geoprobe boring samples will be collected using the following methods:

1. Set up the geoprobe in the pre-selected location using a map and GPS. Create a labeled GPS waypoint for the "as built" location.
2. Concurrent with the setup of the geoprobe location, collect a non-geoprobe soil sample from 0.5 ft bgs and test for nitrate and chloride according to the field test procedures described below. The total sample volume should fill a one quart sealable plastic bag. This is the "background" or "baseline" sample for this location. This sample will be designated as GP-XX-BKG.
3. Probe to refusal to determine subsurface soil conditions and the depth to the top of bedrock (Dakota Formation or Burro Canyon Formation). This is a non-sampling geoprobe boring and is optional, at the discretion of the field team leader.

4. Probe and obtain a continuous soil core from surface to total depth in one geoprobe boring.
5. Measure and mark depth in 1 foot increments on the boring core sleeve. This is adequate sampling interval resolution to identify elevated nitrate or chloride concentrations on the order of 6 ft thick (Scanlon, 2005).
6. Open the sleeve to observe and describe the alluvial texture and/or lithology. Describe or log the soil texture based on the Unified Soil Classification System (USCS).
7. Place the soil from each one-foot increment into a sealable plastic bag. Mix the soil thoroughly in the plastic bag by gently inverting the bag multiple times. The purpose of this procedure is to thoroughly blend the soil so that a sample aliquot from the bag will be representative of the entire one-foot interval. Seal the plastic bag, label and store for additional analysis in the event the interval contains elevated nitrate and/or chloride.
8. Select a sample aliquot from the bag and test for nitrate using the nitrate field test kit test strips. This entails mixing a volume of soil with a volume of double distilled water (prepared by the laboratory) to create a liquid extract. Test the liquid extract with the nitrate test strip. Follow the test strip manufacturer's and USDA Natural Resource Conservation Service instructions, attached to this work plan, Appendix A. Note that the test strip range is 0-50 mg/L. If the test strip reads 50 mg/L, perform a dilution to determine the actual concentration, according to instructions in Appendix A. The chloride test strip range is 30-600 mg/L.
9. Record the test results in the field notebook.
10. If any of the soil column analyses indicate the presence of elevated nitrate, select the balance of that interval sample and place in a second, labeled sealable plastic bag (double bag) for delivery to the analytical laboratory for analysis of nitrate and chloride by synthetic precipitation leaching procedure (SPLP) method. "Elevated" concentrations are defined as those 1 foot intervals with nitrate concentrations at least twice the average background concentration, based on field analysis of a sample 0.5 ft below ground surface. Analytical methods for aqueous leachate analysis are listed in Appendix B. Handle, package, label, fill out chain-or-custody, and deliver the samples according to the soil sampling and handling procedures.
11. Collect a sample from the bottom of the boring, regardless of whether it tests positive for nitrate, and package in a double bag for delivery to the laboratory and analysis for nitrate and chloride by the SPLP. Also collect one sample for SPLP from an interval which lacks evidence of elevated nitrate, as a baseline analysis.

12. Discard the remaining bagged soil on the location and dispose of the plastic bags.
13. Fill the boring with dry bentonite material to seal the boring and restore surface location.
14. Move to the next location.
15. For the purpose of cost estimation, assume 15 test kit analyses per boring and four (4) SPLP analyses for nitrate and chloride per sampling location.
16. The core hole borings will be back filled with cement/bentonite grout after drilling. The location of actual boring location will be recorded with a hand-held GPS instrument for plotting on the map and for future reference.
17. Assess results with management.

5.2 Coring Study to Explore for Natural Nitrate Reservoir

This task consists of advancing a drill hole through the alluvial material and then drilling a rock core of the formation beneath the alluvium, in up to four potential nitrate reservoir locations that are shown to contain elevated nitrate in the soil column within the geoprobe soil samples. The definition of "elevated" is a nitrate concentration at least twice background, based on the concentration of nitrate in near-surface soil samples, as described in Section 5.1. The purpose of this work is to trace the nitrate from the base of the alluvium and into the bedrock column (Dakota Formation and upper Burro Canyon Formation) to the water table.

The coring will be conducted with a conventional truck-mounted drill rig using a combination of hollow stem auger and air rotary methods, without introducing water or other drilling fluids into the borehole.

Using monitoring well MW-31 as an example, the subsurface layers are expected as follows:

Alluvium: 0-22ft bgs (top of bedrock – 22 ft bgs)

Depth to Groundwater (2009, approximate): 77 ft bgs

Length from top of bedrock to groundwater: 77 – 22 = 55 ft

Therefore, the length of core drilling in this example is 55 ft.

The entire core interval will be boxed and logged (described) according to standard geologic methods.

Three one foot core intervals will be collected from the interval between the base of the alluvium and the groundwater table, including the core located at the top of the water table. The three

cores will be evenly spaced within the distance between the alluvium and the water table. For example, if the top of bedrock is 22 ft bgs, the water table is at 77 ft bgs, and the interval from the top of bedrock to the water table is 55 ft, the three cores will be as follows: the top core (from 22 – 23 ft), the middle core (22 + 27 ft = 49 -50 ft) and the bottom core (49 + 27 = 76-77 ft, approximately).

No field testing will be conducted on these rock cores. The one-foot core intervals will be packaged and shipped to a State of Utah certified analytical laboratory for analysis of the presence of nitrate and chloride in the rock cores by the SPLP analysis method. The laboratory will need to crush, pulverize, and blend the rock core material, and measure the pore moisture, before conducting the analysis. Each analysis will be considered representative of the entire one foot interval.

The core hole borings will be backfilled with bentonite grout after drilling. The as-built boring locations will be recorded with a hand-held GPS instrument for plotting on the site map and for future reference in the field.

6.0 INVESTIGATION OF POTENTIAL NITRATE SOURCE LOCATIONS

This investigation combines an initial geoprobe investigation of potential nitrate and chloride sources, followed by bedrock coring if positive results for nitrate and chloride are encountered during geoprobing.

6.1 Geoprobe Investigation of Potential Nitrate Source Locations

The purpose of this investigation of potential nitrate and chloride source locations is to assess the presence or absence of elevated nitrate and chloride concentrations in the alluvial layer (above bedrock) in locations where past or ongoing activities may have contributed nitrate and/or chloride to the soil and/or groundwater. Specifically, the purpose is to test whether nitrate and chloride residues can be found in alluvial soils or at the alluvial bedrock interface. The alluvial bedrock interface marks a change in porosity and permeability and is judged to be the most likely location to find nitrate and chloride residues from potential sources that found a pathway to groundwater.

The potential nitrate source locations include up to seven (7) leach fields, as well as other installations such as ammonia tanks, a sewage vault, and Lawzy Lake, a former pond that may have held contaminated water. The investigation of these potential sources is contingent on access with the geoprobe rig and subject to approval by DUSA management, based primarily on field team health and safety considerations. The subsurface configuration or design of the leach fields, including the potential for underground piping, is not known. Any excavation or borings in these leach fields will require prior identification of underground structures, such as piping, septic tanks, or vaults, using techniques such as air knife or equivalent "daylighting" methods. Design drawings and records will be reviewed prior to work and the borings will only be attempted with the full approval of DUSA management.

The leach field locations and dates of operation listed below are provided by DUSA management and are shown on Figure 21:

Potential Nitrate Source Locations

1. Main leach field (also known as Leach Field east of Scalehouse, 1985 to present)
2. Sewage vault/lift station
3. Scale house leach field, (also known as Leach Field south of Scalehouse, 1977-1979)
4. Former office leach field
5. Ammonia tanks

6. SAG leach field (Leach Field north of mill building, 1998 to 2009)
7. Cell 1 leach field (Leach Field east of Cell #1, up to 1985)
8. Fly ash pond
9. Chlorate tanks
10. Ammonium sulfate crystal tanks
11. Lawzy sump
12. Lawzy Lake
13. Former vault/lift station (to Former Office Leach Field) (1992 to 2009)
14. Truck shop leach field (1979-1985)
15. Counter Current Decant/Solvent Extraction (CCD/SX) leach field

Note that locations 1 and 15 are known to be in use at present. For these locations, optional source influent sampling and analysis may be conducted instead of subsurface soil sampling and field testing. Conducting borings in the active leach fields is not recommended due to the potential to create a pathway for the waste water fluids from the leach field down to the groundwater table. As an alternative, water samples will be collected from influent piping (if possible) near the operating leach field, downstream of the septic tank (if present) that is designed to collect solids. It is not known at this time if such influent piping will be accessible. These waste water influent samples, if any, will be analyzed for nitrate and chloride by the methods shown in Table 2 of this work plan. Sampling and analysis of raw wastewater influent is described in detail in the publication, "Influent Constituent Characteristics of the Modern Waste Stream from Single Sources." (Lowe, et al., 2009). As a point of reference, the average concentration of nitrate in raw waste water from single sources is 2.1 mg/L (Lowe, et al., 2009). If waste water is sampled, it will be analyzed for nitrate and chloride and a mass balance calculation will be performed to determine if the influent source could create the level of nitrate concentrations found currently in groundwater beneath the site.

The following tasks will be conducted on the locations listed above (except for the two leach fields known to be currently in use):

1. If approved by DUSA management, conduct test geoprobe boring (without core sleeve) to refusal to determine alluvial thickness and evaluate subsurface conditions. If subsurface conditions are deemed safe for boring and sampling, proceed as described below.

2. Conduct geoprobe boring with core sleeve to collect soil core through alluvial interval.
3. Collect 6-inch core sample from two intervals within the alluvial interval and one 6-inch core sample from the base of the alluvial interval, at the contact with the bedrock formation.
4. Place the soil material in double, sealable plastic bags and label.
5. Collect an aliquot of the material and test with the nitrate field test kit according to the procedures described in Appendix A.
6. For samples with positive results from the field test kit analysis, handle, pack, and ship to the laboratory, with chain-of-custody, per standard operating procedures.
7. Backfill the geoprobe boring with bentonite to seal the hole.
8. Thoroughly clean the geoprobe drill pipe and other equipment between locations.
9. Analyze for the following, in soil:
    a. Nitrate
    b. Chloride

6.2 Coring Study in Potential Nitrate Source Locations

This task consists of advancing a drill hole through the alluvial material and then drilling a rock core of the geologic formation beneath the alluvium, in up to 13 potential nitrate source locations that are shown to contain elevated nitrate in the soil column within the geoprobe soil samples. These 13 locations are the locations which have been identified as possible nitrate source areas but are not the locations of the two active leach fields at locations 1 and 6. The procedures for conducting this core drilling and sampling are identical to those described in Section 5.2.

7.0 STABLE ISOTOPES STUDY

The purpose of the stable isotope study is to identify the source of the nitrate in the groundwater beneath the site.

Stable (non-radioactive) isotopes are elements that have the same name (i.e. oxygen, nitrogen, carbon, etc.) but differ by the number of neutrons in the atomic nucleus. Physical and biological processes can affect the relative concentrations of light and heavy isotopes of the same element. This relative enrichment or depletion of one stable isotope over another is called isotopic fractionation. During evaporation of water, for example, the heavier ^{18}O becomes enriched in the residual water as more of the lighter ^{16}O enters the vapor phase. Thus, meteoric water, derived largely from the evaporation of ocean water, is enriched in ^{16}O relative to ocean water.

Biological organisms preferentially use ^{14}N, rather than ^{15}N, for respiration and assimilation because the chemical bonds of lighter isotopes are generally broken more easily than those of heavier isotopes. ^{14}N becomes concentrated in cell mass while ^{15}N becomes concentrated in the residual nitrogen source and in human and animal wastes. In addition, a disproportionate amount of ^{14}N as compared to ^{15}N is released to the atmosphere during ammonia volatilization from human and animal waste, fostering enrichment of ^{15}N. Thus, nitrate in groundwater that has been denitrified by microbes, or originates from human and animal waste, is enriched with ^{15}N. These isotope fractionations have long been studied to trace flow paths and mixing of water sources, and to identify sources of nitrate and ammonia in groundwater. Isotopic compositions are usually presented as delta values (e.g., $\delta^{15}N$), which express the ratio of the heavy to light isotopes (i.e., 2H/1H, $^{15}N/^{14}N$, and $^{18}O/^{16}O$), relative to a universal standard.

Figure 2 shows $\delta^{15}N$ results from sampling of various sources of nitrate contamination, including a uranium mill, from McQuillan et al (1989), showing the potential to exclude mill tailings as a source of nitrate in groundwater, depending on the $\delta^{15}N$ signature in the groundwater.

However, Figure 3 shows $\delta^{15}N$ results normalized to N2 in the atmosphere from sampling a different set of sources indicating the complexity that could potentially be encountered, raising the possibility that, while some sources can be readily distinguishable, results of any isotopic study could be inconclusive for distinguishing other sources.

Finally, Figure 4 is a plot of $\delta^{18}O$ versus $\delta^{15}N$ from Roadcap et al (2001), also showing the overlapping nature of various sources but displaying the additional power of adding $\delta^{18}O$. Hurst and Solomon (2008) used Deuterium and $\delta^{18}O$ values to fingerprint groundwater sources during their study at White Mesa and it was part of their evidence that young water in MW-27 and MW-

19 was coming from the wildlife ponds (see Figure 22 for the locations of existing monitoring wells at the site).

The possible nitrate sources at the site include nitrate in waste water (in leach fields), nitrate-fertilizer, ammonium nitrate and other nitrate-producing compounds from historical missile launch activity, and/or a naturally occurring nitrate reservoir in soil. The only potential pathway on the site from the surface to groundwater that is known at this time is the surface water in the wildlife ponds and some other nearby stockponds. Other sources could include historic stock ponds, possible deep disposal wells operated by historic users of the site, leach fields or other installations where continuous head and soil moisture is created from the surface to groundwater and a demonstrated connection between surface water and groundwater on the site could point to a possible connection between a nitrate/chloride source in that surface water and the current elevated nitrate and chloride concentrations in groundwater.

