Tsosie 1 (#55)

Removal Site Evaluation Report

Final | September 26, 2018

Stantec

NAVAJO NATION
AUM Environmental Response Trust-First Phase

Tsosie 1 (#55) Removal Site Evaluation Report - Final

September 26, 2018

Prepared for:

Navajo Nation AUM Environmental Response Trust – First Phase

Prepared by:

Stantec Consulting Services Inc.

Title and Approval Sheet

Title: Tsosie 1 Removal Site Evaluation Report - Final

Approvals

This Removal Site Evaluation Report is approved for implementation without conditions.

Dr. Donald Benn — Date: 10/15/18
Navajo Nation Environmental Protection Agency
Executive Director

Linda Reeves — Date: 10/17/18
US Environmental Protection Agency, Region 9
Remedial Project Manager

Sadie Hoskie — Date: 10/18/2018
Navajo Nation AUM Environmental Response Trust – First Phase
Trustee

Toby Leeson, P.G. — Date: 10/18/2018
Stantec Consulting Services, Inc.
Project Technical Lead

Revision Log

Revision No.	Date	Description
0	April 30, 2018	Submission of Draft RSE report to Agencies for review
1	September 26, 2018	Submission of Final RSE report to Agencies

Sign-off Sheet

This document entitled *Tsosie 1 Removal Site Evaluation Report* was prepared by MWH, now part of Stantec Consulting Services Inc. (Stantec) on behalf of the Navajo Nation AUM Environmental Response Trust – First Phase (the "Client") for submittal to the Navajo Nation Environmental Protection Agency (NNEPA) and United States Environmental Protection Agency (USEPA) (collectively, the "Agencies"). The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Per the *Navajo Nation AUM Environmental Response Trust Agreement – First Phase*, *Section 5.4.1,* (United States [US], 2015) the following certification must be signed by a person who supervised or directed the preparation of the Removal Site Evaluation report: "Under penalty of law, I certify that to the best of my knowledge, after appropriate inquiries of all relevant persons involved in the preparation of this report, the information submitted herein is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Prepared by Emily Yeager

(signature)

Emily Yeager, P.G.

Reviewed by Kelly Johnson

(signature)

Kelly Johnson, PhD, P.G.

Approved by Toby Leeson

(signature)

Toby Leeson, P.G.

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- 2017 Cooper aerial survey orthophotographs and data files
- Historical documents referenced in this RSE Report (refer to Section 7 for complete citation)
    - Chenoweth, 1984 – Historical Review of Uranium-Vanadium Production in the Eastern Carrizo Mountains, San Juan County, New Mexico, and Apache County, Arizona. New Mexico Bureau of Mines and Mineral Resources
    - Chenoweth, 1985 – Historical Review Uranium-Vanadium Production in the Northern and Western Carrizo Mountains, Apache County, Arizona. Arizona Geological Survey
    - Hendricks, 2001 - An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation
    - NAML, 1994 – Tse Tah II/Oakspring II AML Reclamation Project Contract Documents
    - NAML, 1995 – Field Office/Mine Site Visit Report, for the Tse Tah 2 NAML Project
    - US OSM, 1995 – Letter from the US Department of the Interior Office of Surface Mining to Ms. Bernadine Martin, Director of the NAML
    - USEPA, 2007a- Abandoned Uranium Mines and the Navajo Nation. Navajo Nation AUM Screening Assessment Report and Atlas with Geospatial Data
    - Weston Solutions, 2010 - Tsosie 1 AUM Site Navajo Abandoned Uranium Mine Site Screen Report

Executive Summary

Introduction

The Tsosie 1 site (the Site) is located within the Navajo Nation, Shiprock Bureau of Indian Affairs (BIA) Agency, Teec Nos Pos Chapter in northeastern Arizona. The Site is one of 46 "priority" abandoned uranium mines (AUMs) within the Navajo Nation selected by the United States Environmental Protection Agency (USEPA) in collaboration with the Navajo Nation Environmental Protection Agency (NNEPA) for further evaluation based on radiation levels and potential for water contamination (USEPA, 2013). Mining for uranium occurred prior to, during, and after World War II, when the United States (US) sought a domestic source of uranium located on Navajo lands (USEPA, 2007a).

On April 30, 2015, the *Navajo Nation AUM Environmental Response Trust Agreement – First Phase* (the *Trust Agreement*) became effective. The *Trust Agreement* was made by and among the US, as Settlor and as Beneficiary on behalf of the USEPA, the Navajo Nation, as Beneficiary, and the Trustee, Sadie Hoskie. The *Trust Agreement* was developed in accordance with a settlement on April 8, 2015 between the US and Navajo Nation for the investigation of 16 specified priority AUMs. The priority sites were selected by the US and Navajo Nation, as described in the *Trust Agreement*:

> "based on two primary criteria, specifically, demonstrated levels of Radium-226[1]: (a) at or in excess of 10 times the background levels and the existence of a potentially inhabited structure located within 0.25 miles of AUM features; or (b) at or in excess of two times background levels and the existence of a potentially inhabited structure located within 200 feet (ft)."

The purpose of this report is to summarize the objectives, field investigation activities, findings, and conclusions of Site Clearance and Removal Site Evaluation (RSE) activities conducted between August 2015 and June 2017 at the Site. The primary objectives of the RSEs are to provide data required to evaluate relevant site conditions and to support future removal action evaluations at the Sites. It is not intended to establish cleanup levels or determine cleanup options or potential remedies. The purpose of the RSE data (e.g., the review of relevant information and the collection of data related to historical mining activities) is to determine the volume of technologically enhanced naturally occurring radioactive material (TENORM) at the Site in excess of Investigation Levels (ILs) as a result of historical mining activities. ILs are based on the background gamma measurements (in counts per minute [cpm]), and Radium-226 (Ra-226) and metals concentrations, determined through statistical analyses, that are used to evaluate potential mining-related impacts.

[1] The Agencies selected the priority mines based on gamma radiation but the *Trust Agreement* erroneously states "levels of Radium -226".

Site History and Physical Characteristics

The Site is located within the Colorado Plateau physiographic province, which is an area of approximately 240,000 square miles in the Four Corners region of Utah, Colorado, Arizona, and New Mexico. The Site was one of the small mining operations located in the northwestern Carrizo Mountain mining region, along the Chezhindeza Mesa and Tsitah Wash. Bedrock on the Site consists of the Jurassic Morrison Formation. The Morrison Formation produced approximately 4.7 million pounds of uranium from areas of Arizona and New Mexico (USEPA, 2007a). The Site is also located within the San Juan River watershed, an area of approximately 24,600 square miles spanning Utah, Colorado, New Mexico, and Arizona. Topographically the Site is located on a mesa top, mesa sidewall, and plains with elevation ranges from 5,790 feet above mean sea level (ft amsl) to 5,910 ft amsl. On-site overland surface water flow, when present, is controlled by a decrease in elevation from the mesa top to the surrounding plains.

The Site was only in operation during 1955 and was operated by G.B. Cree Drilling Company. Details regarding mine workings at the Site were not provided in historical documents. The United States Atomic Energy Commission (USAEC) ore production records showed production from the Site in 1955 was 25 tons (approximately 50,000 pounds) of ore that contained 55 pounds of 0.11 percent U_3O_8 (uranium oxide) and 647 pounds of 1.30 percent V_2O_5 (vanadium oxide).

In 1994 the Site was included in a reclamation bid document and in 1995 NAML oversaw the following reclamation activities completed at the Site:

- Bulkheads were installed to close two portals
- The portals were backfilled with mine waste as much as possible and the remaining mine waste was buried in a designated area
- A drainage located at one of the portals was diverted and the drainage course was lined with riprap

In 2010, Weston Solutions (Weston) performed site screening on behalf of the USEPA. The screening included: (1) recording site observations (i.e., number of homes, water sources, and sensitive environments[2] around the Site); (2) recording the type, number, and reclamation status of mine features; and (3) performing a surface gamma survey.

Summary of Removal Site Evaluation Activities

The Trust's RSE was performed in accordance with the *Site Clearance Work Plan* (MWH, 2016a) and the *Removal Site Evaluation Work Plan* ([*RSE Work Plan*] MWH, 2016b). The *Site Clearance Work Plan* and the *RSE Work Plan* were approved in April and October 2016, respectively, by the NNEPA and the USEPA (collectively, the Agencies). The Trust conducted Site Clearance activities as the initial task for the RSE work to obtain information necessary to develop the *Removal Site*

[2] Weston defined sensitive environments as "all sensitive environments located within visible range of the mine site, including: wetlands, endangered species, habitats and approximate locations of sites that may be under protection of the government of the Navajo Nation"

Evaluation Work Plan ([*RSE Work Plan*] MWH, 2016b). Following Site Clearance activities, the Trust conducted two sequential tasks to complete the RSE: Baseline Studies activities and Site Characterization Activities and Assessment. Details of the Site Clearance activities, Baseline Studies activities, and Site Characterization and Assessment activities are as follows:

- **Site Clearance activities** consisted of a desktop study of historical information, site mapping, potential background reference area evaluation, biological (vegetation and wildlife) surveys, and cultural resource survey. Results of the Site Clearance activities provided historical information, site access information, potential background reference area data, and vegetation, wildlife, and cultural clearance of the Site for the Baseline Studies activities and Site Characterization and Assessment activities to commence.

- **Baseline Studies activities** included a background reference area study, site gamma radiation surveys, and a Gamma Correlation Study. Results of the Baseline Studies were used to plan and prepare the Site Characterization Activities and Assessment. Data collected in the background reference area (soil sampling, laboratory analyses, surface gamma surveying, and subsurface static gamma measurements) were used to establish ILs for the Site. Data collected from the site gamma radiation survey were used, along with sampling, to evaluate potential mining-related impacts in areas containing radionuclides. The Gamma Correlation Study objectives were to determine the correlations between: (1) gamma measurements and concentrations of Ra-226 in surface soils; and (2) gamma measurements and exposure rates; to use as screening tools for site assessments.

- **Site Characterization Activities and Assessment** included surface and subsurface soil and sediment sampling, and surface water sampling. The results of the surface and subsurface soil and sediment sampling analyses were used to evaluate mining impacts and define the lateral and vertical extent of TENORM at the Site. The results of the surface water analyses were used to evaluate mining impacts to surface water

Findings and Discussion

Surface and subsurface soil and sediment sampling results. Two background reference areas were selected to develop surface gamma, subsurface static gamma, Ra-226, and metals ILs for the Site. Arsenic, molybdenum, uranium, vanadium, and Ra-226 concentrations and gamma radiation measurements in soil/sediment exceeded their respective ILs and are confirmed constituents of potential concern (COPCs) for the Site. An IL for selenium was not identified because selenium sample results were non-detect in the background areas. However, because selenium was detected in soil/sediment samples from the Survey Area (i.e., the full areal extent of the Site surface gamma survey), it is also confirmed as a COPC for the Site. Based on the data analyses performed for this report along with the multiple lines of evidence, approximately 5.2 acres, out of the 35.0 acres of the Survey Area (i.e., the full areal of the Site surface gamma survey), were estimated to contain TENORM. Of the 5.2 acres that contain TENORM, 3.4 acres contain TENORM exceeding the surface gamma ILs. The volume of TENORM in excess of ILs was estimated to be 15,383 yd^3 (11,761 cubic meters).

Gamma Correlation Study results. Results of the Gamma Correlation Study indicated that surface gamma survey results do not correlate sufficiently well with Ra-226 concentrations in soil.

The model was made of the correlation results predicting the concentrations of Ra-226 in surface soils from the mean of the gamma measurements in five correlation locations. Therefore, users of the regression equation should be aware of the limitations of the dataset and be cautious when estimating radium-226 concentrations. Additional correlation studies may be needed to identify the relationship between gamma and Ra-226.

Water sampling results. Water samples were collected from one surface water seep. Analytical results indicated the surface water sample had uranium, Ra-226, adjusted gross alpha, total dissolved solids (TDS), and sulfate concentrations greater than their respective the ILs. All other metals and general chemistry parameters were below their respective ILs. Based on these results, uranium, Ra-226, adjusted gross alpha, TDS, and sulfate are confirmed COPCs for the seep and additional characterization may be considered at the seep in the future.

Based on the Site Clearance and RSE data collection and analyses for the Site, potential data gaps were identified and are presented in Section 4.9 of this RSE report. These potential data gaps can be taken into consideration for subsequent evaluations in support of future Removal or Remedial Action evaluations at the Site.

Acronyms/Abbreviations

°F	degrees Fahrenheit
e.g.	exempli gratia
etc.	et cetera
ft	feet
ft^2	square feet
i.e.	id est
mg/kg	milligram per kilogram
µg/L	micrograms per liter
µR/hr	microRoentgens per hour
pCi/g	picocuries per gram
yd^3	cubic yards
Adkins	Adkins Consulting Inc.
ags	above ground surface
amsl	above mean sea level
AUM	abandoned uranium mine
bgs	below ground surface
BIA	Bureau of Indian Affairs
CCV	continuing calibration verification
C.F.R	Code of Federal Regulations
COPC	constituent of potential concern
Cooper	Cooper Aerial Surveys Company
cpm	counts per minute
Dinétahdóó	Dinétahdóó Cultural Resource Management
DMP	Data Management Plan
DOI	Department of the Interior
DQO	Data Quality Objective
ERG	Environmental Restoration Group, Inc.
ESA	Endangered Species Act
FSP	Field Sampling Plan
GIS	geographic information system
GPS	global positioning system
HASP	Health and Safety Plan
ICAL	initial calibration
ICB/CCB	initial/continuing calibration blank
ICV	initial calibration verification
IL	Investigation Level

LCS/LCSD	laboratory control sample/laboratory control sample duplicate
MARSSIM	Multi-agency Radiation Survey and Site Investigation Manual
MBTA	Migratory Bird Treaty Act
MCL	maximum contaminant level
MLR	Multivariate Linear Regression
MS/MSD	matrix spike/matrix spike duplicate
MWH	MWH, now part of Stantec Consulting Services Inc. (formerly MWH Americas, Inc.)
NaI	sodium iodide
NAML	Navajo Abandoned Mine Lands Reclamation Program
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NNDFW	Navajo Nation Department of Fish and Wildlife
NNDOJ	Navajo Nation Department of Justice
NNDNR	Navajo Nation Division of Natural Resources
NNDWR	Navajo Nation Department of Water Resources
NNEPA	Navajo Nation Environmental Protection Agency
NNESL	Navajo Nation Endangered Species List
NNHP	Navajo Natural Heritage Program
NNHPD	Navajo Nation Historic Preservation Department
NNPDWR	Navajo National Primary Drinking Water Regulation
NORM	Naturally Occurring Radioactive Material
NSDWR	National Secondary Drinking Water Regulation
OSM	Office of Surface Mining
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
R^2	Pearson's Correlation Coefficient
Ra-226	Radium-226
Ra-228	Radium-228
RSE	Removal Site Evaluation
SOP	standard operating procedure
Stantec	Stantec Consulting Services Inc.
T&E	threatened and endangered
Th-230	thorium-230
Th-232	thorium-232
TDS	total dissolved solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
U-235	uranium-235
U-238	uranium-238

U_3O_8	uranium oxide
UCL	upper confidence limit
US	United States
U.S.C.	United States Code
UTL	upper tolerance limit
USAEC	US Atomic Energy Commission
USDA	US Department of Agriculture
USEPA	US Environmental Protection Agency
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
VCA	Vanadium Corporation of America
V_2O_5	vanadium oxide
Weston	Weston Solutions

Glossary

Alluvium – material deposited by flowing water.

Arroyo – a steep sided gully cut by running water in an arid or semiarid region.

Bin Range – as presented in the RSE report, a range of values to present surface gamma measurement data in relation to: (1) the surface gamma Investigation Level (IL); (2) multiples of the surface gamma IL; or (3) the mean and standard deviation of the predicted Radium-226 (Ra-226) concentrations for the Site based on the correlation equation.

Bulkhead – an engineered wall placed inside a mine portal/adit to close the portal/adit.

Colluvium – unconsolidated, unsorted, earth material transported under the influence of gravity and deposited on lower slopes (Schaetzl and Thompson, 2015).

Composite sample – "Volumes of material from several of the selected sampling units are physically combined and mixed in an effort to form a single homogeneous sample, which is then analyzed" (USEPA, 2002a).

Constituent of potential concern (COPC) – analytes identified in the *RSE Work Plan* where their levels were confirmed based on the results of the RSE.

Data Validation – "an analyte- and sample-specific process that extends the evaluation of data beyond, method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set" (USEPA, 2002b).

Data Verification – "the process of evaluating the completeness, correctness and conformance/compliance of a specific data set against the method, procedural, or contractual requirements" (USEPA, 2002b).

Earthworks – human-caused disturbance of the land surface related to mining or reclamation.

Eolian – a deposit that forms as a result of the accumulation of wind-driven products from the weathering of solid bedrock or unconsolidated deposits.

Ephemeral – ephemeral streams flow only in direct response to surface runoff precipitation or melting snow, and their channels are at all times above the water table (USGS, 2003). This concept also applies to ephemeral ponds that contain water in response to surface runoff precipitation or melting snow and are at all times above the water table.

Ethnographic – relating to the scientific description of peoples and cultures with their customs, habits, and mutual differences.

Gamma – a type of radiation that occurs as the result of the natural decay of uranium.

Geochemical – the chemistry of the composition and alterations of the solid matter of the earth (American Heritage Dictionary, 2016).

Geomorphology – the physical features of the surface of the earth and their relation to its geologic structures (English Oxford Dictionary, 2018).

Grab sample – a sample collected from a specific location (and depth) at a certain point in time.

Investigation Level (IL) – based on the background gamma measurements (in counts per minute [cpm]) and, Radium-226 (Ra-226) and metals concentrations, determined through statistical analyses, that are used to evaluate potential mining-related impacts.

Isolated Occurrences – in relation to the Site Cultural Resource Survey: Any non-structural remains of a single event: alternately, any non-structural assemblage of approximately 10 or fewer artifacts within an area of approximately 10 square meters or less, especially if it is of questionable human origin or if it appears to be the result of fortuitous causes. The number and/or composition of observed artifact classes are a useful rule of thumb for distinguishing between a site and an isolate (NNHPD, 2016).

Mineralized – economically important metals in the formation of ore bodies that have been geologically deposited. For example, the process of mineralization may introduce metals, such as uranium, into a rock. That rock may then be referred to as possessing uranium mineralization (World Heritage Encyclopedia, 2017).

Naturally occurring radioactive material (NORM) – "materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products, that are undisturbed as a result of human activities" (USEPA, 2017).

Orthophotograph – an aerial photograph or image geometrically corrected such that the scale is uniform: the photograph has the same lack of distortion as a map. Unlike an uncorrected aerial photograph, an orthophotograph can be used to measure distances, because it is an accurate representation of the earth's surface, having been adjusted for topographic relief, lens distortion, and camera tilt.

Pan Evaporation – evaporative water losses from a standardized pan.

Portal – The surface entrance to a drift, tunnel, adit, or entry (US Bureau of Mines, 2017).

Radium-226 (Ra-226) – a radioactive isotope of radium that is produced by the natural decay of uranium.

Radium-228 (Ra-228) – a radioactive isotope of radium that is produced by the natural decay of uranium.

Remedial Action (or remedy) – "those actions consistent with permanent remedy taken instead of, or in addition to, removal action in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment…For the purpose of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), the term also includes enforcement activities related thereto" (USEPA, 1992).

Remove or removal – "the cleanup or removal of released hazardous substances from the environment; such actions as may be necessary taken in the event of the threat of release of hazardous substances into the environment; such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances; the disposal of removed material; or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare of the United States or to the environment, which may otherwise result from a release or threat of release…" (USEPA, 1992).

Respond or response – "remove, removal, remedy, or remedial action, including enforcement activities related thereto" (USEPA, 1992).

Secular equilibrium – a type of radioactive equilibrium in which the half-life of the precursor (parent) radioisotope is so much longer than that of the product (daughter) that the radioactivity of the daughter becomes equal to that of the parent with time; therefore, the quantity of a radioactive isotope remains constant because its production rate is equal to its decay rate. In secular equilibrium the activity remains constant.

Static gamma measurement – stationary gamma measurement collected for a specific period of time (e.g., 60 seconds).

Technologically enhanced naturally occurring radioactive material (TENORM) – "naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing", which includes disturbance from mining activities. Where "technologically enhanced means that the radiological, physical, and chemical properties of the radioactive material have been concentrated or further altered by having been processed, or beneficiated, or disturbed in a way that increases the potential for human and/or environmental exposures" (USEPA, 2017).

Thorium (Th) – "a naturally occurring radioactive metal found at trace levels in soil, rocks, water, plants and animals. Thorium (Th) is solid under normal conditions. There are natural and man-made forms of thorium, all of which are radioactive" (USEPA, 2017).

Th-230 – a radioactive isotope of thorium that is produced by the natural decay of thorium.

Th-232 – a radioactive isotope of thorium that is produced by the natural decay of thorium.

