

NITRATE INVESTIGATION REVISED PHASES 2 THROUGH 5 WORK PLAN REV. 2.0

White Mesa Mill Site

Blanding, Utah

Prepared for:



Denison Mines (USA) Corp.
1050 17th Street, Suite 950
Denver, Colorado 80265

Prepared by:



6000 Uptown Boulevard NE, Suite 220
Albuquerque, New Mexico 87110

August 18, 2011



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ABBREVIATIONS AND ACRONYMS

Additional Studies	Additional studies to be performed by DUSA in order to complete the CIR
Agreement States	State agencies authorized to implement the U.S. Nuclear Regulatory Commission's licensing program under the Atomic Energy Act
amsl	above mean sea level
Analysis Monitor	employee or agent of the Analytical Laboratory
Analytical Laboratory	contract analytical laboratory
bgs	below ground surface
CAP	Corrective Action Plan
CCD/SX	Counter Current Decant/Solvent Extraction
CIR	Contamination Investigation Report
cm/s	centimeters per second
COC	chain of custody
Co-Executive Secretary	Co-Executive Secretary of the Utah Water Quality Board of the Utah Department of Environmental Quality
Consent Agreement	Stipulated Consent Agreement Docket No. UGW09-03 dated January 27, 2009
CSM	Conceptual Site Model
δ	delta
Data Users	data requestors/users
DOE	U.S. Department of Energy
DQO	data quality objectives
DRC	Utah Division of Radiation Control
DUSA	Denison Mines (USA) Corp.
EPA	U.S. Environmental Protection Agency
ft/yr	feet per year
GPS	global positioning system
GWDP	Groundwater Discharge Permit
ID	identification
INTERA	INTERA Incorporated
LCS	laboratory control sample
LU/LC	land use/land cover



MDL	method detection limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
Mill	White Mesa Mill
NAVLAP	National Voluntary Laboratory Accreditation Program
NELAP	National Environmental Laboratory Accreditation Program
New Theory	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
NOTICE	The October 5, 2010, DRC Notice of Additional Required Action
NRC	U.S. Nuclear Regulatory Commission
PG	Professional Geologist
Plan and Schedule	The plan and schedule for performing Additional Studies and submitting a revised CIR
QA	quality assurance
QA/QC	quality assurance/quality control
QAP	Quality Assurance Plan
QC	quality control
Request	Request for Voluntary Plan and Schedule to Investigate and Remediate Nitrate Contamination at the White Mesa Mill Site
RPD	relative percent difference
SAG	Semi Autogenous Grinding
Sampling and QC Monitor	Sampling and QC data monitor responsible for sample collection, record keeping, and QA/QC activities
SHP	southern high plains
Site	White Mesa Mill
SOP	Standard Operating Procedure
SPLP	Synthetic Precipitate Leaching Procedure
Tolling Agreement	A Tolling Agreement dated December 15, 2010, between DUSA and the Co-Executive Secretary
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality
USCS	Unified Soil Classification System



1.0 INTRODUCTION

Denison Mines (USA) Corp. (“DUSA”) received a Request for Voluntary Plan and Schedule to Investigate and Remediate Nitrate Contamination at the White Mesa Mill (the “Mill”) Site, near Blanding, Utah (the “Request”) from the Co-Executive Secretary (the “Co-Executive Secretary”) of the Utah Water Quality Board, of the Utah Department of Environmental Quality (“UDEQ”) on September 30, 2008. In the Request, the Co-Executive Secretary noted that groundwater nitrate as nitrogen levels have exceeded the State water quality standard of 10 milligrams per liter (“mg/L”) in certain monitoring wells at the Mill Site. For the remainder of this document, any reference to nitrate or ammonium, whether or not the reference specifies “as N,” means the analyte “as nitrogen.”

As a result of the Request, DUSA agreed to submit a plan of action and a schedule for Co-Executive Secretary approval for completion of a Contamination Investigation Report (“CIR”) to determine the physical cause(s), location(s), transfer mechanism(s), and characteristics of all source(s) of the nitrate contamination in order to form a basis for and facilitate later submittal of a groundwater Corrective Action Plan (“CAP”) that meets the requirements of Utah Administrative Code (“UAC”) R317-6-6.15D, or to demonstrate conclusively that DUSA did not cause or contribute to the nitrate contamination in any manner and that, as a result, such a CAP is not necessary. Subsequently, in a letter dated December 1, 2009, UDEQ, noting that elevated chloride concentrations exist, apparently coincident with elevated nitrate concentrations, recommended that DUSA also address and explain the elevated chloride concentrations.

DUSA and the Co-Executive Secretary entered into a Stipulated Consent Agreement Docket No. UGW09-03, dated January 27, 2009 (“Consent Agreement”), related to nitrate contamination at the Mill. Pursuant to Item 6.A of the Consent Agreement, DUSA submitted a Nitrate CIR for the White Mesa Uranium Mill Site, Blanding, Utah, dated December 30, 2009, to the Utah Division of Radiation Control (“DRC”). By a letter dated October 5, 2010, the Co-Executive Secretary notified DUSA of his determination that the CIR is incomplete.

By an email transmitted to the Co-Executive Secretary on October 20, 2010, and pursuant to Item 11 of the Consent Agreement, DUSA requested that the deadline stipulated in item 7.C of the Consent Agreement 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.

- c. DUSA would perform such investigations and submit a revised CIR in accordance with the agreed upon plan and schedule.

At an October 26, 2010, meeting with the Co-Executive Secretary, DRC staff, and legal counsel, DUSA reported that it was premature to submit a schedule for submittal of performance standards and a CAP 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"), specifically, 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. 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, and proposed additional studies relating to the New Theory, and other additional studies that DUSA believes may be relevant. At a November 30, 2010, meeting between DRC Staff and DUSA technical and regulatory staff, DUSA presented a number of additional studies (herein "Additional Studies") to be performed by DUSA in order to complete the CIR. 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. 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.

DUSA submitted a draft Work Plan on February 14, 2011. During subsequent discussions with DRC staff, the Co-Executive Secretary and DUSA agreed that the additional studies could require as many as five phases, and the schedule should include points of consultation between phases at which the Co-Executive Secretary and DUSA could evaluate and agree on the redirection, addition, or elimination of subsequent phases.

The Tolling Agreement was revised on April 28, 2011, to allow time for:



- DUSA to prepare and submit a Revised Work Plan for Phase 1 (the final was submitted May 13, 2011).
- DUSA to prepare and submit a revised Work Plan for Revised Phases 2 through 5 (by June 3, 2011), including a Conceptual Site Model (“CSM”) of potential nitrate sources.
- The Co-Executive Secretary to review and approve the revised Work Plans, including modifications.
- The Co-executive Secretary and DUSA to agree on a revised or replacement Consent Agreement that incorporates the deliverables and timelines in the approved Phase 2 through 5 Work Plan.

The tolling agreement was finalized on June 30, 2011.

This document is the revised Work Plan for Phases 2 through 5, which is being submitted in accordance with the Final Tolling Agreement and which contains information for the execution of Phases 2 through 5 as described in the Final Tolling Agreement. The Phases 2 through 5 Work Plan requirements specified in the Final Tolling Agreement Section 6 are shown below.

6. Phase 2 through 5 Work Plan Rev. 1.0– on or before August 4, 2011, DUSA shall complete and submit for Co-Executive Secretary review and approval a Revised Phase 2 through 5 Work Plan Rev. 1.0, which will include, but is not limited to:

a) Detailed description of the activities, equipment, procedures, performance objectives, and decision criteria involved in each Phase, including, but not limited to a description and incorporation by reference of the Phase 2 Detailed Work Plan and Schedule and a description of the agreed details and schedules relating to Phases 4 and 5.

This revision includes, by reference, the Phase 2 Detailed Work Plan, and provides agreed upon details of Phases 4 and 5.

b) An initial CSM of the facility (Revision 0), that DUSA will use as a guide to plan/conduct the Nitrate Investigation.

This is addressed as Section 2.0 of this document.

c) A logic diagram for each Phase to identify all studies and decision processes that may be required to meet all applicable regulatory requirements including the performance objectives of the Consent Agreement, Item 6(A)(iv).



Logic diagrams are attached as figures to this work plan.

- d) *Deadlines for commencement and completion of all field and laboratory work for each Phase, and the final CIR report preparation.*

Deadlines are provided on the schedule included as Table 1 to this document.

- e) *Deadline for submittal of a final revised CIR for Co-Executive Secretary review and approval.*

Deadlines are provided on the schedule included as Table 1 to this document.

1.1 Problem Definition

1.1.1 Purpose of the Investigation

Based on discussions culminating in the Revised Tolling Agreement, DRC and DUSA have agreed to conduct the nitrate investigation in phases. The multi-phased program is designed to evaluate a number of potential sources of nitrate and chloride that may have contributed to the identified plume, including Mill-related sources, non-Mill-related sources, and sources resulting from historical use. The phased approach will include development of a CSM that will be refined as the investigation progresses and will be used by DRC and DUSA at several decision junctures to:

1. Determine which sources should be removed from further consideration.
2. Assist in quantifying the relative contribution of the remaining sources.
3. Determine whether or not to proceed with future phases of the investigation.

The Phase 1 investigation is described in detail in the *Nitrate Investigation Revised Phase 1 Work Plan, White Mesa Mill Site*, dated May 13, 2011 (INTERA, 2011). The Phase 2 investigation is described in detail in the *White Mesa Uranium Mill Phase 2 Nitrate Investigation Detailed Work Plan and Schedule*, dated July 12, 2011.

This work plan describes the remaining phases of the investigation per the Final Tolling Agreement. Each of the phases contemplated by the Final Tolling Agreement is described briefly below. The purpose of Phases 2 through 5 is to collect data to fill the data gaps, test hypotheses, and update the CSM as described above. Additional plans, as delineated below, will be submitted to address the specific details, activities, equipment, procedures, objectives, and decision criteria for each of the phases specified in the Final Tolling Agreement.



1.1.1.1 Phase 2 – Groundwater Quality Sampling and Analysis

This phase of the investigation will collect groundwater samples from existing on-site wells. Groundwater will be analyzed for specific compounds associated with military activities at the Site and with agricultural use at the Site. A separate Phase 2 Detailed Work Plan and QAP for conventional groundwater sampling and analysis has been submitted which provides the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. The QAP is based upon the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill.

1.1.1.2 Phase 3 – Deep Bedrock Core Sampling and Analysis

This phase of the investigation will look at bedrock as a pathway for contaminant migration. Based on the results of Phase 1, locations will be selected for further analysis to trace nitrate and chloride from the base of the alluvium into bedrock. The activities associated with Phase 3 of the nitrate investigation are described herein. Specific location information will be provided at a later date after the receipt of the analytical data from Phase 1.

1.1.1.3 Phase 4 – Stable Isotopic Sampling and Analysis

Stable isotopes of nitrogen, sulfate, and ammonium will be used to identify and “fingerprint” the contamination in groundwater and compare it to the fingerprint of nitrate and chloride coming from potential sources. A separate Phase 4 Detailed Work Plan and QAP for isotopic groundwater sampling and analysis will be submitted which will provide the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. The Phase 4 QAP will be based upon and utilize the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The Phase 4 QAP will follow the same outline as the approved QAP and will supplement the approved QAP to address those activities which are specific to Phase 4 of the nitrate investigation.

1.1.1.4 Phase 5 – Isotopic Soil Sampling and Analysis

A determination regarding the necessity to complete Phase 5 will be completed after review of the data resulting from the previous phases of the nitrate investigation. If completed, Phase 5 will provide an isotopic “fingerprint” of potential sources of nitrate and chloride in process chemicals, soil, or deep cores. If this phase is required, a separate Work Plan and QAP will be submitted which will provide the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. A submittal date for the draft QAP for this phase will be established if consultation with DRC determines this phase is needed.



1.1.2 Site Description and Background

The Site is a uranium mill with a vanadium co-product recovery circuit located within the Colorado Plateau physiographic province approximately 5 miles south of the city of Blanding, Utah. Mill construction began in 1979, and conventionally mined uranium ore was first processed in May 1980. Over its 25-year operating history, the Mill has processed over 4 million tons of conventionally mined and alternate feed uranium ores for the recovery of 25 million pounds of U₃O₈ and 34 million pounds of vanadium to date.

Potential on-site sources of nitrate and chloride addressed in the Nitrate CIR (INTERA, 2009) include:

- The septic leach fields at the Site.
- The municipal sewage plant discharge water used historically as Mill water makeup.
- Livestock activities at the wildlife ponds.
- Livestock activities at the Historical Pond.
- Agricultural activities.
- The former Fly Ash Pond.
- Potential historical spills of ammonium-bearing and/or chloride-bearing process chemicals.
- A potential breach in the Mill circuit floor drains or tailings transfer lines.
- A potential leak in the Mill's tailings cells.

1.1.2.1 Site Status

The Mill was in standby status from November 1999 to April 2002. During the standby period, the Mill received and stockpiled alternate feed materials from the formerly utilized Ashland 1 and Linde remedial action program sites, as well as from other sources of alternate feed materials.

During the period from April 2002 to May 2003, the Mill processed 266,690 tons of alternate feed materials. Subsequently, the Mill entered standby mode but continued to stockpile alternate feed materials.