Previous sampling and analysis for stable isotopes in groundwater was conducted by the Department of Geology and Geophysics, University of Utah, and documented in the report "Summary of work completed, data results, interpretations and recommendations for the July, 2007 Sampling Event at Denison Mines, USA, White Mesa Uranium Mill Near Blanding, Utah (Hurst, G.T., and Solomon, D.K., 2008) prepared on behalf of the Utah Division of Radiation Control (DRC). The stable isotopes measured for the DRC study were tritium, tritogenic helium-3, deuterium, ^{18}O, ^{15}N, and ^{34}S.

The DRC report concludes the following: "$\delta^{34}S$ and $\delta^{18}O$ isotopic signatures on dissolved sulfate provide distinction between surface water sites and monitoring wells. The tailings cells and wildlife ponds exhibit significantly enriched $\delta^{18}O$-SO_4 values relative to monitoring wells, and depleted $\delta^{34}S$-SO_4values relative to monitoring wells. MW-27 (see Figure 22) is the only monitoring well to bear an isotopic fingerprint closely related to that of the surface water sites, suggesting recharge from the wildlife ponds has reached MW-27 and further evidence that the wildlife ponds are providing recharge to the aquifer. Sites with high concentrations of metals (MW-3, MW-14 shallow and deep, MW-15, MW-18, and MW-22) bear very different isotopic fingerprints than those of the surface water sites. In general, the data collected in this study do not provide evidence that tailings cell leakage is leading to contamination of groundwater in the area around the White Mesa mill. Evidence of old water in the majority of wells, and significantly different isotopic fingerprints between wells with the highest concentrations of trace metals and surface water sites, supports this conclusion. The only evidence linking surface waters to recharging groundwater is seen in MW-27 and MW-19. Measurable tritium and CFC concentrations indicate relative young water, with low concentrations of selenium, manganese, and uranium. Furthermore, stable isotope fingerprints of δD and $\delta^{18}O$ suggest mixing between

wildlife pond recharge and older groundwater in MW-19 (north of northern wildlife pond) and MW-27 (west of southern wildlife pond, at NE corner of tailings cell no. 1). $\delta^{34}S$-SO_4 and $\delta^{18}O$-SO_4 fingerprints closely relate MW-27 to wildlife pond water, while the exceptionally low concentration of sulfate in MW-27, the only groundwater site to exhibit sulfate levels below 100 mg/L, suggest no leachate from the tailings cells has reached the well." (Hurst and Solomon, 2008, p. 59). "The southern margin of artificial recharge is likely to be between MW-27 and MW-31 while the northern margin appears to be between MW-18 and MW-19." (Hurst and Solomon, 2008, p. 27).The Hurst and Solomon study documents that the tailings cells are not discharging to groundwater and thus, the tailings cell fluids are not the nitrate source.

By established convention, isotopic ratios are defined as delta (δ) values, which are obtained by the equation:

$$\delta \text{ (isotope)} = \{[R(\text{sample}) - R(\text{standard})]/R(\text{standard})\} - 1 \ (1{,}000).$$

Where: δ (isotope) = values in per thousand (‰) or per mil and R(sample) = the ratio of the first and second isotope such as $^{18}O/^{16}O$, and R(standard) = the ratio of $^{18}O/^{16}O$ used in international or other standards. For example, the standard for $^{18}O/^{16}O$ is Standard Mean Ocean Water (SMOW). A positive (+) δ value indicates that the heavier isotope (i.e., ^{18}O) in the sample is enriched when compared to the standard. A negative (–) value indicates that the sample has more of the lighter (^{16}O) isotope. The International Atomic Energy Agency (IAEA) and the National Institute of Standards and Technology (NIST) have established and published these standards.

The wells to sample for stable isotopes in groundwater are as follows and are shown on Figure 22:

- MW-20
- MW-31
- TWN-19
- TWN-2
- TWN-9
- TWN-17

If a source of nitrate is discovered during either the investigation of naturally occurring nitrate reservoir in soils or in the investigation of potential nitrate source locations, samples from that source will also be sent for analysis. In addition, a sample of solution from the slimes drain of tailings Cell 2 will be collected and sent for analysis.

The proposed stable isotope and other analyses for the groundwater, leachate, and tailings solution samples are as follows:

- nitrate + nitrite
- total Kjeldal nitrogen
- chloride
- $\delta^{15}N_{nitrate}$ and $\delta^{18}O_{nitrate}$
- $\delta^{18}O_{water}$ and δD_{water} (D = ^{2}H, Deuterium)

The stable isotope groundwater samples will be collected during the regularly scheduled quarterly groundwater sampling event conducted by the Site water sampling team.

7.1 Quality Assurance and Quality Control Procedures

The groundwater sampling and analysis procedures are described in the DUSA Quality Assurance Project Plan (QAP) and on Table 2 of this Work Plan. A commercial laboratory has been identified that maintains an internal quality assurance program and is able to do all the stable isotope analyses that are required. Isotech Laboratories, Inc. in Champaign Illinois states that:

> *"At least 20% of all analyses at Isotech are for quality assurance and quality control (QAQC). In addition to regularly calibrating all instruments with standard materials traceable to the National Institute of Standards and Testing (NIST), or the International Atomic Energy Agency (IAEA), approximately 10% of the analyses are of internal check standards that have compositions similar to those of the samples being analyzed. For example, when analyzing methane in samples that are mostly air, we test our methods and our equipment using standards that are diluted with air, and not with pure gases. An additional 10% of all analyses are duplicates of the customer's samples."*

Isotech will be required to submit all quality assurance back up data with its final data package submission. In addition to Isotech's internal quality assurance, the following field-generated QC samples will be provided: two blind duplicate samples of groundwater, one blind duplicate of any leachate, and one blind duplicate of slimes drain solution will be sent to Isotech for analysis. Sufficient amounts of all samples will be collected such that a split sample can be archived should any reanalysis be required. Any duplicate sample that returns results such that the isotope ratios differ by more than 20% will require reanalysis of all samples. Results of reanalysis will be statistically analyzed to determine error bars around each data point.

8.0 MASS BALANCE CALCULATIONS

It is possible to estimate the mass of nitrate and chloride in the groundwater beneath the mill site by assuming a saturated thickness of groundwater in the aquifer matrix, a porosity of the aquifer matrix, an average concentration of constituents in groundwater, and an area to which the average concentration applies. Any potential source of nitrate and chloride will be evaluated to determine if it has the potential to have caused the mass of nitrate and chloride observed in the groundwater plume beneath the mill site. First, the potential source must have a means to reach groundwater such as sufficient water or other fluid to travel through the vadose zone. Second there must have been sufficient nitrate and chloride in the source to account for the nitrate and chloride mass observed in the groundwater. Both conditions can be evaluated by mass balance calculations.

An example of these mass balance calculations was presented in the December 30, 2009 CIR where one of the suggested possibilities was a groundwater mound from the tailings cells that might cause elevated nitrate and chloride concentrations upgradient in the area of the nitrate and chloride plume. A calculation for nitrate to evaluate this possibility (a calculation for chloride would be similar) suggests that on the order of eleven percent tailings solution (assuming the highest recently observed nitrate concentration in the tailings of 290 mg/L) would have to mix with unimpacted groundwater (assuming 1 mg/L) in order to account for the observed mass of nitrate in groundwater, assuming an average nitrate concentration in the plume above the 20 mg/L isopleth of 30 mg/L.

The size of the nitrate plume above 20 mg/L is approximately 40 acres, or 1,800,000 square feet in map area. Assuming 45 feet of saturation (Chloroform Investigation Report) and a porosity of 0.2, there are 16,200,000 cubic feet or 121,176,000 gallons of groundwater in that area. Eleven percent of that is 13,329,360 gallons (approximately 41 acre feet) which is a conservative estimate of the volume of tailings solution that would have to be mixed with groundwater to account for the mass of nitrate in the portion of the plume above 20 mg/L nitrate.

Assume:

- Nitrate Concentration in Tailings Solution 290 mg/L
- Nitrate Concentration in un-impacted Groundwater 1 mg/L
- Average Plume Concentration 30 mg/L

Mixing Equation: $C_t*V_t + C_g*V_g = C_m*V_m$ (eq 1)

Where: C_t = Concentration of nitrate in tailings solutions

V_t = Volume of tailings solutions

C_g = Concentration of nitrate in unimpacted groundwater

V_g = Volume of unimpacted groundwater

C_m = Concentration of nitrate in mixture of groundwater and tailings solutions

V_m = Volume of mixture of groundwater and tailings solutions

Another Equation: $V_t + V_g = V_m$ (eq 2)

Substituting eq2 in eq1: $C_t*V_t + C_g*V_g = C_m* (V_t + V_g)$ (eq 3)

Substitute Nitrate Concentrations in eq3

$$290*V_t + 1*V_g = 30*(V_t + V_g)$$

$$290*V_t + 1*V_g = 30*V_t + 30*V_g$$

$$260*V_t = 29*V_g$$

$$V_t = 29/260*V_g = 0.11*V_g$$

The volume of tailings solution would have to be eleven percent of the volume of un-impacted groundwater in the mixture.

That amount of seepage from the tailings cells would certainly generate a groundwater mound. Such a mound would have to be on the order of 5 feet on average over the entire 40 acres, but would likely be much higher than that at the centroid of the plume and would taper off toward the edges of the plume. However, no such mounding exists under the tailings cells. While groundwater mounding can be observed towards the eastern portion of the site, away from the tailings cells, it is clearly related to the wildlife ponds and not the tailings cells. As a final point, if the concentration of nitrate in tailings documented in the Statement of Basis (24 mg/L) were used in the calculation, no amount of tailings solution would bring the plume concentration to 30 mg/L.

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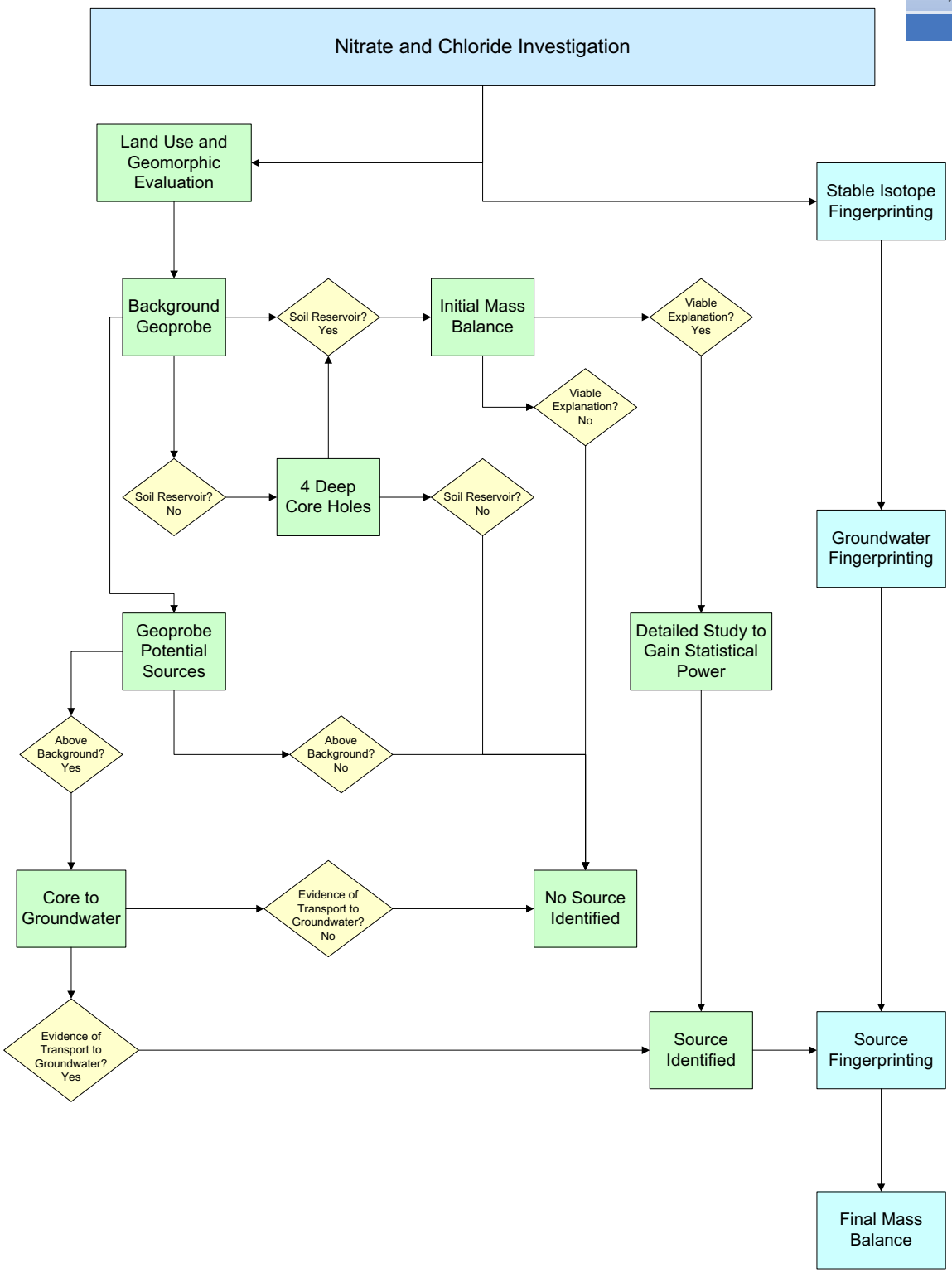
Figures