Upper Confidence Limit (UCL) – the upper boundary (or limit) of a confidence interval of a parameter of interest such as the population mean (USEPA, 2015).

Upper Tolerance Limit (UTL) – a confidence limit on a percentile of the population rather than a confidence limit on the mean. For example, a 95 percent one-sided UTL for 95 percent coverage represents the value below which 95 percent of the population values are expected to fall with 95 percent confidence. In other words, a 95 percent UTL with coverage coefficient 95 percent represents a 95 percent UCL for the 95^{th} percentile (USEPA, 2015).

Uranium (U) – a naturally occurring radioactive element that may be present in relatively high concentrations in the geologic materials in the southwest United States.

U-235 – a radioactive isotope of uranium that is produced by the natural decay of uranium.

U-238 – a radioactive isotope of uranium that is produced by the natural decay of uranium.

Walkover gamma radiation survey – referred to as a scanning survey in the Multi-agency Radiation Survey and Site Investigation Manual (*MARSSIM*; USEPA, 2000). A walkover gamma radiation survey is the process by which the operator uses a portable radiation detection instrument to detect the presence of radionuclides on a specific surface (i.e., ground, wall) while continuously moving across the surface at a certain speed and in a certain pattern (USEPA, 2000). Referred to in the RSE report as surface gamma survey after the first mention in the report.

Wind rose – a circular graph depicting average wind speed and direction.

1.0 INTRODUCTION

1.1 BACKGROUND

This report summarizes the purpose and objectives, field investigation activities, findings, and conclusions of Site Clearance and Removal Site Evaluation (RSE) activities conducted between August 2015 and June 2017 at the Tsosie 1 site (the Site) located in northeastern Arizona, near the border of Arizona and Utah, as shown in Figure 1-1. The Site is also identified by the United States Environmental Protection Agency (USEPA) as abandoned uranium mine (AUM) identification #55 in the *Navajo Nation AUM Screening Assessment Report and Atlas with Geospatial Data* (the *2007 AUM Atlas*; USEPA, 2007a). The *2007 AUM Atlas* was prepared for the USEPA in cooperation with the Navajo Nation Environmental Protection Agency (NNEPA) and the Navajo Abandoned Mine Lands Reclamation Program (NAML). The claim boundary polygon (refer to Figure 2-1) used for the RSE encompassed an area of approximately 10.7 acres (466,092 square feet [ft^2]) and was provided as part of the *2007 AUM Atlas*. Per the *2007 AUM Atlas* this polygon and other factors represent the location and surface extent of the AUM.

Stantec Consulting Services Inc. (Stantec; formerly MWH), performed Site Clearance activities in accordance with the *Site Clearance Work Plan* (MWH, 2016a), and performed RSE activities in accordance with the *Removal Site Evaluation Work Plan* ([*RSE Work Plan*] MWH, 2016b). The *Site Clearance Work Plan* and the *RSE Work Plan* were approved in April and October 2016, respectively, by the NNEPA and the USEPA (collectively, the Agencies). Stantec conducted this investigation on behalf of Sadie Hoskie, Trustee pursuant to Section 1.1.21 of the *Navajo Nation AUM Environmental Response Trust Agreement – First Phase* (the *Trust Agreement*), effective April 30, 2015 (United States [US], 2015). The *Trust Agreement* is made by and among the US, as Settlor, and as Beneficiary on behalf of the USEPA, the Navajo Nation, as Beneficiary, and the Trustee. The *Trust Agreement* was developed in accordance with a settlement on April 8, 2015 between the US and Navajo Nation for the investigation of 16 specified "priority" AUMs.

A "Site" is defined in the *Trust Agreement* as:

> "each of the 16 AUMs listed on Appendix A to the Settlement Agreement, including the proximate areas where waste material associated with each such AUM has been deposited, stored, disposed of, placed, or otherwise come to be located." *Trust Agreement*, § 1.1.25.

The Site is one of 46 priority AUMs within the Navajo Nation selected by the USEPA in collaboration with the NNEPA for further evaluation based on radiation levels and potential for water contamination (USEPA, 2013). The 16 priority AUMs included in the *Trust Agreement* are located on Navajo Lands throughout southeastern Utah, northeastern Arizona, and western New Mexico, as shown in Figure 1-1. The 16 priority AUMs were selected by the US and Navajo Nation, as described in the *Trust Agreement*:

> "based on two primary criteria, specifically, demonstrated levels of Radium-226[3]: (a) at or in excess of 10 times the background levels and the existence of a potentially inhabited structure located within 0.25 miles of AUM features; or (b) at or in excess of two times background levels and the existence of a potentially inhabited structure located within 200 feet (ft)." *Trust Agreement*, Recitals.

In addition, the 16 priority AUMs are, for the purposes of this investigation, a subset of priority mines for which a viable private potentially responsible party has not been identified. Mining for uranium occurred prior to, during, and after World War II, when the US sought a domestic source of uranium located on Navajo lands (USEPA, 2007a). *Trust Agreement*, Recitals.

1.2 OBJECTIVES AND PURPOSE OF THE REMOVAL SITE EVALUATION

The primary objectives of the RSEs are to provide data required to evaluate relevant site conditions and to support future removal action evaluations at the Sites. It is not intended to establish cleanup levels or determine cleanup options or potential remedies. The purpose of the RSE data (e.g., the review of relevant information and the collection of data related to historical mining activities) is to determine the volume of technologically enhanced naturally occurring radioactive material (TENORM) at the Site in excess of Investigation Levels (ILs) as a result of historical mining activities. ILs are based on the background gamma measurements (in counts per minute [cpm]), and Radium-226 (Ra-226) and metals concentrations, determined through statistical analyses, that are used to evaluate potential mining-related impacts. The USEPA (2017) defines TENORM as:

> "naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing" (mine waste or other mining-related disturbance).
>
> "Technologically enhanced means that the radiological, physical, and chemical properties of the radioactive material have been concentrated or further altered by having been processed, or beneficiated, or disturbed in a way that increases the potential for human and/or environmental exposures."

An understanding of the extent and volume of TENORM that exceeds the ILs at the Site is key information for future Removal or Remedial Action evaluations, including whether, and to what extent, a Response Action is warranted under federal and Navajo law. Definitions presented in the glossary for "Removal", "Remedial Action", and "Response" are defined in 40 Code of Federal Regulations (CFR) Section 300.5 of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP; USEPA, 1992).

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[3] The Agencies selected the priority mines based on gamma radiation but the *Trust Agreement* erroneously states "levels of Radium -226".

The Trust conducted Site Clearance activities to obtain information necessary to develop the *RSE Work Plan*. Site Clearance activities consisted of two separate tasks: a "desktop" study (e.g., literature and historical documentation review) and field activities.

Desktop study – included review of readily available and reasonably ascertainable information including:

- Historical and current aerial photographs to identify any potential historical mining features, and to identify if buildings, homes and/or other structures, and potential haul roads were present within 0.25 miles of the Site
- Topographic and geologic maps
- Available data concerning perennial surface water features and water wells
- Previous studies and reclamation activities
- Meteorological data (e.g., predominant wind direction in the region of the Site)

Site Clearance field activities – included the following:

- Site reconnaissance to evaluate in the field: access routes to the Site, location of site boundaries, and observations presented in the Weston Solutions (Weston)(2010) report
- Mapping of site features and boundaries
- Evaluation of potential background reference areas
- Biological surveys (wildlife and vegetation)
- Cultural resource surveys

Following Site Clearance activities, two sequential tasks were conducted to complete the RSE: Baseline Studies and Site Characterization and Assessment. Baseline Studies activities were completed to establish the basis for the Site Characterization and Assessment activities.

Baseline Studies activities – included the following:

- Background Reference Area Study – walkover gamma radiation survey (referred to hereafter as surface gamma survey), subsurface static gamma radiation measurements (referred to hereafter as subsurface static gamma measurements), surface and subsurface soil sampling, and laboratory analyses
- Site gamma survey – surface gamma survey
- Gamma Correlation Study – co-located surface static gamma measurements and exposure-rate measurements at fixed points, high-density surface gamma surveys (intended to cover 100 percent of the survey area), surface soil sampling, and laboratory analyses

Site Characterization Activities and Assessment – included the following:

- Characterization of surface soils and sediments – surface soil and sediment sampling and laboratory analyses.
- Characterization of subsurface soils and sediments – static gamma measurements (at surface and subsurface hand auger borehole locations), and subsurface sampling and laboratory analyses. Hand auger borehole locations are referred to hereafter as boreholes.
- Characterization of perennial surface water – surface water sampling and laboratory analyses.

Details regarding the Site Clearance activities are provided in the *Tsosie 1 Site Clearance Data Report* (*Site Clearance Data Report*; Stantec, 2017a) and summarized in Section 3.2 of this report. Details regarding the Baseline Study activities are provided in the *Tsosie 1 Site Baseline Studies Field Report* (Stantec, 2017b) and summarized in Section 3.3 of this report. Details regarding the Site Characterization Activities and Assessment are provided in Section 3.3 of this report. Findings are presented in Section 4.0 of this report.

1.3 REPORT ORGANIZATION

This report presents a comprehensive discussion of all RSE activities, including applicable aspects of the outline suggested in the *Multi-Agency Radiation Survey and Site Investigation Manual – Appendix A* ([*MARSSIM*] USEPA, 2000), and consists of the following sections:

Executive Summary – Presents a concise description of the principal elements of the RSE report.

Section 1.0 Introduction – Describes the purpose and objectives of the RSE process, and organization of this RSE report.

Section 2.0 Site History and Physical Characteristics – Presents the history, land use, and physical characteristics of the Site.

Section 3.0 Summary of Site Investigation Activities – Summarizes the Site Clearance and RSE activities.

Section 4.0 Findings and Discussion – Presents the results of the Site Clearance and RSE activities, areas that exceed ILs, areas of Naturally Occurring Radioactive Material (NORM) and TENORM, and the volume of TENORM that exceeds the ILs. Potential data gaps are also presented, as applicable.

Section 5.0 Summary and Conclusions – Summarizes data and presents conclusions based on results of the investigations completed to date.

Section 6.0 Estimate of Removal Site Evaluation Costs – A statement of actual or estimated costs incurred in complying with the *Trust Agreement*, as required by the *Trust Agreement*.

Section 7.0 References – Lists the reference documents cited in this RSE report.

Tables Included at the end of this RSE report.

Figures Included at the end of this RSE report.

Appendices – Appendices A through F.1 are included at the end of this RSE report and Appendix F.2 is provided as a separate electronic file due to its file size and length.

- **Appendix A** – Includes the radiological characterization report for the Site
- **Appendix B** – Includes photographs of the Site
- **Appendix C** – Includes copies of RSE field activity forms
- **Appendix D** – Provides the potential background reference areas selection and the methods and results of the statistical data evaluation for the Site
- **Appendix E** – Includes the biological evaluation report and the biological and cultural resources compliance forms
- **Appendix F** – Includes the Data Usability Report, laboratory analytical data, and data validation reports for the RSE analyses

Attachments – Site-specific geodatabase, tabular database files, and available historical documents referenced in this RSE report.

2.0 SITE HISTORY AND PHYSICAL CHARACTERISTICS

2.1 SITE HISTORY AND LAND USE

2.1.1 Mining Practices and Background

The Site is located on the Navajo Nation near the border of Arizona and Utah and approximately 8 miles southeast of Red Mesa, Arizona, as shown in Figure 1-1 inset. The Site is located in the northwestern Carrizo Mountain mining region, along the Chezhindeza Mesa and Tsitah Wash, as shown in Figure 2-1. A summary of historical mining on the Site is presented below.

During the 1920s and 1930s, mining on the Navajo Nation primarily focused on vanadium mining. In November 1920, the first recorded shipment of uranium and vanadium ore was shipped from the Carrizo Mountain mining region (Chenoweth, 1984 and Chenoweth, 1985). Between 1942 and 1944 Vanadium Corporation of America (VCA) operated numerous vanadium mines in the Carrizo Mountain mining region. By 1945, mines in the Carrizo Mountain region became inactive due to the decreased market for vanadium. After 1947, prospecting and mining for uranium increased in the Carrizo Mountains region. In light of new regulations, exploration drilling by both the US Atomic Energy Commission (USAEC) and uranium mining companies increased in 1953 and additional ore bodies were discovered. To fill the USAEC's need for uranium, VCA reopened its inactive vanadium mines in the Carrizo Mountain region and began mining for uranium. During the mid-1950s, there were more mining operations in the northern and western Carrizo Mountains than at any other time, resulting in large mines, as well as numerous small mining operations throughout the Carrizo Mountain mining region (Chenoweth, 1984 and Chenoweth, 1985).

The Site was one of the small mining operations in the Carrizo Mountain mining region, located in the northwestern Carrizo Mountain mining region. The Site was only in operation during 1955 and was operated by G.B. Cree Drilling Company (Chenoweth, 1984 and Chenoweth, 1985). Details regarding mine workings at the Site were not provided in either the Chenoweth (1984) or Chenoweth (1985) historical documents. The USAEC ore production records showed production from the Site in 1955 was 25 tons (approximately 50,000 pounds) of ore that contained 55 pounds of 0.11 percent U_3O_8 (uranium oxide) and 647 pounds of 1.30 percent V_2O_5 (vanadium oxide).

2.1.2 Ownership and Surrounding Land Use

The Site is located within the Navajo Nation, Shiprock Bureau of Indian Affairs (BIA) Agency in Section 18 of Township 40 North, Range 29 East, Gila and Salt River Principal Meridian. Land ownership where the Site is located falls under Navajo Trust lands. The Site is located within the Teec Nos Pos Chapter of the Navajo Nation, as shown in Figure 1-1, and is in Grazing Unit 9, as designated by the Navajo Nation Division of Natural Resources (NNDNR, 2006). The Site is currently uninhabited, but one home-site is located north of and within 0.25 miles of the Site, as shown in Figure 2-1. Three home-sites are located north of and within 0.5 miles of the Site, as shown in Figure 2-1.

2.1.3 Site Access

In 2015, the Navajo Nation Department of Justice (NNDOJ) provided the Trustee with legal access to all Navajo Trust lands to implement work in accordance with the *Trust Agreement*. The Trustee also obtained individual written access agreements from residents living at or near the Site, or with an interest in lands at or near the Site, such as home-site leases and grazing rights, as applicable. In addition, the Trustee consulted with the Teec Nos Pos Chapter officials and nearby residents and notified them of the work.

2.1.4 Previous Work at the Site

2.1.4.1 1994 through 1999 Aerial Radiological Surveys

Between 1994 and 1999, aerial radiological surveys were conducted at 41 geographical areas within the Navajo Nation, including the Tsetah Wash area, which included the location of the Site (Hendricks, 2001). The surveys were done at the request of the USEPA Region 9 and were performed by the Remote Sensing laboratory, a US Department of Energy facility, National Nuclear Security Administration Nevada Operations Office. The intent of the surveys was to characterize the overall radioactivity levels and excess bismuth-214 activity (i.e., a radioisotope that is an indicator of uranium ore deposits and/or uranium mines) within the surveyed areas. Data collected from the surveys was used to assess the risks (i.e., average gross exposure rate) in mined areas and to determine what action, if any, was needed.

The aerial radiological survey for the Tsetah Wash area covered approximately 16.8 square miles and included the location of the Site. The aerial radiological survey results for the area within a 0.25 mile radius of the Site indicated a gross exposure rate range of 5 μR/hr to 16 μR/hr and excess bismuth (i.e., bismuth activity greater than approximately 3.5 μR/hr) present in approximately 0.008 square miles (5.3 acres) of the area (*2007 AUM Atlas*). The aerial radiological survey results for the Tsetah Wash area indicated a gross exposure rate range of 3.54 μR/hr to 38.62 μR/hr and excess bismuth (i.e., bismuth activity greater than approximately 3.5 μR/hr) present in approximately 0.11 square miles of the 16.8 square miles of the Tsetah Wash flight area (Hendricks, 2001).

2.1.4.2 1994 Tse Tah II/Oakspring II Reclamation Project Invitation for Reclamation Bids

In 1994, NAML issued an invitation for bids for the reclamation of 11 AUMs, referred to as the Tse Tah II/Oakspring II NAML Reclamation Project (NAML, 1994). The Site was one of the 11 included in the bid document and was referred to as NA-0912 in the bid document. The bid document reported the following mining features were present on-site: two portals (with an average size of 7.5 ft wide by 6.5 ft high and of unknown depth), 70 ft of highwall, and 1,555 cubic yards (yd^3) of mine waste. The highwall was the excavated area located around the portals. The bid document included a historical drawing of the Site (refer to Map #13 in the bid document) that showed the locations of the portals, highwall, and mine waste. The bid document listed the need for the following reclamation activities for the Site:

- Improve 1,320 ft of access road to the Site
- Close the portals with an 18-inch thick concrete filled reinforced block bulkhead
- Backfill the bulkhead closure with mine waste material to a 3h:1v (horizontal to vertical) slope or less
- Backfill the highwall with mine waste material to a 3h:1v slope or less
- Consolidate and bury excess mine waste on-site
- On the reclaimed areas, place 18-inches of topsoil, grade, improve/divert drainage, and revegetate

2.1.4.3 1995 Reclamation Activities

NAML oversaw reclamation activities for the Site and reported the progress of the activities in field notes dated May 2, 1995 and May 12, 1995 (NAML, 1995). In the field notes the Site was referred to as NA-0912. As reported by NAML, the following reclamation activities were completed at the Site in 1995:

- Bulkheads were installed to close two portals
- The portals were backfilled with mine waste as much as possible and the remaining mine waste was buried in a designated area
- A drainage located at one of the portals was diverted and the drainage course was lined with riprap

On July 11, 1995, the US Department of the Interior (USDOI) Office of Surface Mining (OSM) Reclamation and Enforcement visited the 11 AUMs reclaimed as part of the Tse Tah II/Oakspring II NAML Reclamation Project (US OSM, 1995). The purpose of the visits was to view completed and ongoing reclamation conducted by NAML. The OSM reported their visit findings in a letter addressed to NAML dated July 18, 1995. In the letter the OSM reported their findings (for the 11 AUMs reclaimed as part of the Tse Tah II/Oakspring II NAML Reclamation Project) as follows: all portal closures were intact, and reclaimed areas were top-dressed, seeded, and mulched. Reconstructed drainages were armored with riprap in a number of areas. Access roads in the immediate vicinity of the reclaimed sites were similarly reclaimed.

2.1.4.4 2010 Site Screening

In 2010, Weston performed site screening on behalf of the USEPA (Weston, 2010). The screening included: (1) recording site observations (i.e., number of homes, water sources, and sensitive environments[4] around the Site); (2) recording the type, number, and reclamation status of mine features; and (3) performing a surface gamma survey. Weston reported no home-sites were within 0.25 miles of the Site, no water features were within a one-mile radius of the Site, and no sensitive environments were identified. Weston also reported the Site was reclaimed and identified one sealed portal, a reclamation cap, and one waste pile. Based on Weston's performance of a surface gamma survey, Weston determined that the highest gamma measurements were greater than 61 times the site-specific background level used for its gamma screening.

2.2 PHYSICAL CHARACTERISTICS

2.2.1 Regional and Site Physiography

The Site is located within the Colorado Plateau physiographic province, which is an area of approximately 240,000 square miles in the Four Corners region of Utah, Colorado, Arizona, and New Mexico. Figure 2-2 presents a current regional aerial photograph (NAIP, 2018) of the Site within a portion of the Colorado Plateau. The Colorado Plateau is typically high desert with scattered forests and varying topography having incised drainages, canyons, cliffs, buttes, arroyos, and other features consistent with a regionally uplifted, high-elevation, semi-arid plateau (Encyclopedia Britannica, 2017). The physiographic province landscape includes mountains, hills, mesas, foothills, irregular plains, alkaline basins, some sand dunes, and wetlands. This physiographic province is a large transitional area between the semi-arid grasslands to the east, the drier shrub-lands and woodlands to the north, and the lower, hotter, less-vegetated areas to the west and south.

The Colorado Plateau includes the area drained by the Colorado River and its tributaries: the Green, San Juan, and Little Colorado Rivers (Kiver and Harris, 1999). The physiographic province is composed of six sections: Uinta Basin, High Plateaus, Grand Canyon, Canyon Lands, Navajo, and Datil-Mogollon. The Site is located within the Navajo section.

The Site is located in the northwestern Carrizo Mountain mining region in the central portion of the Colorado Plateau. Figure 2-3 presents the regional US Geological Survey (USGS) topographic map of a portion of the Colorado Plateau in the vicinity of the Site. Figure 2-4 presents the Site topography (Cooper Aerial Surveys Company [Cooper; refer to Section 3.2.2.1]) within a portion of the Colorado Plateau. The Site is located on a mesa top, mesa sidewall, and plains with elevation ranges from 5,790 feet above mean sea level (ft amsl) to 5,910 ft amsl (refer to Figure 2-4).