Uranium mills are licensed to operate either by the U.S. Nuclear Regulatory Commission ("NRC") or by state agencies authorized to implement the NRC's licensing program under the Atomic Energy Act ("Agreement States"). The Mill received its initial source material license from the NRC in 1980. The State of Utah became an Agreement State in 2005, at which time



regulatory authority for the Mill passed to the Utah DRC. The Mill is regulated under Utah Radioactive Materials License UT 1900479. Groundwater quality is regulated by the Mill's Utah Groundwater Discharge Permit ("GWDP") UGW370004.

The Mill is currently operating, having commenced operations in March 2005 with the processing of Cameco alternate feed materials. The Mill has since processed natural ores and alternate feeds. Alternate feeds have been processed both in the main Mill circuit and the alternate feed circuit, which was constructed in 2009.

1.1.2.2 Physical Setting

The Mill is located near the western edge of the Blanding Basin within the Canyonlands section of the Colorado Plateau physiographic province. Broad, generally horizontal uplift and subsequent erosion have produced topography consisting of high plateaus, mesas, buttes, monuments, and deep canyons incised into the relatively flat-lying Mesozoic and Paleozoic sedimentary rocks.

Northeast of the Mill Site, igneous intrusions forming the core of the Abajo Mountains have disturbed the classic flat-lying Colorado Plateau stratigraphy, resulting in uncharacteristic local folding and faulting of sedimentary rocks. The Abajo Mountains rise to more than 11,000 feet above mean sea level ("amsl"), and have likely provided a source of sediments to the Mill Site (5,600 feet amsl) during intrusion and disturbance of older rocks.

Quaternary deposits overlie the sequence of Mesozoic rocks present in the region. The Cretaceous Mancos Shale and Dakota Sandstone represent the local top of the Mesozoic section in the region and are underlain by the Lower Cretaceous Burro Canyon Formation. This unit is underlain in turn by the Jurassic Morrison Formation (which includes the Brushy Basin, Westwater Canyon, Recapture, and Salt Wash Members), the Summerville Formation, the Entrada Sandstone, and the Navajo Sandstone. The Navajo is underlain by the Jurassic Kayenta Formation, which in turn is underlain by the Triassic Chinle and Moenkopi Formations. Paleozoic sedimentary rocks underlie these Mesozoic units.

Cretaceous geologic units that stratigraphically overlie the Burro Canyon Formation regionally (Mancos Shale and Dakota Sandstone) have been removed by erosion in the vicinity of the Mill. Thus, the lower Cretaceous Burro Canyon Formation (already present during the Mid-Tertiary Abajo igneous intrusive event) is directly overlain by Quaternary deposits at the Mill Site. The Quaternary colluvial/alluvial sediments are typically coarse-grained deposits that contain little water. The Burro Canyon Formation is described as interbedded conglomerate and grayish-green shale with light-brown sandstone lenses deposited in a fluvial environment (Aubrey, 1989). The



average thickness of the unit is approximately 75 feet (U.S. Department of Energy [“DOE”], 2004).

The Burro Canyon Formation hosts the uppermost occurrence of groundwater at the Mill Site. Groundwater in this unit is perched (i.e., isolated from groundwater that occurs in geologic units that underlie the Burro Canyon Formation). Perched water is supported by the relatively impermeable, underlying, fine-grained Brushy Basin Member of the Morrison Formation. The permeability of the Burro Canyon Formation is generally low. Some conglomeratic zones may exist east to northeast of the tailings cells, potentially explaining a relatively continuous zone of higher permeability. The saturated thickness of the perched groundwater zone ranges from approximately 82 feet in the northeast portion of the Mill Site to less than 5 feet in the southwest portion of the Site (DOE, 2004). Groundwater isopleths, based on water level data collected in 2010, indicate that flow in the perched zone is generally from northeast to southwest, although in the eastern portion of the Mill Site, the gradient has a more southerly component.

Groundwater in the regional Entrada/Navajo aquifer is under artesian pressure (upward flow gradient), providing a hydrologic barrier to any potential seepage from overlying geologic units. Perched groundwater within the Burro Canyon Formation is characterized by low yields and is generally of poor quality, containing moderate to high concentrations of chloride, sulfate, and total dissolved solids (Hunt, 1996).

1.1.3 Summary of Previous Investigations

Previous investigations with respect to the presence of nitrate in groundwater under the Mill include a Nitrate and Chloride Source Review Memo (Tischler, 2009), a Nitrate CIR (INTERA, 2009), an Initial Nitrate Monitoring Report (DUSA, 2009), quarterly nitrate and chloride reporting to the DRC (DUSA, 2010-2011), and ongoing investigations into historical land uses, which have not yet been published.

The Nitrate and Chloride Source Review Memo (Tischler, 2009) identifies and discusses potential nitrate sources at the Mill Site, including septic leach fields, municipal sewage plant discharge water used historically as Mill water makeup, livestock activities at the wildlife ponds and the Historical Pond, the former Fly Ash Pond, potential historical spills of ammonium-bearing process chemicals, a potential breach in the Mill circuit floor drains or tailings transfer lines, Mill laboratories, and a potential leak in the Mill’s tailing cells. The Memo also discusses potential historical sources and offsite sources. The Memo concludes that the most likely sources of nitrate and chloride come from upgradient of the current plume in the municipal sewage plant discharge water used historically as Mill water makeup, from possible livestock activity near the Historical Pond, and possibly from septic leach fields at the Site, in particular, the Semi



Autogenous Grinding (“SAG”) leach field and the Main Leach Field. Since the publication of the Nitrate and Chloride Source Review Memo, DUSA’s understanding of historical land uses has continued to be updated through literature, Internet, and other land use studies, which are discussed below.

Land uses proximal to the Mill include farming, ranching, cattle grazing, and feed and grain silos. A further evaluation of historical land use in the vicinity of the Site will be performed to supplement the source evaluation (Source Review Report) (Tischler, 2009) that was included in the Nitrate 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 the goal is to sample areas that have not been subject to human activities. This analysis includes evaluation of historical aerial photography and historical Landsat satellite imagery, and an Internet-based search of historical military activities in the region.

The Nitrate CIR (INTERA, 2009) also discusses the potential sources identified in the Source Review Memo (Tischler, 2009) and describes the sampling design and installation of 19 new wells used to characterize the nitrate and chloride plumes. The CIR characterizes the nitrate and chloride plumes with the data collected from existing and new monitoring wells at the Mill. The investigation concludes that the nitrate and chloride appear to originate from the same source, which is upgradient of the Mill property more than 1.2 miles from the Mill facilities and was not caused by or contributed to in any manner by Mill activities. In the October 5, 2010 DRC NOTICE of Additional Required Action (“NOTICE”), DRC determined that the 2009 CIR is incomplete, and considered the conclusion regarding the sole source of the nitrogen contamination to be unsubstantiated with direct and reliable evidence. Furthermore, the NOTICE stated that DUSA has additionally identified several on-site sources which have a likelihood of being contributors to the contamination and have yet to be fully examined.

Beginning with the third quarter of 2009, DUSA performed quarterly sampling and analysis of the new nitrate wells.

1.2 Project Description

1.2.1 Project Objectives

The purpose of this nitrate investigation is to quantify nitrate and chloride in the alluvial soil column in selected locations at the Site with the following goals:



1. To establish background concentrations of nitrate and chloride in the alluvial soil in the vicinity of the Mill.
2. To use the data generated by this investigation to test the “new theory” hypothesis 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, which have been mobilized by natural and/or artificial recharge (Walvoord, et al., 2003; Scanlon, et al., 2005; and others).
3. To use the data to test hypotheses regarding to what extent Mill-related sources contributed, if at all, to the groundwater nitrate plume.
4. To use the data to test hypotheses regarding to what extent present or historic non-Mill-related sources contributed, if at all, to the groundwater nitrate plume.

The nitrate investigation has been divided into five phases which are described in detail in Section 3.0.

1.2.2 Project Measurements

Project measurements will include laboratory analysis of groundwater, soil, and rock chemistry, and Unified Soil Classification System (“USCS”) soil type classification made at the time of collection by visual-manual inspection as described in the *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) ASTM D 2488 – 09a* (ASTM, 2009). Note that the classifications presented in *ASTM D 2488 – 09a* are identical to the classifications presented in the *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) ASTM D 2487 – 10* (ASTM, 2010), but are derived from field observations rather than laboratory analysis. Rock core logging conventions, handling, sample preparation, and curating will be completed using best field judgment of a Utah State Professional Geologist, INTERA’s Standard Operating Procedure (SOP) 11 – Rotary Drilling and Coring, and the U.S. Bureau of Reclamation’s Engineering Geology Field Manual, Chapter 10, pages 276-287, as appropriate (Appendix A). Groundwater, soil, and rock samples will be submitted to the contract analytical laboratory (“Analytical Laboratory”) for analysis of the analytes specified in each of the activity-specific documents. The bedrock core analyses completed in Phase 3 of the investigation will be analyzed using the Synthetic Precipitation Leaching Procedure (“SPLP”) using U.S. Environmental Protection agency (“EPA”) Method 1312. Method 1312 will produce a leachate which will be analyzed for nitrate, chloride and sulfate, and ammonium using EPA Method 353.2, EPA Method 300.0, and EPA Method 350.1, respectively.



1.3 Quality Objectives

Specific quality objectives have been established for each of the data assessment parameters identified. These objectives are expressed as quantitative and qualitative statements concerning the type of data needed to support a decision, based on a specified level of uncertainty. The criteria (predetermined acceptance limits) are expressed as numerical values for laboratory analyses and field tests identified. Further discussion of the deep bedrock core sampling for each parameter and the rationale for its use is presented below.

1.3.1 Precision

Precision is defined as the measure of variability that exists between individual sample measurements of the same property under identical conditions. Precision is measured through the analysis of samples containing identical concentrations of the parameters of concern. For duplicate measurements, precision is expressed as the relative percent difference (“RPD”) of a data pair and will be calculated by the following equation:

$$RPD = [(A-B)/\{(A+B) /2\}] \times 100$$

Where A (original) and B (duplicate) are the reported concentrations for field duplicate sample analyses (or, in the case of analyses performed by the Analytical Laboratory, the percent recoveries for matrix spike and matrix spike duplicate samples) (EPA, 1994a, SW-846, Chapter 1, Section 5.0, page 28).

1.3.2 Accuracy

Accuracy is defined as a measure of bias in a system or as the degree of agreement between a measured value and a known value. The accuracy of laboratory analyses is evaluated based on analyzing standards of known concentration both before and during analysis. Accuracy will be evaluated by the following equation (EPA, 1994a, SW-846, Chapter 1, Section 5.0, page 24):

$$\% \text{ Recovery} = (| A - B | / C) \times 100$$

Where:

- A = the concentration of analyte in a sample
- B = the concentration of analyte in an unspiked sample
- C = the concentration of spike added

1.3.3 Representativeness

Representativeness is defined as the degree to which a set of data accurately represents the characteristics of a population, parameter, conditions at a sampling point, or an environmental



condition. Representativeness is controlled by performing all sampling in compliance with this work plan.

1.3.4 Completeness

Completeness refers to the amount of valid data obtained from a measurement system in reference to the amount that could be obtained under ideal conditions. Laboratory completeness is a measure of the number of samples submitted for analysis compared to the number of analyses found acceptable after review of the analytical data. Completeness will be calculated by the following equation:

$$\text{Completeness} = (\text{Number of valid data points} / \text{total number of measurements}) \times 100$$

Where the number of valid data points is the total number of valid analytical measurements based on the precision, accuracy, and holding time evaluation.

Completeness is determined at the conclusion of the data validation.

1.3.5 Comparability

Comparability expresses the confidence with which one data set can be compared with another. Comparability of data will be achieved by consistently following standard field and laboratory procedures and by using standard measurement units to report analytical data.

1.3.6 Detection and Quantitation Limits

The method detection limit (“MDL”) is the minimum concentration of an analyte that can be reliably distinguished from background for a specific analytical method. The quantitation limit represents the lowest concentration of an analyte that can be accurately and reproducibly quantified in a sample matrix. Project-required reporting limits are minimum quantitation limits for specific analytical methods and sample matrices that are typically several times the MDL to allow for matrix effects.

1.4 Project Organization

1.4.1 Functional Groups

This work plan specifies roles for a Quality Assurance (“QA”) Manager as well as representatives of three different functional groups: the data requestors/users, the data generators, and the data reviewers/approvers. The roles and responsibilities of these representatives are described below.



1.4.2 Overall Responsibility for the QA/QC Program

The overall responsibility for ensuring that the Quality Assurance/Quality Control (“QA/QC”) measures are properly employed is the responsibility of the QA Manager. The QA Manager is typically not directly involved in the data generation (i.e., sampling or analysis) activities. The QA Manager is a qualified person designated by DUSA corporate management.

1.4.3 Data Requestors/Users

The generation of data that meets the objectives of this work plan is necessary for management to make informed decisions to quantify nitrate and chloride in the bedrock in selected locations at the Site. The data generated by this investigation will be used to test hypotheses regarding potential sources of nitrate and chloride contamination, including naturally occurring sources. Accordingly, the data requestors/users (the “Data Users”) are DUSA’s corporate management and regulatory authorities. The data quality objectives (“DQOs”) required for any sampling event, such as acceptable minimum detection limits, are specified in this work plan.

1.4.4 Data Generators

The individuals who carry out the sampling and analysis activities at the request of the Data Users are the data generators. Field sampling activities, QA/QC activities, record keeping, and chain-of-custody (“COC”) activities are conducted by one or more sampling and quality control (“QC”)/data monitors (each a “Sampling and QC Monitor”) in accordance with this work plan. Data generation at the Analytical Laboratory utilized by the Mill to analyze the environmental samples is performed by or under an employee or agent (the “Analysis Monitor”) of the Analytical Laboratory, in accordance with the specific requirements of the Analytical Laboratory’s own QA/QC program.