Process Flow for the Supplemental Contaminant Investigation, White Mesa Mill Site, San Juan County, Utah

Saturday, February 12, 2011



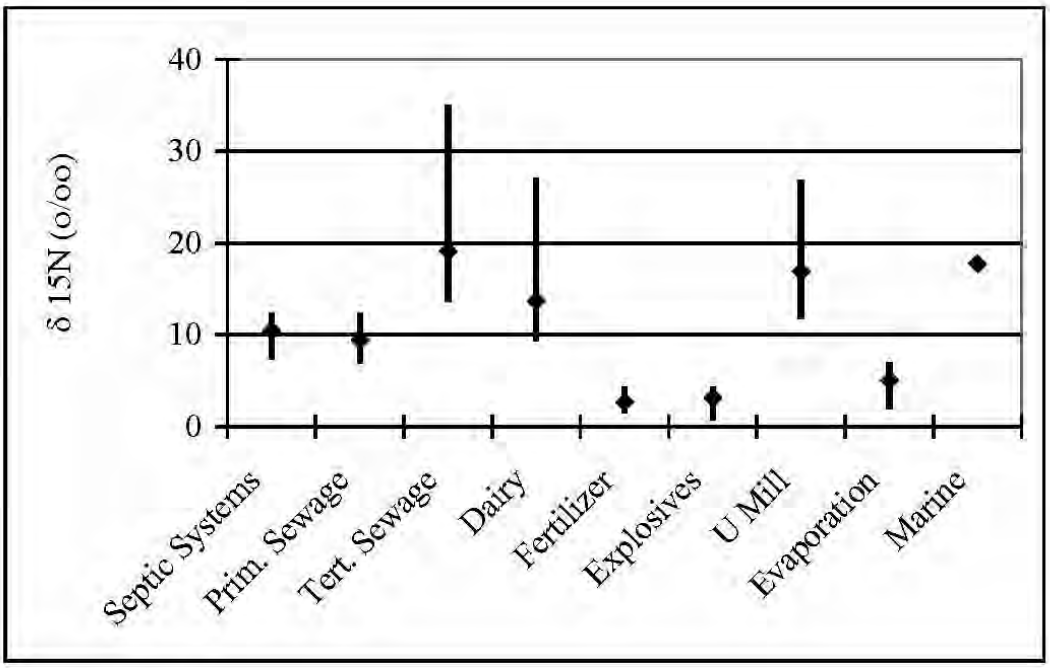


Figure 2. δ15N results from sampling of various sources of nitrate contamination

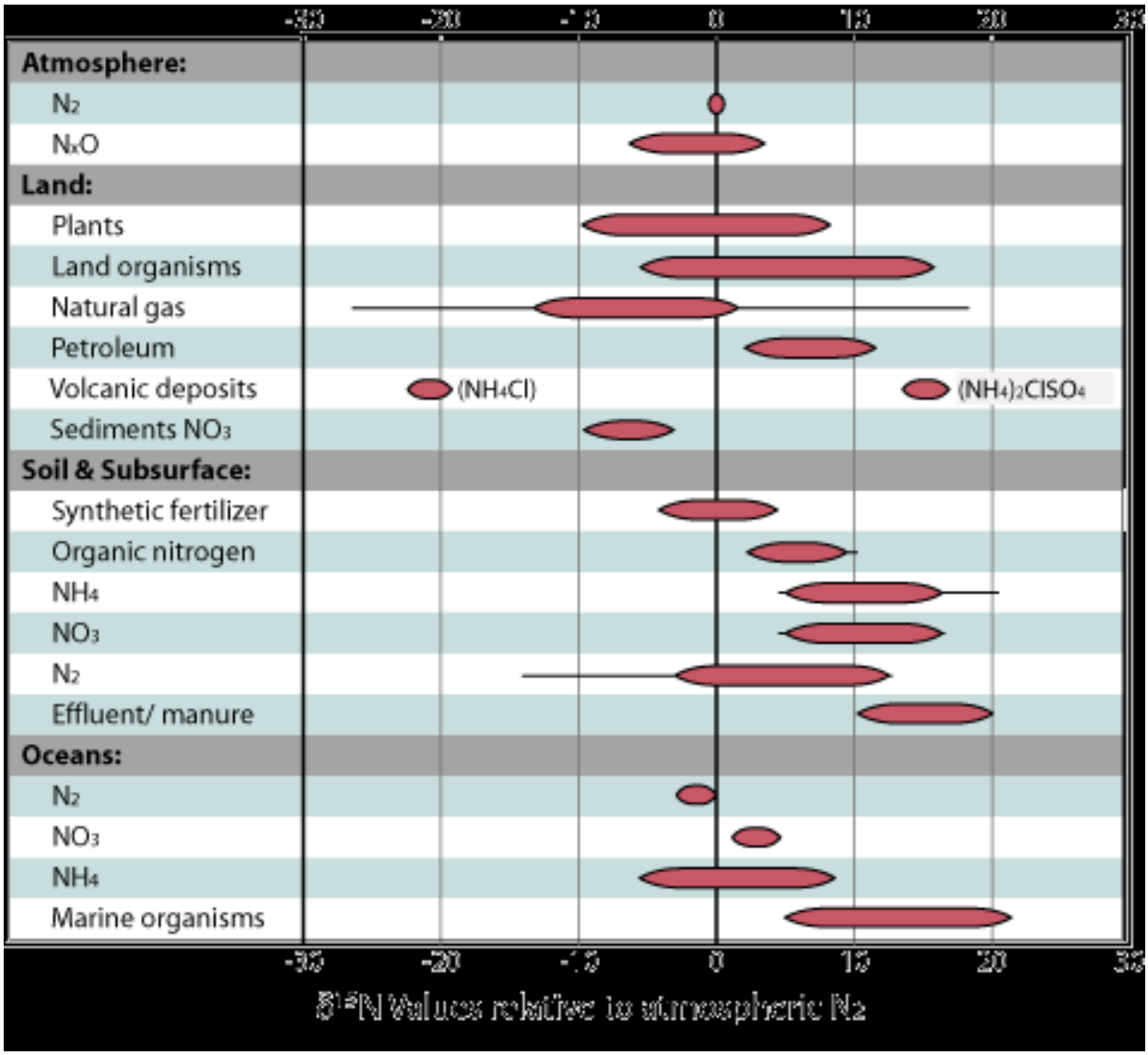


Figure 3. δ15N results normalized to N2 in the atmosphere from sampling a wider range of sources

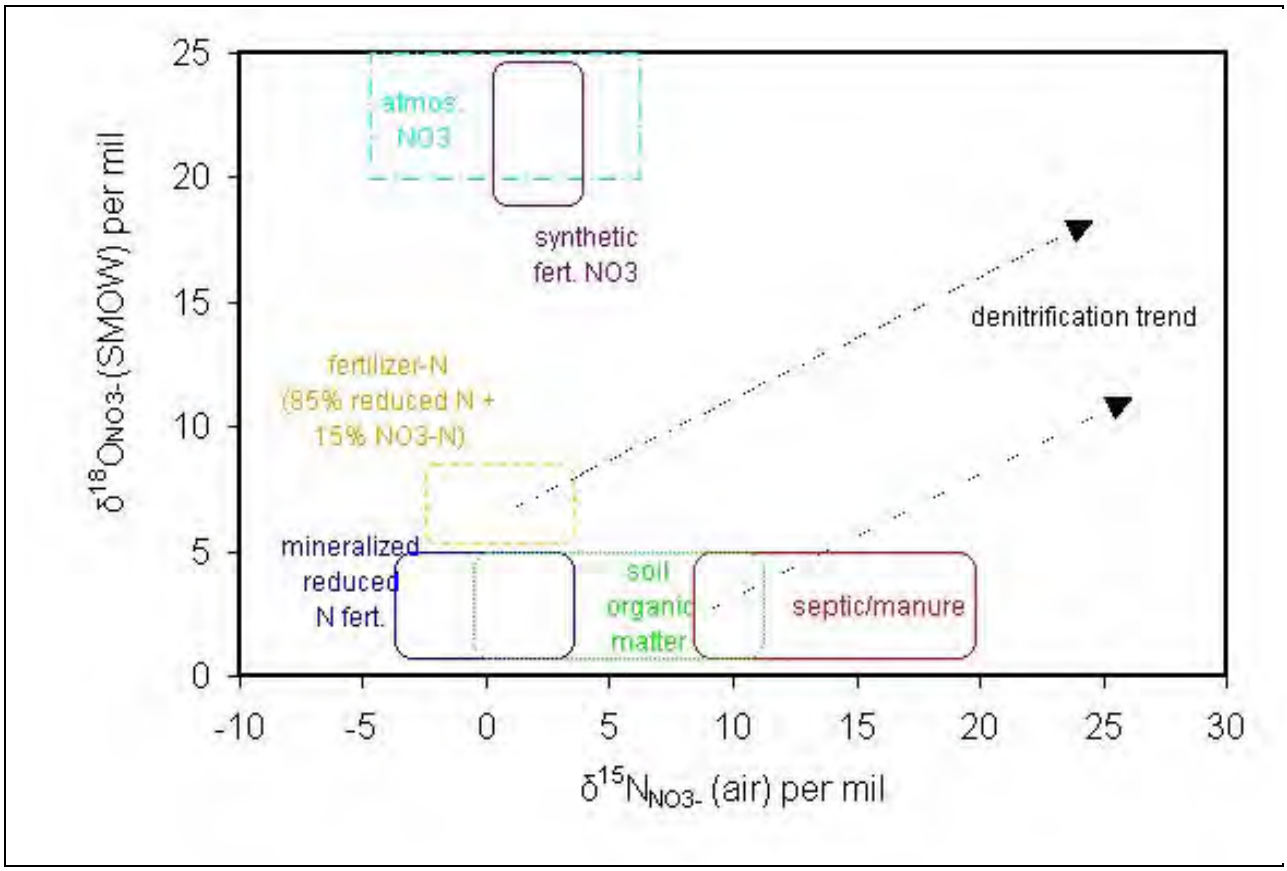


Figure 4. A plot of $\delta^{18}O$ versus $\delta^{15}N$

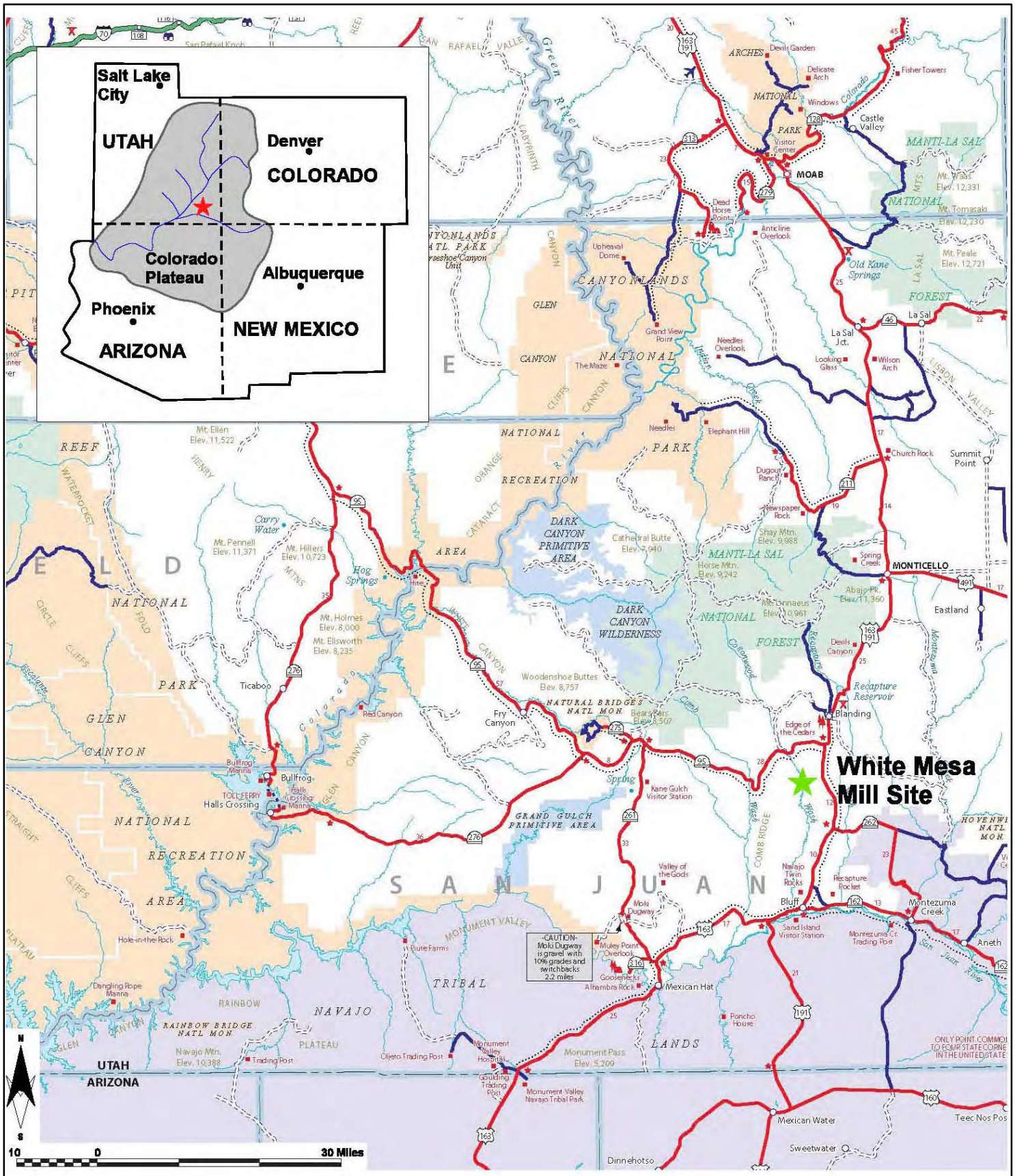


Figure 5
Location Map
Nitrate and Chloride
Source Investigation

Source(s):