[4] Weston defined sensitive environments as "all sensitive environments located within visible range of the mine site, including: wetlands, endangered species, habitats and approximate locations of sites that may be under protection of the government of the Navajo Nation"

2.2.2 Geologic Conditions

2.2.2.1 Regional Geology

Regionally the Site is located within the Colorado Plateau, which is a massive outcrop of generally flat-lying sedimentary rocks ranging in age from the Paleozoic Era to the Cenozoic Era (USGS, 2017). The plateau has very little regional structural deformation, compared with the mountainous basin-and-range region to the west, and the sedimentary beds range widely in thickness from less than one inch to hundreds of feet. Changes in paleoclimate and elevation produced alternating occurrences of deserts, streams, lakes, and shallow inland seas; and these changes contributed to the type of rock deposited in the region. The rock units of the plateau consist of shallow submarine or sub-aerially deposited rocks including sandstone, shale, limestone, mudstone, siltstone, and various other sedimentary rock subtypes.

Bedrock on or adjacent to the Site consists of the Jurassic Summerville Formation, and the Jurassic Brushy Basin and Salt Wash Members of the Morrison Formation. Regionally the Summerville Formation is of marginal marine and tidal origin composed of reddish-brown, thinly bedded sandstone with interbedded gypsiferous siltstone, sandy siltstone, or mudstone and is known for its thin beds of rippled sandstones and mud cracks (University of Utah, 2018). Regionally, the Morrison Formation is composed of various rocks of lacustrine and fluvial continental origin, including mudstone, sandstone, limestone, and siltstone (USGS, 1967). Figure 2-5 depicts a regional geology map showing the Site in relation to the regional extent of the Morrison Formation. The sandstone strata of the Morrison Formation contains the majority of uranium ore reserves in the US. Deposition of the Morrison Formation may have coincided with uplift of the western basin-and-range region and the beginning of the Nevadan orogeny. The Morrison Formation covers an area of approximately 600,000 square miles (USGS, 1967) and is centered in Wyoming and Colorado, with outcrops in Canada, Montana, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Utah, Idaho, New Mexico, and Arizona (Turner and Peterson, 2004). Approximately 4.7 million pounds of uranium was mined from the Morrison Formation within areas of Arizona and New Mexico (USEPA, 2007a).

2.2.2.2 Site Geology

Bedrock outcrops on or adjacent to the Site consist of the Jurassic Salt Wash and Brushy Basin Members of the Morrison Formation and the Jurassic Summerville Formation, as shown in Figure 2-6a. The Brushy Basin Member of the Morrison Formation consists of green, purple, and gray shale and siltstone; gray and tan sandstone and conglomeratic sandstone. The Salt Wash Member of the Morrison Formation consists of yellowish-gray to greenish-gray cross-bedded very fine to medium-grained calcareous sandstone interbedded with greenish-gray and reddish–brown claystone. The Summerville Formation consists of reddish-brown to light-orange very fine- to fine-grained flat bedded silty sandstone and tin-bedded silty sandstone, claystone, and siltstone. The transition between the Summerville Formation and the Quaternary deposits on-site is not a defined boundary and the Summerville Formation is often overlain by the Quaternary deposits. Shallow or outcropping mineralized bedrock on Site is shown in Figure 2-6b.

Unconsolidated deposits on-site are alluvium, colluvium, and eolian deposits consisting of poorly graded sand, poorly graded sand with gravel, silty sand with gravel, and silty sand. During the Site Characterization field activities, boreholes were advanced through the unconsolidated deposits using a hand auger until termination due to stable low gamma measurements or refusal at either bedrock or cobbles (refer to Section 3.3.2.2 and Appendix C.2 for borehole logs). The unconsolidated deposits ranged in depth from 0.7 ft to greater than 3.9 ft below ground surface (bgs).

According to the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey for Apache County, Arizona, soils on-site that have not been disturbed, are classified as the Arches-Kitsili-Mido complex soil consisting of loamy fine sand which is highly permeable and has a low available water storage (NRCS, 2006).

2.2.3 Regional Climate

The Colorado Plateau is located in a zone of arid temperate climates characterized by periods of drought and irregular precipitation, relatively warm to hot growing seasons, and winters with sustained periods of freezing temperatures (National Park Service, 2017). The average monthly high temperature at weather station 028468, Teec Nos Pos, Arizona (Western Regional Climate Center, 2017) located approximately 11 miles east of the Site, ranges between 41.5 degrees Fahrenheit (°F) in January to 93.1°F in July. Daily temperature extremes reach as high as 105°F in summer and as low as 18°F in winter. Teec Nos Pos receives an average annual precipitation of 8.1 inches, with August being the wettest month, averaging 1.16 inches, and June being the driest month, averaging 0.26 inches.

Potential evaporation in the area is greater than the area's average annual precipitation. The potential evaporation noted at the Many Farms School, Arizona weather station, located approximately 40 miles southwest of the Site, averages 91 inches of pan evaporation annually (Western Regional Climate Center, 2017). Average wind speeds in the area are generally moderate, although relatively strong winds often accompany occasional frontal activity, especially during late winter and spring months. Blowing dust, soil erosion, and local sand-dune migration/formation are common during dry months. The Cortez, Colorado airport, located approximately 50 miles to the northeast of the Site, had the most complete record of wind conditions. A wind rose for the Cortez airport is presented on Figure 1-1. The wind rose was produced using data contained in the *2007 AUM Atlas* for the years 1996 to 2006. Predominant winds were from the east-northeast (refer to the wind rose on Figure 1-1). However, Stantec field personnel (field personnel) generally observed wind from the west when in the area of the Site.

2.2.4 Surface Water Hydrology

The Site is located within the San Juan River watershed, an area of approximately 24,600 square miles spanning Utah, Colorado, New Mexico, and Arizona, as shown in Figure 1-1. On-site surface water flow (i.e. overland flow), when present, is controlled by a decrease in elevation from the mesa top to the surrounding plains (refer to Figures 2-4 and 2-7). Parallel patterned ephemeral drainages are present on-site that drain north/northwest into an unnamed drainage, as shown in

Figures 2-1 and 2-7. The western most drainages drain into a temporary ponding area before connecting with the unnamed drainage. The unnamed drainage connects to the Tsitah Wash approximately 0.75 miles north of the Site (refer to Figure 2-1). Tsitah Wash joins the San Juan River approximately 20 miles northeast of the Site, as shown in Figure 1-1 inset. In addition, surface water flow is controlled around a reclaimed area on-site, located at the base of the mesa edge, by two drainage channels that are armored with riprap (refer to Figure 2-7).

Adkins Consulting Inc. (Adkins), under contract to Stantec, performed a wildlife evaluation as part of the Site Clearance field investigations and did not identify any wetlands, seeps, springs, or riparian areas within the Site that would be attractive to wildlife (refer to Appendix E).

2.2.5 Vegetation and Wildlife

In May 2017, Adkins conducted a wildlife survey and a vegetation survey as part of Site Clearance activities. Information about each survey is provided in Appendix E, which includes the Site biological evaluation reports and the *Navajo Nation Department of Fish and Wildlife* (NNDFW) *Biological Resources Compliance Form*. A summary of the survey activities and findings are provided in Section 3.2.2.3.

Vegetation communities found within the physiographic transitional area described in Section 2.2.1 include shrublands with big sagebrush, rabbitbrush, winterfat, shadscale saltbush, and greasewood; and grasslands of blue grama, western wheatgrass, green needlegrass, and needle-and-thread grass. Higher elevations may support pinyon pine and juniper woodlands. The Site is predominantly sparsely vegetated sage brush/shrubland with scattered pinyon pine and juniper trees (refer to Appendix E). During the surveys, Stantec and/or its subcontractors observed on-site wildlife including common raven, cottontail rabbit, coyote, turkey vulture, and Scotts' oriole (refer to Appendix E).

2.2.6 Cultural Resources

In October 2016, as part of Site Clearance activities, Dinétahdóó Cultural Resource Management (Dinétahdóó), under contract to Stantec, conducted a cultural resource survey, as well as ethnographic and historical data reviews, and interviewed a local resident living near the Site (Dinétahdóó, 2016). The local resident stated that family members had worked at the mine and that it was last in operation around 1948 or 1950 by VCA. The resident also stated the mine had one long main tunnel that branched off into two tunnels. The main tunnel was all underground and was over a mile long and exited on the other side of Tsitah Wash.

During the cultural resource survey Dinétahdóó identified one archaeological site and eight isolated occurrences. Appendix E includes a copy of the *Cultural Resource Compliance Form,* and findings of the cultural resource survey are summarized in Section 3.2.2.4.

2.2.7 Observations of Potential Mining and Reclamation

During RSE activities, field personnel observed the following features indicative of potential mining or reclamation activities at the Site: potential haul roads, a waste pile, one of the sealed portals, a reclaimed area, and historical boreholes. Details regarding these observations are presented in Section 3.2.2.1.

On July 28, 2017, a representative from NAML confirmed via email that the following reclamation activities had occurred on-site:

- Mine waste from the Site was buried within the open portals to the extent possible
- Both portals were bulk headed with 18 inches of concrete and rock
- Mine waste that would not fit into the portals was then piled against the steep slope where the buried portal was located and covered with clean/borrow material from within the NAML project boundaries (refer to the reclaimed area on Figure 2-7)
- Drainages surrounding the reclaimed area were addressed with rip rap to prevent erosion

These observations and NAML confirmations were used, along with additional lines of evidence (refer to Section 3.3.3), to identify areas at the Site where TENORM was present (refer to Section 4.6).

3.0 SUMMARY OF SITE INVESTIGATION ACTIVITIES

3.1 INTRODUCTION

This section summarizes Site Clearance and other RSE activities conducted between August 2015 and June 2017. Site Clearance activities were conducted initially to obtain information necessary to develop the *RSE Work Plan*. Site Clearance activities were performed in accordance with the approved *Site Clearance Work Plan.* Resulting RSE activities were performed in accordance with the approved *RSE Work Plan.*

The primary objectives of the RSEs are to provide data required to evaluate relevant site conditions and to support future removal action evaluations at the Sites. It is not intended to establish cleanup levels or determine cleanup options or potential remedies.

The *RSE Work Plan* is comprised of a Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), Health and Safety Plan (HASP), and a Data Management Plan (DMP). The FSP guided the fieldwork by defining sampling and data-gathering methods. The QAPP presented quality assurance/quality control (QA/QC) requirements designed to meet Data Quality Objectives (DQOs) for the environmental sampling activities. The HASP listed site hazards, safety procedures and emergency protocols. The DMP described the plan for the generation, management, and distribution of project data deliverables. The FSP, QAPP, HASP, and DMP provided the approved requirements and protocols to be followed for the RSE data collection, data management, and data analyses performed to develop this RSE report. Any deviations or modifications from the *RSE Work Plan* are described in the appropriate RSE report sections.

The RSE process followed applicable aspects of the USEPA DQO Process and *MARSSIM*, to verify that data collected during the RSE activities would be adequate to support reliable decision-making (USEPA, 2006). The USEPA DQO Process is a series of planning steps based on the scientific method for establishing criteria for data quality and developing survey designs. *MARSSIM* provides technical guidance on conducting radiation surveys and site investigations.

The USEPA DQO Process is a seven-step process[5] that was performed as part of the *RSE Work Plan* to identify RSE data objectives. The goal of the USEPA DQO Process is to minimize expenditures related to data collection by eliminating unnecessary, duplicate, or overly precise data and verifies that the type, quantity, and quality of environmental data used in decision making will be appropriate for the intended application. It provides a systematic procedure for defining the criteria that the survey design should satisfy. This approach provides a more effective survey design combined with a basis for judging the usability of the data collected (USEPA, 2006).

[5] (1) State the problem; (2) Identify the goals of the study; (3) Identify the information inputs; (4) Define the boundaries of the study; (5) Develop the analytical approach; (6) Specify the tolerance on decision errors; and (7) Optimize sampling design (USEPA, 2006).

The USEPA DQO Process performed for the RSE is presented in the *RSE Work Plan*, Section 3, and identifies the purpose of the data collected as follows:

1. Background reference area soil sampling, laboratory analyses, surface gamma surveying, and subsurface static gamma measurements to establish background analyte concentrations and gamma measurements, which will be used as the ILs, for the Site.
2. Site sampling (soil and sediment), laboratory analyses, surface gamma surveying, and subsurface static gamma measurements for comparison with ILs, to define the lateral and vertical extent of contamination at the Site to characterize the Site to support future Removal or Remedial Action evaluations.

The USEPA DQO Process was used in conjunction with *MARSSIM* guidance for RSE planning and data collection. Per *MARSSIM* guidance, "planning radiation surveys, using the USEPA DQO Process, can improve radiation survey effectiveness and efficiency, and thereby the defensibility of decisions" (USEPA, 2000).

The applicable aspects of *MARSSIM* incorporated into the RSE process include:

- Historical site assessment
- Determining RSE DQOs
- Selecting background reference areas
- Selecting radiation survey techniques
- Site preparation
- Quality control
- Health and safety
- Survey planning and design
- Baseline surface gamma surveys and subsurface static gamma measurements
- Field measurement methods and instrumentation
- Media sampling and preparation for laboratory analyses

The RSE process also used applicable aspects of *MARSSIM* for interpretation of the RSE results, including:

- Data quality assessment through statistical analyses
- Evaluation of the analytical results
- Quality assurance and quality control

Sections 3.2 and 3.3 summarize the preparation, field investigation methods, and procedures for data collection during the Site Clearance activities and other RSE activities. Activities subsequent to the Site Clearance are described in detail in the *RSE Work Plan,* Section 4. Appendix A includes the radiological characterization report prepared by Environmental Restoration Group, Inc. (ERG), under contract to Stantec. Appendix B includes photographs of features at the Site and the surrounding area, Appendix C.1 includes soil/sediment sample field forms, Appendix C.2 includes borehole logs, and Appendix C.3 includes water sample field forms.

3.2 SUMMARY OF SITE CLEARANCE ACTIVITIES

The Site Clearance activities consisted of two tasks: a desktop study and field investigations. The desktop study was completed prior to field investigations, and the findings of the desktop study were used to guide field investigations. The Site Clearance activities are detailed in the *Site Clearance Data Report* and are described below.

3.2.1 Desktop Study

The desktop study included:

- Review of historical aerial photographs (USGS, 2016). Photographs were selected based on sufficient scale, quality, resolution, and whether the photograph met one or more of the following criteria:
    - Showed evidence of active mining or grading of the Site, or provided information on how the Site was developed or operated (e.g., haul roads and open pits).
    - Showed evidence of reclamation (e.g., soil covers).
    - Showed significant changes in ground cover compared to current photographs.
- Review of current aerial photographs for identification of buildings, homes and other structures, and potential haul roads within 0.25 miles of the Site.
- Review of topographic and geologic maps.
- Review of information related to surface water features and water wells on the Navajo Nation within a one-mile radius of the Site, provided by: (1) the Navajo Nation Department of Water Resources (NNDWR, 2016); and (2) ESRI Shapefiles data contained in the *2007 AUM Atlas*.
- Review of previous studies, information related to potential past mining, and reclamation activities.
- Identification of the predominant wind direction in the region of the Site.

Based on the list above, the following findings were identified during the desktop study:

- Historical photographs (USGS, 2016) for the Site were selected from 1949, 1976, 1997, and 2005 for comparison against a current 2017 image (Cooper, 2017). The selected historical photographs are shown in Figure 3-1a. Figure 3-1b compares the aerial photograph from 1997 and a current image. In the 1997 image, the reclaimed area is visible.

- The current aerial photograph review confirmed that the Site was uninhabited, but one home-site was located north of and within 0.25 miles of the Site and three home-sites were located north of and within 0.5 miles of the Site, as shown in Figure 2-1. Numerous dirt roads were identified within 0.25 miles of the Site, refer to Figure 2-1. The road type (i.e., potential haul road or road unrelated to historical mining) was identified by the current aerial photograph review, historical document review, and visual identification during the Site Clearance field investigations (refer to Section 3.2.2.1).

- Eleven potential water features were identified based on the review of information provided by the NNDWR and the *2007 AUM Atlas*, refer to Table 3-1 and Figure 2-1.

- The predominant regional winds were from the east-northeast (refer to Section 2.2.3 and Figure 1-1).

Previous studies and information related to past mining/exploration are discussed in Sections 2.1.1 and 2.1.4.

3.2.2 Field Investigations

3.2.2.1 Site Mapping

The *Site Clearance Work Plan* specified that the following features at and near the Site, if present, should be mapped, marked, and/or their presence confirmed:

- Claim boundaries and the 100-ft buffers of the claim boundaries

- Roads, fences/gates, utilities: haul roads to a distance of 0.25 miles or to the intersection with the next major road, whichever is closer

- Structures, homes, buildings, livestock pens, etc.

- Surface water and water well locations: surface water channels that drain the Site to a distance of 0.25 miles away from the Site or to the confluence with a major drainage, whichever is closer; surface water features and water wells identified within a one-mile radius of the Site

- Topographic features

- Potential background reference areas

- Type of ground cover, including rock, soil, waste rock, etc.

- Physical hazards

Based on the list above, the following site features were mapped during field investigations:

- Claim boundaries – 100-ft buffers of the claim boundaries, as shown in Figure 2-7, were marked in the field with stakes and/or flagging and mapped with a global positioning system (GPS).
- Topographic features – The mapped area can be divided into three primary topographic areas, as shown in Figure 2-4: the mesa top, the mesa sidewall, and the plains.
- Roads – A dirt road was mapped along the mesa top, as shown in Figures 2-1 and 2-7.
- Potential haul roads – Two potential haul roads were mapped, as shown in Figures 2-1 and 2-7. The two potential haul roads extended to the north-northeast of the claim boundary on either side of the unnamed drainage. The potential haul roads did not provide access to those areas of the Site where mining occurred. This is likely due to NAML reclamation efforts (refer to Section 2.1.4) where access roads in the immediate vicinity of the reclaimed sites were also reclaimed.
- Portals – Two portals were mapped, as shown in Figure 2-7. Both portals were sealed with concrete-filled cinder blocks, and one of portals was buried during reclamation activities. The approximate buried portal location is shown in Appendix B-1 photograph number 3. The sealed portal is shown in Appendix B-1 photograph number 5.
- Temporary ponded area – A dammed, temporary ponded area was mapped, as shown in Figure 2-7. Surface water can temporarily collect behind an earthen dam and then evaporate. Field personnel did not observe standing water in the temporary ponding area during RSE site visits. Per discussions with nearby residents, the earthen dam was placed to create a reservoir (temporary ponding area) for livestock. The date the dam was installed is unknown; NNDWR was contacted about the dam, and it did not have any information about the dam. The earthen dam was approximately 20 ft high. The earthen dam is shown in Appendix B-1 photograph numbers 10 and 11.
- Historical boreholes – Two 5.5-inch diameter boreholes were mapped, as shown in Figure 2-7. The boreholes were observed in the southeast portion of the Site, on the mesa top where bedrock was exposed at the surface. The boreholes were located approximately 200 ft southeast of the buried portal. The historical boreholes are shown in Appendix B-1 photograph number 1.
- Reclaimed area – A reclaimed area was mapped, as shown in Figure 2-7. This area was below the approximate buried portal location and is also shown as part of the earthworks in Figures 2-6a and 2-6b. The reclaimed area is shown in Appendix B-1 photograph numbers 6, 7, and 8.
- Drainages – Parallel patterned ephemeral drainages were mapped, as shown in Figures 2-1 and 2-7. The drainages drain north/northwest into an unnamed drainage. The westernmost drainages drain into a temporary ponding area before connecting with the unnamed drainage. The unnamed drainage connects to the Tsitah Wash approximately 0.75 miles north of the Site. Tsitah Wash joins the San Juan River approximately 20 miles northeast of the

Site, as shown in Figure 1-1 inset. In addition, surface water flow was controlled around the reclaimed area on-site, located at the base of the mesa edge, by two drainage channels that were armored with riprap (refer to Figure 2-7). The drainage on one portion of the reclaimed area has left the riprap channel and created an incised channel within the reclamation area and gray sediment that is potential mine waste is present. Drainages are shown in Appendix B-1 photograph numbers 4, 9, and Appendix B-2 photograph number 14.

- Waste pile – One waste pile was mapped, as shown in Figure 2-7. The waste pile was below the sealed portal, comprised of disturbed sediment with limited vegetation present, and is also shown as part of the earthworks in Figures 2-6a and 2-6b. The waste pile is shown in Appendix B-1 photograph number 2.
- Structures – The Site is currently uninhabited, but one home-site was located north of and within 0.25 miles of the Site and three home-sites were located north of and within 0.5 miles of the Site, as shown in Figure 2-1. Weston Solutions (2010) did not identify any home-sites within 0.25 miles of the Site.
- Livestock – field personnel observed cattle, sheep, and feral horses within the Site.
- Ground cover – Ground cover and vegetation observed on-site are discussed in Sections 2.2.2.2 and 2.2.5, respectively.
- Water features – Field personnel assessed the 11 water features identified from the desktop study, as shown in Figure 2-1. The water features and field personnel observations are included in Table 3-1. In addition, during site mapping activities field personnel assessed a seep identified by a resident that lived near the Site. Field personnel identified the seep as S055-Seep-1/Donkey Spring (refer to Figure 2-1). The seep was located in a drainage approximately 0.33 miles southeast of the Site and day-lighted along a contact between sandstone beds, as shown in Appendix B-2 photograph number 17.