The responsibilities of the data generators are outlined below.

1.4.4.1 Sampling and QC Monitors

The Sampling and QC Monitors are responsible for field activities. These include:

- a. Ensuring that samples are collected, preserved, and transported as specified in the work plan.
- b. Checking that all sample documentation (labels, field data worksheets, COC records, packing lists) is correct and transmitting that information, along with the samples, to the Analytical Laboratory in accordance with this work plan.
- c. Maintaining records of all samples, tracking those samples through subsequent processing and analysis, and, where applicable, appropriately disposing of those samples at the conclusion of the program.



- d. Preparing QC samples for field sample collection during the sampling event.
- e. Preparing QC and sample data for review by the QA Manager.
- f. Preparing QC and sample data for reporting and entry into a computer data base, where appropriate.

INTERA Incorporated's ("INTERA's") field manager, Rob Sengebush, will serve as Sampling and QC Monitor for Phase 3.

1.4.4.2 Analysis Monitor

The Analysis Monitor is responsible for QA/QC activities at the Analytical Laboratory. These include:

- a. Training and qualifying personnel in specified Analytical Laboratory QC and analytical procedures prior to receiving samples.
- b. Receiving samples from the field and verifying that incoming samples correspond to the packing list or COC sheet.
- c. Verifying that Analytical Laboratory QC and analytical procedures meet the Analytical Laboratory's QA/QC program, and are in accordance with the requirements for maintaining National Environmental Laboratory Accreditation Program ("NELAP") and/or National Voluntary Laboratory Accreditation Program ("NAVLAP") certification.

1.4.4.3 Data Reviewers/Approvers

The QA Manager has broad authority to approve or disapprove project plans, specific analyses, and final reports. In general, the QA Manager is responsible for reviewing and advising on all aspects of QA/QC, including:

- a. Ensuring that the data produced by the data generators meet the specifications set out in this work plan.
- b. Making on-site evaluations and submitting audit samples to assist in reviewing QA/QC procedures.
- c. Determining (with the Sampling and QC Monitor and Analysis Monitor) appropriate sampling equipment and sample containers, in accordance with this work plan, to minimize contamination.
- d. Supervising all QA/QC measures to assure proper adherence to this work plan and determining corrective measures to be taken when deviations from this work plan occur.



The QA Manager may delegate certain of these responsibilities to one or more Sampling and QC Monitors or to other qualified personnel.

1.5 Special Training and Certification

All soil and rock core logging will be overseen or conducted by a State of Utah Certified Professional Geologist (“PG”), using the *ASTM D 2488 – 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)* (ASTM, 2009), INTERA’s SOP 11 – Rotary Drilling and Coring, and the U.S. Bureau of Reclamation’s Engineering Geology Field Manual, Chapter 10, pages 276-287, as appropriate (Appendix A).

Site-specific training for all field personnel will be completed as required by Mill procedures and will be conducted by Mill personnel.

1.6 Documents and Records

1.6.1 Field Documentation

Field documentation will consist of, but not be limited to, detailed field note books, COC forms, and digital photographs. In addition, the locations of borings and other field activities will be recorded using a hand-held global positioning system (“GPS”) instrument. Soil and rock core logging and details from the boring such as sampling intervals and sample location will be recorded on a field boring log. Information from the field boring log will be used to create a final boring log. Copies of these forms are included in Appendix B. Completed forms will be included in the report. DRC requested the use of a boring log that matched WMMW-16. The log that will be used is located in Appendix B and contains the same relevant information fields. The boring log form does not include gamma or neutron logging fields or well completion fields, since those elements are not part of this investigation.

1.6.2 Reports Generated

Upon completion of the field work and laboratory analysis, a Report describing the results and the results of the QA/QC checks will be generated and submitted to the DRC.



2.0 CONCEPTUAL SITE MODEL

This CSM follows the *ASTM E1689-95(2003)e1 Standard Guide for Developing Conceptual Site Models for Contaminated Sites* (Appendix C).

2.1 Site Summary

DUSA's White Mesa property hosts an active uranium mill that is currently processing uranium ore. Concentrations of nitrate as nitrogen have exceeded the State of Utah's water quality standard of 10 mg/L in certain monitoring wells at the Mill Site. Typically, samples from wells that have exceeded the nitrate standard also have higher concentrations of chloride than samples from other wells at the Site.

2.2 Site Description

The purpose of this section is to identify the constituents of concern, establish background concentrations of those constituents, discuss potential source locations (including decisions and data needs for determining if a source is viable or can and should be eliminated), and discuss timing and duration of events required to account for the constituent mass observed in groundwater.

2.2.1 Identify Contaminants

DUSA received a *Request for Voluntary Plan and Schedule to Investigate and Remediate Nitrate Contamination at the White Mesa Mill Site*, near Blanding, Utah. The Request was dated September 30, 2008, and was received from the Co-Executive Secretary of the Utah Water Quality Board, of the UDEQ. In the Request, the Co-Executive Secretary noted that groundwater nitrate levels have exceeded the State water quality standard of 10 mg/L in certain monitoring wells at the Mill Site. Figure 1 is a regional map showing the location of the Mill Site. Subsequently, in a letter dated December 1, 2009, UDEQ noted that elevated chloride concentrations exist, apparently coincident with elevated nitrate concentrations. Therefore, nitrate and chloride are considered to be constituents of concern for this investigation. Table 2 presents the first quarter 2011 chloride and nitrate concentrations in groundwater.

2.2.2 Establishing Background Concentrations of Contaminants

Installation of 19 new monitoring wells has allowed the nitrate and chloride plumes to be fully bounded at the Site (Figures 2 and 3). On Figure 2, nitrate iso-contours start at 5 mg/L because that value appears to separate the plume from background. However, as evident from Figure 2, the 10 mg/L contour that defines the groundwater compliance limit for nitrate at a number of wells at the Site as specified in GWDP No. UGW370004 is completely closed and defined at the



Site. Per discussions with UDEQ, the nitrate plume is considered to have been bounded when the concentrations of nitrate in monitoring wells upgradient, downgradient, and in both crossgradient directions are less than 10 mg/L. There is no groundwater standard for chloride, but the iso-contours start at 100 mg/L because that value appears to separate the plume from background.

A feature of the plume maps is that the nitrate (Figure 2) and chloride plumes (Figure 3) are co-located geographically. Almost all locations that have elevated nitrate concentrations also have elevated chloride concentrations, implying that the nitrate and chloride impacts to groundwater had the same source. However, the nitrate plume shows a lobe extending to the southeast coincident with the chloroform plume (Figure 4), but the chloride plume does not. This indicates that elevated nitrate was present in the chloroform plume but chloride was not. The chloride plume demonstrates that there are two distinct plumes, a nitrate-chloride plume and a chloroform plume, which have distinctly different sources.

2.2.3 Source Locations, Boundaries, and Volumes

Potential on-site sources of nitrate and chloride addressed in the CIR (INTERA, 2009) include:

- The septic leach fields at the Mill Site.
- The municipal sewage plant discharge water used historically as Mill water makeup.
- Livestock activities at the wildlife ponds.
- Livestock activities at the Historical Pond.
- Agricultural activities.
- The former Fly Ash Pond.
- Potential historical spills of ammonium-bearing and/or chloride-bearing process chemicals.
- A potential breach in the Mill circuit floor drains or tailings transfer lines.
- A potential leak in the Mill's tailings cells.¹

Subsequent to publication of the CIR, other potential sources have been identified. One potential source is a natural nitrate reservoir. Such concentrations or “reservoirs” of nitrate and chloride have been identified in the scientific literature (Walvoord, et al., 2003; Scanlon, et al., 2005; and others).

¹ Based on extensive analysis in the background report, age dating of the groundwater reported in the University of Utah Report (Hurst and Solomon, 2008), mass balance analysis in the original CIR, and the fact that the presence of the nitrate plume is upgradient, the tailings cells are not considered a potential source and will not be studied specifically in Phases 1 through 5.

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).

A second potential source that has been identified is military use of the Mill Site as part of the Blanding Pershing Missile Launch Complex. Pershing missiles were tested by launching them from the Blanding site to a target at the White Sands, New Mexico, Missile Base. The Blanding operation was described as a “shoot and scoot” operation in which mobile launch vehicles would deploy to Black Mesa, adjacent to the White Mesa Bivouac site, fire their missiles and “scoot” back to the bivouac site. One possible scenario that may have resulted in nitrate and chloride contamination at White Mesa is as follows:

- The missile firing at Black Mesa caused clouds of oxidized constituents from burning of rocket motors to “exhaust” on the launch vehicles.
- Launch vehicles “scooted” back to White Mesa where they needed to be cleaned prior to the next launch.
- The military required a water source with which to clean the launch vehicles and several ponds were available at the White Mesa Site (notably, the Historical Pond, which was highly developed at the time – see 1968 aerial photograph with nitrate plume overlain [Figure 5]).
- Cleaning the launch vehicles involved washing them with pond water and letting that water drain directly to the soil near the pond where it infiltrated to groundwater, or returning it to the pond or other containment where it infiltrated to groundwater.

2.2.4 Time of Initiation, Duration, and Rate of Contaminant Release

Any potential source of nitrate and chloride must meet three necessary conditions 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.



Third, there must have been sufficient time to travel from the source through the vadose zone and then downgradient in groundwater to account for the current distribution of the nitrate/chloride plume.

Travel times through the vadose zone depend on the amount of head available to drive them, but have been calculated to be on the order of 18-20 feet per year (“ft/yr”) for a pond-like source that maintains a constant head (HGC, 2009). Thus, it would take approximately two to three years for nitrate and chloride from a pond-like source to reach groundwater, assuming groundwater is 40-60 feet below ground surface (“bgs”).

Perched zone pore velocities beneath and immediately upgradient of the tailings cells were calculated in HGC (2005), based on data from wells MW-23, MW-25, MW-27, MW-28, MW-29, MW-30, MW-31, MW-32, TW4-20, TW4-21, and TW4-22. Estimated hydraulic conductivities range from approximately 2×10^{-7} to 1×10^{-4} centimeters/second (“cm/s”) and yield a geometric average of approximately 3×10^{-5} cm/s or 31 ft/yr. Using hydraulic gradients in the vicinity of each well, the estimated conductivity at each well, and an effective porosity of 0.18, the estimated pore velocities ranged from 49.5 ft/yr at TW4-21, to 0.010 ft/yr at MW-23, and have a geometric average of approximately 4.5 ft/yr. Hydraulic gradients in the vicinity of most of these wells have not changed significantly since 2005, nor have the estimated pore velocities.

The current locus of highest nitrate concentrations in the plume is monitor well TWN-2, approximately 2,850 feet upgradient of monitor well MW-31 where nitrate concentrations have been stable since sampling began at that location in 2005. The average nitrate concentration in samples from MW-31 is 23 mg/L with a standard deviation of 3 mg/L. Assuming that 1) the highest of the estimated range of pore velocities (49.5 ft/yr) is representative, 2) the nitrate between TWN-2 and MW-31 resulted from a single source, and 3) no significant spreading or retardation of seepage occurred in the vadose zone, it would have taken a minimum of 57 years for nitrate to travel from TWN-2 to MW-31 in groundwater. If the Historical Pond had maintained a higher gradient in the vicinity of TWN-2 as was likely (see Figure 5 – current nitrate plume and wells overlain on 1968 aerial photograph), travel times may have been somewhat faster. However, the White Mesa Mill has been present at the Mill Site for only 31 years and there has been no pond at that location since then.

2.3 Migration Pathway Descriptions

A migration pathway is defined as the course through which contaminants in the environment may move away from the source(s) to potential environmental receptors, creating a potential exposure pathway. An exposure pathway is incomplete if any of the following elements are missing: 1) a mechanism of contaminant release from primary or secondary sources, 2) a



transport medium if potential environmental receptors are not located at the source, and 3) a point of potential contact of environmental receptors with the contaminated medium. As discussed in Section 2.4, for the Mill nitrate and chloride, there is no contact with human or ecological receptors.

Thirty-two (32) potential sources were identified in Section 2.3.3.1. Due to the large number of potential sources, similar sources will be grouped together for purposes of discussion. The first group consists of potential process-related sources such as on-site leach fields, Mill circuit sources, and chemical storage facilities. The second group contains ponds and pond-like features including disturbances observed on aerial photographs near far-upgradient and far-downgradient wells that contain elevated nitrate and chloride. This second group of sources also includes the locations of potential impact by military or agricultural uses of the Mill Site, described above. The third group of sources is related to the possibility that a natural nitrate reservoir existed in the vadose zone across the Mill Site prior to modern land use and that the change in land use mobilized that vadose zone reservoir and transported it to groundwater.

Figure 6 is a map showing the location of structural cross sections across the Mill Site. Figures 7 through 9 are structural cross sections with the locations of potential sources plotted on them. Note that the vertical exaggeration of the cross sections ranges from 3:1 to 20:1, which magnifies the apparent slopes of the contacts depicted in the diagrams. Figure 10 is a wire frame diagram of the elevation of the bedrock surface beneath the alluvium, the distribution and thickness of the Mancos Shale at the Site, and the location of structural cross sections. The distribution of the Mancos shown in Figure 10 coincides with the area(s) where the Mancos is estimated to be at least 5 feet thick. Figure 11 is an isopach map showing the thickness of the Mancos Shale with potential nitrate sources overlain. Figures 12 through 15 are schematic diagrams depicting pathways for each group of sources. There are two schematic diagrams for potential process-related sources, one depicting a thick section of Mancos Shale beneath the source and one depicting a thin section, due to the importance of that low permeability unit in the time and or pathway from the surface to groundwater.