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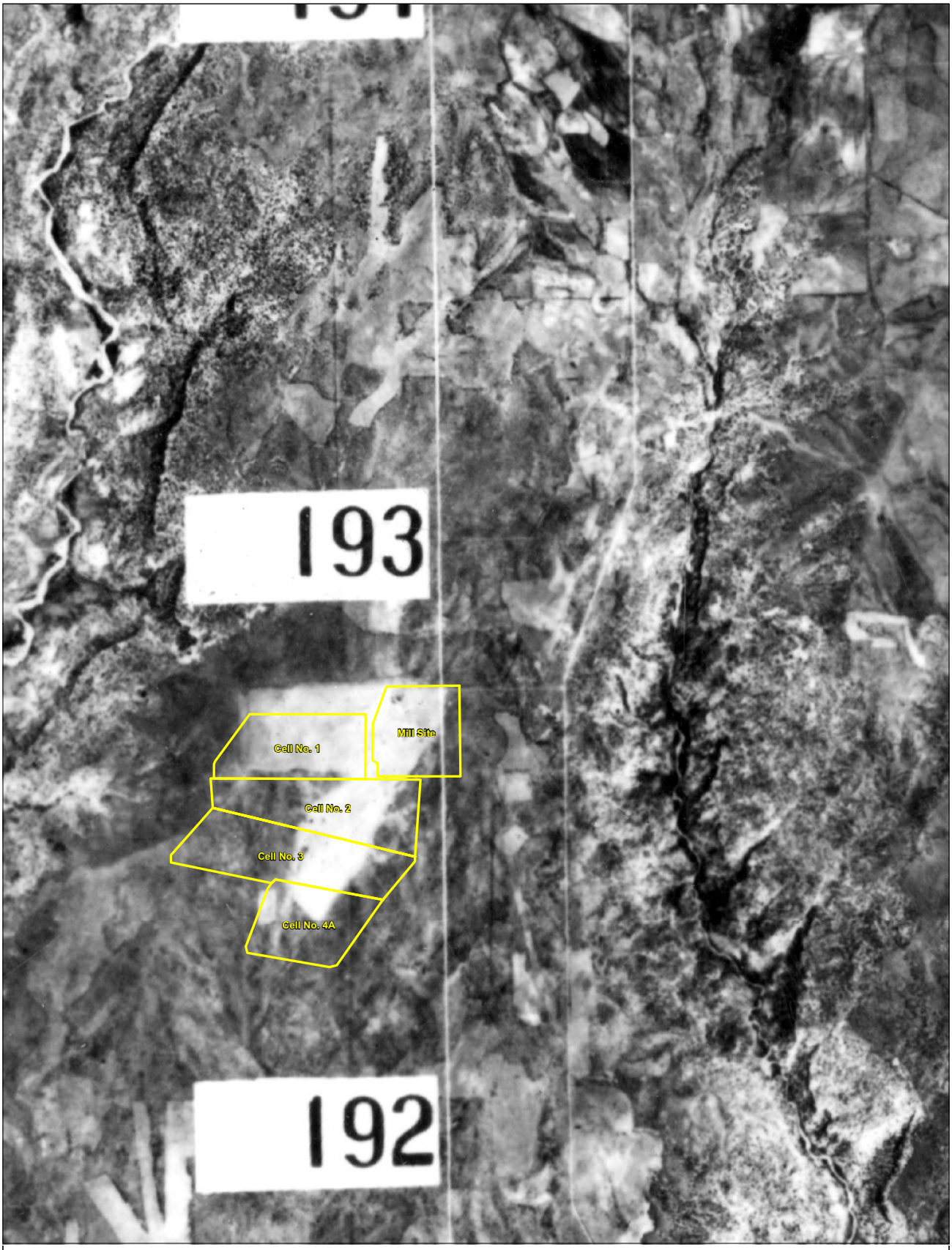


Source(s): Aerial – Earth Data Analysis Center, New Mexico.

N
S

1,500 750 0 1,500
Feet

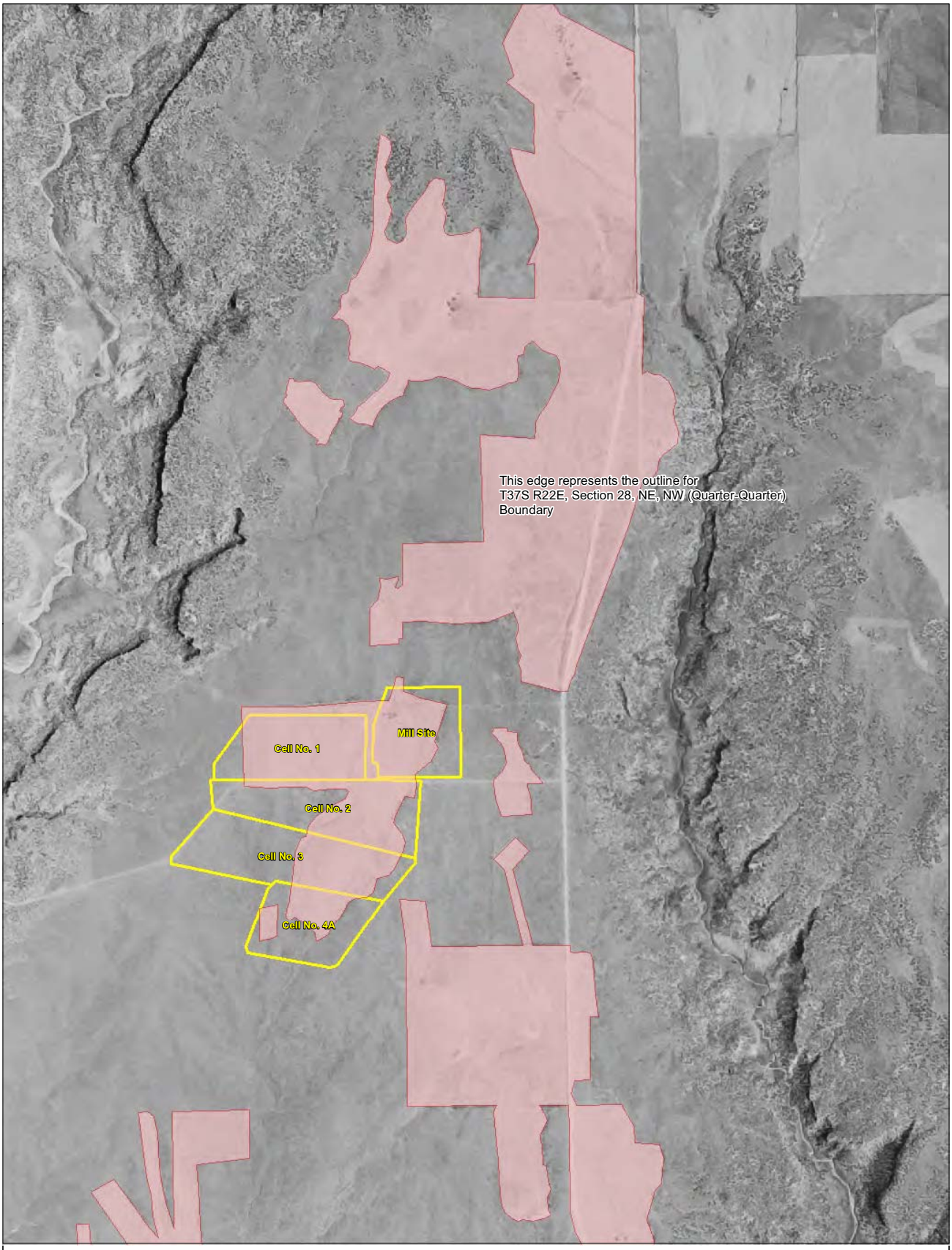
Legend

Site Feature

Figure 6
Historical Aerial Imagery
1937 Aerial Photo

INTERA

S:\Projects\IUC-001-01-001 Denison Mines\GIS\mapdocs\2010_AerialImageryResearch\Figure1_1937Aerial.mxd 12/28/2010



Source(s): Aerial – Earth Data Analysis Center, New Mexico.

N
S

1,500 750 0 1,500
Feet

Legend

Historical Clearing (From 1955 Imagery)

Site Feature

Figure 7
Historical Aerial Imagery
1955 Aerial Photo

S:\Projects\UC-001-01-001 Denison Mines\GIS\mapdocs\2010_AerialImageryResearch\Figure2_1955Aerial.mxd 01/10/2011

Source(s): Landsat from GLOVIS, U.S. Geological Survey

N
S

1,500 750 0 1,500
Feet

Legend

Site Feature

Figure 8
Historical Aerial Imagery
June 30, 1985 Landsat

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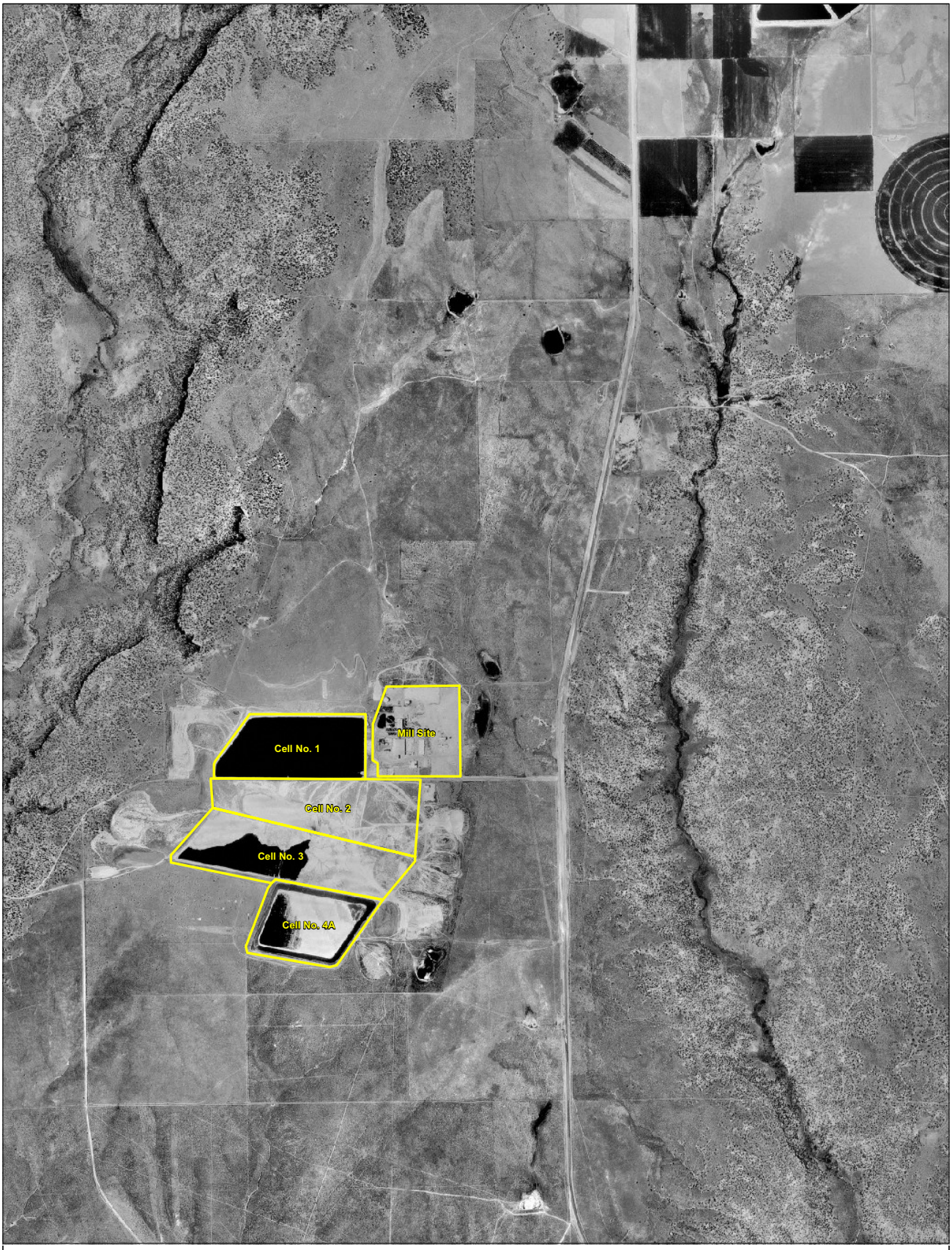