In June 2018, the USEPA provided the Trust with a copy of a NNDWR database that was generated in 2018. The USEPA stated that there were discrepancies between the NNDWR water feature locations in the 2018 database and those provided in the 2016 NNDWR database used by the Trust. This information was provided after Site Characterization activities had occurred and was therefore not included in the RSE for the Site. Comparison of the 2018 NNDWR database against the 2016 NNDWR database and the *2007 AUM Atlas* will require additional field work and it is recommended that this be addressed in future studies for the Site.

In addition to the Site mapping activity, the Trust took high-resolution aerial photographs and collected topographic data at the Site. The objective of the high-resolution aerial photography survey was to develop orthophotographs and topographic data of the Site to:

- Assist with identifying ground cover (e.g., soil versus bedrock)
- Assist with delineating historical mine features (e.g., haul roads, portals, and waste piles)
- Allow additional evaluation of areas that were inaccessible due to steep or unsafe terrain

- Provide site base maps (high resolution imagery and elevation data) that could be used to support future Removal or Remedial Action evaluations at the Site

Stantec proposed to perform aerial photography in order to provide an overview of the Site and identify features that could not otherwise be accomplished safely on foot. USEPA is not authorized to allow drones on sites it oversees: therefore, drone use was not an option. Although aerial photography was not included in the approved *Scope of Work* (MWH, 2016c), the Trustee notified the Agencies and obtained approval prior to commencement of the work. The Trust also consulted with Teec Nos Pos Chapter officials and nearby residents and notified them of the aerial photography survey. On June 16, 2017, Cooper flew over the Site in a piloted fixed-wing aircraft and collected 3.5-centimeter digital color stereo photographs of the Site. Cooper provided the following data:

- Digital, high-resolution color orthophotograph imagery
- AutoCAD files (2-dimensional and 3-dimensional) that included elevation contours (refer to Figure 2-4) and plan features
- Elevation point files
- Triangular Irregular Network surface files

The site orthophotographs and supporting data files were used for data analyses, including estimating volumes of potentially mining-impacted material at the Site. They also were used as the base image for selected figures included in this RSE report, to the extent applicable.

3.2.2.2 Potential Background Reference Area Evaluation

The desktop study findings and field investigation observations were used to identify four potential background reference areas (BG-1 through BG-4) for the Site, as shown in Figure 3-2, and described in Appendix D.1. BG-1and BG-2 were selected as suitable background reference areas for the Site for the following reasons:

- BG-1 encompassed an area of 1,812 ft^2 (approximately 0.04 acres), was located 520 ft northeast of the claim boundary, and was cross-wind and hydrologically cross-gradient from the Site. The unconsolidated deposits in BG-1 represented the portions of the Survey Area that were within the Summerville Formation. The vegetation and ground cover at BG-1 were similar to the portions of the Site on the plains. While the area around BG-1 is mapped mostly as the Summerville Formation, it should be noted that the ground surface consists of soils similar to soils observed at BG-3 (mapped as Quaternary deposits).
- BG-2 encompassed an area of 510 ft^2 (approximately 0.01 acres), was located 520 ft northeast of the claim boundary, and was cross-wind and hydrologically cross-gradient from the Site. The thin soils, colluvium-covered slopes, and bedrock outcrops represented the portions of the Survey Area that are within the Morrison Formation. The vegetation and ground cover at BG-2 were similar to the portions of the Site on the mesa sidewall.

BG-3 and BG-4 were not selected as background reference areas for the Site for the reasons described in Appendix D.1. The Agencies have suggested that further evaluation of background conditions for the Morrison Formation may be warranted, including investigation of the differences observed in the mesa sidewall (BG-2) and mesa top (BG-4) (NNEPA, 2018).

The potential background reference areas were selected based on *MARSSIM* guidance (i.e., similar geology and ground conditions, upwind of the Site, distance from the Site, etc.) to:

1. Represent undisturbed conditions at the Site (e.g., pre-mining conditions)
2. Provide a basis for establishing the ILs

The approved *RSE Work Plan* did not specify any minimum or maximum size criteria for these areas. Stantec does not view the size of the selected background reference areas as affecting the validity of the background concentrations. The sizes were based on professional judgment that the identified areas were generally representative of the Site.

The background reference areas were selected in areas outside of the Site that were considered to be representative of the general conditions observed at the Site. However, an important consideration is that the background gamma radiation and metals concentrations within soil and bedrock can be variable and often contain a wider range of concentrations than what was measured at the selected background reference areas. The ILs derived from the background reference areas provide a useful reference for comparison to the Site. However, it will be important to consider the variations in concentrations when conducting site assessment work and/or to support future Removal or Remedial Action evaluations at the Site.

3.2.2.3 Biological Surveys

The objective of the biological surveys was to determine if identified species of concern or potential federal or Navajo Nation Threatened and Endangered (T&E) species and/or critical habitat are present on or near the Site. Biological (vegetation and wildlife) clearance was required at the Site before RSE activities could begin, to determine if the RSE activities could affect potential species of concern or federal or Navajo Nation listed T&E species and/or critical habitat. The Site biological evaluation reports, the *NNDFW Biological Resources Compliance Form*, and the US Fish and Wildlife Service (USFWS) consultation email are provided in Appendix E.

The Federal Endangered Species Act (ESA) of 1973, 16 U.S.C. §1531 et seq., requires that each Federal agency confer with the USFWS on any agency action that is likely to jeopardize the continued existence of any proposed T&E species or result in the destruction or adverse modification of critical habitat proposed to be designated for such species 16 U.S.C. §1536(a)(4). An "action area", as defined in the regulations implementing the ESA, includes "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action". 50 C.F.R §402.2.

The vegetation and wildlife surveys were conducted according to guidelines of the ESA and the NNDFW-Navajo Natural Heritage Program (NNHP), including the procedures set forth in the Biological Resource Land Use Clearance Policies and Procedures, RCS-44-08 (NNDFW, 2008), the Species Accounts document (NNHP, 2008), and the USFWS survey protocols and recommendations (USFWS, 1996).

Based on the results of the vegetation and wildlife surveys, the NNDFW's opinion was that the RSE Baseline Studies and Site Characterization Activities,

> "with applicable conditions, [were] in compliance with Tribal and Federal laws protecting biological resources including the Navajo Endangered Species and Environmental Policy Codes, US Endangered Species, Migratory Bird Treaty, Eagle Protection and National Environmental Policy Acts".

A copy of the *NNDFW Biological Resources Compliance Form* is included in Appendix E. In addition, after the Trust submitted the results of the biological survey, USEPA consulted with John Nystedt of the USFWS on August 26, 2016, and received an email response on August 29, 2016 stating:

> "Based on the information you [Stantec] provided [i.e., there is no habitat for any Federally listed species in the action area], we [the USFWS] believe no endangered or threatened species or critical habitat will be affected by the project; nor is this project likely to jeopardize the continued existence of any proposed species or adversely modify any proposed critical habitat" (Nystedt, 2016).

A copy of the Nystedt email is included in Appendix E. In light of the results of the biological surveys described below, the USFWS recommended no further action from the USFWS for the project unless the project or regulations change, or a new species is listed.

<u>**Vegetation Survey**</u> - In May 2017, Adkins performed a spring vegetation survey as part of the Site Clearance field investigations. Complete details of the vegetation survey, including the *NNDFW Biological Resources Compliance Form*, are included in Appendix E and summarized below.

In preparation for the vegetation survey, Adkins submitted data requests for species of concern to the NNDFW and NNHP, and for Federal T&E species, to the USFWS. The NNDFW-NNHP responded to MWH (now Stantec) by letter dated November 19, 2015. The letter provided a list of species of concern known to occur within the proximity of the Site and included their status as either Navajo Nation Endangered Species List (NNESL), and/or Federally Endangered, Federally Threatened, or Federal Candidate. The NNESL species were further classified as G2, G3, or G4[6]. A copy of this letter is included in Appendix E. A summer vegetation survey was not required for

[6] G2 classification includes endangered species or subspecies whose prospect of survival or recruitment are in jeopardy, G3 classification includes endangered species or subspecies whose prospect of survival or recruitment are likely to be in jeopardy in the foreseeable future, and G4 classification are "candidates" and includes those species or subspecies which may be endangered but for which sufficient information is lacking to support being listed (refer to Appendix E).

the Site because the species of concern data provided by NNDFW-NNHP did not include listed potential plant species that require a summer survey.

The NNDFW listed one T&E plant species that may occur on-site: Parish's alkali grass (G4). The USFWS did not list any T&E plant species that may occur on-site. Parish's alkali grass is a native annual grass that grows in a series of widely disjunct populations ranging from southern California to eastern Arizona and western New Mexico in alkaline springs, seeps, and seasonally wet areas that occur at the heads of drainages or on gentle slopes at elevations from 2,600 ft to 7,200 ft amsl.

Before beginning the Site vegetation surveys, Adkins reviewed the ecologic and taxonomic information for the T&E species to understand ecological characteristics of the species, habitat requirements, and key taxonomic indicators for proper identification (Arizona Native Plant Society, 2000). Adkins also reviewed currently accepted resource agency protocols and guidelines for conducting and reporting botanical inventories for special status plant species (USFWS, 1996). An experienced Adkins botanist with local flora knowledge conducted the rare plant survey. The botanist walked transect lines on the Site with emphasis on areas with suitable habitat for Parish's alkali grass, specifically alkaline seeps.

The Redente botanist did not identify Parish's alkali grass at the Site, based on observations he made during the on-site survey. The botanist concluded he did not identify Parish's alkali grass at the Site because the Site was not a likely habitat for the T&E species. The Site was predominantly sparsely vegetated sage brush/shrubland with scattered pinyon pine and juniper trees.

Wildlife Survey - In May 2017, Adkins performed a wildlife evaluation survey as part of the Site Clearance field investigations. The completed wildlife survey, including the *NNDFW Biological Resources Compliance Form*, are included in Appendix E and are summarized below.

Adkins performed the survey under a permit issued by NNDFW for the purpose of assessing habitat potential for ESA-listed or NNESL animal species. Adkins biologists with experience identifying local wildlife species led the field survey, which consisted of walking transects 10 ft apart throughout the Site, including a 100-ft buffer beyond the claim boundary. The surrounding areas were visually inspected with binoculars for nests, raptors, or signs of raptor use.

The wildlife evaluation was performed for species listed as NNESL, Federally Endangered, Federally Threatened, or Federal Candidate, and species protected under the Migratory Bird Treaty Act (MBTA) that have the potential to occur on-site. Prior to the start of the wildlife survey, Adkins submitted data requests to USFWS and NNDFW for animal species listed under the ESA. The NNESL species were further classified as G2, G3, or G4. The USFWS included seven ESA-species with the potential to occur in the area of the Site; two birds (Mexican spotted owl and western yellow-billed cuckoo), two fish (roundtail chub and Zuni bluehead sucker), two mammals (black-footed ferret and gray wolf), and one reptile (northern Mexican gartersnake). The NNDFW included: five birds (mountain plover [G4], golden eagle [G3], southwestern willow flycatcher [G2], American peregrine falcon [G4], and western burrowing owl [G4]), one fish (Colorado pikeminnow [G2]), and one amphibian (northern leopard frog [G2]). All species on the USFWS list and all species from the NNDFW list, with the exception of the golden eagle, were eliminated from further evaluation because there was no potential for those species to occur on the Site due to lack of suitable habitat. Based on the preparation data, one bird (golden eagle) remained as species of concern warranting further analysis during the Site survey.

In addition, Adkins reviewed species protected under the MBTA that have the potential to occur in the area of the Site. The MBTA review resulted in the potential for identification of 16 bird species in addition to those listed above, known as "Priority Birds of Conservation Concern with the Potential to Occur"[7] in the areas of the Site: black-throated sparrow, Brewer's sparrow, gray vireo, loggerhead shrike, mountain bluebird, mourning dove, sage sparrow, sage thrasher, scaled quail, Swainson's hawk, vesper sparrow, bald eagle, Bendire's thrasher, pinyon jay, prairie falcon, and ferruginous hawk. These 16 MBTA bird species were added for further analysis during the survey for effects to potential habitat.

The wildlife survey revealed one NNESL species of concern that has the potential to occur within or near the Site based on habitat suitability or actual recorded observation: golden eagle. Based on these findings Adkins recommended the use of best management practices to protect potential habitat during RSE activities, specifically: (1) confining equipment travel to within the boundaries of the Site; (2) minimizing travel corridors as much as possible; (3) limiting truck and equipment travel within the Site when surfaces are wet and soil may become deeply rutted; and (4) using previously disturbed areas for travel when possible. The recommended best management practices were followed to protect potential habitat during RSE activities.

3.2.2.4 Cultural Resource Survey

In October 2016, Dinétahdóó conducted a cultural resource survey as part of the Site Clearance field investigations. Navajo Nation Historic Preservation Department (NNHPD) issued a Class B permit to Dinétahdóó on behalf of the Trust to conduct the cultural resource survey. Following the cultural resource survey, the NNHPD issued a Cultural Resources Compliance Form that included a "Notification to Proceed" with RSE field work. A copy of the Cultural Resources Compliance Form is included in Appendix E. According to NNHPD, this form is the equivalent of a "permit" to conduct the work (NNHPD, 2018[8]).

The survey included the areas within the claim boundary and the 100-ft claim boundary buffer, as shown in Figure 2-7. The survey identified one archaeological site and eight isolated occurrences. For confidentiality reasons, details regarding the archaeological site and isolated occurrences are not provided herein. NNHPD can be contacted for additional information. NNHPD contact information is located on the *Cultural Resource Compliance Form* included in Appendix E.

Based on the survey findings, Dinétahdóó recommended during RSE activities that the boundaries of the archaeological site be flagged and that an archaeologist monitor all ground

[7] USFWS, 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

[8] Call with Sadie Hoskie, Tamara Billie of NNHPD, and Linda Reeves, June 8, 2018

disturbing activities, including soil sampling, within 50 ft of the archaeological boundaries. Dinétahdóó also stipulated that RSE activities be halted at any time if cultural resources were encountered. Stantec complied with Dinétahdóó's recommendations while conducting RSE activities on–site.

Dinétahdóó also escorted field personnel during: (1) the collection of subsurface soil samples at the background reference areas (refer to Section 3.3.1.1); and (2) during Site Characterization borehole subsurface soil sample collection in locations outside the 100-ft buffer (refer to Section 3.3.2.2). The Trust and NNHPD agreed that Dinétahdóó's archeologist would be present because the subsurface sample locations were outside of the area originally surveyed during the Site Clearance cultural resource survey.

3.3 SUMMARY OF REMOVAL SITE EVALUATION ACTIVITIES

The RSE activities consisted of two additional tasks following the Site Clearance Activities: Baseline Studies and Site Characterization activities. The Baseline Studies included a Background Reference Area Study, Site gamma survey, and Gamma Correlation Study. The results of the Baseline Studies were used to plan and prepare the Site Characterization field investigations, which included surface and subsurface soil and sediment sampling, and surface water sampling. Results of the RSE activities are presented in Section 4.0. Baseline Studies and Site Characterization activities are summarized in Sections 3.3.1 and 3.3.2, respectively.

3.3.1 Baseline Studies Activities

3.3.1.1 Background Reference Area Study

The Background Reference Area Study activities were completed at the background reference areas selected for the Site. Refer to Section 3.2.2.2 for an explanation of the selection of the background reference areas for the Site. The Background Reference Area Study included a surface gamma survey, static surface and subsurface gamma measurements, surface soil sampling, and subsurface soil sampling. The soil sample locations in the background reference areas were initially selected using a triangular grid, set on a random origin. Where possible, samples were collected at the center points of the triangles. However, in some instances, the actual sample locations had to be moved in the field if sampling was not possible (e.g., the location consisted of exposed bedrock or there was a large bush blocking access). In these cases, the closest accessible location was selected instead.

The background reference areas were selected based on a variety of factors, including *MARSSIM* criteria, which indicated whether the areas were representative of unmined locations, regardless of the sizes of the area. These factors are described in this RSE report and accompanying appendices. The objectives of the background reference area study were to measure gamma radiation levels emitted by naturally occurring, undisturbed uranium-series radionuclides, and concentrations of other naturally occurring constituents. The results were used to establish background gamma levels and concentrations of Ra-226 and specific metals (uranium, arsenic, molybdenum, selenium, and vanadium). The soil sampling locations at the background reference areas are presented in Figure 3-3. Field personnel performed the Background Reference Area Study in accordance with the *RSE Work Plan,* Sections 4.2, 4.4, and 4.5.

The background reference area surface gamma surveys at BG-1 and BG-2 were completed in October 2016. ERG performed the surface gamma surveys using Ludlum Model 44-10 2-inch by 2-inch sodium iodide (NaI) high-energy gamma detectors (the detectors). Each detector was coupled to a Ludlum Model 2221 ratemeter/scaler that in turn was coupled to a Trimble ProXRT GPS unit with a NOMAD 900 series datalogger. The detector tagged individual gamma measurements with associated geopositions recorded using the Universal Transverse Mercator Zone 12 North coordinate system. ERG matched and calibrated the detector to a National Institute of Standards and Technology-traceable cesium-137 check source, and function-checked the equipment prior-to and after each workday. ERG performed the surveys by walking the background reference areas with the detector carried by hand, along transects that varied depending on encountered topography. The gamma measurements were collected with the height of the detector varying from 1 ft to 2 ft above ground surface (ags) with an average height of 1.5 ft ags to accommodate vegetation, rocks, or other surface features. If field personnel encountered an immovable obstruction (e.g., a tree) during the surface gamma surveys they went around the obstruction. Subsequent to each workday, ERG downloaded the gamma measurements to a computer and secure server.

The same equipment used for the surface gamma surveys was also used to collect static one-minute gamma measurements at the ground surface and down-hole (subsurface) at borehole locations S055-BG1-011 (BG-1) and S055-BG2-011 (BG-2). Refer to Appendix C.2 for borehole logs. Static gamma measurements were categorized as surface measurements where they were collected at ground surface (0.0 ft) and as subsurface measurements where depths were below ground surface due to the influence of downhole geometric effects on subsurface static gamma measurements (refer to Section 4.1). Gamma measurements were collected according to the methods described in the *RSE Work Plan,* Section 4.2 and Appendix E.

Soil samples collected as part of the background study are detailed in Table 3-2 and sample locations are shown in Figure 3-3. Soil samples were categorized as surface samples where sample depths ranged from 0.0 to 0.5 ft bgs and as subsurface samples where sample depths were greater than 0.5 ft bgs. Field personnel collected the following samples from the background reference areas:

- BG-1 – In June 2017, 11 surface soil grab samples were collected from 11 locations and two subsurface soil grab samples were collected from borehole S055-BG1-011
- BG-2 – In June 2017, 11 surface soil grab samples were collected from 11 locations and two subsurface soil grab samples were collected from borehole S055-BG2-011

Samples were shipped to a USEPA approved laboratory, ALS Environmental Laboratories in Fort Collins, Colorado for analyses. Samples were collected according to the methods described in the *RSE Work Plan,* Section 3.8.1.1. The results of the surface gamma survey, static surface and subsurface gamma measurements, and surface and subsurface soil sample analytical results provided background reference data to guide the Site Characterization surface and subsurface soil/sediment sampling (refer to Section 3.3.2). The Background Reference Area Study results are presented in Section 4.1. The ERG survey report in Appendix A provides further details on the gamma surveys. Field forms, including borehole logs, are provided in Appendix C.1 and C.2.

3.3.1.2 Site Gamma Radiation Surveys

Baseline Studies activities included a surface gamma survey of the Site in accordance with the *RSE Work Plan,* Section 4.2 and Appendix E. The shoulders of the potential haul roads were surveyed, but the approximate center-lines were not surveyed, due to miscommunication with the field personnel. This is identified as a potential data gap in Section 4.9.

The surface gamma survey was used to evaluate the extent of potential mining-related impacts or areas containing elevated radionuclides associated with uranium mineralization. In addition, surface and subsurface soil and sediment samples and surface water samples were also collected and used to evaluate mining-related impacts (refer to Section 3.3.2).

In October 2016, and June and September 2017, the surface gamma survey was performed using the methods and equipment described in Section 3.3.1.1 with the exception that the detector was carried in a backpack when topographical features did not allow field personnel to carry the detector by hand for safety reasons. The surface gamma survey included the claim area, a 100-ft buffer around the claim area, and roads and drainages out to approximately 0.25 miles from the Site. The *RSE Work Plan* specified that the surface gamma survey would be an iterative process where the surface gamma survey would be extended laterally until gamma measurements appeared to be within background levels. Subsequent to each workday, the gamma measurements were evaluated by ERG and Stantec, and compared to the background reference areas to determine if additional surface gamma surveying was needed.