Figures 10 and 11 show a paleoridge of Mancos Shale in the vicinity of the Mill Site that would presumably impact seepage from potential sources in two ways: 1) the thicker the Mancos, the slower the expected average rate of downward movement due to the relatively low permeability of the Mancos, and the greater the potential for lateral spreading; and 2) the steeper the slope of the alluvium/Mancos contact, the greater the potential for deflection of seepage downslope. Furthermore, should a mound develop beneath a seepage source, lateral flow from the center of the mound could cause seepage to move laterally in all directions including upslope. With regard to the potential for downslope movement at the margins of the Mancos paleoridge, seepage from



potential process-related sources such as the scale house leach field, may move in an easterly or southerly direction when it encounters the alluvial-Mancos interface, whereas seepage from potential process-related sources such as the SAG leach field on the other side of the paleoridge may be constrained to move in a westerly direction. Note that the thickness of the Mancos Shale beneath the location of the western half of the Historical Pond is less than 5 feet and is not expected to be a significant barrier.

Although the slope of the Mancos surface and the thickness of the Mancos are expected to influence potential seepage as discussed above, the Mancos does not appear to have significantly impacted chloroform seepage from either the abandoned scale house leach field or from the former office leach field. Chloroform migration rates based on hydraulic conductivity measurements in the Burro Canyon Formation south of the abandoned scale house leach field are consistent with relatively minor retardation of seepage in the vadose zone even though the Mancos is relatively thick in this area. Furthermore, the abandoned scale house leach field straddles the bedrock paleoridge suggesting that chloroform should have been diverted to the east or to the southwest away from the axis of the ridge if the ridge had exerted a significant influence. However, chloroform from this former source moved primarily south to MW-4 in the direction of the historic perched groundwater hydraulic gradient. Currently wells TW4-18, TW4-5, TW4-9, and TW4-3, located south of the abandoned scale house leach field, are outside the chloroform plume. Prior to 2002, all of these wells except TW4-9 were within the plume at one time or another. This indicates that prior to 2002, chloroform migration within the Burro Canyon Formation in this area was primarily to the south. In addition, if chloroform seepage had been diverted southwest along the slope of the bedrock surface, it is likely that the plume would have reached TW4-10 sooner than shown by the data. The past and current distributions of chloroform near the abandoned scale house leach field appear to be more a function of changing hydraulic gradients and flow directions due to seepage from the wildlife ponds, the permeability distribution of the Dakota Sandstone/Burro Canyon Formation, and chloroform pumping.

With regard to the former office leach field, chloroform has migrated to the northeast toward TW4-21, which is upslope with respect to the Mancos paleoridge. This behavior is more consistent with the presence of a former perched water mound that caused chloroform to move in all directions away from the leach field source area rather than with diversion along the bedrock slope.

The behavior of chloroform originating from former leach field source areas suggests that Mancos surface topology and/or thickness may or may not exert a significant influence on seepage from potential nitrate sources.



Once seepage migrates into the Dakota Sandstone/Burro Canyon Formation, the relatively thin, sub-horizontal, discontinuous, interbedded shale and conglomeratic zones depicted in the cross sections are expected to exert some influence on the movement of the seepage. The impact of the interbedded shales is expected to be retardation and lateral spreading of seepage because of the relatively low permeability of the shales. The impact of the interbedded conglomeratic zones is expected to be mainly lateral spreading of the seepage. Hydraulic testing at the Mill Site indicates that conglomeratic zones may or may not have higher permeability than surrounding sandstones, and suggests that the degree of cementation is an important control in the permeability of these materials. Overall, the Mancos Shale, where thicker than about 5 feet, is expected to exert more influence on seepage than the sub-horizontal, relatively thin and discontinuous shale and conglomeratic zones present in the Dakota Sandstone and Burro Canyon Formations. However, as discussed above, the Mancos appears to have had minimal impact on chloroform in seepage originating from the abandoned scale house and former office leach fields, suggesting that its impact may be similarly small on seepage from potential nitrate sources.

2.3.1 Soil and Bedrock

Assuming that the nitrate and chloride sources originated at the ground surface or within the alluvial soil (natural nitrate reservoir), alluvial soils and bedrock at the Mill Site would be a potential pathway for contaminant migration. A soil and bedrock investigation is ongoing in Phases 1 and 3 of this investigation and early indications are that there is a nitrate and chloride presence connected with this source.

2.3.2 Groundwater

Groundwater flow at the Mill Site is generally to the southwest toward discharge points such as Ruin Springs. Groundwater is a potential pathway for contaminant migration. It has been estimated that travel times between the downgradient edge of Tailings Impoundment 3 and Ruin Spring (the nearest location of a potential receptor), a distance of 10,000 feet, would be between 3,300 to 14,000 years.

2.3.3 Specific Source Locations and Data Needs

This section evaluates each potential source location or feature and states the hypothesis that describes the potential pathway to groundwater that might cause observed concentrations of nitrate and chloride in groundwater. The decision that is required to determine whether any hypothesis is correct is stated explicitly. Data needs, data gaps, and data that will be collected for each potential source are also described. For the purpose of developing the logic diagrams (Figures 16-19) and the CSM diagram (Figure 20), potential source locations can be classified by type: potential mill-process-related sources, potential pond-related sources (Fly Ash Pond,



Historical Pond, wildlife pond, Lawzy Lake, and other pond-like sources), and the potential natural nitrate/chloride reservoir source. Please refer to the logic diagrams and the CSM for each group of sources.

The following section will discuss each source and the decision criteria. The terms as defined below are used in the discussions in Section 2.3.3.1.

1. Hydrogeologic Study

DUSA will perform a hydrogeologic evaluation (the “Hydrogeologic Evaluation”) of each potential source to determine if any potential contamination from the potential source could have contributed to the plume. The Hydrogeologic Evaluation will evaluate the vertical permeability of soil and bedrock beneath the surface area from available lithologic logs of soil and bedrock (including logs from Phase 1 and Phase 3 activities). The Hydrogeologic Evaluation will also evaluate the permeabilities within the perched aquifer and rates of groundwater movement in that aquifer between each potential source to the upgradient and downgradient edges of the plume, as appropriate, based on existing permeability information. To the extent data is available, the Hydrogeologic Evaluation will also consider elevations of the alluvial/bedrock interface and other geologic information if appropriate. The Hydrogeologic Evaluation will be submitted to the Executive Secretary for review and comment on or before December 17, 2011.

2. Isotopic Analysis

Phase 4 of the investigation contemplates the performance of a stable isotope analysis of groundwater, with details to be provided later, and Phase 5 contemplates the performance of isotopic soil sampling and analysis, if needed. These Phase 4 and Phase 5 analyses, which may include age dating of water, are referred to in this work plan as the “Isotopic Analysis.” The purpose of the Isotopic Analysis is to determine the isotopic fingerprint (the “Isotopic Fingerprint”) of the plume and of each source, if required. Each Isotopic Fingerprint may be based in part on stable isotope analyses and in part on age dating of water. The details of the Isotopic Analysis and the factors to be considered in developing each Isotopic Fingerprint will be determined, in connection with the review and Executive Secretary approval of more specific plans for Phase 4 and Phase 5, which will be submitted at later dates. The terms “statistically comparable” and “uniquely identifiable” will be defined in the QAPs for these phases.

3. Weight of Evidence

In those circumstances where a potential source cannot be dismissed as not contributing to the plume or included as contributing to the plume based on definitive criteria specified in Section 2.3.3.1, it will be necessary to make a determination whether or not to dismiss or include the



potential source based on the existing weight of evidence (the “Weight of Evidence”). For the purposes of this work plan, a Weight of Evidence analysis means an analysis that weighs the preponderance of all relevant available information to arrive at a decision. It is expected that such an analysis will involve evaluating several different lines of evidence, each of which may not be conclusive by itself in arriving at the decision, but which together can lead to the decision.

4. Potential and Possible Sources

In the discussion in Section 2.3.3.1 below, all sources to be evaluated under this work plan are referred to as “potential sources.” Potential sources that cannot be definitively rejected or included based on the criteria in Section 2.3.3.1, and which must undergo a Weight of Evidence analysis, are referred to in Section 2.3.3.1 as “possible sources.”

2.3.3.1 Potential Nitrate/Chloride Source Locations

Potential Nitrate Source Locations:

1. Main leach field (also known as leach field east of scale house, 1985 to present)
2. Sewage vault/lift station (currently active)
3. Scale house leach field, (also known as leach field south of scale house, 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. Sodium chlorate tanks (as a potential chloride source)
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. New Counter Current Decant/Solvent Extraction (“CCD/SX”) leach field (currently active)
16. Historical Pond (two hypotheses, 16-1 and 16-2)



17. Wildlife pond (two hypotheses, 17-1 and 17-2)
18. CCD (included inadvertently and eliminated as discussed below)
19. YC Precip Mini-Lab
20. V2O5 Mini-Lab & V2O5 Precip (two hypotheses, 20-1 and 20-2)
21. SX Mini-Lab
22. Chem Lab
23. Met Lab
24. V2O5 oxidation tanks (two hypotheses, 24-1 and 24-2)
25. Natural nitrate reservoir
26. – 32. Other ponds or pond-like sources

1. Main leach field (also known as leach field east of scale house, 1985 to present)

Hypothesis 1: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: The main leach field is more than 1,800 feet south of the upgradient boundary of the main nitrate and chloride plumes. Further, this potential source is cross gradient to the plumes.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1985) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).



Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background as defined in section 3.3.1, perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background as defined in section 3.3.1, proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



2. Sewage vault/lift station (currently active)

Hypothesis 2: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: This potential source is more than 1,900 feet downgradient of the upgradient boundary of the main plume. Therefore it is unlikely that this source could be a major contributor to the nitrate and chloride plumes.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background as defined in section 3.3.1, perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the



hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background as defined in section 3.3.1, proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



3. Scale house leach field, (also known as leach field south of scale house, 1977-1979)

Hypothesis 3: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: The scale house leach field is approximately 2,000 feet south of the upgradient boundary of the main nitrate and chloride plumes.. Further, this potential source is cross gradient to the plumes.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1977) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the



hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



4. Former office leach field

Hypothesis 4: Nitrates and chlorides originating from sewage or process chemicals and/or laboratory wastes (prior to 1981) may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: This potential source is more than 2,000 feet downgradient of the upgradient boundary of the main plume. Therefore it is unlikely that this source could be a major contributor to the nitrate and chloride plumes.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the



hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

5. Ammonia tanks

Hypothesis 5: Ammonium may have leaked from the tanks through the alluvial soil and bedrock to groundwater to the plume and oxidized from ammonia to nitrate. Nitrogen in the ammonia tanks is solely in the ammonium (NH_4^+) form. Ammonium cations are typically strongly retarded in a soil-water system and likely would not travel through the alluvium and bedrock in the ammonia form. It would have to be converted to the nitrate in a process above the alluvium or in the near subsurface. Subsequently, there would have to be a source of water or other fluid (such as a pond) immediately below or adjacent to the ammonium tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater. If this were the case, nitrogen would be detected as the nitrate (not ammonia) form continuously through the alluvium and the bedrock. The ammonia tanks are not a source of chloride.

Known Conditions: There is no evidence that there has ever been ponded water in the vicinity of the ammonia tanks. Further, this feature is more than 1,500 feet downgradient of the upgradient boundary of the main plume, making it unlikely that this potential source is a major contributor to the nitrate plume.

Necessary Conditions: a) Is there evidence of nitrate concentration in the vadose zone beneath this feature? b) Is nitrate present in the alluvium and bedrock cores below this feature? c) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonia to nitrate? d) Was there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this potential source have sufficient mass to have contributed measurably to nitrate observed in the plume? f) Has there been sufficient time since this potential source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach the plume? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume. And g) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction



potential in the groundwater beneath this feature. Possible need for Isotopic Analysis Data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Need ammonium and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis Data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



6. SAG leach field (leach field north of mill building, 1998 to 2009)

Hypothesis 6: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: The SAG leach field is 1,000 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1998) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is



not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



7. Cell 1 leach field (leach field east of Cell #1, 1979 to 1985)

Hypothesis 7: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: The cell 1 leach field approximately 1,600 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is



not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

8. Fly Ash Pond

Hypothesis 8: Nitrates and chlorides associated with coal and coal ash, and potential runoff from Site processes, could have ponded and may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. The pond received coal fly ash, containing oxidized nitrogen (the nitrate not ammonium form) sporadically from 1980 to 1989. The pond could have potentially received some washwaters containing ammonium nitrogen from the vanadium circuit from 1980 through the present.

Known Conditions: The Fly Ash Pond is approximately 2,200 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate, and/or ammonium, and chloride concentrations in the vadose zone beneath this feature? b) If ammonium is present, is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonium to nitrate? c) Was there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? d) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? And e) Has there been sufficient time since this potential source was put into service (circa 1981) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times



background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



9. Sodium chlorate tanks

Hypothesis 9: Chlorides associated with sodium chlorate storage may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. If this were an appreciable source, it would also be associated with measurably elevated sodium in soil and/or groundwater adjacent to and beneath the tank area. Sodium chlorate is not a source of nitrogen atoms and has been retained for evaluation as a chloride source.

This is a low priority source, and is inaccessible to drilling and coring. Since it is not a source of nitrate, it will not be subject to physical investigation and has only been retained in the list of hypotheses for completeness.