Source(s): 1997 7.5-Minute DOQQ County Mosaic, U.S. Geological Survey

N
S

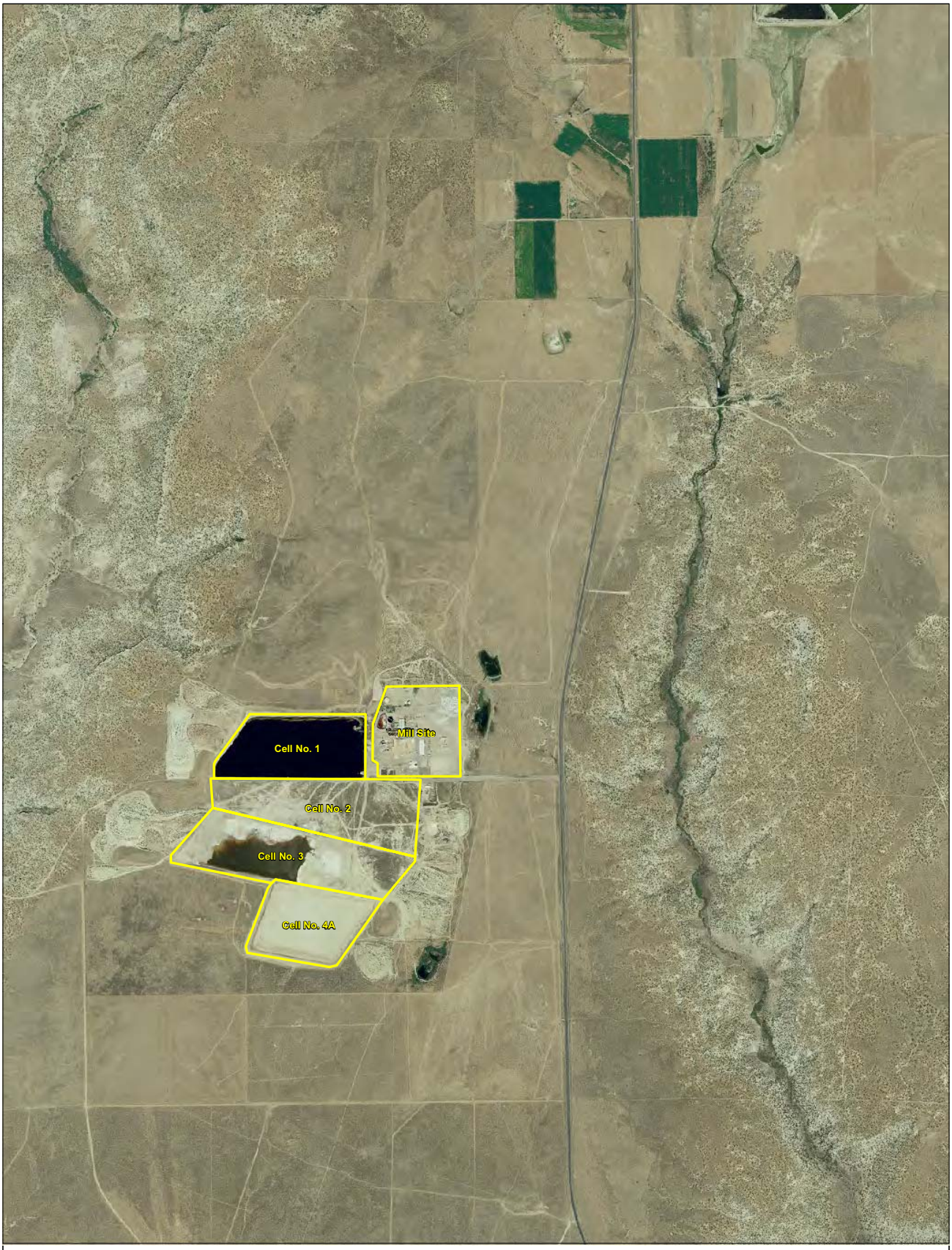
1,500 750 0 1,500
Feet

Legend

Site Feature

Figure 9
Historical Aerial Imagery
1997 DOQQ

S:\Projects\IUC-001-01-001 Denison Mines\GIS\mapdocs\2010_AerialImageryResearch\Figure4_1997Aerial.mxd 12/28/2010



Source(s): 2006 7.5-Minute DOQQ County Mosaic, U.S. Geological Survey

N
S

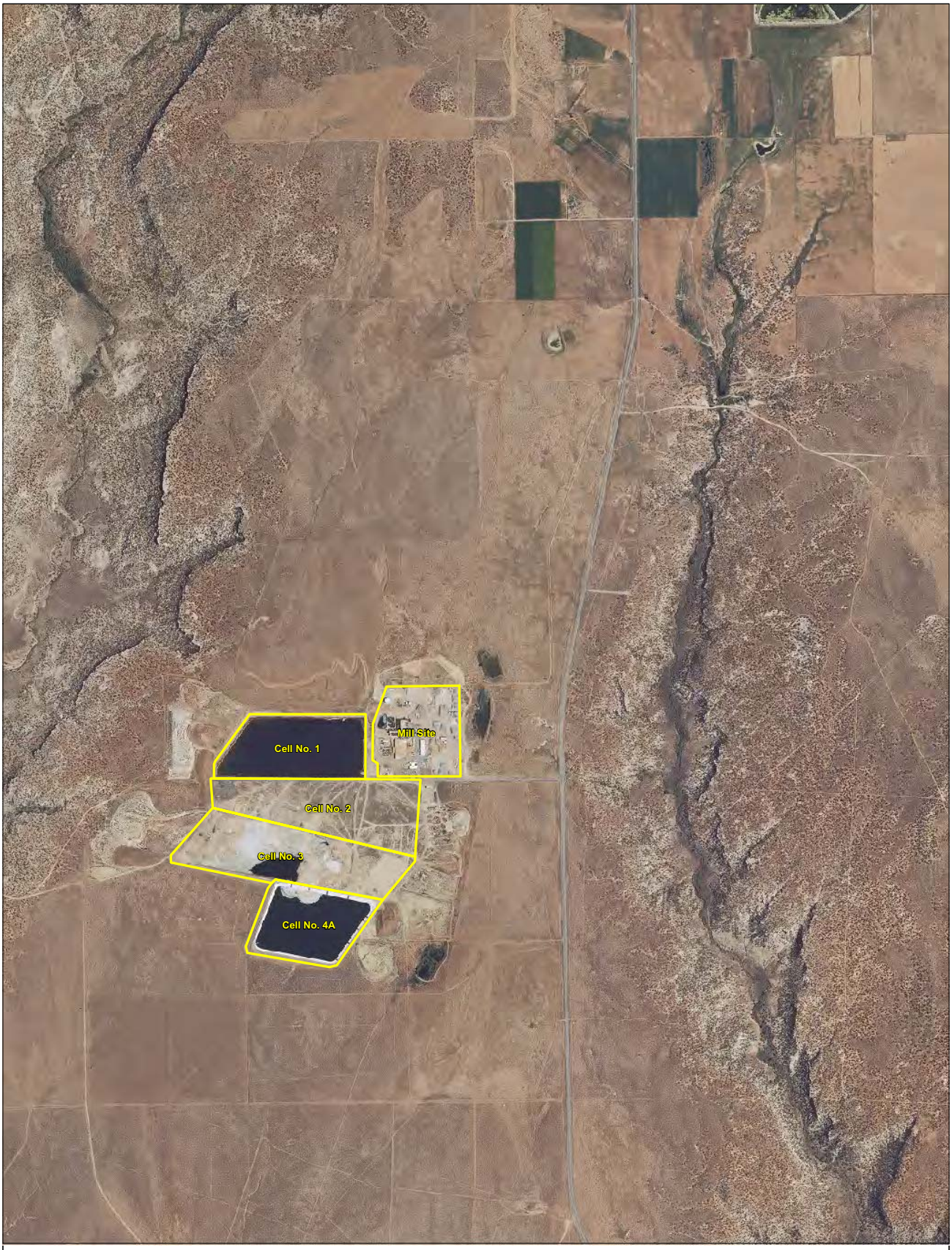
1,500 750 0 1,500
Feet

Legend

Site Feature

Figure 10
Historical Aerial Imagery
2006 DOQQ

S:\Projects\IUC-001-01-001 Denison Mines\GIS\mapdocs\2010_AerialImageryResearch\Figure5_2006Aerial.mxd 12/28/2010



Source(s): 2009 7.5-Minute DOQQ County Mosaic, U.S. Geological Survey

N
S

1,500 750 0 1,500
Feet

Legend

Site Feature

Figure 11
Historical Aerial Imagery
2009 DOQQ

INTERA

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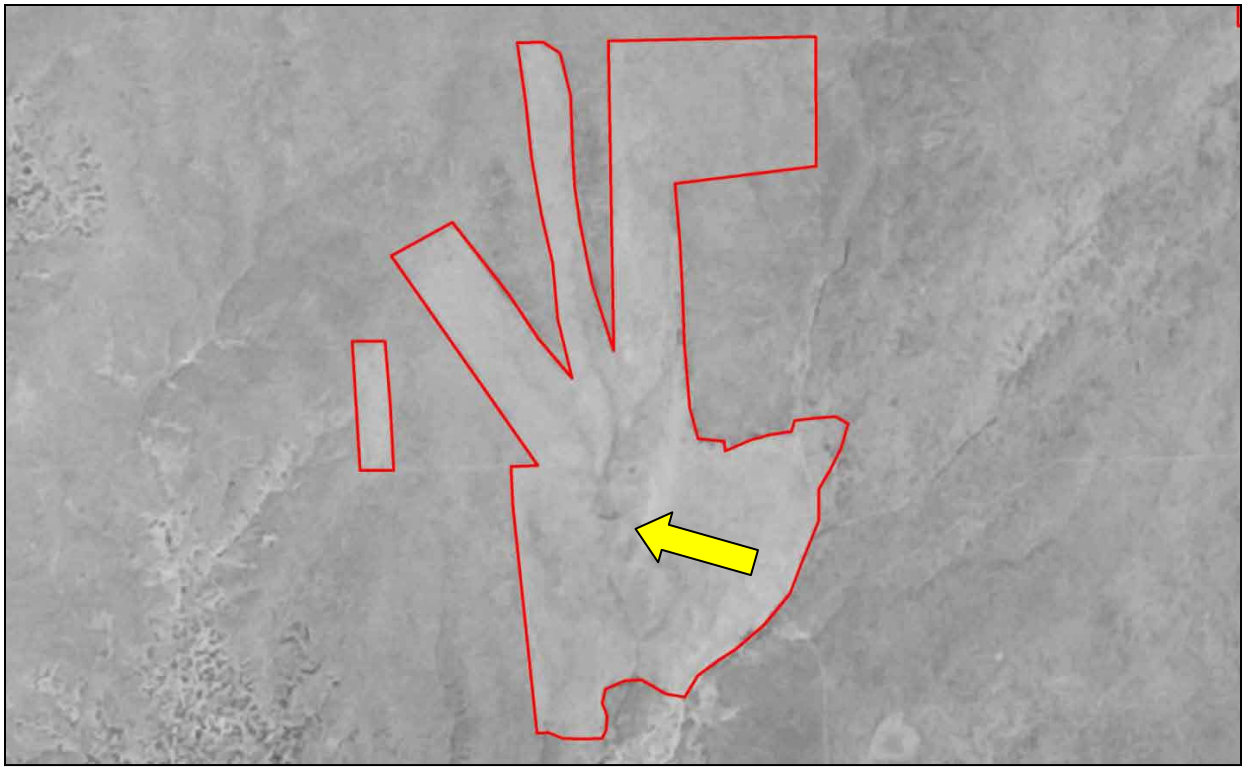


Figure 12. From the 1955 Photo Showing Pasture is Coincident with Drainages, which are Wetter than the Surrounding Area
(A stock pond is visible near the center of the pasture area [yellow arrow]).

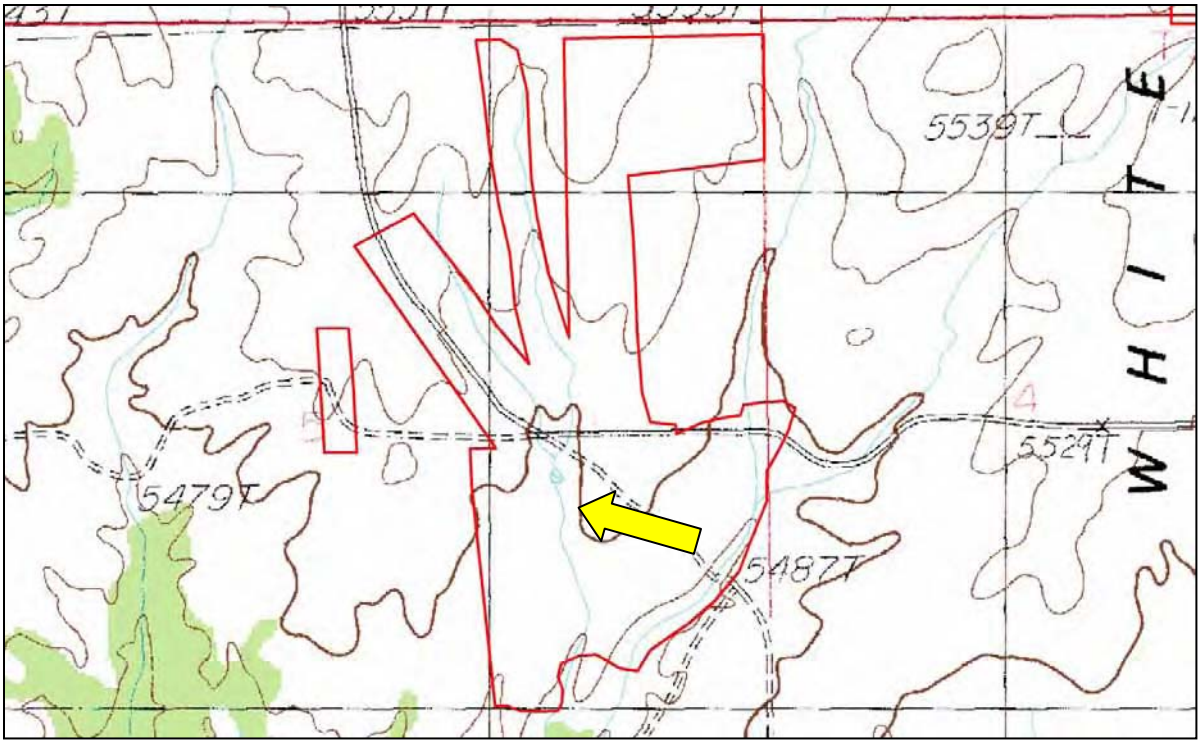


Figure 13. Outline of 1955 Pasture Overlain over the USGS Topographic Map Showing Drainages and a Stock Pond (Yellow Arrow) in the Central Portion of the Pasture