The full areal extent of the surface gamma survey is referred to as the Survey Area, as shown in Figure 3-4. The Survey Area was 35.0 acres and was subdivided into two separate survey areas, as shown in Figure 3-4, based on *MARSSIM* criteria, including different geologic conditions on-site. Survey Area A is within the Summerville Formation and the Quaternary deposits (based on BG-1), and Survey Area B is within the Salt Wash Member of the Morrison Formation (based on BG-2).

It was necessary to subdivide the Survey Area based on geologic conditions and present the findings in Section 4.0 based on the subdivision, because geologic formations can have different geochemical compositions (i.e., gamma levels and concentrations of Ra-226, uranium, arsenic, molybdenum, selenium, and vanadium). The surface gamma survey results are presented in Section 4.2. The ERG survey report in Appendix A provides further detailed information on the surface gamma survey.

3.3.1.3 Gamma Correlation Study

Baseline Studies activities included a Gamma Correlation Study in accordance with the *RSE Work Plan,* Section 4.3. The objectives of the Gamma Correlation Study were to determine correlations between the following constituents to use as screening tools for site assessments:

- Gamma measurements (in cpm) and concentrations of Ra-226 in surface soils (in picocuries per gram [pCi/g])
- Gamma measurements (in cpm) and exposure rates (in microRoentgens per hour [µR/hr])

Two regression analyses were conducted for these correlations. The first regression analysis was performed using co-located high-density surface gamma measurements and laboratory concentrations of Ra-226 in surface soils to develop a correlation equation (refer to Section 4.2.2). The correlation equation allows for Ra-226 concentrations in soil and sediment to be estimated (predicted) based on gamma measurements in the field.

This correlation equation was not used in the field to estimate Ra-226 concentrations or to evaluate the extent of Ra-226 concentrations. The correlation was used to develop a site-specific prediction for Ra-226 concentrations from the actual gamma survey data as presented in Section 4.2.2. The correlation can be used as a site-specific field screening tool during site assessments, using the same gamma survey methods as in this RSE (e.g., walkover gamma survey) and based on site-specific conditions. The data related to the correlations are provided in Appendices A and C.

The second regression analysis was performed using co-located static one-minute gamma measurements and exposure rates to develop an exposure-rate correlation equation. Exposure rates can be predicted, based on gamma measurements, using the developed exposure-rate correlation equation. The exposure rate correlation also provides a standard by which future gamma measurements can be compared to previous gamma measurements, if those previous gamma measurements were also correlated with exposure. In addition, exposure rates can be used to provide an estimate of gamma radiation levels when an exposure meter is used as a health and safety tool for field personnel working on-site. The exposure rate correlation was not used for Site Characterization. Because the exposure rates are not part of the data analyses for the RSE report, a summary of the exposure rate correlation is not presented in this report. Appendix A provides a discussion of the correlations and the regression equations for both correlations.

In June 2017, field personnel identified five areas for the Gamma Correlation Study, as shown in Figure 3-5, by considering the results of the Site surface gamma survey (described in Section 3.3.1.2), field conditions (e.g., suitable terrain), and feasibility of sampling. To minimize variability when determining a correlation between gamma measurements (in cpm) and concentrations of Ra-226 in soil, the study area soils must: (1) represent a specific gamma measurement within the range of gamma measurements collected at the Survey Area; and (2) be as homogenous as possible with respect to soil type, and gamma measurement within the correlation area. At each area, field personnel completed a high-density surface gamma survey (intended to cover 100 percent of the survey area) and collected one five-point composite surface soil sample per area (refer to Table 3-2). Field personnel made a field modification from the *RSE Work Plan* by adjusting the size of the 900 ft^2 area smaller at the Gamma Correlation Study locations, to minimize the variability of gamma measurements observed. The area used for the Gamma Correlation Study is shown in Figure 3-5, where the box shown at the five study locations represents a 900 ft^2 area in comparison to the actual area covered for the study, as shown by the extent of the gamma measurements within each area. During subsequent review of the gamma correlation survey data it was identified an error occurred with the GPS datalogger and gamma data were not recorded for two correlation locations. Field personnel re-surveyed the correlation locations in September 2017.

Field personnel collected, logged, classified, packaged, and shipped the samples in accordance with the *RSE Work Plan,* Sections 4.4, 4.9, 4.11, and Appendix E. Soil samples were collected for analyses of Ra-226 and isotopic thorium, as described in the *RSE Work Plan,* Section 3.4.1.

The objectives of the thorium analyses were for site characterization and evaluation of potential effects of thorium on the correlation. The data can be used to assess the potential effects of thorium-232 (Th-232) series radioisotopes on the correlation of gamma measurements to concentrations of Ra-226 in surface soils (i.e., if gamma-emitting radioisotopes in the Th-232 series, such as actinium-228, lead-212, and thallium-208, are impacting gamma measurements at the Site), as discussed in Section 4.2.2. Uranium, radium, and thorium occur in three natural decay series (uranium-238 [U-238], Th-232, and U-235), each of which include significant gamma emitters (USEPA, 2007b). Therefore, in order to develop a correlation between gamma radiation and Ra-226 concentrations, the gamma radiation from each significant decay series present at the Site, may need to be considered. Typically, only U-238, and sometimes Th-232, are present in significant quantities. The contribution from the U-235 decay series to gamma measurements can be excluded because U-235 is only approximately 0.72 percent of the total uranium concentration. If the Th-232 decay series is present in significant quantities, it should be accounted for in the correlation to accurately predict Ra-226 concentrations based on all significant sources of gamma radiation.

3.3.1.4 Secular Equilibrium

The Gamma Correlation Study soil samples (refer to Section 3.3.1.3) were also analyzed for thorium-230 (Th-230), in accordance with the *RSE Work Plan,* Section 3.4.1. The activities of Th-230 and Ra-226 can be compared to evaluate the status of secular equilibrium within the U-238 decay series (USEPA, 2007b). The U-238 decay series is in secular equilibrium when the radioactivity of a parent radionuclide (e.g., U-238) is equal to its decay products (refer to Appendix A). If the U-238 decay series is out of secular equilibrium, the quantities of the daughter products become depleted. This could be considered for potential site assessments (e.g., when evaluating the contribution of the daughter products to the total risk related to U-238 during a human health and/or ecological risk assessment). As part of the RSE, the secular equilibrium evaluation was a general indicator (e.g., screening level assessment) of the status of equilibrium at the sites. It was not used to characterize the extent of constituents of potential concern (COPCs) at the Site. The secular equilibrium evaluation is discussed here only because Th-230 was included in the isotopic thorium analysis.

3.3.2 Site Characterization Activities and Assessment

3.3.2.1 Surface Soil and Sediment Sampling

Site Characterization activities included surface soil and sediment sampling and associated laboratory analyses. The soil and sediment surface sampling locations within the Survey Area were selected based on professional judgment (i.e., non-randomly) to evaluate concentrations of Ra-226 and metals in relation to the surface gamma survey measurements and site features (e.g., historical mining features and geologic features). Based on the surface gamma survey results and site features, a limited number of samples were collected and analyzed where the gamma survey measurements were within background levels, mining and or exploration-related features were not present, and no ground disturbance was observed. The results were compared to the site-specific ILs and published regional concentrations to support the overall evaluation of potential mining impacts (refer to Section 4.3). Soil/sediment samples were categorized as surface samples where sample depths ranged from 0.0 to 0.5 ft bgs and as subsurface samples where sample depths were greater than 0.5 ft bgs. Samples collected in drainages were classified as sediment samples.

In June 2017, samples were collected from the locations shown in Figure 3-6a and are summarized in Table 3-2. Sample locations and the locations of mining-related features are shown in Figure 3-6b. The number of surface samples collected within specific mine features are listed in Table 3-3. Twenty-one surface soil/sediment grab samples were collected from 21 locations in the Survey Area (11 from Survey Area A and 10 from Survey Area B). Field personnel collected, logged, classified, packaged, and shipped the samples in accordance with the *RSE Work Plan,* Sections 4.4, 4.9, 4.11, and Appendix E. Samples were shipped to ALS Environmental Laboratories in Fort Collins, Colorado for analyses of: Ra-226, uranium, arsenic, molybdenum, selenium, and vanadium, as described in the *RSE Work Plan,* Section 4.13.1. The surface soil and sediment analytical results are presented in Section 4.3. Field forms are provided in Appendix C.1 and the laboratory analytical data, data validation reports, and Data Usability Report for the analyses are provided in Appendix F.

3.3.2.2 Subsurface Soil and Sediment Sampling

Site Characterization activities included subsurface soil and sediment sampling and associated laboratory analyses. Similar to the surface soil/sediment sampling discussed in Section 3.3.2.1, subsurface sampling locations were selected based on professional judgment (i.e., non-randomly) to evaluate concentrations of Ra-226 and metals in relation to the surface gamma survey measurements and site features (e.g., historical mining features and geologic features). Grab samples were collected with the intent to characterize specific intervals of interest (e.g., material within zones with elevated static gamma measurements). Composite samples were collected to provide a screening level assessment across an interval (e.g., soil collected from the potential staging area). Surface and subsurface static gamma measurements were collected in the borehole using the same equipment as described in Section 3.3.1.1. Static gamma measurements were collected by holding the detector in the borehole for a one-minute integrated count and are not comparable to the surface gamma survey measurements, which were collected as a walkover survey.

Eleven boreholes were advanced in the Survey Area (eight in Survey Area A and three in Survey Area B). The boreholes were advanced through the unconsolidated deposits (from 0.7 ft to 3.9 ft bgs; refer to Table 3-2 and Appendix C.2) until: (1) termination due to stable low gamma measurements (the use of this criterion was a field error and has been identified as a potential data gap in Section 4.9); or (2) refusal at either bedrock or cobbles. Field personnel manually advanced the subsurface boreholes to a desired sample depth by using a 3-inch diameter hand auger. The boreholes were advanced through poorly graded sand, poorly graded sand with gravel, silty sand with gravel, and silty sand (refer to Appendix C.2 for borehole information). A drill rig was not employed at the Site because the primary areas of Site disturbance were on the mesa sidewall or the reclaimed area (inaccessible to a drill rig) and it was assumed the depth of mining-related impacts could be evaluated successfully with a hand auger. However, a hand auger was not adequate to evaluate the depth of potentially mining-impacted sediments in the temporary ponding area (this is identified as a data gap in Section 4.9).

In June 2017, samples were collected from the locations shown in Figure 3-6a and are summarized in Table 3-2. Sample locations and the locations of mining-related features are shown in Figure 3-6b. The numbers of subsurface samples collected within specific mine features are listed in Table 3-3. Fifteen subsurface soil/sediment samples were collected from 11 borehole locations in the Survey Area (multiple subsurface samples were collected from boreholes S055-SCX-003, -SCX-005, -SCX-007, and -SCX-008). Eleven subsurface samples were collected from Survey Area A and four from Survey Area B.

Field personnel logged, classified, packaged, and shipped the samples in accordance with the *RSE Work Plan,* Sections 4.5, 4.9, 4.11, and Appendix E. Samples were shipped to ALS Environmental Laboratories in Fort Collins, Colorado for analyses of Ra-226, uranium, arsenic, molybdenum, selenium, and vanadium, as described in the *RSE Work Plan,* Section 4.13.1. The subsurface analytical results are presented in Section 4.3. Field forms, including borehole logs showing static gamma measurements and Ra-226 analytical results, are provided in Appendix C.2. The laboratory analytical data, data validation reports, and Data Usability Report for the analyses are provided in Appendix F.

3.3.2.3 Water Sampling

Eleven potential water features were identified during the Site Clearance desktop study and one water feature was identified during site mapping, as shown in Figure 2-1 and Table 3-1. Ten of the 12 features were not sampled because field personnel did not observe a surface water or well water feature at those locations. Two water features were sampled as described below.

On May 24, 2016, a surface water sample (S055-WS-001) was collected from a seep identified in the NNDWR database and the *2007 AUM Atlas* as 09-6-14. The seep was located approximately 0.78 miles southwest of the Site along a geologic contact on a bedrock sidewall and was approximately 50 ft long, as shown in Appendix B-2 photograph number 16. A rock drain was constructed downgradient of the seep that drained into a polyvinyl chloride (PVC) pipe that gravity fed to a cement vault approximately 170 ft northwest of the seep. The cement vault was approximately 4 ft square and had a hole on top where large livestock (horses) could access water, as shown in Appendix B-2 photograph number 15. The seep water sample was collected from the cement vault.

On April 23, 2018, surface water field parameters (S055-WS-0012) were collected from a seep identified by Stantec/Trust as S055-Seep-1/Donkey Spring. This seep was identified by a resident that lived near the Site and the resident notified the Trust about the presence of the seep. A water sample was not collected for laboratory analyses because of the low flow rate of the seep (approximately less than 10 milliliters per minute). However, there was enough water present to collect field parameters. The seep was located in a drainage, approximately 0.33 miles southeast of the Site, along a contact between sandstone beds, as shown in Appendix B-2 photograph number 17.

The water sample collected for dissolved metals analyses was sampled and field filtered using a peristaltic pump, Teflon® tubing, and 0.45-micron inline filter in the field at the time of sample collection per the *RSE Work Plan*, Section 4.6.1. All other analyses did not require in-field filtering. The sample was collected, packaged, and shipped in accordance with the *RSE Work Plan,* Sections 4.6, 4.9, 4.11, and Appendix E. ACZ Laboratories, Inc. in Steamboat Springs, Colorado conducted the mercury analysis and ALS Environmental Laboratories in Fort Collins, Colorado conducted all other analyses including Ra-226 and Radium-228 (Ra-228), adjusted gross alpha, and the following total and dissolved metals: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, uranium, vanadium, and zinc.

Additional general water quality analyses or field measurements included: total dissolved solids (TDS), anions (carbonate, bicarbonate, chloride, and sulfate), cations (sodium and calcium), and field measurements (pH, conductivity, turbidity, temperature, and oxidation reduction potential). Salinity was not collected as part of the specified field measurements because the water quality meter the field personnel were using could not measure salinity. This is identified as a data gap in Section 4.9. Table 3-4 provides a summary of the water analyses. Per the *RSE Work Plan*, if surface water sample analyte concentrations are above the established ILs then those sample areas would be considered for additional characterization in the future. Surface water analytical results are presented in Section 4.8. Field forms are provided in Appendix C.3 and the laboratory analytical data and Data Usability Report for the analyses are provided in Appendix F. Investigation of groundwater is not included in the scope of this RSE.

3.3.3 Identification of TENORM Areas

Areas at the Site where TENORM is present were identified using multiple lines of evidence including:

1. Historical Data Review
   a. Aerial photographs
   b. USAEC records
   c. Reclamation records
   d. Other documents relevant to the Site, including those in the *2007 AUM Atlas*
   e. Interviews with residents living closest to the Site (for those sites where residents were available for interview)
   f. Consultation and site visits with NAML staff to identify reclamation features (for those sites reclaimed by NAML)
2. Geology/Geomorphology
   a. Hydrology/transport pathways with drainage delineation
   b. Site-specific geologic mapping including areas of mineralization
   c. Topography
3. Disturbance Mapping
   a. Exploration
   b. Mining
   c. Reclamation
4. Site Characterization
   a. Surface gamma surveys and subsurface static gamma measurements
   b. Soil/sediment sampling and analyses

Any areas where TENORM was not observed are considered to contain NORM, because soil and/or rock at the Site contain some amount of natural uranium and its daughter products. This area was mined because of the high levels of naturally occurring uranium ore. The areas containing NORM and/or TENORM are presented in Section 4.6. The volume of TENORM is presented in Section 4.7. The areas containing NORM and/or TENORM, along with additional findings of the RSE report, are identified to support future Removal or Remedial Action evaluations at the Site.

3.4 DATA MANAGEMENT AND DATA QUALITY ASSESSMENT

This section summarizes the data management and data quality assessment activities performed for the RSE.

3.4.1 Data Management

The DMP included in the *RSE Work Plan* describes the plan for the generation, validation, and distribution of project data deliverables. Successful data management comes from coordinating data collection, quality control, storage, access, reduction, evaluation, and reporting. A summary of the data management activities performed as part of the RSE process included:

- **Database** – Field-collected and laboratory analytical RSE data were stored in an Oracle SQL relational database, which increased data handling efficiency by using previously developed data entry, validation, and reporting tools. The Oracle SQL database was also used to export project data to a tabular format that can be used in a spreadsheet (e.g., Excel) and to the USEPA Scribe database format.

- **Scribe** – The Stantec Data Manager/Data Administrator was responsible for meeting the project data transfer requirements from the Oracle SQL database to Scribe, which is a software tool developed by the USEPA's Environmental Response Team to assist in the process of managing environmental data. Stantec maintained an Oracle SQL database and exported data from the Oracle SQL database to a Scribe compatible format following completion of each field investigation phase. Custom data queries and "crosswalk" export routines were built in Oracle SQL, to facilitate data export to the Scribe database format with the required frequency.

- **Geographic Information System (GIS)** – Spatial data collected during the RSE (e.g., sample locations and gamma measurements) were stored in a dedicated File Geodatabase for use in the project GIS. The geodatabase format enforces data integrity, version control, file size compression, and ease of sharing to preserve GIS output quality. Periodic geodatabase backups were performed to identify accidentally deleted or otherwise corrupt information that were then repaired or recovered, if applicable.

3.4.2 Data Quality Assessment

The QAPP, included in the *RSE Work Plan*, Appendix B, was followed for RSE data quality assessment, where the QAPP presents QA/QC requirements designed to meet the RSE DQOs. Data quality refers to the level of reliability associated with a particular data set or data point. The Data Usability Report included in Appendix F.1 provides a summary of the data quality assessment activities and qualified data for the RSE. A summary of findings, from the data quality assessment, are included below.

- **Data Verification** – The data were verified to confirm that standard operating procedures (SOPs) specified in the *RSE Work Plan* and *FSP* were followed and that the measurement systems were performed in accordance with the criteria specified in the QAPP. Any deviations or modifications from the *RSE Work Plan* are described in the appropriate RSE report sections. The USEPA definition (USEPA, 2002b) for data verification is provided in the glossary.

- **Data Validation** – The data were validated to confirm that the results of data collection activities support the objectives of the RSE as documented in the QAPP. The data quality assessment process was then applied using the validated data and determined that the quality of the data satisfies the intended use. The USEPA definition (USEPA, 2002b) for data validation is provided in the glossary. A copy of the Data Usability Report is included in Appendix F.1 and a summary of the validation results is presented below:
  - **Precision** Based on the matrix spike/matrix spike duplicate (MS/MSD) sample, laboratory control sample/laboratory control sample duplicate (LCS/LCSD) sample, laboratory duplicate sample, and field duplicate results, the data are precise as qualified.
  - **Accuracy** Based on the initial calibration (ICAL), initial calibration verification (ICV), continuing calibration verification (CCV), MS/MSD, and LCS, the data are accurate as qualified.
  - **Representativeness** Based on the results of the sample preservation and holding time evaluation, the method and initial/continuing calibration blank (ICB/CCB) sample results, the field duplicate sample evaluation, and the reporting limit evaluation, the data are considered representative of the Site as reported.
  - **Completeness** All media and QC sample results were valid and collected as scheduled (i.e., as planned in the *RSE Work Plan*); therefore, completeness for these is 100 percent.
  - **Comparability** Standard methods of sample collection and standard units of measure were used during this project. The analyses performed by the laboratory were in accordance with current USEPA methodology and the QAPP.

Based on the results of the data validation, all data are considered valid as qualified.

4.0 FINDINGS AND DISCUSSION

4.1 BACKGROUND REFERENCE AREA STUDY RESULTS AND CALCULATION OF INVESTIGATION LEVELS

The results of the background reference area surface gamma survey are shown in Figures 4-1a through 4-1c with sample locations in the background reference areas shown for BG-1 and BG-2 on Figures 4-1b and 4-1c, respectively. The surface gamma survey in BG-1 did not cover the areal extent of the sample locations. Analytical results of the samples collected from BG-1 and BG-2 are summarized in Table 4-1. The gamma measurements and surface soil sample analytical results collected from BG-1 and BG-2 were evaluated statistically to calculate ILs (refer to Appendix D.2) for each corresponding Survey Area (i.e., Survey Area A and Survey Area B, respectively). As previously discussed in Section 3.3.1.2, the Site was subdivided into two separate Survey Areas based on the geologic formations on-site.

Statistical evaluation of the gamma measurements and soil sample analytical results included identifying potential outlier values, interpreting boxplots and probability plots, comparing group means between the background reference areas and the respective Survey Area data, and calculating descriptive statistics for each of the background reference areas. The descriptive statistics included the 95 percent upper confidence limit (UCL) on the mean gamma measurements and Ra-226/metals concentrations, and the 95-95 upper tolerance limits (UTLs). The data were analyzed using R statistical programming packages and ProUCL 5.1 software (USEPA, 2016c).