10. Ammonium sulfate crystal tanks

Hypothesis 10: Ammonium sulfate crystals may have spilled around the ammonium sulfate crystal tanks. Over time and with rain, the ammonium converts to nitrate and may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. Nitrogen in the ammonium sulfate tanks is solely in the ammonium (NH_4^+) form. Ammonium cations are typically strongly retarded in a soil-water system and likely would not travel through the alluvium and bedrock in the ammonium form. It would have to be converted to the nitrate from a process above the alluvium or in the near subsurface. That is, there would have to be a source of oxygenated water or other oxidizing fluid (such as a pond) immediately below or adjacent to the ammonium sulfate tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater. If this were the case, nitrogen would be detected as the nitrate (not ammonium) form continuously through the alluvium and the bedrock. The ammonium sulfate tanks are not a source of chloride. A combination of elevated nitrate and sulfate in the soil adjacent to or beneath the tanks or in the groundwater near the tanks would support this as a possible source.

Known Conditions: The ammonium sulfate crystal tanks are approximately 1,200 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate concentration in the vadose zone beneath this feature? b) Are nitrate and sulfate both elevated in the alluvium and bedrock cores below this feature? c) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonium to nitrogen? d) Was there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this source have sufficient mass to have contributed measurably to nitrate observed in the plume? f) Has there been sufficient time since this source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach groundwater? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume. And g) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction



potential in the groundwater beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Need ammonium and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

11. Lawzy sump

Hypothesis 11: This unlined sump was used to pump water from Lawzy Lake (which was filled from the frog pond that may have contained water from the municipal water treatment plant located north of the Mill) to Mill processes. Nitrate- and chloride-laden water from the sump may have leached through alluvial soil and bedrock to groundwater and contributed to the plume. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin.

Known Conditions: Lawzy sump is approximately 1,100 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in groundwater? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, ammonium, and cryptosporidium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times



background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



12. Lawzy Lake

Hypothesis 12: Nitrate- and chloride-laden water from Lawzy Lake (which was filled from the frog pond, which may have contained water from the municipal water treatment plant located north of the Mill) may have leached through alluvial soil and bedrock to groundwater and contributed to the plume. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin.

Known Conditions: Lawzy Lake is approximately 300 feet upgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine



if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



13. Former vault/lift station (to former office leach field, 1992 to 2009)

Hypothesis 13: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: The former vault is approximately 1,500 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1992) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is



not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



14. Truck shop leach field (1979-1985)

Hypothesis 14: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: The truck shop leach field is approximately 2,300 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is



not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



15. New CCD/SX leach field (currently active)

Hypothesis 15: Nitrates and chlorides originating from sewage or process chemicals may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Known Conditions: The CCD/SX leach field is approximately 1,200 feet downgradient of the upgradient margin of the main plume. This leach field did not yet exist when the nitrate plume was identified.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (2009) for detectable levels of constituents from this potential source to reach groundwater, and if so, to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the



hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

16. Historical Pond

Hypothesis 16-1: The Historical Pond was associated with agriculture and may have been used as a stock pond or a fertilizer mixing pond, or may have collected fertilizer from runoff of nearby agricultural land. Nitrate- and chloride-laden water from the Historical Pond may have leached through the alluvial soil and bedrock to groundwater. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin. Based on anecdotal information (interviews with landowners), the pond area was one of several areas that may have been used for dumping truckloads of salt for cattle salt licks. If this is correct, elevated levels of sodium chloride may be present in soil and/or groundwater in the areas of the Historical Pond. Historical sheep dipping activities may also have impacted the pond.

Known Conditions: The Historical Pond has been in existence since the 1920's and has had sufficient head to infiltrate to groundwater at various times throughout that history. The source of ponded water and its quality is unknown but the primary purpose of the pond has been agricultural. Historical aerial imagery from 1968 shows that the Historical Pond at that time was larger than the current Northern Wildlife Pond, which is responsible for the current groundwater mound beneath the mill site. The Historical Pond was in place and full during the time frame that the Blanding Pershing Missile Launch Complex was using the White Mesa site but was removed before the White Mesa uranium mill began operations. The Historical Pond was located directly above the upgradient portion of the uranium and nitrate plumes beneath the mill site and directly above the locus of highest nitrate concentrations. As stated in Section 2.2.4, travel times in the perched aquifer suggest that it took a minimum of 57 years for the nitrate and chloride plumes to develop to their current extent and the Historical Pond is one of the few potential sources that were present on White Mesa 57 years ago.

Necessary Conditions: a) Is there evidence of nitrate, sodium, or chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in groundwater? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is

statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Sufficient (But Not Necessary) Condition: Is cryptosporidium present in the same media (soil or groundwater) with elevated levels of nitrate?

Data Needs for Decision: Data on the concentration of nitrate and/or ammonium, sodium, chloride, and cryptosporidium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on concentrations of the same constituents in groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, ammonium, sodium, and cryptosporidium concentration data from the bedrock portion of the vadose zone. Data on the same constituents in groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Collect data on concentrations of chemical constituents in groundwater that might be associated with agricultural uses of this feature along with cryptosporidium (Phase 2). If cryptosporidium is present along with elevated nitrate in water or alluvium, support is provided for an agricultural source.

If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.



If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



Hypothesis 16-2: Historical pond was filled with water from one or more ponds north of the Mill Site and used by the military during the Pershing Missile Operation at the Blanding Launch Site (1963-1970) as wash water for equipment used to launch missiles. Launch equipment may have become coated with nitrate and chloride as oxidized material from “blow down” rained down on the launch vehicle during missile launch. Aerial photography of the Site shows that the pond was full of water during the period of military use, and was dry in a 1973 photo, after the military left the Site. Nitrate- and chloride-laden water from the Historical Pond may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume.

Per the current owner of Morton-Thiokol, ATK, the Thiokol Pershing Missile rocket motors (models Thiokol TX-174 and TX-175) used aluminum fuel with ammonium perchlorate as an oxygen source. Since ammonium would have been oxidized during the launch combustion process, if ammonium residuals from Pershing equipment decontamination reached the pond, the residuals would already have been oxidized to the nitrate form. Therefore, for this activity to be a nitrate source, an oxidizing environment in groundwater or the alluvium is not required.

Known Conditions: The Historical Pond has been in existence since the 1920's and has had sufficient head to infiltrate to groundwater at various times throughout that history. The source of ponded water and its quality is unknown but the primary purpose of the pond has been agricultural. Historical aerial imagery from 1968 shows that the Historical Pond at that time was larger than the current Northern Wildlife Pond, which is responsible for the current groundwater mound beneath the mill site. The Historical Pond was in place and full during the time frame that the Blanding Pershing Missile Launch Complex was using the White Mesa site but was removed before the White Mesa uranium mill began operations. The Historical Pond was located directly above the upgradient portion of the uranium and nitrate plumes beneath the mill site and directly above the locus of highest nitrate concentrations. As stated in Section 2.2.4, travel times in the perched aquifer suggest that it took a minimum of 57 years for the nitrate and chloride plumes to develop to their current extent and the Historical Pond is one of the few potential sources that were present on White Mesa 57 years ago.

Necessary Conditions: a) Is there evidence of nitrate or ammonium, perchlorate, and/or aluminum concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was possibly used by the Pershing Missile Operation (1963 to 1970) for detectable levels of

constituents from this activity to reach the plume or for existing constituents in the pond to reach groundwater by hydraulic head generated during this period? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Gaps: Need nitrate, chloride, aluminum, perchlorate, and ammonium concentration data from the bedrock portion of the vadose zone. Data on concentrations of the same constituents in groundwater. Need background concentrations of aluminum in alluvial soils. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 or subsequent sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, ammonium, aluminum, or perchlorate) are present above two times background (as defined in Section 3.3.1), conduct a coring study of bedrock to groundwater (Phase 3). If aluminum or perchlorate are elevated in alluvium and/or bedrock, military use is confirmed. Analyze bedrock core samples for concentration data of those constituents. If none of those constituents are present above two times background (as defined in Section 3.3.1), this can be eliminated as a potential source. If any of those constituents are present above two times background (as defined in Section 3.3.1), conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.



17. Wildlife pond

Hypothesis 17-1: The wildlife pond was historically filled with water from the frog pond, which may have contained water from the municipal wastewater treatment facility located north of the Mill. Nitrate- and chloride-laden water from the wildlife pond may have leached through the alluvial soil and bedrock to groundwater.

Known Conditions: The wildlife pond is approximately 600 feet upgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the



results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

Hypothesis 17-2: The wildlife pond was historically associated with agriculture and may have been used as a stock pond or a fertilizer mixing pond, or may have collected fertilizer from runoff of nearby agricultural land, or may have been utilized in connection with historic sheep dipping activities. Nitrate- and chloride-laden water from the wildlife pond may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. It is also possible that military activity could have been associated with the wildlife pond.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, ammonium, and cryptosporidium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Collect data on concentrations of chemical constituents in groundwater that might be associated with agricultural uses of this feature along with cryptosporidium (Phase 2). If cryptosporidium is present along with elevated nitrate in water or alluvium, support is provided for an agricultural source.

If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents

(nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



18. CCD Circuit

This area was inadvertently added to the Phase 1 Plan. The CCD circuit uses no chlorinated, ammoniated, or nitrated compounds. The CCD area contains no chlorinated, ammoniated, or nitrated process solutions. The former sewage vault and current leach field near the CCD area are addressed as individual sources elsewhere in this section. This area will not be considered further.



19. YC Precip Mini-Lab

Hypothesis 19: Ammonium or nitrate-bearing chemicals from the mini-lab may have spilled or leaked. Ammonium-, nitrate-, or chloride-laden water from the mini-lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. The mini-lab areas use very small quantities of reagents and process solutions which drain either to an above-the-floor bucket or to an in-floor drain sump, which is pumped back to the process. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump. This potential source is inaccessible to geoprobe and core drilling equipment and is a low priority due to generally small amounts of nitrate or chloride that it could possibly have contributed to the plume. Therefore, no sampling will be conducted at this location.

Known Conditions: The YC Precip Mini-Lab is approximately 1,400 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonium-bearing chemicals or chloride-bearing chemicals used in this mini-lab and at what time periods? b) Is there evidence of a failure of the floor sump and/or floor drains? c) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? d) If only ammonium-bearing compounds were used, is there an oxidation source adjacent to or beneath the mini-lab sufficient to convert ammonium to nitrogen? e) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? And f) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this mini-lab. Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this building. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need information on the structure and history of the floors and drains. Need information on chemicals and use rates in the mini-lab. Need nitrate, ammonium, and dissolved oxygen from adjacent monitor wells. Data on concentrations of nitrate, chloride,



and ammonium are already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the sink, sump, or collection bucket. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonium-bearing or chloride-bearing compounds were used in this lab, this potential source can be eliminated. Is there any evidence of a failure of the building floor or sumps? If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonium to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If the answer to any of these is no, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

20. V₂O₅ Mini-Lab & V₂O₅ Precip

Hypothesis 20-1: Ammonium or nitrate-bearing chemicals from the mini-lab may have spilled or leaked. Ammonium-, nitrate-, or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. The mini-lab areas use very small quantities of reagents and process solutions which drain either to an above-the-floor bucket or to an in-floor drain sump, which is pumped back to the process. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump.

Known Conditions: The V₂O₅ mini-lab is 1,300 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonium-bearing chemicals, or chloride-bearing chemicals used in this mini-lab and at what time periods? a) Is there evidence of a failure of the floor sump and/or floor drains? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) If only ammonium-bearing compounds were used, is there an oxidation source adjacent to or beneath the mini-lab sufficient to convert ammonium to nitrogen? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? And e) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this mini-lab. Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need information on the structure and history of the floors and drains. Need information on chemicals and use rates in the mini-lab. Need nitrate, ammonium, and dissolved oxygen from adjacent monitor wells. Data on concentrations of nitrate, chloride, and ammonium are already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).



Decision Process: Determine if there has been a failure or breach of the sink, sump, or collection bucket. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonium-bearing, or chloride-bearing compounds were used in this mini-lab, this potential source can be eliminated. If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonium to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If the answer to any of these is no, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.



Hypothesis 20-2: Ammonium sulfate from the mix tanks on the first floor or the precip tanks on the upper floor may have spilled and leached through the alluvial soil and bedrock to groundwater. Nitrogen in the ammonium sulfate mix and precip tanks is solely in the ammonium (NH_4^+) form. Ammonium cations are typically strongly retarded in a soil-water system and likely would not travel through the alluvium and bedrock in the ammonium form. It would have to be converted to the nitrate from a process above the alluvium or in the near subsurface. That is, there would have to be a source of oxygenated water or other oxidizing fluid (such as a pond) immediately below or adjacent to the ammonium tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater. If this were the case, nitrogen would be detected as the nitrate (not ammonium) form continuously through the alluvium and the bedrock. The ammonium sulfate mix and precip tanks are not a source of chloride.

Necessary Conditions: a) Is there evidence of nitrate concentration in the vadose zone beneath this feature? b) Is nitrate present in the alluvium and bedrock cores below this feature? c) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonium to nitrate? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this potential source have sufficient mass to have contributed measurably to nitrate observed in the plume? f) Has there been sufficient time since this potential source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach groundwater? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume. And g) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Need ammonium and dissolved oxygen from adjacent monitor



wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the floor or floor drain sump. If not, this potential source has been eliminated.