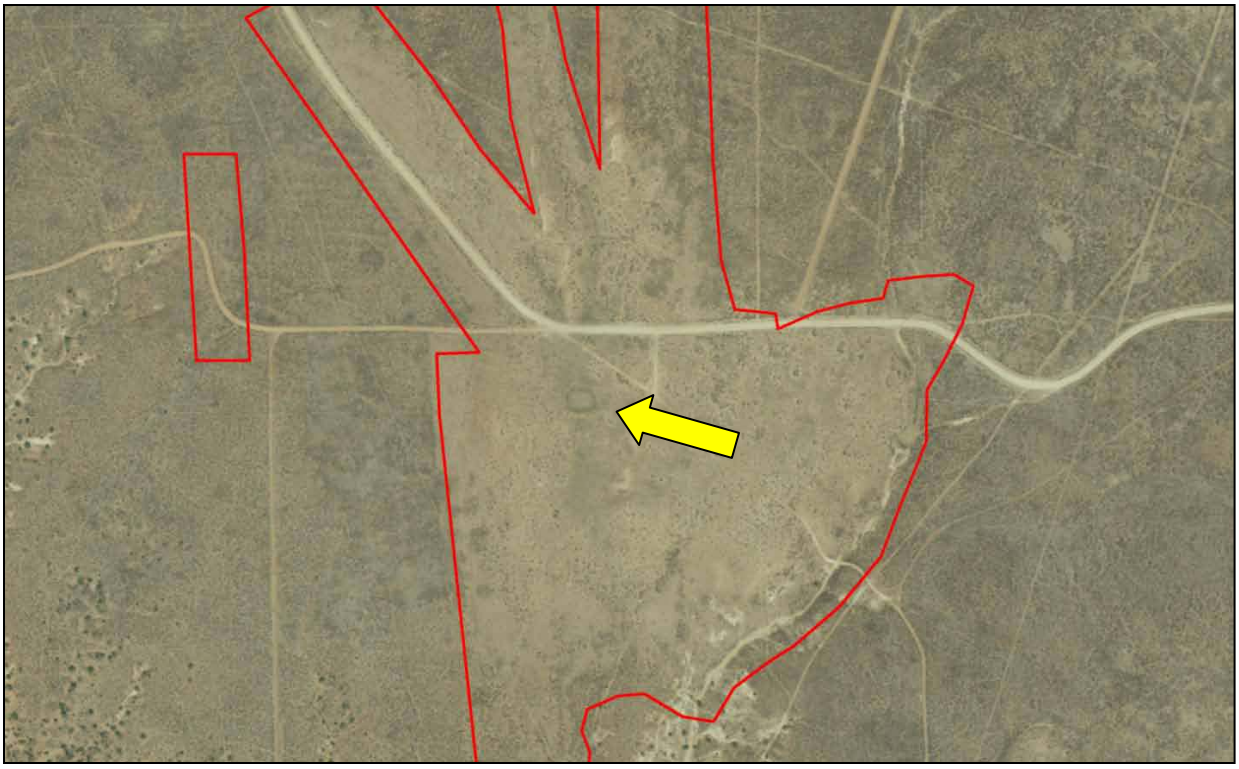
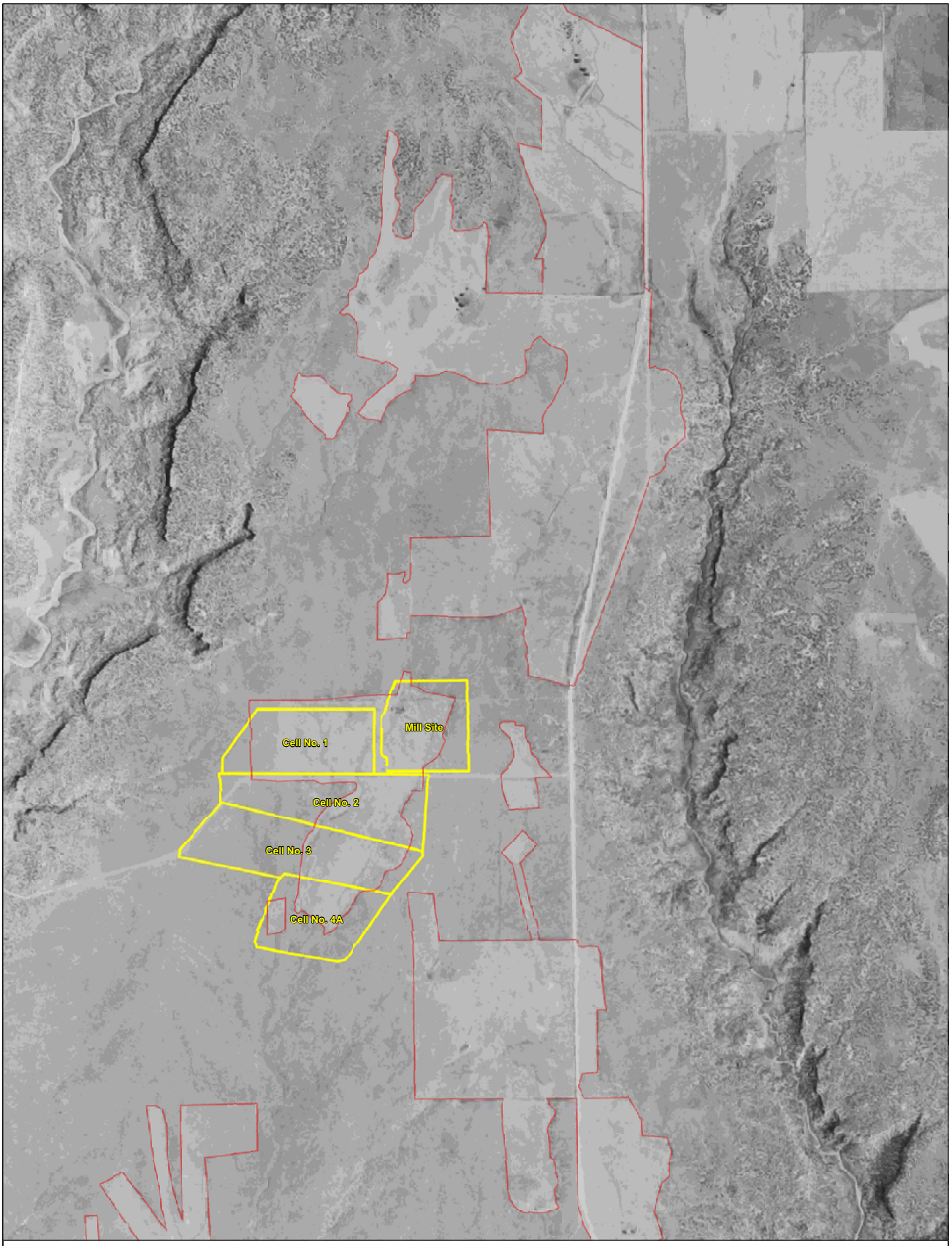


Figure 14. 2006 Aerial Photograph Showing the Stock Pond



Source(s): Aerial – Utah GIS Portal website

N
S

1,500 750 0 1,500
Feet

Legend

Historical_Clearings

Site Feature

Figure 15
Pasture Areas Interpreted
from 1955 Imagery

S:\Projects\UC-001-01-001 Denison Mines\GIS\mapdocs\2010_AerialImageryResearch\HistoricalAerialResearch_CP.mxd 01/10/2011

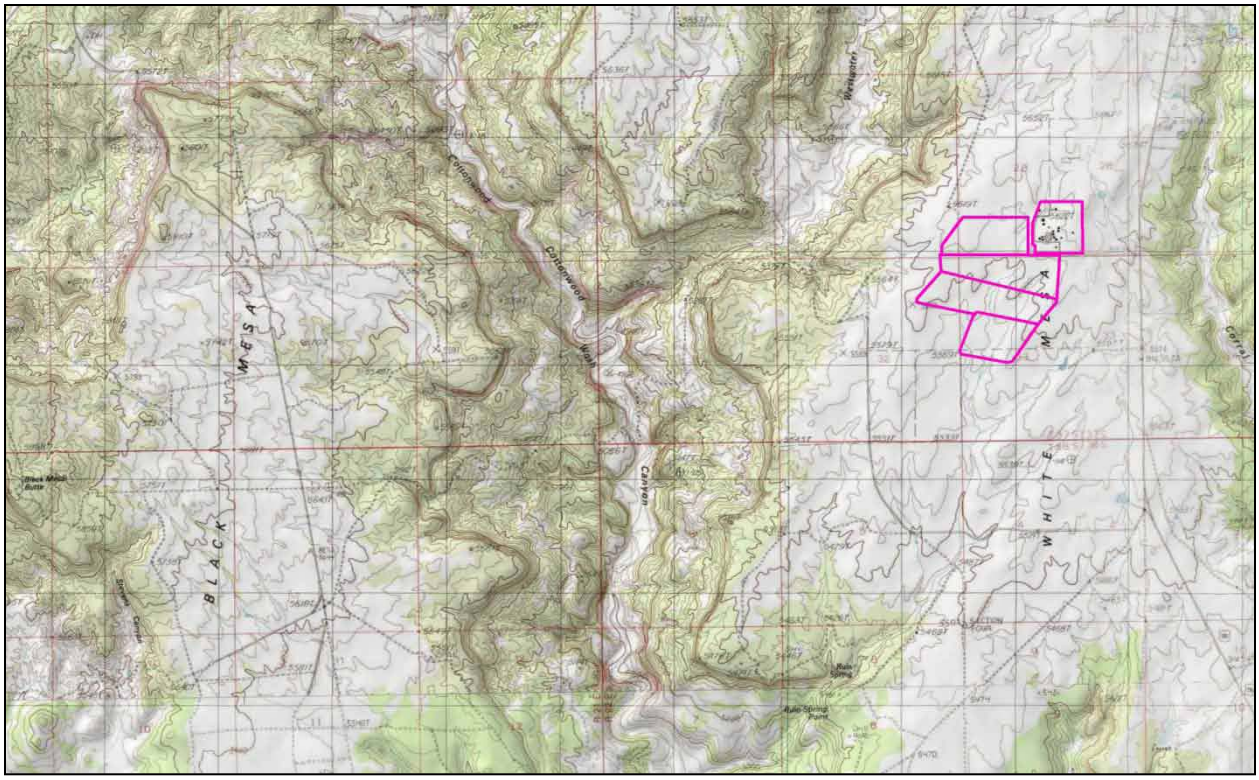
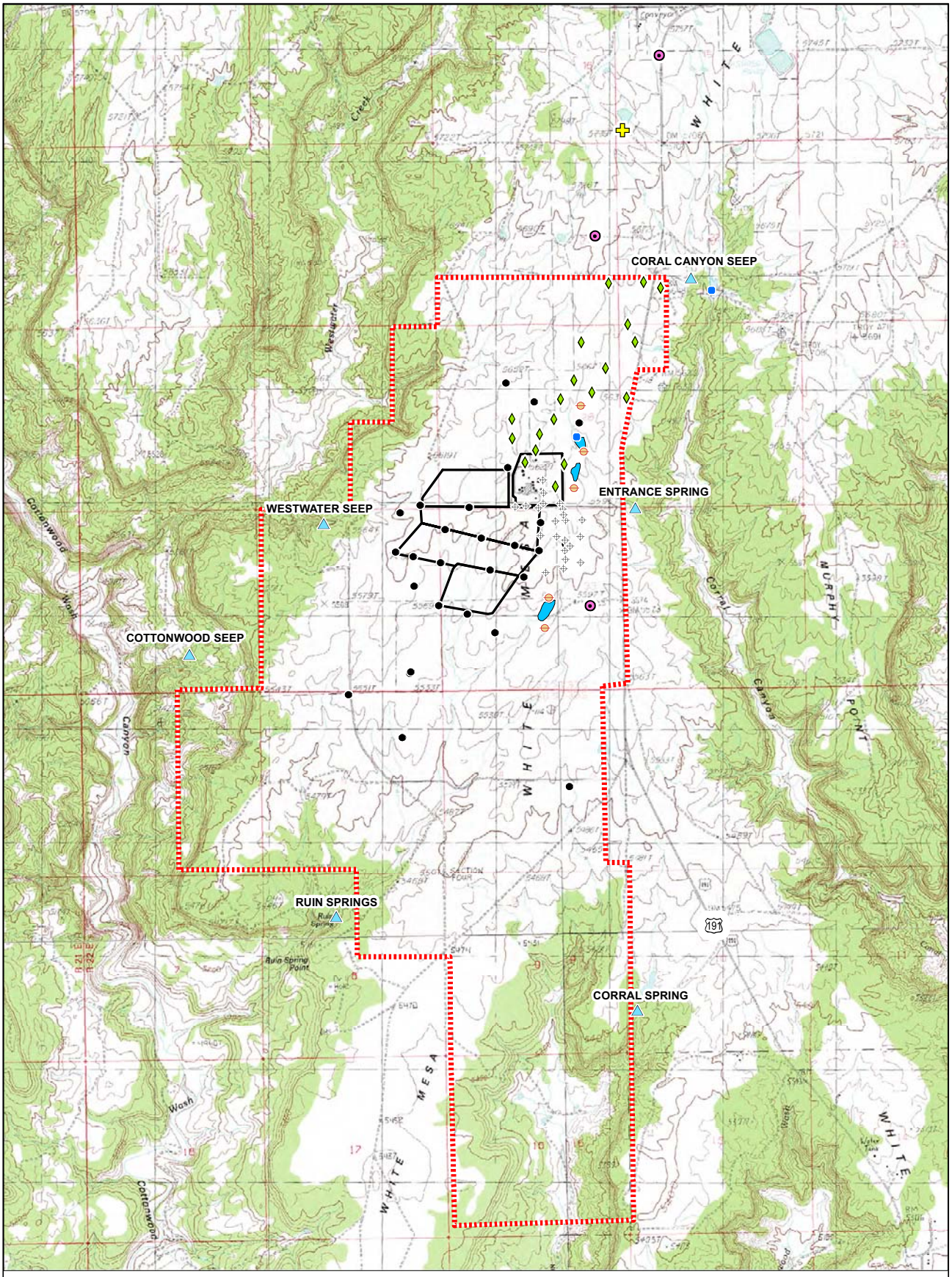