The DQOs presented in the RSE Work Plan indicate that the ILs would be developed using the 95 percent UCL on the mean of the background sample results. However, the 95-95 UTL was used as the basis for the ILs instead because it better reflects the natural variability in the background data and lends itself to single-point comparisons to the Survey Area data. This was a change from the *RSE Work Plan*, as agreed upon with the Agencies, prior to the change. The UTL represents a 95 percent UCL for the 95th percentile of a background dataset whereby Survey Area results above this value are not considered representative of background conditions. The UTL is a statistical parameter for the entire population of the variable, whereas the actual results are from a sample of the population. UTLs were calculated in accordance with USEPA's *ProUCL 5.1 Technical Guidance*, Sections 3.4 and 5.3.3 (USEPA, 2015). Appendix D.2 presents a comprehensive discussion on the derivation of the ILs for the Site, which are presented below. The *RSE Work Plan* also stated that gamma radiation measurements from the background surface and subsurface soil would be combined to develop the IL for surface gamma radiation at the Site. However, the surface gamma radiation ILs were instead developed from the surface gamma survey data only. The Agencies have commented that this should be noted as a deviation from the *RSE Work Plan*. The subsurface static gamma measurements were excluded from the derivation of the surface gamma IL for two reasons: (1) they were collected using a different method (static one-minute measurements versus a walkover gamma survey); and

(2) because of the downhole geometric effects that influence subsurface static gamma measurements (refer to the discussion of geometric effects below).

The ILs for Survey Area A (i.e.; the Summerville Formation and Quaternary deposits; refer to Figure 2-6a) were established using statistical analysis of background data collected from BG-1(refer to Figure 3-3) and are as follows:

- Arsenic – 2.67 milligrams per kilogram (mg/kg)
- Molybdenum – an IL for molybdenum was not identified because, with the exception of one sample, molybdenum sample results in BG-1 were all non-detect
- Selenium – an IL for selenium was not identified because selenium sample results in BG-1 were all non-detect
- Uranium – 1.57 mg/kg
- Vanadium – 7.98 mg/kg
- Ra-226 – 1.75 pCi/g
- Surface gamma measurements – 10,273 cpm

The ILs for Survey Area B (i.e., the Salt Wash Member of the Morrison Formation; refer to Figure 2-6a) were established using statistical analysis of background data collected from BG-2 (refer to Figure 3-3) and are as follows:

- Arsenic – 14.3 mg/kg
- Molybdenum – 0.974 mg/kg
- Selenium – an IL for selenium was not identified because selenium surface sample results in BG-2 were all non-detect
- Uranium – 7.57 mg/kg
- Vanadium – 16.2 mg/kg
- Ra-226 – 7.96 pCi/g
- Surface gamma measurements – 29,861 cpm

It is important to note that comparisons to the IL (i.e., 1.5 times the IL) are provided for context, and evaluations of: (1) areas of the Site; (2) samples or; (3) TENORM that exceed the ILs, which are based on the statistically derived IL values.

In addition to the surface gamma survey performed in background reference areas, subsurface static gamma measurements were collected in the boreholes completed in the background reference areas. These measurements were used to establish a subsurface static gamma screening level for Survey Areas A. Where possible, the selected subsurface static gamma screening level value for Survey Area A met the following criteria: (1) it was the lowest value measured at or below 1 ft bgs and (2) it was not directly measured on bedrock. These subsurface static gamma screening levels provide a comparison and assessment tool for Survey Areas A and B and are included as ILs for the Site.

However, it is important to consider that the subsurface static gamma IL is based on a single measurement, and it is not statistically derived. For this reason, subsurface static gamma IL exceedances should be considered in conjunction with additional lines of evidence including: (1) down-hole trends of static gamma measurements; (2) changes in lithology within the borehole; and (3) a qualitative comparison of subsurface static gamma measurements to Ra-226 and/or metals concentrations in subsurface samples.

Subsurface static gamma measurements from the background reference areas are summarized in Table 4-2 and in Appendix C.2. Subsurface static gamma measurements used to derive subsurface static gamma ILs were as follows:

- Survey Area A – Five subsurface static gamma measurements of 11,204, 12,719, 13,219, 12,865, and 13,219 cpm were collected from BG-1 borehole S055-BG1-011 at down-hole depths of 0.5, 1.0, 1.5, 2.0, and 2.4 ft bgs, respectively. The lowest measured value, at or below 1 ft bgs and not directly measured on bedrock, was 12,719 cpm. This value was used as the subsurface static gamma IL for Survey Area A.
- Survey Area B – four subsurface static gamma measurements of 30,739, 45,615, 49,324, and 51,193 cpm were collected from BG-2 borehole S055-BG2-011 at down-hole depths of 0.5, 1.0, 1.5, and 1.8 ft bgs, respectively. The lowest measured value, at or below 1 ft bgs and not directly measured on bedrock, was 45,615 cpm. This value was used as the subsurface static gamma IL for Survey Area B.

It is important to consider that the subsurface static gamma IL measurements may be elevated relative to the surface gamma IL because increases in static gamma measurements with depth can result from the detector being in closer proximity to bedrock that has naturally elevated concentrations of radionuclides, and/or geometric effects. Geometric effects are the result of the detector measuring gamma radiation from all directions, regardless of whether it is in a borehole or suspended in air. Gamma radiation measured with the detector held at the ground surface is primarily from the ground beneath the detector. As the detector is advanced down the borehole it measures gamma radiation from the surrounding material emanating from an increasing number of angles. Therefore, as the detector is lowered in the borehole it will generally measure increasingly higher values to a certain depth given a constant source. At approximately 1ft to 2 ft bgs, the detector is essentially surrounded by solid ground and further increases related to borehole geometry are not expected. Because downhole geometric effects influence static gamma measurements just below ground surface, static gamma measurements collected at or greater than 0.1 ft bgs are considered subsurface.

Due to the differing geometric effects, surface static gamma measurements at borehole locations may only be qualitatively compared to subsurface static gamma measurements, and the subsurface static gamma IL does not apply to the surface static gamma measurements. Instances where the surface static gamma measurement is greater than subsurface static gamma measurements suggest higher levels of radionuclides and may be indicative of the presence of TENORM at the surface, but additional lines of evidence are generally needed to support that conclusion.

The Site gamma measurements, and soil and sediment sample analytical results were compared to their respective ILs to confirm COPCs (refer to Section 4.4) and to identify areas of the Site where ILs are exceeded (refer to Section 4.5). The calculated ILs provide a line of evidence to evaluate potential mining-related impacts, and to support future Removal or Remedial Action evaluations at the Site.

4.2 SITE GAMMA RADIATION SURVEY RESULTS AND PREDICTED RADIUM-226 CONCENTRATIONS

4.2.1 Site Gamma Radiation Results

4.2.1.1 Surface Gamma Survey

Results of the Site surface gamma survey are shown in Figure 4-1a where the calculated surface gamma ILs for each background reference area are used to set bin ranges with color coding to illustrate the spatial extent and patterns of surface gamma measurements within the entire Survey Area. The bins ranges were based on the minimum site gamma measurement, the background reference area ILs, and the maximum site gamma measurement. The maximum survey measurement was 89,945 cpm, which was more than three times the maximum IL (i.e. BG-2 IL of 29,861 cpm), and occurred within Survey Area B, adjacent to the sealed portal (refer to Figure 2-7 alongside Figure 4-1a). Surface gamma measurements were generally highest in the vicinity of the reclaimed area, the sealed portal, and area of the waste pile. A description and photographs of these areas are provided in Section 3.2.2.1 and Appendix B-1 photograph numbers 2, 3, 5, and 6.

The spatial distribution of surface gamma measurements and IL exceedances are shown in Figures 4-1b and 4-1c for Survey Areas A and B, respectively, and are described below:

- Survey Area A (refer to Figure 4-1b) surface gamma IL exceedances (greater than 10,273 cpm) occurred primarily in four areas: (1) the plains located adjacent to the mesa sidewall; (2) downgradient from the waste pile, sealed portal, reclaimed area, and buried portal; (3) the potential haul roads; and (4) the drainages. The maximum measurement in Survey Area A, of 68,902 cpm, was greater than six times the IL. Of note, in the north of the northern corner of the claim boundary the surface gamma survey was not extended until background values were reached (i.e., surface gamma measurements exceeded the BG-1 IL; refer to Figure 4-1b). However, mining-related impacts were not identified in this area. Furthermore, the majority of the surface gamma measurements only slightly exceeded the

BG-1 IL (less than 1.5 times), and if runoff and overland flow of water was present from the mining- and reclamation-related disturbances in this area, the runoff and flow was likely limited to the mapped drainages shown on Figure 2-7. Therefore, the elevated gamma measurements in this area are assumed to be the result of greater mineralization present in the surface soil and sediments than was present in BG-1, and also may be the result of the transport of NORM material from the mesa sidewall.

- Survey Area B (refer Figure 4-1c) surface gamma IL exceedances (greater than 29,861 cpm) occurred along the mesa sidewall and in the vicinity of the reclaimed area, the sealed portal, and area of the waste pile. The maximum measurement, in Survey Area B, of 89,945 cpm was greater than three times the IL. In addition, because there were two exploration boreholes on the mesa top (i.e., limited mining-related activity), and the radiological conditions within BG-4 were more similar to the mesa top than those in BG-2, Survey Area B was also compared to the BG-4 surface gamma survey UTL of 12,391 cpm in Figure 4-1c (refer to Appendix D.1 and Table D.1-2 for statistical information regarding BG-4). It should also be noted that, other than the two boreholes, there is no evidence of mining-related activity on the mesa top. Results of the comparison showed that surface gamma measurements were below the BG-4 UTL on the mesa top portions of the Site, supporting the conclusion that additional mining-related disturbances were not present on the mesa top. However, surface gamma measurements were higher than the BG-4 UTL for a majority of the mesa sidewall, including areas that were undisturbed (e.g., northeast of the sealed portal and on the portion of the mesa sidewall west of the reclaimed area). Therefore, BG-4 was not considered representative of background conditions on the mesa sidewall. While gamma measurements were not used to select background reference areas, they were evaluated where more than one background reference area was considered for a geologic formation, in this case, the Morrison Formation.

Three potential data gaps were identified for the surface gamma survey, as listed below:

1. Only the approximate shoulders of the potential haul roads were surveyed, and the centerlines of the potential haul roads were not surveyed due to a miscommunication with the field personnel. This is a minor data gap because the roads are narrow two-track roads and it is assumed that the gamma surveys of the shoulders provided adequate coverage.

2. The gamma survey was not extended laterally from the potential haul roads where gamma measurements were greater than the IL as the result of an oversight. Gamma measurements on the potential haul roads were less than 1.5 times the IL (refer to Figure 4-1b).

3. The gamma survey was not extended north from the Site until all gamma measurements were less than the surface gamma survey IL based on professional judgement that the area contained only NORM. The surface gamma survey was extended beyond areas where mining- and reclamation-related impacts were present. The gamma measurements in these extended areas were less than 1.5 times the IL (refer to Figure 4-1b) and the gamma measurements were generally consistent across the area.

4.2.1.2 Subsurface Gamma Survey

Surface and subsurface static gamma measurements were collected at all 11 borehole locations. Surface and subsurface static gamma measurement locations are shown in Figure 3-6a. Measurements and corresponding measurement depths are provided in Table 4-2 and are shown on the borehole logs in Appendix C.2. Surface and subsurface static gamma measurements from the boreholes are presented below by Survey Area:

- Survey Area A (refer to Figure 4-1b) – Eight boreholes were completed in Survey Area A. The subsurface static gamma IL (12,719 cpm) was exceeded in all eight of the boreholes in Survey Area A. However, all of the exceedances were less than two times the IL. The maximum measurement (19,924 cpm) was measured at a depth of 1.0 ft bgs in borehole S055-SCX-002, which was located in the drainage downgradient from the reclaimed area and buried portal. Subsurface static gamma measurements were variable with depth at three boreholes and increased with depth at four boreholes.

- Survey Area B (refer to Figure 4-1c) – Three boreholes were completed in Survey Area B. The subsurface static gamma IL (45,615 cpm) was exceeded in one (S005-SCX-001) of the three boreholes in Survey Area A. The maximum measurement (116,500 cpm) was measured at a depth of 0.8 ft bgs in borehole S055-SCX-001, which was located in the reclaimed area. Within the three boreholes, the subsurface static gamma measurements increased with depth.

4.2.2 Gamma Correlation Results

The high-density surface gamma measurements and concentrations of Ra-226 in surface soils obtained from the Gamma Correlation Study (refer to Section 3.3.1.3) were used to develop a correlation equation, using regression analysis, between the mean gamma measurements and Ra-226 concentrations measured in the co-located composite surface soil samples. This correlation is meant to be used as a general screening tool and provides approximate predicted Ra-226 concentrations.

Analytical results of the correlation samples, which were used to develop the correlation equation, are presented in Table 4-3. The mean value of the gamma survey results from the correlation plots, with their corresponding Ra-226 concentrations and a graph showing the linear regression line and adjusted Pearson's Correlation Coefficient (R^2) value for the correlation, are shown in

Figure 4-2a. The regression produced an adjusted R^2 value of 0.66 which is not within the acceptance criterion of 0.8 to 1.0 described in the *RSE Work Plan* and indicates that surface gamma results do not correlate well with Ra-226 concentrations in soil. The correlation model may have been influenced by the limited number of correlation sample locations. Users of the regression equation should be aware of the limitations of the dataset and be cautious when estimating radium-226 concentrations. The inability to construct a statistically defensible correlation model is identified as a data gap. The correlation equation to convert gamma measurements in cpm to predicted surface soil Ra-226 concentrations in pCi/g for the Site is:

$$\text{Gamma (cpm)} = 609 \times \text{Surface Soil Ra-226 (pCi/g)} + 12{,}683$$

The predicted Ra-226 concentrations in soil, as calculated from the gamma measurements using the developed correlation equation, are shown in Figure 4-2a. Ra-226 concentrations predicted using gamma measurements lower than the minimum (10,854 cpm) and greater than the maximum (37,736 cpm) mean gamma measurements from the Gamma Correlation Study are extrapolated from the regression model and are therefore uncertain. Using the correlation equation, the predicted Ra-226 concentration associated with the minimum mean gamma measurement is -3.0 pCi/g and the concentration associated with the maximum mean gamma measurement is 12.8 pCi/g. Therefore, predicted Ra-226 concentrations less than -3.0 pCi/g and greater than 12.8 pCi/g should be limited to qualitative use only. The correlation locations were intentionally selected to be focused on the lower range of gamma measurements observed at the Site. Mean gamma measurements for correlation locations ranged from 10,854 to 37,736 cpm. The correlation was focused on the lower range because future Removal or Remedial Action decisions are more critical at lower Ra-226 concentrations where the limits of remediation may be defined.

The correlation equation predicted Ra-226 concentrations that were less than zero for gamma survey measurements below 12,683 cpm. The predicted concentrations are shown in Figure 4-2a and the values less than zero are widely distributed throughout most of the Site. The elevated predicted Ra-226 concentrations shown in Figure 4-2a occur in the same areas where the elevated surface gamma measurements occur (refer to Section 4.2.1). This is because the predicted Ra-226 concentrations are based on a correlation with the gamma measurements. Predicted Ra-226 concentrations in the Survey Area range from -11.9 to 126.9 pCi/g, with a mean of -3.1 pCi/g, and a standard deviation, of 6.1 pCi/g. Bin ranges in Figure 4-2a are based on these mean and standard deviation values. Negative values for Ra-226 are a function of the linear regression equation and are not physically possible.

The gamma correlation was not used for the Site Characterization, which instead relied on actual gamma radiation measurements and soil analytical results. However, predicted Ra-226 concentrations were compared to the Ra-226 laboratory concentrations measured in surface soil samples collected at surface and borehole locations, as shown in Figure 4-2b. The correlation results were also compared to investigation levels, as shown in Figure 4-2c. Per the Agencies, these comparisons can be used for site characterization and are one of many analyses that can be used to interpret the data (NNEPA, 2018).

When comparing the predicted Ra-226 concentrations to the Ra-226 laboratory concentrations, soil/sediment sample locations are generally not co-located with specific gamma measurement locations (refer to Figure 4-2b). Therefore, the measured Ra-226 laboratory concentrations can only be qualitatively compared to the nearby predicted Ra-226 concentrations. The measured Ra-226 laboratory concentrations were within the applicable predicted Ra-226 bin ranges for 10 of the 22 sample locations. In 10 of the 12 sample locations where the predicted Ra-226 concentration and the Ra-226 concentration detected in the soil/sediment sample did not agree, the predicted concentration was lower than the reported laboratory concentration. For the majority of the sample locations where the predicted Ra-226 was low, the laboratory Ra-226 concentration was less than 2.0 pCi/g. Of the two locations where the predicted Ra-226 concentration was higher than the laboratory Ra-226 concentration, one location was within the reclaimed area (S055-SCX-001) and the other location was within an undisturbed area west of the reclaimed area (S055-CX-05). The differences observed between the predicted and actual Ra-226 values are partially a function of the natural heterogeneity in Ra-226 concentrations and gamma radiation measurements, which affects the correlation based on the five Gamma Correlation Study areas, and the predicted values, based on the subsequent gamma measurements.

The predicted Ra-226 concentrations were also compared to the Ra-226 ILs from each Survey Area, as shown in Figure 4-2c. The symbols for surface sample locations and boreholes where Ra-226 concentrations in surface soil/sediment samples exceeded the IL are highlighted with yellow halos. The predicted Ra-226 concentrations exceeded the Ra-226 ILs for a limited area of the Site, and were generally coincident with the mesa sidewall, the reclaimed pile, and the area downgradient from the reclaimed pile. In addition, the majority of the sample locations where laboratory Ra-226 samples exceeded the IL are within an area where the predicted Ra-226 concentrations exceeded the ILs. The area of the Site where predicted Ra-226 values exceeded the ILs is compared to surface gamma IL exceedances in the surface gamma survey in Section 4.5.

The correlation soil samples were also analyzed for thorium isotopes Th-232 and Th-228. The objectives of the thorium analyses were to assess the potential effects of Th-232 series radioisotopes on the correlation of gamma measurements to concentrations of Ra-226 in surface soils (i.e., to evaluate whether gamma-emitting radioisotopes in the Th-232 series are impacting gamma measurements at the Site). The justification for the analysis is provided in Section 3.3.1.3. A multivariate linear regression (MLR) model was performed by ERG to relate the gamma count rate to multiple soil radionuclides simultaneously. The MLR and results are described extensively in Appendix A. ERG identified that the thorium series radionuclides do not affect the prediction of concentrations of Ra-226 from gamma survey measurements at the Site.

4.2.2.1 Secular Equilibrium Results

The activities of Th-230 and Ra-226 were compared to consider whether the uranium series is in secular equilibrium at the Site (refer to Section 3.3.1.4 and Appendix A). A linear regression was performed on the dataset (refer to Appendix A Figure 9). The p-value for the regression slope is significant (i.e., $p < 0.05$) and the adjusted R^2 meets the study DQO (adjusted $R^2 > 0.8$), indicating that Ra-226 and Th-230 exist in equilibrium. However, when compared to a y=x line (this line represents a perfect 1:1 ratio between Th-230 and Ra-226, indicating secular equilibrium), the y=x line falls partially outside of the 95% UCL bands of the Th-230/Ra-226 regression, indicating Ra-226 and Th-230 are not in secular equilibrium at the Site (refer to figures in Appendix A). This may be a consideration in the future if a human health and/or ecological risk assessment is performed.

4.3 SOIL METALS AND RADIUM-226 ANALYTICAL RESULTS

A total of 21 surface soil/sediment grab samples (18 soil and three sediment) from 21 locations, and 15 subsurface soil/sediment samples (11 soil and four sediment) from 11 borehole locations were collected in Survey Areas A and B (refer to Table 3-2). Five of the subsurface samples were composite samples and 10 were grab samples. The metals and Ra-226 analytical results for each Survey Area are compared to their respective ILs and presented in Tables 4-4a and 4-4b. Figure 4-3 presents the spatial patterns, both laterally and vertically, of metals and Ra-226 detections and IL exceedances in the soil/sediment. The correlation soil samples were inadvertently analyzed for arsenic, molybdenum, selenium, uranium, and vanadium as the result of laboratory error. The analytical results for these samples are presented in Table 4-3; however, these composite samples were not used for direct comparison to the ILs and no further evaluation was completed on these samples.