If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

21. SX Mini-Lab

Hypothesis 21: Ammonium-, nitrate-, or chloride-bearing chemicals from the mini-lab may have spilled or leaked. Ammonium-, nitrate-, or chloride-laden water from the mini-lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. This potential source is inaccessible to geoprobe and core drilling equipment and is a low priority due to generally small amounts of nitrate that it could possibly have contributed to the plume. Therefore, no sampling will be conducted at this location. The mini-lab areas use very small quantities of reagents and process solutions which drain either to an above-the-floor bucket or to an in-floor drain sump, which is pumped back to the process. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump.

Known Conditions: The SX Mini-Lab is approximately 1,500 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonium-bearing chemicals, or chloride-bearing chemicals used in this mini-lab and at what time periods? b) Is there evidence of a failure of the floor sump and/or floor drains? c) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? d) If only ammonium-bearing compounds were used, is there an oxidation source adjacent to or beneath the mini-lab sufficient to convert ammonium to nitrogen? e) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? And f) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this mini-lab. Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need information on the structure and history of the floors and drains. Need information on chemicals and use rates in the mini-lab. Need nitrate, ammonium, and dissolved oxygen from adjacent monitor wells. Data on concentrations of nitrate, chloride, and ammonium are already available from the groundwater and nitrate monitoring



programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the sink, sump, or collection bucket. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonium-bearing, or chloride-bearing compounds were used in this lab, this source can be eliminated. Is there any evidence of a failure of the building floor or sumps? If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonium to nitrogen? Is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If the answer to any of these is no, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

22. Chem Lab

Hypothesis 22: Ammonium-, nitrate-, or chloride-bearing chemicals from the Chem Lab may have spilled or leaked, or lab sink drain water may have leaked from the underground piping that conveys lab drain wastes to the tailings cells. Ammonium-, nitrate-, or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. This potential source is inaccessible to geoprobe and core drilling equipment and is low priority due to generally small amounts of nitrate that it could possibly have contributed to groundwater. Therefore, no sampling will be conducted at this location.

Known Conditions: The Chem Lab is approximately 1,800 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonium-bearing chemicals, or chloride-bearing chemicals used in this lab and at what time periods? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) If only ammonium-bearing compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonium to nitrogen? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? And e) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this lab. Data on concentrations of the same chemical constituents in groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need data on the types and amounts of chemicals used at this facility. Data on concentrations of nitrate, chloride, and ammonium are already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If no nitrate-bearing, ammonium-bearing or chloride-bearing compounds were used in this lab, this potential source can be eliminated. If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert



ammonium to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If not, this potential source can be eliminated. Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

23. Met Lab

Hypothesis 23: Ammonium-, nitrate-, or chloride-bearing chemicals from the Met Lab may have spilled or leaked, or lab sink drain water may have leaked from the underground piping used to convey lab drain wastes to the tailings cells. Ammonium-, nitrate-, or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. This potential source is inaccessible to geoprobe and core drilling equipment and is a low priority due to generally small amounts of nitrate that it could possibly have contributed to groundwater. Therefore no sampling will be conducted at this location.

Known Conditions: The Met Lab is approximately 1,800 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonium-bearing chemicals, or chloride-bearing chemicals used in this lab and at what time periods? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) If only ammonium-bearing compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonium to nitrogen? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? And e) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this lab. Data on concentrations of the same chemical constituents in groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need data on the types and amounts of chemicals used at this facility. Data on concentrations of nitrate, chloride, and ammonium are already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as



follows. If no nitrate-bearing, ammonium-bearing, or chloride-bearing compounds were used in this lab, this potential source can be eliminated. If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonium to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If not, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.



24. V₂O₅ oxidation tanks

Hypothesis 24-1: Ammoniated solutions from the V₂O₅ oxidation area could have spilled or overflowed, entered the floor drains and/or drain sumps, and leaked out of the drains and through the alluvial soil and bedrock into groundwater before entering the tailings system, contributing to the plume. Anhydrous ammonia is added to raffinate solution from the uranium solvent extraction area in this part of the plant. Nitrogen in this area is solely in the ammonium (NH₄⁺) form. Anything spilled or washed down to floors or sumps is pumped back from the sumps into the process and remains within the building. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump. Ammonium cations are typically strongly retarded in a soil-water system and likely would not travel through the alluvium and bedrock in the ammonia form. It would have to be converted to nitrate from a process above the alluvium or in the near subsurface. That is, there would have to be a source of oxygenated water or other oxidizing fluid (such as a pond) immediately below or adjacent to the ammonium tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater.

Known Conditions: The V₂O₅ Oxidation Tanks are approximately 1,700 feet downgradient of the upgradient margin of the main plume.

Necessary Conditions: a) Is there evidence of a failure of the floor sump and/or floor drains? b) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonium to nitrate? c) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? d) Did this potential source have sufficient mass to have contributed measurably to nitrate observed in the plume? e) Has there been sufficient time since this potential source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach the plume? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume. And f) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature.



Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need information on the structure and history of the floors and drains. Need nitrate, ammonium, and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



Hypothesis 24-2: Sodium chlorate or chlorinated solutions from the V_2O_5 oxidation area could have spilled or overflowed, entered the floor drains and/or drain sumps, and leaked out of the drains and through the alluvial soil and bedrock into groundwater before entering the tailings system, contributing to the plume. Anything spilled or washed down to floors or sumps is pumped back from the sumps into the process and remains within the building. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump. If this were an appreciable source, it would also be associated with measurably elevated sodium in soil and/or groundwater adjacent to and beneath the tank area. Sodium chlorate is not a source of nitrogen atoms, and this hypothesis has been retained for evaluation only as a chloride source.

Necessary Conditions: a) Is there evidence of chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need information on the structure and history of the floors and drains. Need nitrate, ammonium, and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine



if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

25. Natural nitrate reservoir

Hypothesis 25: Increased recharge or irrigation of dry land could have led to leaching of salts that have been accumulating in the unsaturated zone for thousands of years, forming a nitrate reservoir in the subsurface alluvium which is driven through the alluvial soil and bedrock to groundwater by surface water (wildlife or other ponds) percolation.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the



groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.

26. – 32. Other ponds or pond like sources

Hypothesis 26: These areas were used historically as agriculture-related stock ponds and fertilizer mixing ponds. Anecdotal evidence suggests ponds may have been used for sheep dipping, that occasionally cattle broke through the ice and drowned, and that truckloads of salt crystals were deposited in the vicinity for the cattle. Nitrates and chlorides associated with these agricultural-related activities may have leached through the alluvial soil and bedrock to groundwater. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin. There is also the potential for military activity in connection with any of the historical ponds near the Site.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? And d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data Needs for Decision: Data on the concentration of nitrate, chloride, ammonium, and cryptosporidium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data Gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Collect data on concentrations of chemical constituents in groundwater that might be associated with agricultural uses of this feature along with cryptosporidium (Phase 2). If cryptosporidium is present along with elevated nitrate in water or alluvium, support is provided for an agricultural source.



If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If the results of Phase 3 sampling of the bedrock provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), perform a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, perform a mass balance to determine source viability. If the source is viable, move to Phases 4 and 5 Isotopic Fingerprint analysis of groundwater, alluvial soil, and bedrock core. If the groundwater and potential source fingerprints match to a reasonable degree, the Weight of Evidence suggests that a source has been identified. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified.

If the results of Phase 1 sampling of the alluvium do not provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above two times background (as defined in Section 3.3.1), proceed to a hydrogeologic evaluation to determine if this potential source could have generated sufficient mass during the time frame required to produce the plume and if there was a plausible pathway for any potential contamination from this potential source to have contributed to the plume. If the results of the hydrogeologic evaluation are negative, the Weight of Evidence suggests that this feature is not a potential source. If the results of the hydrogeologic evaluation are positive, proceed to a mass balance to determine source viability. If the mass balance determines that the potential source is not viable, the Weight of Evidence suggests that a source has not been identified. If the mass balance determines that the potential source is viable, the Weight of Evidence suggests that a source has been identified.



2.4 Environmental Receptor Identification

Environmental receptors can include humans or other living organisms (ecological receptors) potentially exposed to and adversely affected by contaminants because they are present at the source(s) or along the contaminant migration pathway.

2.4.1 Humans

Humans are a potential receptor because they may be present at the source; however nitrate and chloride in soil pose no risk to humans. Humans do not come in contact with groundwater at the Site; therefore, the human risk pathway is incomplete. That is, there is no exposed human individual, no human health risk, and no environmental concern associated with humans.

2.4.2 Ecological

Potential ecological receptors are not at risk from nitrates and chlorides in soil. Potential ecological receptors do not come in contact with groundwater at the Mill Site; therefore, the ecological risk pathway is incomplete. That is, there is no exposed ecological receptor, no ecological risk, and no environmental concern associated with ecological receptors.



3.0 DATA GENERATION AND ACQUISITION

3.1 Phase 1 Geoprobe Investigation of Background, Natural Nitrate Reservoir, and Potential Site Sources

The purpose of the Phase 1 investigation was to determine background concentrations of nitrate and chloride in the alluvial soil column in undisturbed areas in the vicinity of the Mill, to locate a natural nitrate and chloride reservoir in the alluvial soil, and to compare nitrate and chloride concentrations found in soil near potential Mill sources to background concentrations. The Phase 1 investigation is described in more detail in DUSA's May 13, 2011, submittal to the DRC titled *Nitrate Investigation Revised Phase 1 Work Plan, White Mesa Mill Site, Blanding, Utah* (INTERA, 2011).

3.2 Phase 2 Groundwater Quality Sampling and Analysis

The purpose of groundwater sampling for non-isotopic analytes is to test the hypotheses that nitrate and chloride mass observed in groundwater was caused by either military or agricultural uses of the White Mesa Site and to:

1. Establish background for comparison to analytes not already addressed in the Mill's existing background study reports and monitoring programs.
2. Produce valid data for comparison to background.
3. Identify locations of groundwater elevated in the constituents of concern.
4. Provide data for incorporation in the CSM and decision process regarding nitrate sources.

A separate Detailed Work Plan and QAP was submitted to the DRC on July 13, 2011. The Phase 2 Detailed Work Plan and QAP specifies the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. The Phase 2 Detailed Work Plan and QAP is based upon the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The Phase 2 Detailed Work Plan and QAP follows the same outline as the approved QAP and: a) supplements the approved QAP to address additional activities which are specific to Phase 2 of the nitrate investigation and are not currently addressed in the QAP, and b) adjusts existing procedures in the approved QAP which need to be modified or omitted to be suitable for the nitrate investigation.

3.2.1 Sampling Design

The following analytes will act as a "fingerprint" of either military or agricultural activities:

- *Cryptosporidium*



- RDX
- HMX
- Perchlorate

It is assumed that any such uses would be associated with ponds or pond-like features to carry constituents to groundwater. Not all locations with elevated nitrate and chloride are associated with an active pond. However, disturbances visible on aerial imagery far upgradient and far downgradient near wells containing elevated concentrations of nitrate and chloride may have been related to historical ponds at those locations. Therefore, the following wells, which are also presented on Figure 21 and Table 3, will be sampled for non-isotopic constituents:

- MW-20
- MW-31
- TWN-19
- TWN-2
- TWN-9
- TWN-17
- MW-19
- MW-27
- MW-30
- TW4-1
- TW4-22
- TW4-24

TWN-2 and TW4-22 will be sampled for cryptosporidium, RDX, and HMX. The other wells will be analyzed for perchlorate only.

3.2.2 Field Activities and Sampling Methods

Field activities are described in detail in the Phase 2 Detailed Work Plan and QAP.

3.2.2.1 Sample Identification

Each sample collected at the Site during the nitrate investigation will be identified using a unique sample identification number (“ID”). The description of the sample type and the point name will be recorded on the chain-of-custody (“COC”) forms, as well as in the field notes.



Field log books will be used to document field sampling information. Sample IDs will be listed on the sample labels and the COC forms submitted to the laboratory, and will be cross-referenced to the name in permanently bound field log books, on sample data sheets, and on COC forms.

Ground water samples will be named according to the well ID where the sample was collected.

QC samples will be named as follows:

- Duplicate samples will be identified with a fictitious name and time which will be recorded in the field log book.
- Equipment blanks will also have a fictitious name and time which will be recorded in the field log book.

3.2.3 Sample Containers and Holding Times

All sample containers will be supplied by the laboratory and will be certified as new. The type of sample containers to be used for each analysis, the sample volumes required, the preservation requirements, and the holding times for samples prior to extraction and analysis are presented in Table 1 of the Phase 2 QAP (DUSA, 2011).

3.2.4 Analytical Methods

3.2.4.1 Field Analytical Methods

Field parameters will be collected according to Section 6.2 of the Phase 2 QAP.

3.2.4.2 Laboratory Analytical Methods

Groundwater samples will be submitted to the analytical laboratory for analysis. A list of analytes and their analytical methods is presented below:

Explosives (RDX and HMX)	EPA Method 8330
Perchlorate	EPA Method 6850
Cryptosporidium	EPA Method 1623

3.3 Phase 3 Deep Bedrock Core Sampling and Analysis

The objective of deep bedrock core sampling and analysis is to trace nitrate and chloride 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 take place in two separate sub-phases:



1. Phase 3A Deep Bedrock Coring in Undisturbed Locations.
2. Phase 3B Deep Bedrock Coring of Potential Nitrate Source Locations.

Analytical results and data collected from Phase 1 of the nitrate investigation will be shared with the DRC. DUSA and the DRC will decide on coring locations based on data and discussion.