Figure 16. Location of Black Mesa relative to White Mesa

Figure 17. Radar Site at White Mesa near Blanding, Utah, June 21, 1967 (J. Willard Marriott Library, University of Utah, 2011)

Figure 18. Bivouac Site at White Mesa near Blanding, Utah, June 21, 1967 (J. Willard Marriott Library, University of Utah, 2011)



Source(s): Utah GIS Portal website

N
S

0.5 0.25 0 0.5 Miles

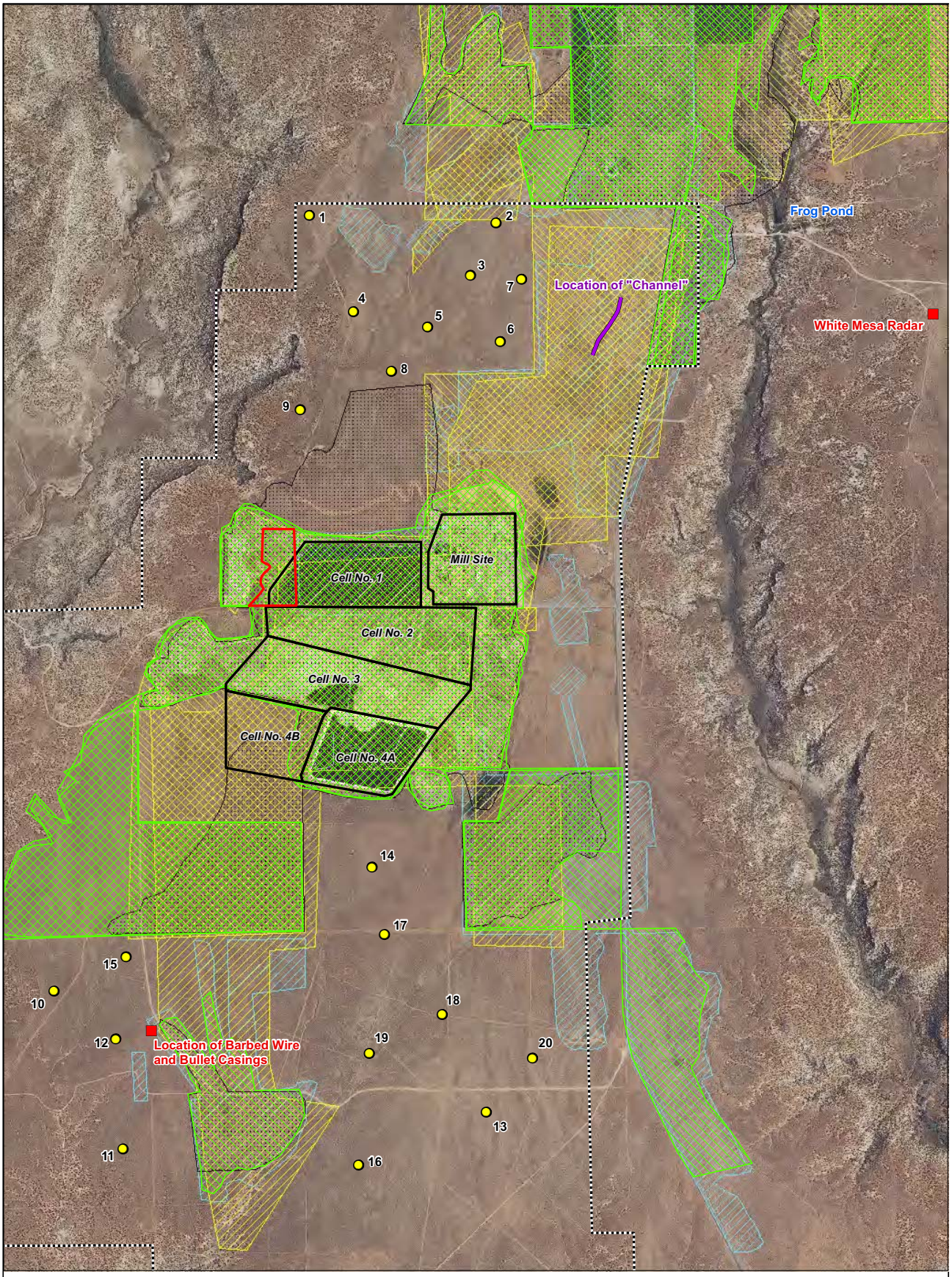
Legend

- DUSA Property Boundary
- Monitoring Well
- Piezometer
- Regional Well
- Spring/Seep
- Surface Water
- Chloroform Monitoring Well
- Nitrate Monitoring Well
- Windmill

Figure 19
Site Map with DUSA Property Boundary
Nitrate and Chloride Source Investigation

INTERA

S:\Projects\IUC-001-01-001 Denison Mines\GIS\mapdocs\2011_WP_Nitrate_Response\20110124SiteMap.mxd



Source(s): Utah GIS Portal website, dated 2009; U.S. Geological Survey

N
S

1,500 750 0 1,500
Feet

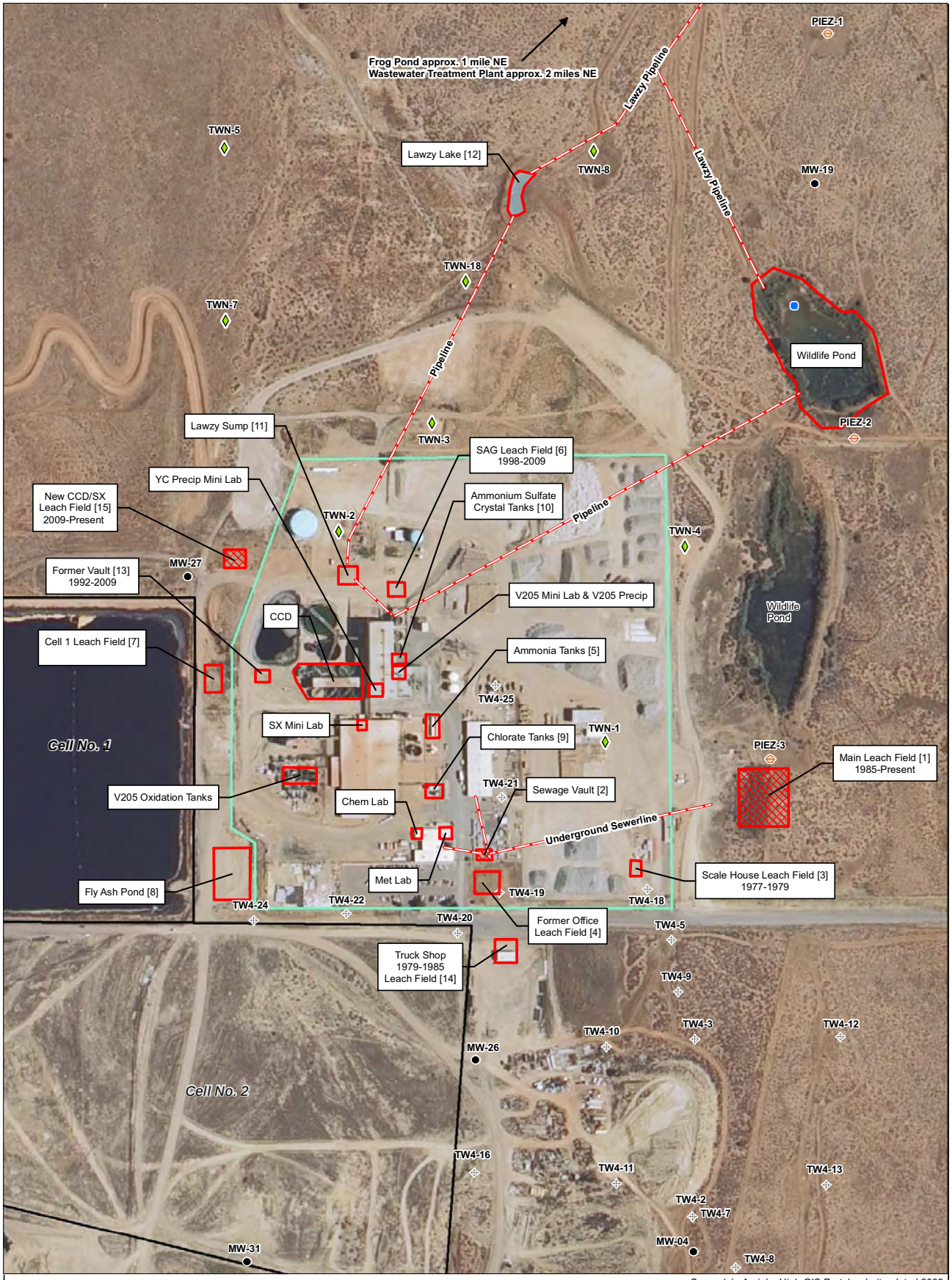
Legend

- Geoprobe Boring Location
- Pershing Missle Staging Area
- DUSA Property Boundary
- Historical Disturbance (From 2009 Imagery)
- Historical Disturbance (From 2006 Imagery)
- Historical Disturbance (From 1997 Imagery)
- Historical Disturbance (From 1984 Imagery)
- Historical Disturbance (From 1973 Imagery)
- Historical Disturbance (From 1955 Imagery)

INTERA

Figure 20
Natural Nitrate Reservoir:
Geoprobe Boring Locations
Supplemental Containment Investigation

S:\Projects\IUC-001-01-001 Denison Mines\GIS\mapdocs\2011_WP_Nitrate_Response\20110217Geoprobes.mxd



Source(s): Aerial – Utah GIS Portal website, dated 2009; Wells – HGC, Inc., May 2008 report.

N
S

300 150 0 300 Feet

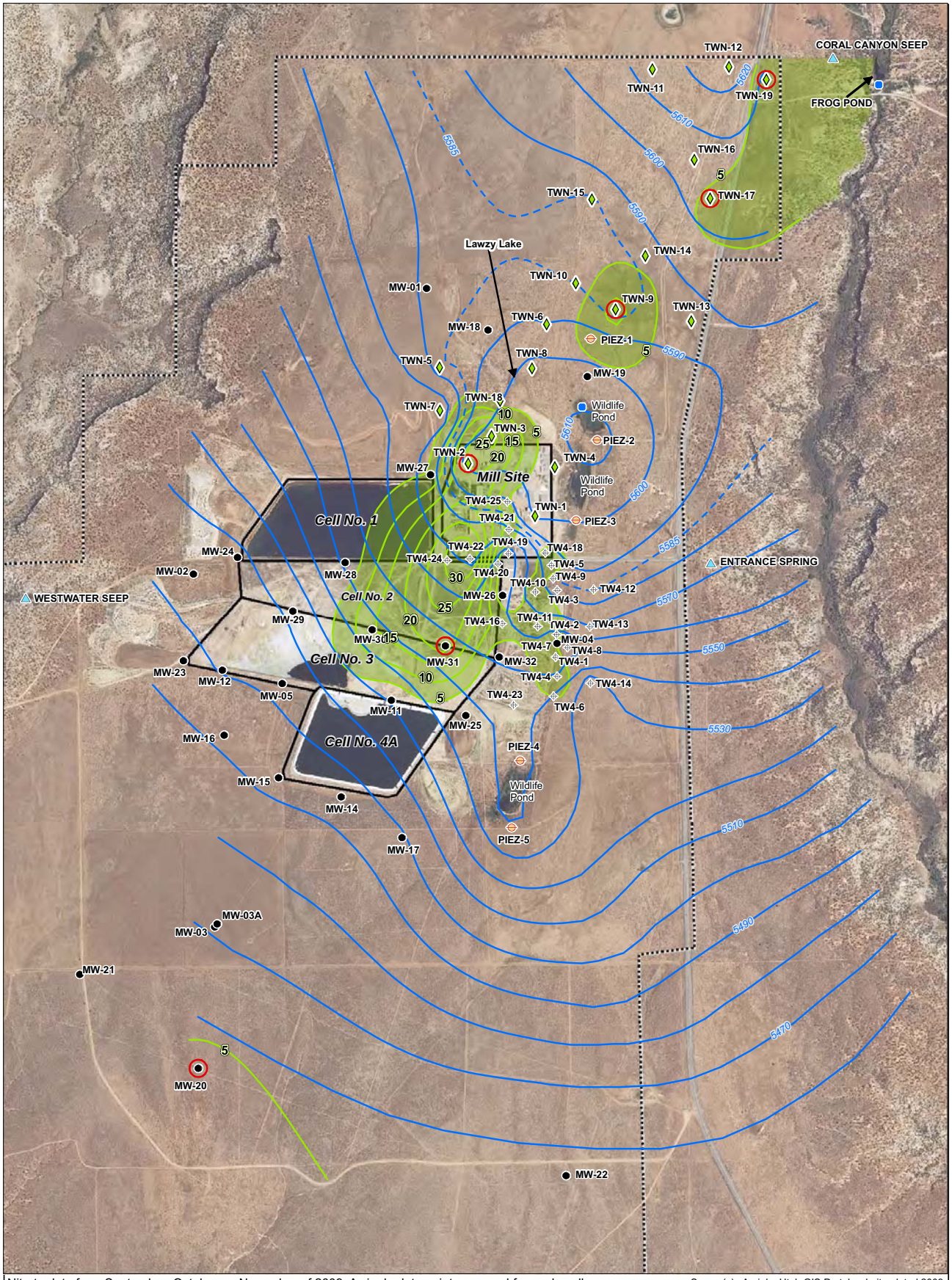
Legend

- Pipeline
- Potential Nitrate and Chloride Sources
- Leach Field (currently in operation)
- Leach Field – Geoprobe Boring and Core Drilling Location
- Monitoring Well
- Piezometer
- Spring/Seep
- Surface Water
- Chloroform Monitoring Well
- Nitrate Monitoring Well

INTERA

Figure 21
Nitrate Source Areas: Geoprobe Boring and Core Drilling Locations
Nitrate and Chloride Source Investigation

S:\Projects\IUC-001-01-001 Denison Mines\GIS\mapdocs\2011_WP_Nitrate_Response\20110121BoringsCoreDrilling.mxd



Nitrate data from September, October, or November of 2009. A single data point was used for each well.