Ra-226 and/or metals concentrations exceeded their respective ILs in all but two subsurface and four surface samples in Survey Area A and in all but three surface samples in Survey Area B. In general, the greatest exceedances of Ra-226 and metals ILs were in: (1) within the reclaimed area; (2) downgradient from the waste pile, sealed portal, reclaimed area, and buried portal; and (3) the plains located adjacent to the mesa sidewall. The maximum concentrations for Ra-226, arsenic, selenium, and uranium were detected in surface soil sample S055-CX-006, collected in Survey Area B and was residual soil from undisturbed bedrock located along the mesa sidewall. The maximum concentrations of molybdenum and vanadium were detected in surface soil sample S005-CX-011, collected in Survey Area B and located downgradient from the buried portal and on the eastern edge of the reclaimed area. Only vanadium concentrations exceeded the ILs in the temporary ponding area. Surface and subsurface soil/sediment IL exceedances for each analyte, with respect to each of the two survey areas, are described below. Presented sample counts include normal samples and do not include duplicate samples:

- Ra-226
    - Survey Area A – the Ra-226 IL (1.75 pCi/g) was exceeded in five out of 11 surface soil/sediment samples and five out of 11 subsurface soil/sediment samples from five boreholes. Ra-226 concentrations ranged from 0.59 to 6.06 pCi/g. The maximum Ra-226 detection (6.06 pCi/g) was from surface sediment sample S055-SCX-002, located in the drainage downgradient from the reclaimed area and buried portal.
    - Survey Area B – the Ra-226 IL (7.96 pCi/g) was exceeded in four out of 10 surface soil/sediment samples and two out of four subsurface soil/sediment samples from two boreholes. Ra-226 concentrations ranged from 0.8 to 59.1 pCi/g, and the maximum detection of 59.1 pCi/g was from surface soil sample S055-CX-006, which was residual soil from undisturbed bedrock located along the mesa sidewall.
- Uranium
    - Survey Area A – the uranium IL (1.57 mg/kg) was exceeded in three out of 11 surface soil/sediment samples and five out of 11 subsurface soil/sediment samples from five

boreholes. Uranium concentrations ranged from 0.31 to 4.5 mg/kg. The maximum uranium detection (4.5 mg/kg) was from surface sediment sample S055-SCX-002, located in the drainage downgradient from the reclaimed area and buried portal.

- Survey Area B – the uranium IL (7.57 mg/kg) was exceeded in three out of 10 surface soil/sediment samples and two out of four subsurface soil/sediment samples from two boreholes. Uranium concentrations ranged from 0.84 to 61 mg/kg, and the maximum detection of 61 mg/kg was from subsurface soil sample S055-SCX-001, collected from 0.5 to 0.9 ft bgs, and located in the reclaimed area.

As a broader point of reference, a regional study of the Western US documented uranium concentrations in soil that ranged from 0.68 to 7.9 mg/kg, with a mean value of 2.5 mg/kg (USGS, 1984). Uranium concentrations in Survey Area A and Survey Area B were within the typical range of regional values in soil/sediment samples, with the exception of five samples in Survey Area B that were greater than the regional range.

- Arsenic
  - Survey Area A – the arsenic IL (2.67 mg/kg) was exceeded in three out of 11 surface soil/sediment samples and three out of 11 subsurface soil/sediment samples from three boreholes. Arsenic concentrations ranged from 0.62 to 7.5 mg/kg. The maximum arsenic detection (7.5 mg/kg) was from subsurface soil sample S055-SCX-009, collected from 0.5 to 2.1 ft bgs, and located in the plains adjacent to the mesa sidewall.
  - Survey Area B – the arsenic IL (14.3 mg/kg) was exceeded in one out of 10 surface soil/sediment samples and one out of four subsurface soil/sediment samples from one borehole. Arsenic concentrations ranged from 1.6 to 140 mg/kg, and the maximum detection of 140 mg/kg was from surface soil sample S055-CX-006, which was residual soil from undisturbed bedrock located along the mesa sidewall.

As a broader point of reference, a regional study of the Western US documented arsenic concentrations in soil that ranged from less than 0.10 to 97 mg/kg, with a mean value of 5.5 mg/kg (USGS, 1984). Arsenic concentrations in Survey Area A and Survey Area B were within the typical range of regional values in soil/sediment samples, with the exception of one sample in Survey Area B that was greater than the regional range.

- Molybdenum
  - Survey Area A – an IL for molybdenum was not identified because, with the exception of one sample, molybdenum sample results in BG-1 were non-detect. On-site, molybdenum was detected in eight out of 11 surface soil/sediment samples and nine out of 11 subsurface soil/sediment samples from seven boreholes. Molybdenum concentrations ranged from non-detect to 2.1 mg/kg. The maximum molybdenum detection (2.1 mg/kg) was from subsurface soil sample S055-SCX-002, collected from 0.5 to 1.0 ft bgs, and located in the drainage downgradient from the reclaimed area and buried portal.
  - Survey Area B – the molybdenum IL (0.974 mg/kg) was exceeded in six out of 10 surface soil/sediment samples and two out of four subsurface soil/sediment samples from two

boreholes. Molybdenum concentrations ranged from non-detect to 16 mg/kg. The maximum detection of 16 mg/kg was from subsurface soil sample S055-SCX-001, collected from 0.5 to 0.9 ft bgs, and located in the reclaimed area.

As a broader point of reference, a regional study of the Western US documented molybdenum concentrations in soil that ranged from less than 3 to 7 mg/kg, with a mean value of 0.85 mg/kg (USGS, 1984). Molybdenum concentrations in Survey Area A and Survey Area B were within the typical range of regional values in soil/sediment samples, with the exception of one sample in Survey Area B.

- Selenium – ILs for selenium were not identified because selenium surface sample results in BG-1 and BG-2 were all non-detect.
    - Survey Area A – selenium results were below the laboratory reporting limit for all surface and subsurface soil/sediment samples collected in Survey Area A.
    - Survey Area B – selenium was detected in two out of 10 surface soil/sediment samples and one out of four subsurface soil/sediment samples from one borehole. Selenium concentrations ranged from non-detect to 2.3 mg/kg. The maximum detection of 2.3 mg/kg was from subsurface soil sample S055-SCX-001, collected from 0.5 to 0.9 ft bgs, and located in the reclaimed area.

As a broader point of reference, a regional study of the Western US documented selenium concentrations in soil that typically ranged from less than 0.10 to 4.3 mg/kg, with a mean value of 0.23 mg/kg (USGS, 1984). Selenium concentrations were within the typical range of regional values in soil/sediment samples from Survey Areas A and B.

- Vanadium
    - Survey Area A – the vanadium IL (7.98 mg/kg) was exceeded in seven out of 11 surface soil/sediment samples and seven out of 11 subsurface soil/sediment samples from six boreholes. Vanadium concentrations ranged from 3 to 35 mg/kg. The maximum vanadium detection (35 mg/kg) was from subsurface soil sample S055-SCX-002, collected from 0.5 to 1.0 ft bgs, and located in the drainage downgradient from the reclaimed area and buried portal.
    - Survey Area B – the vanadium IL (16.2 mg/kg) was exceeded in five out of 10 surface soil/sediment samples and four out of four subsurface soil/sediment samples from three boreholes. Vanadium concentrations ranged from 4.3 to 400 mg/kg. The maximum detection of 400 mg/kg was from subsurface soil sample S055-SCX-001, collected from 0.5 to 0.9 ft bgs, and located in the reclaimed area.

As a broader point of reference, a regional study of the Western US documented vanadium concentrations in soil that ranged from 7 to 500 mg/kg, with a mean value of 70 mg/kg (USGS, 1984). Vanadium concentrations were within the typical range of regional background values in Survey Areas A and B.

4.4 CONSTITUENTS OF POTENTIAL CONCERN

Based on the results presented in Sections 4.2 and 4.3, gamma radiation and concentrations of Ra-226, arsenic, molybdenum, uranium, and vanadium in soil/sediment exceeded their respective ILs in Survey Areas A and B. Therefore, these constituents were confirmed COPCs for the Site. In addition, selenium was also confirmed as a COPC because it was detected in soil samples from Survey Area B, even though it was non-detect in the background reference area samples and soil/sediment samples collected from Survey Area A.

4.5 AREAS THAT EXCEED THE INVESTIGATION LEVELS

The approximate lateral extent of surface gamma IL exceedances in soil/sediment is 18.7 acres, as shown in Figure 4-4a. To estimate this area, polygons were contoured around portions of the Site that had multiple, contiguous surface gamma IL exceedances and then the total area within the polygons was calculated. Figures 4-4b and 4-4c show larger scale views of each of the two Survey Areas to better display those areas with multiple, contiguous surface gamma IL exceedances. Five sample locations, where IL exceedances occurred, were not included in the 18.7 acres, as follows:

- Survey Area A – surface and subsurface soil samples from borehole S055-SCX-006 had detections of molybdenum; however, an IL for molybdenum for Survey Area A was not identified because, with the exception of one sample, molybdenum sample results in BG-1 were all non-detect. In addition, molybdenum concentrations in Survey Area A were within the typical range of regional values in soil/sediment samples. One subsurface static gamma measurement collected at 1.5 ft bgs in S055-SCX-006 (13,329 cpm) exceeded the subsurface static gamma IL by less than 1,000 cpm.
- Survey Area B – surface soil sample S055-CX-005 had molybdenum and vanadium concentrations less than two times their respective ILs. Surface soil sample S055-CX-006 had arsenic, molybdenum, uranium, and Ra-226 concentrations greater than four times their respective ILs, and a detection of selenium. However, the surface soil sample S055-CX-006 was collected from residual soil from undisturbed bedrock. Three surface soil sample locations, S055-CX-011 and S055-SCX-001 and –SCX-004, had detections that exceeded their respective ILs; however, these locations are within or directly adjacent to the reclamation area and a volume estimate for TENORM in this area is included in Section 4.7.

Figure 4-5 shows the vertical extent of IL exceedances in each borehole by incorporating information from each location, including: (1) depth to bedrock; (2) total borehole depth; and (3) depth range of IL exceedances. Table 4-5 lists the IL exceedances identified at each borehole location and Figure 4-5 also shows the surface gamma IL exceedances for reference.

IL exceedances in metals and Ra-226 concentrations at surface and subsurface sample locations were typically, but not always co-located with surface gamma survey measurements and/or subsurface static gamma measurements that also exceeded their ILs. Variations occur due to natural variability and the different field methods. For example, a small piece of mineralized rock or petrified wood may have been collected in a soil sample but may not have been detected by the gamma meter in the gamma survey due to distance from the meter, the depth below ground surface, or because the gamma meter measures radiation over a larger area than the discrete soil sample location.

The lateral extent of the IL exceedances (for surface gamma data) shown in Figure 4-4a were compared to the predicted Ra-226 concentrations that exceeded ILs in Figure 4-2c. Predicted Ra-226 concentrations exceeded the Ra-226 IL in a smaller area of the Site than the surface gamma IL exceedances. In particular, surface gamma measurements exceed the IL over much of the valley floor, whereas predicted Ra-226 exceedances are generally located on the mesa sidewalls and in the area of the reclaimed pile and waste pile and areas directly downgradient of these features. The inconsistency between the predicted Ra-226 exceedances and the surface gamma exceedances are likely the result of the low predicted Ra-226 concentrations when compared to the Ra-226 ILs.

4.6 AREAS OF TENORM AND NORM

A multiple lines of evidence approach was used to evaluate the Site and distinguish areas of TENORM from areas of NORM within the Survey Area, as described in Section 3.3.3. Based on this evaluation, 5.2 acres, out of the 35.0 acres of the Survey Area, were estimated to contain TENORM at the Site. This estimate is inclusive of the following areas: the reclaimed area, the buried portal, the area downgradient of the reclaimed area, the temporary ponding area, potential haul roads, the waste pile, and the sealed portal. Representations of NORM are shown in Appendix B-1 photograph numbers 12 and 13. The area containing TENORM is shown in relation to the lateral extent of IL exceedances in Figure 4-6 and in relation to the gamma measurements in Figure 4-7.

The RSE data that supports the delineation of TENORM at the Site includes:

- Historical Data Review Conclusions
  - Historical document indicated the Site was only in operation during 1955, and 25 tons (approximately 50,000 pounds) of ore that contained 55 pounds of 0.11 percent U_3O_8 and 647 pounds of 1.30 percent V_2O_5 was produced from the Site.
  - Historical document review indicated the following reclamation activities were completed at the Site: (1) bulkheads were installed to close two portals; (2) the portals were backfilled with mine waste as much as possible and the remaining mine waste was buried in a designated area; and (3) a drainage located at one of the portals was diverted and the drainage course was lined with riprap.
- Geology/geomorphology
  - Bedrock at the Site consisted of two geologic formations: Jurassic Salt Wash and Brushy Basin Members of the Morrison Formation and the Jurassic Summerville Formation. The Morrison Formation is known to have natural enrichments of uranium. In addition, portions of the Site consisted of shallow or outcropping bedrock. Therefore, the geology and

geomorphology of the Site was conducive to the presence of NORM at or below the ground surface.

- Parallel patterned ephemeral drainages are present on-site that drain north/northwest into an unnamed drainage that could transport NORM/TENORM to the north/northwest. The western most drainages drain into a temporary ponding area before connecting with the unnamed drainage. The unnamed drainage connects to the Tsitah Wash approximately 0.75 miles north of the Site. Surface water flow is controlled around a reclaimed area on-site, located against the mesa sidewall, by two drainage channels that are armored with riprap. The drainage on one portion of the reclaimed area has left the riprap channel and created an incised channel within the reclamation area. Historically, drainage from the reclaimed area could have fed into the temporary ponding area; however, the current site configuration has the drainage channel from the reclaimed area bypassing the temporary ponding area.

- Disturbance Mapping – Stantec field personnel observed the following features:
  - Two potential haul roads were observed that extend to the north-northeast of the claim boundary on either side of the unnamed drainage. The potential haul roads did not provide access to those areas of the Site where mining occurred. This was likely due to NAML reclamation efforts where access roads in the immediate vicinity of the reclaimed sites were also reclaimed.
  - One portal was observed, and the approximate location of the second portal was identified. Both portals were sealed with concrete-filled cinder blocks, and one of portals was buried during reclamation activities.
  - A dammed, temporary ponded area was observed, where surface water temporarily collects behind an earthen dam and then evaporates. Per discussions with nearby residents, the earthen dam was placed to create a reservoir (temporary ponding area) for livestock. The downstream side of the earthen dam was approximately 20 ft high. The date of the installation of the earthen dam is unknown.
  - Two 5.5-inch diameter boreholes were observed in the southeast portion of the Site, on the mesa top where bedrock is exposed at the surface. The boreholes were located approximately 200 ft southeast of the buried portal.
  - A reclaimed area was observed in the area of the approximate buried portal location.
  - One waste pile was observed below the sealed portal.

- Site Characterization
  - Survey Area A was comprised of the following: (1) the plains located adjacent to the mesa sidewall; (2) areas downgradient from the waste pile, sealed portal, reclaimed area, and buried portal; (3) the temporary ponding area; (4) the potential haul roads; and (5) the drainages. Surface gamma IL exceedances in Survey Area A occurred primarily down gradient of the sealed portal, waste pile, reclaimed area, and buried portal, in the temporary ponding area, and along the two potential haul roads. In general, the greatest exceedances of Ra-226 and metals ILs were from samples

collected near or downgradient from the sealed portal, waste pile, reclaimed area, and buried portal. Further evaluation of the reclaimed area may be warranted in the future (see Section 4.9).

- Survey Area B was comprised of the mesa sidewall and mesa top, and included the waste pile, sealed portal, reclaimed area, and buried portal. Surface gamma IL exceedances in Survey Area B occurred primarily in the areas coincident with the waste pile, sealed portal, reclaimed area, and buried portal. In general, the greatest exceedances of Ra-226 and metals ILs were from samples collected from the reclaimed area or from samples collected from residual soil from undisturbed bedrock located along the mesa sidewall.

- Potential mine waste material was observed in the erosional feature within the reclaimed area, as shown in Appendix B, photograph number 7. Potential mine waste material was observed within the reclaimed area in borehole S055-SCX-001, based on a grayish color (see Appendix C). Potential mine waste material was observed within the waste pile at the ground surface.

- An area of TENORM was identified in the area of the boreholes on the mesa top due to the boreholes proximity to the Site. However, it is unknown when exploration took place on the mesa top and whether it was related to the mining that occurred at the Site. Per discussions with nearby residents in April 2018 and the presence of numerous mine claims in the area (refer to Figure 2-1) exploration for uranium in the area was extensive.

- Characterization of the temporary ponding area was limited. The date of the installation of the earthen dam is unknown, but the structure was present in the 1976 historical aerial photograph and it is potentially present in the 1949 historical aerial. Runoff and overland flow from the mining-related and reclamation-related activities may have been impounded in the ponding area behind the dam over time. The current site configuration has the drainage channel from the reclaimed area bypassing the temporary ponding area.

- The portion of the mesa sidewall west/southwest of the reclaimed area was not visibly disturbed by mining activities and the area is assumed to contain NORM.

- Gamma survey measurements were less than 1.5 times the IL in the area in the northeast portion of the claim boundary and the area north of the claim boundary. Elevated gamma measurements in this area are assumed to be the result of mineralization present in the surface soil and sediments and also may be the result of the transport of NORM material from the mesa sidewall. This area is assumed to contain NORM.

- Metals concentrations in samples collected outside the area of TENORM (10 locations locations) were less than or within the regional concentration values.

- It is important to consider that the subsurface static gamma ILs were not used as the only evidence to delineate the vertical extent of TENORM that exceeded the IL within borehole locations at the Site.

The area of the Site considered to contain TENORM (i.e., multiple lines of evidence indicated the presence of mining-related impacts) was 5.2 acres, as shown on Figure 4-8a. Portions of the TENORM exceeded one or more IL, where approximately 3.4 acres contained TENORM that exceeded the surface gamma IL and the majority of the sample locations where TENORM exceeded ILs. TENORM exceeding the ILs was observed at 3 sample locations in the upper portion of the reclaimed area that were not coincident with areas of the Site that exceeded the surface gamma IL. TENORM that exceeded the ILs in Survey Area A and Survey Area B is shown on Figures 4-8b and 4-8c, respectively, and is compared to mining-related features in Figure 4-8d.

4.7 TENORM VOLUME ESTIMATE

The volume estimate of TENORM that exceeded one or more ILs is approximately 15,383 yd^3, as shown in Figure 4-9a. The volume and area of TENORM associated with specific mine features is listed in Table 3-3. This estimate was calculated using ESRI ArcGIS Desktop 10.3.1 Spatial Analyst Extension cut/fill tool (ESRI, 2017) utilizing the ground surface elevation contours developed from the orthophotographs coupled with hand-derived contours based on field personnel observations, depth to bedrock in boreholes, gamma measurements, sample analytical data, and historical mining documentation. Field observations included observations of disturbance, changes in vegetation, estimating/projecting the slope of underlying bedrock, and estimating the shape and topography of waste material and/or soil deposits.

TENORM exceeding the ILs at the Site was split into groups based on the depth or type of material to aid in analysis and describing the basis of the volumes. The locations, volume, and areas of these groups are shown in Figure 4-9a. The assumptions that were used to calculate the volume of TENORM with IL exceedances were as follows:

General Assumptions

- It was assumed that subsurface bedrock encountered in boreholes was not previously modified by human activity and is therefore NORM.
- For areas of TENORM at the Site containing large cobble- or boulder-sized rocks at the surface whose heights exceeded the assumed depth of TENORM in that area (e.g., a 5-ft-tall boulder in an area where TENORM was assumed to extend 1 ft bgs), the additional volume was assumed to be accounted for by the TENORM depth estimates.

Group Assumptions

- Group 1 (979 yd^3) – the reclaimed area was estimated to contain 979 yd^3 of TENORM that exceeds the ILs. Contours of the thickness of the reclaimed area were created to support this volume calculation (refer to Figure 4-9b). The contours were based on general field observations of the apparent thickness of the pile and estimates of the geometry of the reclamation area and the pre-mining surface below the reclamation area that were calculated during review of the aerial photographs and the ground surface elevation contours developed from the orthophotographs for the areas adjacent to the reclamation area. One hand auger borehole was advanced in the reclaimed area and it did not extend beyond 1.0 ft bgs.

- Group 2 (74 yd^3) – TENORM that exceeds the ILs in the area of the waste pile was assumed to be 2 ft thick, based on field observations of the limited vertical and lateral extent of the waste pile and one subsurface borehole that was advanced in the area. The borehole met refusal on rock at 1.75 ft bgs and this was assumed to be bedrock based areas of bedrock observed near the borehole.

- Group 3 (13,136 yd^3) – TENORM that exceeds the ILs was assumed to extend to 4.0 ft bgs, based on four boreholes that were advanced in that area. The depths of TENORM that exceeded the ILs in the boreholes were up to 4.0 feet bgs and included a portion of the temporary ponding area. Some of these exceedances may be related to NORM due to the presence of mineralized bedrock outcrops along undisturbed portions of the mesa sidewall upgradient from this area; however, it was not possible to differentiate the NORM from TENORM, and so the depth was assumed to extend to 4.0 ft bgs. Additional considerations regarding the temporary ponding area are included below.

- Group 4 (148 yd^3) – TENORM that exceeds the ILs was assumed to extend to 1.0 ft bgs in this portion of the temporary ponding area, based on field observations of the location of the limited surface gamma IL exceedances within Group 4 with respect to the location of mining- and reclamation-related disturbances. For TENORM to be present in the area of Group 4, TENORM material from the mining- and reclamation-related activities would have to have drained to the temporary ponding area and ponding would have had to occur to transport solid TENORM or dissolved TENORM upgradient (from the area where TENORM entered the ponding area) to the area of Group 4.