3.3.1 Sampling Design

Phase 3A: At this time it is anticipated that at least four coring locations associated with locating the natural nitrate reservoir will be chosen based on field test kit and analytical results from the 20 background soil borings advanced during Phase 1A of this investigation. Figure 22 presents the potential locations for coring. Preliminary results from Phase 1A indicate the presence of a nitrate and chloride spike at one of the deeper, undisturbed alluvial locations with nitrate and chloride concentrations rising gradually with depth to a peak and then falling with depth below the peak. This observation is consistent with the findings reported by Walvoord, et al. (2003), in which they described a natural nitrate reservoir beneath desert soils. Some alluvial borings at undisturbed locations saw the highest concentrations of nitrate and chloride at the base of the alluvial material. Still other borings yielded samples in which there was no detected nitrate or chloride in alluvial materials. The alluvium is generally thin at the Mill property, and the presence of a nitrate and chloride spike in the deepest of the alluvial borings suggests that evidence of a natural nitrate reservoir may be found in the upper part of the bedrock at the undisturbed sites. Therefore, the bedrock cores to test the natural nitrate reservoir hypothesis will be advanced through the alluvial soil to approximately 20 feet below the surface of the bedrock, and samples will be taken at 4-foot intervals for shipment to the Analytical Laboratory. Remaining core will be archived. If any nitrate and/or chloride are detected above two times background (background is defined as the 95% upper confidence interval of data collected in Phase 1A) in samples sent to the Analytical Laboratory, additional samples from adjacent intervals will be selected from the archived core and sent for Analytical Laboratory analysis. All samples will undergo an SPLP leaching procedure and the leachate will be analyzed for nitrate, chloride, sulfate, and ammonium.

Phase 3B: One coring location associated with each pond or pond-like source and each potential process-related source where nitrate and chloride are detected above two times background in alluvial material will be selected based on analytical results from the source borings conducted in Phase 1B of this investigation. The bedrock core will be advanced through the alluvium and bedrock to groundwater. For all deep bedrock borings drilled, the depth of each will extend to the upper geologic contact of the Brushy Basin Member of the Morrison Formation. Water levels in the perched aquifer have been relatively stable for the last 20 years. Therefore, the presence of nitrate and chloride above two times background in the 10-foot interval above the water table



would provide strong evidence that a source had indeed contributed those constituents to groundwater. Three (3) samples will be collected from each bedrock core location. Bedrock core samples will be collected randomly from the first $\frac{1}{3}$, second $\frac{1}{3}$, and third $\frac{1}{3}$ interval of the total penetrated depth at each location, but during the evaluation of results, special emphasis will be placed on the sample from the interval above the groundwater table. All samples will undergo an SPLP leaching procedure and the leachate will be analyzed for nitrate, chloride, sulfate, and ammonium. If nitrate and/or chloride are detected above two times background as defined in section 3.3.1 in samples sent to the Analytical Laboratory, additional coring will be collected from the same location during Phase 5.

3.3.2 Field Activities and Sampling Methods

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.

Cores will be logged by a Utah-Licensed Professional Geologist. Photographs of cores will be collected and GPS coordinates will be recorded.

No field testing will be conducted on these rock cores. The core intervals for Analytical Laboratory analysis will be packaged and shipped to a State of Utah-certified Analytical Laboratory for analysis for the presence of nitrate, chloride, sulfate, and ammonium in the rock cores following the SPLP leaching method. The Analytical Laboratory will need to crush, pulverize, and blend the rock core material before conducting the analysis. Results will be reported in milligrams per kilogram (“mg/kg”).

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

Equipment decontamination will be implemented for all non-disposable equipment that comes in contact with bedrock before moving equipment to a new location or collecting a new sample. Commercial third-party deionized water will be used for rinsate blank collection.

3.3.2.1 Sample Identification

Each sample collected at the Site during the nitrate investigation will be identified using a unique sample ID. The description of the sample type and the point name will be recorded on the COC forms, as well as in the field notes.



Field log books will be used to document field sampling information. Sample IDs will be listed on the sample labels and the COC forms submitted to the Analytical Laboratory, and will be cross-referenced to the name in permanently bound field log books, on sample data sheets, and on COC forms.

Coring samples will be named according to the coring location and top and bottom of the depth interval at which they were collected, following the convention C-††X-tt-dd, where †† X is the core location which will be previously determined based on the soil boring locations given in Phase 1, tt is the top of the depth interval, and dd is the bottom of the depth interval expressed in feet bgs. For example, the sample collected at C-01A in the depth interval between 25 and 26 feet bgs would be named C-01A-25-26.

QC samples will be named as follows:

- Duplicate samples will have the same name as the parent sample with a D added at the end of the sample name.
- Equipment blanks will have the same name as the boring location with a terminal RB added at the end.

3.3.3 Sample Containers and Holding Times

The type of sample containers to be used for each analysis, the sample volumes required, the preservation requirements, and the holding times for samples prior to extraction and analysis are presented in Tables 4 and 5.

3.3.4 Analytical Methods

All rock samples will be submitted to the Analytical Laboratory for SPLP analysis using EPA Method 1312 using Extraction Fluid #3. Method 1312 will produce a leachate of all rock samples which will be analyzed for nitrate, chloride, sulfate, and nitrogen as ammonium using EPA Method 353.2, EPA Method 300.0, and EPA Method 350.1 respectively.

3.4 Phase 4 Stable Isotopic Sampling and Analysis of Groundwater in Existing Wells

The purpose of the Phase 4 isotopic sampling and analysis is to provide additional data, if required, to support or reject hypotheses presented in this Nitrate Investigation Revised Phases 2 through 5 Work Plan, including the hypothesis of a natural nitrate source and hypotheses regarding Mill Site sources.



The most direct method for identifying the source of nitrate in the Mill site plume should be similarity in isotopic composition, this assumes that the nitrogen at the point of origin has a unique signature, and that the isotopic composition did not change or it changed predictably during migration. It is already acknowledged that for the Mill site, many of the potential nitrate sources such as human and animal waste should have nitrate isotopic values that are similar to each other within a range. These sources occur in several locations, existed over different time frames, and may contribute indistinguishable nitrate; however, the individual sources may have unique location specific co-migrating species which will be examined. Similarly, other sources are different from wastewater, but the range of known isotopic signatures overlap with wastewater and in such cases the variety of isotopes being analyzed may draw the needed distinction. Nevertheless, the expectation is that the nitrate in the Mill site plume may have been derived from a very limited number of sources in which case the possibility of circumventing the problem of overlap is improved; conversely, multiple sources with overlapping signatures may not provide the needed unequivocal source identification.

The analyses of nitrate ($\delta^{15}\text{N}$) isotopic composition may be distinctive when compared among background monitoring wells, nitrate plume, chloroform plume, and other selected monitoring wells. Similarly, when these data are compared with other potential discriminators such as the $\delta^{18}\text{O}-\text{NO}_3$, as well as chemical concentration and isotopic signature of a co-migrating species like sulfate and ammonium, the distinction may be definitive. Comparisons of all data will be made to known ranges of values for sources identified for this site. Subsequent analysis will search for clusters of values, or trends in values that indicate compositions similar to sources, or indicate mixing between endmembers.

In the final analysis, an acceptable identification of source(s) for the nitrate in the groundwater must ultimately conform to the composition of an existing source, or conform to the signature that a source would have had based on historical or literature values, or be tested against residual signatures of sources in soil or aquifer material (Phase 5). Furthermore, the suspected sources must be plausibly related to the nitrate plume with respect to the hydrogeology, proximity, reaction pathway, and time frame. If the analysis of data does not yield interpretable populations or trends, and instead yields an ill-defined overlap of results, then additional testing and analysis using other indicator species may be recommended.

3.4.1 Sampling Design

The conventional isotopic measurements for nitrate, ammonium, and sulfate will be performed on groundwater samples from the Mill Site to attempt to determine the source and degree of mixing of these compounds in groundwater in light of chemical and hydrologic data already available. Samples will be collected for nitrate ($\delta^{15}\text{N}$, $\delta^{18}\text{O}-\text{NO}_3$), ammonium ($\delta^{15}\text{N}$), and sulfate



($\delta^{34}\text{S}$, $\delta^{18}\text{O-SO}_4$) isotopic analysis from selected well locations based on existing conceptual models to attempt to determine the Isotopic Fingerprint or ratios in groundwater in the selected wells. Each well will be purged and monitored until key parameters stabilize. Samples will be collected and analyzed for:

1. Analytical concentration of dissolved nitrate (EPA method 353.2), ammonium (EPA method 350.1), and chloride and sulfate (using EPA Method 300.0).
2. Isotopic composition.

All samples will be preserved, shipped, and analyzed in accordance with a new QAP to be developed for isotopic groundwater sampling and analysis. This new QAP (the "Phase 4 QAP") will specify the specific details, activities, equipment, procedures, objectives, schedules, laboratories, and decision criteria for this phase of the investigation. The Phase 4 QAP will be based upon and utilize the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The Phase 4 QAP will follow the same outline as the existing approved QAP for groundwater sampling at the Mill and will supplement the approved QAP to address those activities which are specific to Phase 4 of the nitrate investigation.

The Phase 4 QAP will address the following additional requirements:

- Schedule for sampling
- Sample turnaround
- Selected laboratory(ies)
- Analytical methods
- Sample volumes
- Minimum detection limits for analytes
- Field QA procedures
- Laboratory QC

Wells will be sampled along a transect essentially north to south through the long axis of the nitrate-chloride plume approximately parallel to the estimated direction of groundwater flow. Wells that will be sampled within the mapped nitrate-chloride plume include TWN-3, TWN-2, TW4-22, TW4-24, and MW-31. Similarly, wells will be sampled from within the separate nitrate-chloroform plume to characterize the nitrogen accompanying infiltration from the septic leach fields (TW4-18, TW4-11, and TW4-1). Well locations containing elevated tritium indicating the groundwater contained a component of recent recharge (Hurst and Solomon, 2008) will be sampled for the isotopes listed above to expand the application of these results to



potential surface sources (MW-30, MW-27, and MW-19, in addition to MW-31 already identified). In addition, water samples will be collected from two (2) distinct occurrences of elevated nitrate in groundwater upgradient and northeast of the Mill Site plumes, and from one downgradient location southwest of the Mill Site, to determine if the nitrate sources are similar or if there is continuity of transport processes across the Site (TWN-19, TWN-17, TWN-9, and MW-20) (Figure 23 and Table 6).

Two specific technical concepts are incorporated in this isotopic Phase to improve the probability of interpreting what is often an inconclusive overlap of signature for nitrogen isotopic data in discriminating among multiple sources. First the $\delta^{18}\text{O}$ of both sulfate and nitrate molecules will be analyzed because the exchange of oxygen isotopes in these molecules occurs in both atmospheric and aqueous environments. The consequence of this analysis is that different $^{18}\text{O}/^{16}\text{O}$ ratios are indicative of the antecedent environment, which further contributes to interpretation of solute source and evolutionary pathway.

Secondly, nitrogen may be present as ammonium in the groundwater in wells affected by septic leach field drainage or infiltration from the Historical Pond or natural wildlife ponds. If nitrate and/or ammonium are detected in the groundwater chemical analysis, then the sample will be tested for $\delta^{15}\text{N}$ of ammonium as well as nitrate.

3.4.2 Field Activities and Sampling Methods

Field activities will be described in detail in the Phase 4 Detailed Work Plan and QAP.

3.4.2.1 Sample Identification

Each sample collected at the Site during the nitrate investigation will be identified using a unique sample ID. The description of the sample type and the point name will be recorded on the COC forms, as well as in the field notes.

Field log books will be used to document field sampling information. Sample IDs will be listed on the sample labels and the COC forms submitted to the laboratory, and will be cross-referenced to the name in permanently bound field log books, on sample data sheets, and on COC forms.

Groundwater samples will be named according to the well ID where the sample was collected.

QC samples will be named as follows:

- Duplicate samples will be identified with a fictitious name and time which will be recorded in the field log book.



- Equipment blanks will also have a fictitious name and time which will be recorded in the field log book.

3.4.3 Sample Containers and Holding Times

All sample containers will be supplied by the laboratory and will be certified as new. The type of sample containers to be used for each analysis, the sample volumes required, the preservation requirements, and the holding times for samples prior to extraction and analysis will be presented in Table 1 of the Phase 4 QAP.

3.4.4 Analytical Methods

3.4.4.1 Field Analytical Methods

Field parameters will be collected according to Section 6.2 of the Phase 4 QAP.

3.4.4.2 Laboratory Analytical Methods

Groundwater and wastewater samples will be submitted to the analytical laboratory for isotopic analysis. SOPs from the analytical laboratory are included as Appendix D.

3.5 Phase 5 Isotopic Soil Sampling and Analysis

A determination regarding the necessity to complete Phase 5 will be made after review of the data obtained from the previous phases of the nitrate investigation. For example, if the isotopic values of nitrogen and sulfur in groundwater samples analyzed in Phase 4 indicate that a distinction can be made among potential sources, then Phase 5 will be pursued. Criteria for evaluating isotopic data are described in Section 3.4. The objective of this phase is to identify potential and possible endmember source candidates and characterize the nitrogen and sulfur isotopic composition according to the criteria described in Section 2.3.3.1 of this Nitrate Investigation Revised Phases 2 through 5 Work Plan.

This sampling will include:

- (a) Any soils and/or bedrock that DUSA determines could represent a natural nitrate reservoir.
- (b) Any soils and/or bedrock representative of any of the Phase 1 or 3 Mill Site sources that DUSA and the executive Secretary agree, based on the results from Phase 1 or Phase 3, could have contributed to the plume.
- (c) Influent to any sewage vault or leach field identified in paragraph B as requiring isotopic analysis.