Source(s): Aerial – Utah GIS Portal website, dated 2009; Wells – HGC, Inc., May 2008 report.

N
S

1,200 600 0 1,200 Feet

Legend

- DUSA Property Boundary
- Groundwater Elevation Contour (interval 10 ft)
- Groundwater Elevation Contour (interval 5 ft)
- Nitrate Concentration (mg/L)
- Stable Isotope Sampling Well
- Monitoring Well
- Piezometer
- Spring/Seep
- Surface Water
- Chloroform Monitoring Well
- Nitrate Monitoring Well

INTERA

Figure 22
Stable Isotope Sampling Wells
Nitrate and Chloride
Source Investigation

S:\Projects\IUC-001-01-001 Denison Mines\GIS\mapdocs\2011_WP_Nitrate_Response\20110121NitrateMap.mxd

Tables

Table 1. Work Plan Schedule

Denison White Mesa Mill Nitrate and Chloride Investigation

Task No.	Task and Subtask Description	Month													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	HISTORICAL LAND USE AND GEOMORPHIC STUDY														
	Order and evaluate satellite imagery														
2	GEOPROBE INVESTIGATION OF POTENTIAL NATURAL NITRATE RESERVOIR, 20 LOCATIONS														
	Borings, field tests														
	Laboratory analysis SPLP														
3	GEOPROBE BORINGS IN POTENTIAL NITRATE SOURCE LOCATIONS, 13 BORINGS, 2 INFLUENT WATER SAMPLES														
	Borings, field tests														
	laboratory analysis SPLP and influent water														
4	CORING STUDY TO EXPLORE FOR NATURAL NITRATE RESERVOIR														
	Core up to 4 locations														
	Laboratory preparation and SPLP analysis														
5	CORING STUDY IN POTENTIAL NITRATE SOURCE LOCATIONS														
	Core up to 13 locations														
	Up to 13 locations, core to laboratory for preparation and SPLP														
6	STABLE ISOTOPE STUDY, LABORATORY ANALYSIS														
	Water sampling from 6 existsing well locations, coordinate with quarterly groundwater monitoring event														
	Laboratory analysis														
7	MASS BALANCE CALCULATIONS														
	Integrate information from other studies and evaluate potential sources														
8	REPORT OF FINDINGS														
	Draft and Denison Review														
	Final														

Table 2
Laboratory Analytical Parameters by Task and Media

SOIL AND ROCK			
Geoprobe Borings			
All field test kit tests: Nitrate and Chloride			
Media:	**Soil**		
	Analyte	**Method**	**Container/Vol**
	Nitrate-Nitrite	SPLP[1]	sealable plastic bag 1 qt
	Total Keldal Nitrogen	SPLP	sealable plastic bag 1 qt
	Chloride	SPLP	sealable plastic bag 1 qt
Coring Study			
Media:	**Rock**		
	Analyte	**Method**	**Container/Vol**
	Nitrate-Nitrite	SPLP	sealable plastic bag 1 qt
	Total Keldal Nitrogen	SPLP	sealable plastic bag 1 qt
	Chloride	SPLP	sealable plastic bag 1 qt

GROUNDWATER				
Stable Isotopes Study				
Analyte	**Method**	**Container/Vol**	**Preservative**	**Comments**
d15N nitrate	mass spectrometer	1-L HDP[2]	None	means delta 15/14 ratio, seal tightly to eliminate evaporation
d18O nitrate	mass spectrometer	1-L HDP	None	means delta 18/16 ratio, seal tightly to eliminate evaporation
d18O water	mass spectrometer	1-L HDP	None	means delta 18/16 ratio, seal tightly to eliminate evaporation
dDeuterium water	mass spectrometer	1-L HDP	None	seal tightly to eliminate evaporation
Nitrate-Nitrite	300	250 mL HDP	H2SO4, cool	
Total Kjeldal nitrogen	351.2	125 mL HDP	none	
Chloride	300	125 mL HDP	cool	

Follow-up notes:

[1]synthetic precipitation leaching procedure (SPLP) No. 1312

[2]HDP=High Density Plastic

Andy Freeman, Hall Environmental Laboratory: 345-3975

Chris Eastoe, University of Arizona Isotopic Laboratory: 520 621-1638

deuterium "heavy water", "2H", "heavy hydrogen"

Appendix A

Nitrate Extraction and Field Test Procedure

5. Electrical Conductivity Test

Soil samples for the electrical conductivity (EC) test are taken from the 0- to 3-inch depth. Bulked soil samples from across the field can be collected, and two subsamples can be taken for analysis (See Chapter 1, Sampling Guidelines). **Electrical conductivity, pH, and soil nitrate are all measured from the same soil subsample.**

Materials needed to measure electrical conductivity (EC):

- **1/8-cup (30 mL) measuring scoop**
- **120-mL plastic containers with lid**
- **EC pocket meter (blue with black cap)**
- **squirt bottle**
- **calibration solution (0.01 M KCl)**
- **distilled water**

Did You Know?
Excess salts in soil can be a detriment to plant health. Salts can also hamper water movement into the soil and increase the occurrence of surface compaction.

1 Extract Subsample

The soil sample should be thoroughly mixed before taking a subsample. Measure a 1/8-cup level scoop subsample of soil and place it in the plastic container. If soil nitrates will be measured on this subsample (Chapter 7), weigh the subsample for a more accurate estimate of soil nitrates. Enter the subsample weight on the Soil Data worksheet.

2 Add Water to Subsample and Mix

- Add 1/8-cup (30 mL) of distilled water to the container with the subsample. The resulting soil/water mixture equates to a 1:1 soil to water ratio on a volume basis.
- Put the lid on the container and shake vigorously about 25 times.

Calibration Tip: Make sure the EC meter is calibrated before making a measurement. See Appendix C for calibration instructions.

3 Measure and Record EC (See Calibration Tip)

- Open the container and insert the EC pocket meter into the soil-water mixture. Take the reading while the soil particles are still suspended in solution. To keep the soil particles from settling, stir gently with the EC pocket meter. Do not immerse the meter above the immersion level (See Appendix C, Figure 1c). Allow the reading to stabilize (stays the same for about 10 seconds).
- Enter the EC reading on the Soil Data worksheet in decisiemens per meter (dS/m). The DiST WP 4 meter gives readings directly in dS/m. For the Microsensor 4 meter, divide the reading by 10, and for the Microsensor 3 meter, divide the reading by 100 to get readings in dS/m.
- Save the soil-water mixture for the pH measurement (Chapter 6).

4 Turn the meter off. Thoroughly rinse meter with distilled water and replace cap.

6. Soil pH Test

Use the same soil-water mixture prepared in the EC test to conduct the pH Test. **If you are starting with a fresh soil sample, read the introduction and follow Steps 1-3 in the EC Test Chapter on preparing the sample.**

Materials needed to measure pH:

- **1/8-cup (30 mL) measuring scoop**
- **plastic specimen bottle**
- **calibration buffer solutions**
- **squirt bottle**
- **pH pocket meter (red with black cap)**
- **distilled water**

Did You Know?
Soil acidification can also be an indication of excessive N fertilizer applications and N leaching loss.

Considerations: If the soil sample is saturated or very wet, a 1:1 ratio, on a volume basis, of soil to water will not be obtained in the soil-water mixture (See Step 2, Chapter 5). Let the soil dry before proceeding with Step 1 in Chapter 5. Also, a small amount of salts diffuse out of the pocket pH meter; therefore, **EC measurements should always be taken first when measuring both EC and pH on the same sample**.

1 Measure and Record pH

- Make sure to periodically calibrate your pH meter (See Appendix C for instructions). If the meter has not been used in a while, place the meter in tap water for about 5 minutes before calibrating or taking a reading.

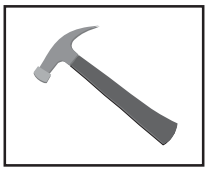
- Wait about 10 to 15 minutes after the EC measurement before measuring the pH. This gives the soil particles time to settle. Insert the pH pocket meter into the topmost portion of the solution and turn the meter on. Wait until the reading stabilizes (0-30 seconds), and record the digital reading on the Soil Data worksheet.

2 Rinse Pocket Meter

- Thoroughly rinse the electrode with distilled water.

- Store the electrode with a few drops of the **pH 7** buffer solution and replace the cap. (See Appendix C on storage of pH meter)

Maintenance Tips: Check the batteries and calibrate the EC and pH meters periodically. Be sure to clean the meters thoroughly to keep them working properly.



7. Soil Nitrate Test (NO_3^-)

Use the same sample prepared for the EC and pH tests to measure soil nitrates. **If you are starting with a fresh soil sample, read the introduction and follow Steps 1-3 in the EC Test Chapter on preparing the sample.**

Materials needed to measure soil nitrate:

- **filter paper**
- **120-mL plastic container with lid**
- **eye dropper**
- **nitrate/nitrite test strips**
- **stopwatch or timer**
- **distilled water**

Did You Know?
Soil nitrates are good measures of plant-available nitrogen, but they can be readily lost from the soil by leaching and volatilization.

1 Fold Filter

Fold the filter paper in half (into a semicircle). Fold it again, but not quite into a quarter-circle. Leave the edges a little uneven as in **Figure 7.1** (A black line is drawn for demonstration purposes.)

Figure 7.1

2 Insert Filter Paper into Subsample

Open the filter paper into the shape of a cone and push it (pointed part first) quickly into the jar with the soil/water mixture until it touches the bottom of the jar **(Figure 7.2)**. **Wait** until about an eye dropper-full of the solution has seeped through to the inside of the filter paper. **(Note: Inserting the filter paper quickly prevents it from wetting up and tearing as it is inserted.)**

[For Steps 3 & 4, it would be helpful to first familiarize yourself with the directions on the side of the bottle of nitrate strips.]

Figure 7.2

3 Place Drops on Nitrate Strips

Using the eye dropper and one nitrate/nitrite test strip, place 1 or 2 drops of the filtered solution on each of the strip's two pads. **Note the time.**

NOTE: One pad measures the amount of nitrite, and the other measures the amount of nitrite and nitrate combined. Nitrite rarely occurs in measurable amounts in soils, so nitrite readings from the test strips are not recorded.

4 Measure and Record Nitrate

- Align the nitrate/nitrite test strip with the bottom of the bottle with your thumb corresponding to the diagram on the bottle.

- **After 60 seconds,** compare the first pad (furthest from your thumb) along the nitrate scale as shown in **Figure 7.3**. Estimate the nitrate amount according to the degree of color change. Enter the value from the nitrate scale on the Soil Data worksheet in ppm. This value is an estimate of nitrate-N concentration in the extract.

NOTE: The nitrate test strips have a shelf-life. Check the expiration date on the bottle.

Figure 7.3

CALCULATIONS:

Estimated (lb NO_3-N/acre) =

$$\frac{\text{(ppm extract } NO_3\text{-N) x (depth of soil sampled in cm) x bulk density x 0.89}}{10}$$

Exact (lb NO_3-N/acre) =

$$\frac{\text{(ppm } NO_3\text{-N) x (volume water used) x (depth of soil sampled, cm) x bulk density x 0.89}}{\text{(dry weight of soil) x 10}}$$

Volume water used = 30.0 mL + [dry weight of soil x soil water content (g/g)]

Note: The maximum nitrate-N reading on the nitrate/nitrite test strip container is 50 ppm. If the sample reading falls into the 50 ppm category, the sample can be diluted to get a better estimate of the actual amount over 50 ppm. To dilute the sample, fill the eye dropper with filtered solution and place five drops in a plastic container. Add five drops of distilled water; mix gently by swirling the container. Take a reading with a new test strip as stated in Step 4. Multiply the estimated nitrate-N in ppm by 2 before using the calculations. If the nitrate reading falls into the category of 50 ppm again, repeat the dilution steps, and multiply the estimated nitrate-N in ppm by 4.

Did You Know?

Water samples may be taken from drinking water, well water, tile drainage, drainage ditches, and ponds. Dip a nitrate/nitrite test strip into the water and estimate the nitrate or nitrite concentration from the color chart on the test strip bottle. This test can give you an idea of how much N fertilizer is lost from the soil. **(See Chapter 12).**

Appendix B

Analytical Methods List

Appendix B

Analysis Methods for Soil Leachte

Synthetic Precipitation Leaching Procedure (SPLP): EPA Method 1312

Analysis for Nitrate and Chloride (Anions): EPA Method 300.0

Analysis for Total Kjeldhal Nitrogen (TKN): EPA Method 351.2