Each sample will be collected and analyzed for:

1. Analytical concentration of dissolved nitrate, ammonium, chloride, and sulfate (using EPA Methods to be identified in the QAP).
2. Isotopic composition.

Samples will be collected for nitrogen, oxygen ($\delta^{15}\text{N}$, $\delta^{18}\text{O-NO}_3$), and sulfate ($\delta^{34}\text{S}$, $\delta^{18}\text{O-SO}_4$) isotopic analysis according to the criteria in Section 2.3.3.1 of this Nitrate Investigation Revised Phases 2 through 5 Work Plan to evaluate the possibility of each being a source.

Representative leach samples will be collected from background alluvial boring sediments from three (3) natural nitrate reservoirs and three (3) gypsum lithologies for nitrogen and sulfur isotopic composition respectively. Samples from each boring or medium will be collected at approximately the same intervals as specified in Phases 1 and 3 for non-isotopic characterization in this Nitrate Investigation Revised Phases 2 through 5 Work Plan. Since isotopic results from these potential samples will be compared directly to Isotopic Fingerprints of groundwater, background samples are not required.

All samples will be collected, preserved, shipped, and analyzed following a separate QAP to be developed for isotopic sampling and analysis of soil, extracts, and manufactured products. The QAP will be submitted specifying the specific details, activities, equipment, procedures, laboratories, procedures, schedules, and decision criteria for this phase of the investigation. The QAP will be based upon and utilize the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The QAP will follow the same outline as the approved QAP and will supplement the approved QAP to address those activities which are specific to Phase 5 of the nitrate investigation.

The QAP will address the following additional requirements:

- Schedule for sampling
- Sample turnaround
- Selected laboratory(ies)
- Analytical methods
- Sample volumes
- Minimum detection limits for analytes
- Field QA procedures
- Laboratory QC



3.6 Sample Handling and Custody

3.6.1 Sample Labeling

Alluvial material will be collected in glass jars. Deep bedrock core samples will be collected in resealable plastic bags due to the inflexible nature of the samples and the inability to “fit” rock cores into a traditional sample jar.

Resealable plastic bags which are archived will be labeled with an indelible marker with the following information:

- Sample identification
- Date

Alluvium and deep bedrock cores provided to the Analytical Laboratory for analysis will be labeled with an adhesive label showing the following information:

- Sample identification
- Date
- Time of collection
- Project name
- Sampler’s initials
- Analysis required

Glass jars and resealable bags will be sealed and placed on ice in a cooler.

3.6.2 Sample Documentation

Documentation during sampling is essential to proper sample identification. All personnel will adhere to the following general guidelines for maintaining field documentation:

- Documentation will be completed in permanent black or blue ink.
- All entries will be legible.
- Errors will be corrected by crossing out the entry with a single line and then dating and initialing the lineout.
- Any serialized documents will be maintained by INTERA and referenced in the field log book.



- Unused portions of pages will be crossed out, and each page will be signed and dated.

The field team leader and sampling personnel are responsible for proper documentation of activities.

3.6.3 Chain of Custody

Standard sample custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample will be considered to be in custody if one of the following statements applies:

- It is in a person's physical possession or view.
- It is in a secure area with restricted access.
- It is placed in a container and secured with an official seal in such a way that the sample cannot be reached without breaking the seal.

COC procedures provide an accurate written record that traces the possession of individual samples from the time of collection in the field to the time of acceptance at the Analytical Laboratory. The COC form will also be used to document all samples collected and the analyses requested. Information that the field personnel will record on the COC form includes the following:

- Project name and number
- Sampling location
- Name and signature of sampler
- Destination of sample (Analytical Laboratory name)
- Sample ID
- Date and time of collection
- Number and type of containers filled
- Analyses requested
- Preservatives used (if applicable)
- Filtering (if applicable)
- Signatures of individuals involved in custody transfer, including the date and time of transfer
- Air bill number (if applicable) or courier information
- Project contact and phone number



Unused lines on the COC form will be crossed out. Field personnel will sign COC forms. The COC form will be placed in a waterproof plastic bag and taped to the inside of the shipping container used to transport the samples. Signed air bills will serve as evidence of custody transfer between field personnel and the courier, and between the courier and the Analytical Laboratory. Copies of the COC form and the air bill will be retained and filed by field personnel before the containers are shipped.

The Analytical Laboratory sample custodian will receive all incoming samples, sign the accompanying COC forms, and retain copies of the forms as permanent records. The Analytical Laboratory sample custodian will record all pertinent information concerning the samples, including the persons delivering the samples, the date and time received, sample condition at the time of receipt (e.g., sealed, unsealed, or broken container; temperature; or other relevant remarks), the sample IDs, and any unique Analytical Laboratory IDs for the samples. When the sample transfer process is complete, the custodian is responsible for maintaining internal log books, tracking reports, and other records necessary to maintain custody throughout sample preparation and analysis.

The Analytical Laboratory will provide a secure storage area for all samples. Access to this area will be restricted to authorized personnel. The custodian will ensure that samples requiring special handling, including samples that are heat- or light-sensitive or radioactive, or that have other unusual physical characteristics, are properly stored and maintained pending analysis.

3.6.4 Sample Shipment

The following procedures will be implemented when samples collected during the remediation activities are shipped:

- The cooler will be filled with bubble wrap, sample containers, and packing material. Sufficient packing material will be used to minimize sample container breakage during shipment.
- The COC forms will be placed inside a plastic bag. The bag will be sealed and taped to the inside of the cooler lid. The air bill, if required, will be filled out before the samples are handed over to the carrier. The Analytical Laboratory will be notified if the sampler suspects that the sample contains any substance that would require Analytical Laboratory personnel to take safety precautions.
- The cooler will be closed and taped shut with packing tape around both ends. If the cooler has a drain, it will be taped shut both inside and outside of the cooler.
- Signed and dated custody seals will be placed on the front and side of each cooler. Wide clear tape will be placed over the seals.



- The COC form will be transported within the taped, sealed cooler. When the cooler is received at the Analytical Laboratory, Analytical Laboratory personnel will open the cooler and sign the COC form to document transfer of samples.
- Multiple coolers may be sent in one shipment to the Analytical Laboratory. The outsides of the coolers will be marked to indicate the number of coolers in the shipment.

3.7 Quality Control

3.7.1 Field Quality Control Methods

Field QC measures include complete documentation of all field activities on the appropriate forms. Field QC samples include the collection of field duplicates for analysis by the Analytical Laboratory. Field duplicates will be collected at a frequency of 1 duplicate per 10 field samples. Duplicates will be collected by mixing the field sample and splitting the sample into 2 containers. The samples will be labeled as separate samples and submitted blind to the Analytical Laboratory. Duplicate assessment will be completed as described in Section 3.7.3.4, below.

3.7.2 Analytical Laboratory Quality Control Methods

Analytical QA/QC will be governed by the QA/QC program of the Analytical Laboratory. Every effort will be made to use Analytical Laboratories that are certified by the State of Utah and by NELAP and/or NAVLAP, and are capable of performing the analytical procedures specified in the Phase 2 Work Plan and QAP, and have a QA/QC program that includes the spikes, blanks, and duplicates described below.

3.7.2.1 Spikes, Blanks, and Check Samples

Analytical Laboratory QC samples will assess the accuracy and precision of the analyses. Following are descriptions of the types of QC samples that may be used by the Analytical Laboratory to assess the quality of the data. Analytical QC will be completed as required by the specific method used for analysis. Assessment of Analytical Laboratory QC samples will be as specified in the method.

a. Matrix Spike/Matrix Spike Duplicate

A spiked field sample analyzed in duplicate may be analyzed with every analytical batch. Analytes stipulated by the analytical method, by applicable regulations, or by other specific requirements may be spiked into the samples. Selection of the sample to be spiked depends on the information required and the variety of conditions within a typical matrix. The matrix spike sample serves as a check evaluating the effect of the sample matrix on the accuracy of analysis. The matrix spike duplicate serves as a check of the



analytical precision. Assessment of the matrix spike/matrix spike duplicate will be completed using the method- and Analytical Laboratory-established limits.

b. Method Blanks

Each analytical batch shall be accompanied by a method blank. The method blank shall be carried through the entire analytical procedure. Contamination detected in analysis of method blanks will be used to evaluate any Analytical Laboratory contamination of environmental samples which may have occurred. Method blank detections will be assessed to determine if there is any effect on the sample data usability. Method blank effects will be discussed and a determination made on a case-by-case basis.

c. Check Samples

Each analytical batch shall contain a number of check samples. For each method, the Analytical Laboratory will analyze the check samples or their equivalents specified in the analytical method. Check samples may include a laboratory control sample (“LCS”), calibration checks, laboratory fortified blanks, or sample duplicates. Check samples will be reviewed for compliance with the Analytical Laboratory and method-specified acceptance limits.

3.7.3 Internal Quality Control Checks

3.7.3.1 Field Quality Control Check Procedures

The QA Manager will perform the QA/QC analysis of field procedures as described below.

3.7.3.2 Review of Compliance with Procedures in this Work Plan

Observation of technician performance is monitored by the QA Manager on a periodic basis to ensure compliance with this work plan.

3.7.3.3 Completeness Review

The QA Manager will review all analytical results to confirm that the analytical results are complete (i.e., there is an analytical result for each required constituent). The completeness goal for this project is 95%.

3.7.3.4 Duplicates

The following analysis will be performed on duplicate field samples:

- Relative percent difference.



RPDs will be calculated in comparisons of duplicate and original field sample results. Non-conformance will exist when the RPD is greater than 35, unless the measured concentrations are less than 5 times the required detection limit (EPA, 1994b).

3.7.3.5 Use of QC Samples to Assess Conformance with this Work Plan

QC samples generated during field activities and in the Analytical Laboratory will be used to assess the usability of the data for meeting project objectives. QC data which do not meet the requirements specified herein may require that the associated sample data be flagged for limited use or be removed from the overall data pool. Data flagging will follow standard EPA guidelines specified in Functional Guidelines as applicable to the analytical method. QC samples will be used to determine if the data meet the project objectives.

3.7.4 Instrument Equipment Testing, Inspection, and Maintenance

The Analytical Laboratory is responsible for the maintenance of its instruments in accordance with Analytical Laboratory procedures and as required in order to maintain its NELAP and/or NAVLAP certifications. Preventive maintenance will be performed on a scheduled basis to minimize downtime and the potential interruption of analytical work.

Sampling and field equipment shall be tested, inspected, and maintained in accordance with manufacturers' recommendations.

3.7.5 Instrument Calibration

A fundamental requirement for collection of valid data is the proper calibration of all sample collection and analytical instruments. Analytical Laboratory equipment shall be calibrated in accordance with Analytical Laboratory procedures and as described in the analytical methods.



4.0 DATA EVALUATION

Data evaluation will be completed as described throughout this work plan. Analytical data will be evaluated as described using Analytical Laboratory generated QC samples as specified in the analytical methods. Field data will be evaluated against the specific QC samples generated in the field and documentation will be reviewed for completeness and accuracy.

For the SPLP, Extraction Fluid #3 will be used. Standard extraction requires the addition of nitric acid and sulfuric acid during the leaching process. Since the leachates will be analyzed for nitrate+nitrite and sulfate, the deionized leaching process contemplated by the method (for cyanide-containing samples) will be used in lieu of the standard leaching procedure.

As previously described, the soil samples are being leached and analyzed using water methodologies, which will yield concentrations in liquid units (such as mg/L). During the data interpretation and preparation of a revised CSM, the calculations and/or the relationship for converting the results to soil mass units will be provided.

Data usability will be assessed based on compliance with the QC standards specified in the analytical method.

Separate detailed work plans and QAPs will be provided for Phases 2, 4, and 5 which will describe the data evaluation process to be used for each of those phases.



5.0 AUDITS

DUSA may perform system and performance audits in order to ensure that data of known and defensible quality are produced during a sampling program. The frequency and timing of system and performance audits shall be as determined by DUSA.

5.1 System Audits

System audits are qualitative evaluations of all components of field and Analytical Laboratory QC measurement systems. They determine if the measurement systems are being used appropriately. System audits will review field and Analytical Laboratory operations, including sampling equipment, Analytical Laboratory equipment, sampling procedures, and equipment calibrations, to evaluate the effectiveness of the QA program and to identify any weakness that may exist. The audits may be carried out before all systems are operational, during the program, or after the completion of the program. Such audits typically involve a comparison of the activities required under this work plan with those actually scheduled or performed. A special type of systems audit is the data management audit. This audit addresses only data collection and management activities.

5.2 Performance Audits

The performance audit is a quantitative evaluation of the measurement systems of a program. It requires testing the measurement systems with samples of known composition or behavior to evaluate precision and accuracy. With respect to performance audits of the analytical process, either blind performance evaluation samples may be submitted to the Analytical Laboratory for analysis, or the auditor may request that it provide results of the blind studies that the Analytical Laboratory must provide to its NELAP and/or NAVLAP accreditation agency on an annual basis. The performance audit is carried out without the knowledge of the analysts, to the extent practicable.

5.3 Follow-Up Actions

Response to the system audits and performance audits is required when deviations are found.

5.4 Audit Records

Audit records for all audits conducted will be retained in DUSA Central Files. These records will contain audit reports, written records of completion for corrective actions, and any other documents associated with the audits supporting audit findings or corrective actions.



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