- Group 5 (1,046 yd^3) – TENORM that exceeds the ILs along the potential haul roads was assumed to extend to 1.0 ft bgs. The potential haul roads follow existing topography (e.g., potentially impacted fill material was not placed to build the haul roads); however, there was little to no bedrock present along the bed of the roads. Therefore, TENORM may potentially extend deeper than just surficial material, so the volume estimate was extended to 1.0 ft bgs.

Historical reclamation planning documents stated that approximately 1,555 yd^3 of mine waste material was present at the Site. NAML oversaw reclamation activities for the Site and reported the progress of those activities in field notes (NAML, 1995). As reported by NAML: (1) the portals were backfilled with mine waste as much as possible and the remaining mine waste was buried in a designated area; and (2) bulkheads were installed to close the two portals. Based on RSE activities, approximately 979 yd^3 of TENORM (including cover material) was estimated to be present in the reclaimed area. The calculated volume is a reasonable comparison to what NAML may have placed in the reclaimed area. However, it is important to consider that the reclamation documents were planning documents and a final volume from reclamation activities was not provided.

Per discussions with nearby residents, the earthen dam on-site was placed to create a reservoir (temporary ponding area) for livestock. The date when the dam was installed in unknown. Over time sediment has built up behind the dam. The primary source of the sediment is the drainage that is south of the Site. However, mine waste material from the area of the portals (within Survey Area B) may have drained into the temporary ponding area (within Survey Area A) and contributed TENORM to that area over time. Based on the height of the dam, sediments within the temporary ponding area may extend up to approximately 10 to 15 bgs. While the majority of the sediment in the temporary ponding area is likely from the drainage south of the Site, the depth of potential mining impacts (TENORM) is not known because borehole depths in the area were shallow due to the use of hand augers. The current site configuration has the drainage channel from the reclaimed area bypassing the temporary ponding area. The lack of characterization data from deeper boreholes within the temporary ponding area is considered a data gap for the Site. Additional boreholes (that require drilling) within the temporary ponding area would provide a more accurate estimate of the volume of TENORM in that portion of the Group 3 area.

4.8 WATER ANALYTICAL RESULTS

An analytical surface water sample and field parameter measurements were collected as part of the Site Characterization activities. The analytical sample was analyzed for the constituents listed in Section 3.3.2.3. At one water feature location a surface water sample was collected for laboratory analyses and field parameters were also measured. At a second surface water sample location only field parameters were collected (refer to Section 3.3.2.3). The locations of the water features are shown in Figure 2-1 and included the following:

- Water sample (S055-WS-001) and field parameter measurements were collected from the cement vault approximately 170 ft northwest of seep 09-6-14, which was located approximately 0.78 miles southwest of the Site.
- Field parameter measurements (S055-WS-002) were measured at seep S055-Seep-1/Donkey Spring located in a drainage approximately 0.33 miles southeast of the Site. The seep was along a contact between sandstone beds.

The analytical results from the S055-WS-001 sample were compared to the water ILs, which are defined as the lowest value from the following regulations/standards: the National Secondary Drinking Water Regulations (NSDWR), the Navajo Nation Surface Water Quality Standards, the Navajo Drinking Water maximum contaminant levels (MCLs), and/or the National Primary Drinking Water Regulations. The water ILs are shown in Table 4-6a and the analytical results compared to the water ILs are shown in Table 4-6b.

Analytical results indicated the surface water sample (S055-WS-001) had total and dissolved uranium concentrations of 450 micrograms per liter (µg/L) and 470 µg/L, respectively (greater than 15 times the IL). Radium (Ra-226) was detected in the total water sample at a concentration of 5.8 pCi/L (less than two-times the IL). The adjusted gross alpha concentration in the duplicate sample collected at S055-WS-001 was 23.2 pCi/g (less than two-times the IL). All other metals were below their respective ILs. Results of general chemistry parameters indicated that TDS and sulfate were also above their respective ILs. All other general chemistry parameter results were below their respective ILs. Based on these results, uranium, Ra-226, adjusted gross alpha, TDS, and sulfate are confirmed COPCs for seep 09-6-14. Because uranium, Ra-226, adjusted gross alpha, TDS, and sulfate exceeded their respective ILs for the surface water sample, additional characterization may be considered at seep 09-6-14 in the future. The laboratory analytical data and Data Usability Report are provided in Appendix F.

4.9 POTENTIAL DATA GAPS AND SUPPLEMENTAL STUDIES

4.9.1 Data Gaps

Seven potential data gaps were identified based on the Site Clearance and RSE data collection and analyses for the Site. Three of the potential data gaps are considered minor, as described in Section 4.2.1.1; the potential need for additional characterization within the temporary ponding area (as described in Section 4.7) would require a larger field campaign. These data gaps can be considered for subsequent evaluations in support of future Removal or Remedial Action evaluations at the Site.

1. The shoulders of the potential haul roads were surveyed but the centerlines of the potential haul roads were not surveyed during the surface gamma survey. Field personnel observed that the portions of the potential haul roads that accessed the mining-disturbed areas of the Site were destroyed. The destruction of the potential haul roads could have been because they were eliminated during reclamation. Given that the detector records gamma emissions from at least a 3-foot diameter, and the haul roads were less than 10 ft wide, this is not considered a significant data gap.

2. The gamma survey was not extended laterally out from the potential haul road or the drainage where gamma measurements were greater than the IL. This area is considered to contain NORM, and so this is not considered a significant data gap.

3. The surface gamma survey was not extended laterally to the north until measurements were within background levels. However, this area is considered to contain NORM, and so this is not considered a significant data gap.

4. Field personnel terminated two boreholes due to consistently low static gamma measurements (the use of this criterion was a field error).

5. The correlation to compare Ra-226 concentrations to surface gamma survey data did not meet the DQO.

6. While the majority of the sediment in the temporary ponding area is likely from the drainage south of the Site, the depth of potential mining impacts (TENORM) is not known because the borehole depth was shallow and limited due to the use of a hand auger. The lack of characterization data from deeper boreholes within the temporary ponding area is considered a data gap for the Site. Additional boreholes within the temporary ponding area would provide a more accurate estimate of the volume of TENORM in that area.

7. Salinity was not collected as part of the specified field measurements because the water quality meter the field personnel were using could not measure salinity.

4.9.2 Supplemental Studies

Following review of the RSE report data and discussions with the Agencies, a limited number of items were identified for supplemental work to be considered for subsequent evaluations in support of future Removal or Remedial Action evaluations at the Site, as follows:

1. The Agencies have suggested that further evaluation of background conditions for the Morrison Formation may be warranted, including investigation of the differences observed in the mesa sidewall (BG-2) and mesa top (BG-4).
2. Further characterization and investigation of the reclaimed area where waste materials were buried may be warranted as part of future work at the Site.
3. Additional correlation studies may be needed to identify the relationship between gamma and Ra-226.
4. The USEPA identified that there were potential discrepancies between the NNDWR database used for this study (received from NNDWR in 2016) and a 2018 version of the database that the USEPA reviewed. It is recommended that the two databases are compared (with additional field work, if necessary) to confirm the locations of water features.

5.0 SUMMARY AND CONCLUSIONS

This report details the purpose and objectives, field investigation activities, findings, and conclusions of the Site Clearance and RSE activities conducted for the Site between August 2015 and June 2017. The Site is known as the Tsosie 1 site and is also identified by the USEPA as AUM identification #55 in the *2007 AUM Atlas*.

The primary objectives of the RSEs are to provide data required to evaluate relevant site conditions and to support future removal action evaluations at the Sites. It is not intended to establish cleanup levels or determine cleanup options or potential remedies. The purpose of the RSE data (e.g., the review of relevant information and the collection of data related to historical mining activities) is to determine the volume of TENORM at the Site in excess of ILs as a result of historical mining activities. ILs are based on the background gamma measurements (in cpm), and Ra-226 and metals concentrations, determined through statistical analyses, that are used to evaluate potential mining-related impacts. The RSE included historical data review, visual observations, surface gamma surveys, surface and subsurface static gamma measurements, and soil/sediment sampling and analyses. An estimate of areas containing TENORM was made based on an evaluation of the RSE information/data and multiple lines of evidence. A surface water sample was also collected as part of the RSE to evaluate potential mining-related impacts. The correlation between gamma measurements (in cpm) and concentrations of Ra-226 in surface soils (pCi/g) was developed as a potential field screening tool for future Removal or Remedial Action evaluations. The gamma correlation was not used for the Site Characterization, which relied instead on the actual gamma radiation measurements and soil/sediment analytical results. However, predicted Ra-226 concentrations were compared to the actual Ra-226 laboratory results and ILs from the surface soil/sediment samples at the Agencies' request.

The Site was one of the small mining operations located in the northwestern Carrizo Mountain mining region, along the Chezhindeza Mesa and Tsitah Wash. The Site was only in operation during 1955 and was operated by G.B. Cree Drilling Company. Details regarding mine workings at the Site were not provided. The USAEC ore production records showed production from the Site in 1955 was 25 tons (approximately 50,000 pounds) of ore that contained 55 pounds of 0.11 percent U_3O_8 and 647 pounds of 1.30 percent V_2O_5.

In 1995, NAML oversaw the following reclamation activities completed at the Site (NAML, 1995):

- Bulkheads were installed to close two portals
- The portals were backfilled with mine waste as much as possible and the remaining mine waste was buried in a designated area
- A drainage located at one of the portals was diverted and the drainage course was lined with riprap

Two background reference areas (BG-1 and BG-2) were identified and used to develop surface gamma, Ra-226, and metals ILs for the two Survey Areas (Survey Area A and B) at the Site. Subsurface static gamma ILs were identified for Survey Area A and Survey Area B.

Four potential background reference areas were considered. Two background reference areas (BG-1 and BG-2) were selected to develop surface gamma, subsurface gamma, Ra-226, and metals ILs for the two Survey Areas (Survey Area A and Survey Area B) at the Site.

Arsenic, molybdenum, uranium, vanadium, and Ra-226 concentrations and gamma radiation measurements in soil/sediment exceeded their respective ILs and are confirmed COPCs for the Site. An IL for selenium was not identified because selenium sample results were non-detect in the background areas. However, because selenium was detected in soil/sediment samples from the Survey Area, it is also confirmed as a COPC for the Site.

Surface gamma measurements, Ra-226, and metals concentrations were generally highest in areas near and downgradient from the sealed portal, the waste pile, reclaimed area, and in an undisturbed area located along the mesa sidewall. The maximum gamma survey measurement was 89,945 cpm, which was greater than three times the maximum IL (i.e. BG-2 IL of 29,861 cpm) and occurred within Survey Area B, adjacent to the sealed portal. The highest Ra-226 and arsenic concentrations were measured in a sample collected from an undisturbed area located along the mesa sidewall; and the highest subsurface static gamma measurements, uranium, and vanadium concentrations were measured in a sample collected from the reclaimed area.

Results of the Gamma Correlation Study indicated that surface gamma survey results do not correlate sufficiently well with Ra-226 concentrations in soil. Therefore, users of the regression equation should be aware of the limitations of the dataset and be cautious when estimating radium-226 concentrations. Additional correlation studies may be needed to identify the relationship between gamma and Ra-226.

Based on the data analysis performed for this RSE report along with the multiple lines of evidence, approximately 5.2 acres out of the 35.0 acres of the Survey Area were estimated to contain TENORM. This estimate is inclusive of the following areas: the reclaimed area, the buried portal, the area downgradient of the reclaimed area, a portion of the temporary ponding area, potential haul roads, the waste pile, and the sealed portal. The areas outside of the TENORM boundary show no signs of disturbance related to mining and, therefore, are considered NORM (i.e., naturally occurring). Of the 5.2 acres that contain TENORM, 3.4 acres contain TENORM exceeding the surface gamma ILs and TENORM that exceeded the ILs at nine of the twelve soil/sediment sample locations. The volume of TENORM is estimated to be 15,383 yd^3 (11,761 cubic meters). It should be noted that the COPC measurements and concentrations in the area that contains TENORM which exceeds the ILs are similar to NORM located outside the TENORM boundary.

An analytical surface water sample and field parameter measurements were collected as part of the Site Characterization activities. An analytical sample (S055-WS-001) and field parameters were collected from the seep identified as 09-6-14. Field parameters only were collected from the seep identified as S055-Seep-1/Donkey Spring because of the low flow rate of the seep. Analytical results indicated the surface water sample (S055-WS-001) had total and dissolved uranium concentrations of 450 µg/L and 470 µg/L, respectively (greater than 15 times the IL). Radium (Ra-226) was detected in the total water sample at a concentration of 5.8 pCi/L (less than two-times the IL). The adjusted gross alpha concentration in the duplicate sample collected at S055-WS-001 was 23.2 pCi/g (less than two-times the IL). All other metals were below their respective ILs. Results of general chemistry parameters indicated that TDS and sulfate were also above their respective ILs. All other general chemistry parameter results were below their respective ILs. Based on these results, uranium, Ra-226, adjusted gross alpha, TDS, and sulfate are confirmed COPCs for seep 09-6-14. Because uranium, Ra-226, adjusted gross alpha, TDS, and sulfate exceeded their respective ILs for the surface water sample, additional characterization may be considered at seep 09-6-14 in the future.

Seven potential data gaps were identified based on the Site Clearance and RSE data collection and analyses for the Site, as listed in Section 4.9. These data gaps can be taken into consideration for subsequent evaluations in support of future Removal or Remedial Action evaluations at the Site.

6.0 ESTIMATE OF REMOVAL SITE EVALUATION COSTS

The Tsosie 1 RSE was performed in accordance with the requirements of the *Trust Agreement* to characterize existing site conditions. Project costs related to the RSE include the planning and implementation of the scope of work stipulated in the *Site Clearance Work Plan* and *RSE Work Plan,* and community outreach. Stantec's costs associated with the Tsosie 1 RSE were $492,193. Stantec's costs associated with interim actions (sign installation) were $4,000. In addition, Administrative costs provided by the Trust were estimated currently at $191,500[9,10]. Administrative costs will change due to continued community outreach and close out activities.

[9] This cost is based on an approved budget of May 8, 2018; Administrative work, including community communications, are not yet complete.
[10] Administrative costs were averaged across all Sites.

7.0 REFERENCES

American Heritage Dictionary, 2016®. American Heritage Dictionary of the English Language, Fifth edition. Published by Houghton Mifflin Harcourt Publishing Company.

Arizona Native Plant Society, 2000. Arizona Rare Plant Field Guide. US Government Printing Office. Washington, D.C.

BING® Maps, 2016. BING Maps imagery web mapping service [Webpage] located at https://www.bing.com/maps. Accessed March 2016.

Chenoweth, W.L. 1984. Historical Review of Uranium-Vanadium Production in the Eastern Carrizo Mountains, San Juan County, New Mexico, and Apache County, Arizona. New Mexico Bureau of Mines and Mineral Resources.

Chenoweth, W.L. 1985. Historical Review Uranium-Vanadium Production in the Northern and Western Carrizo Mountains, Apache County, Arizona. Arizona Geological Survey. Open-File Report 85-13. June.

Cooper Aerial Surveys Company (Cooper), 2017. Collection of high-resolution aerial photographs and topographic data using a piloted fixed-wing aircraft. June 16.

Dinétahdóó Cultural Resource Management, 2016. Archaeological Inventory Report for Tsosie 1. October.

Encyclopedia Britannica, 2017. [Webpage] located at https://www.britannica.com/place/Colorado-Plateau. Accessed June 05, 2017.

English Oxford Dictionary, 2018. [Webpage] located at https://en.oxforddictionaries.com/definition/geomorphology. Accessed January 16, 2018.

ESRI World Imagery Map Service, 2018. [Webpage] located at (http://www.esri.com/data/imagery. June.

Hendricks, T.J., 2001. An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation. Overview of Acquisition and Processing Methods used for Aerial Measurements of Radiation Data for the USEPA by the US Department of Energy under IAG DW 8955235-01-5. Survey conducted in Arizona, New Mexico, Utah.

Kiver, E.P. and Harris, D.V., 1999. Geology of US Parklands (5th ed.). John Wile & Sons. ISBN0-471-33218-6.

MWH, now part of Stantec Consulting Services Inc. (formerly MWH Americas, Inc.) (MWH), 2016a. Site Clearance Work Plan, Navajo Nation Abandoned Uranium Mines Environmental Response Trust. April.

MWH, 2016b. Navajo Nation AUM Environmental Response Trust – First Phase Removal Site Evaluation Work Plan. October.

MWH, 2016c. *Scope of Work*, Navajo Nation Abandoned Uranium Mines Environmental Response Trust, (SOW), April.

Navajo Abandoned Mine Lands (NAML), 1994. Tse Tah II/Oakspring II AML Reclamation Project Contract Documents. October.

NAML, 1995. Field Office/Mine Site Visit Report, for the Tse Tah 2 NAML Project. May.

Navajo Nation Environmental Protection Agency (NNEPA), 2018. Letter and Agency Comments on Draft Tsosie 1 Removal Site Evaluation (RSE) Report. June15, 2018.

National Agriculture Imagery Program (NAIP), 2018. [Webpage] located at https://gis.apfo.usda.gov/arcgis/services. Accessed July 2018.

National Park Service, 2017. [Webpage] located at https://science.nature.nps.gov/im/units/scpn/climate/climate.cfm. Accessed 2017 August 21.

Natural Resources Conservation Service (NRCS). 2006. Web Soil Survey. Version 1.1. NRCS. http://websoilsurvey.nrcs.usda.gov/app.

Navajo Nation Department of Fish and Wildlife (NNDFW), 2008. Biological Resource Land Use Clearance Policies and Procedures, RCS-44-08. September 10.

Navajo Nation Division of Natural Resources (NNDNR), 2006. GIS Section; Navajo Nation BIA Agency, Grazing, and Chapter Boundaries. Map. February.

Navajo Nation Environmental Protection Agency (NNEPA), 2015. September 2015 Public Comment Draft-Navajo Nation Surface Water Quality Standards.

Navajo Natural Heritage Program (NNHP), 2008. *Species Accounts*, Navajo Nation Endangered Species List, version 3.08.

Navajo Nation Historic Preservation Department (NNHPD), 2016. The Navajo Nation Permit Package 2016, Section Three: Fieldwork, Report Standard and Guidelines.

NNHPD, 2018. Call with Sadie Hoskie, Tamara Billie of NNHPD, and Linda Reeves, June 8, 2018.

Navajo National Primary Drinking Water Regulations (NNPDWR), 2015. Part II: Maximum Contaminant Levels Navajo NNPDWR. http://navajopublicwater.org/NNPDWR2.html. Accessed 2015 September 14.

Nystedt, J., 2016. "Re: Navajo Nation AUM Environmental Response Trust--First Phase." E-mail Message to Justin Peterson (Stantec). November 07. (Included in Appendix E of this RSE report)

O'Sullivan, R.B., and Beikman, H.M., 1963. Geology, structure and uranium deposits of the Shiprock quadrangle, New Mexico and Arizona: U .S. Geological Survey I-345, scale 1:250,000.

Schaetzl, R., and Thompson, M.L., 2015. Soils: Genesis and geomorphology. 2nd ed. Cambridge Univ. Press, Cambridge, UK.

Stantec Consulting Services Inc. (Stantec), 2017a. Tsosie 1 Site Clearance Data Report – Draft. November 2017.

Stantec, 2017b. Tsosie 1 Site Baseline Studies Field Report - Draft. November.

Turner, C.E., Peterson, F. 2004. *Reconstruction of the Upper Jurassic Morrison Formation extinct ecosystem – a synthesis. Sedimentary Geology*.

University of Utah, 2018. [Webpage] located at https://sed.utah.edu/Summerville.htm. Accessed February 2018.

United States (US), 2015. Settlement Agreement between the United States of America and the Navajo Nation, April 8.USGS National Geologic Map Database. [Webpage] located at https://ngmdb.usgs.gov. Accessed February 23, 2017.

US Bureau of Mines, 2017. [Webpage] located at http://dictionary.infomine.com/default.aspx?term=portal. Accessed December 29, 2017.

US Department of Energy, 2011. Fernald Preserve 2010 Site Environmental Report. Doc. No. S07409. Page vi. May.

US Department of the Interior Office of Surface Mining (US OSM), 1995. Letter from the US Department of the Interior Office of Surface Mining to Ms. Bernadine Martin, Director of the NAML. July 18.

US Environmental Protection Agency (USEPA), 1992. National Oil and Hazardous Substances Pollution Contingency Plan. Publication 9200.2-14. January.

USEPA, 2000. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), EPA 402-R-97-016, Rev. 1.

USEPA, 2002a. Guidance on Choosing a Sampling Design for Environmental Data Collection. EPA QA/G-5S, December.

USEPA, 2002b. Guidance on Environmental Data Verification and Data Validation. EPA QA/G-8, November.

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA/240/B- 06/001, February.

USEPA, 2007a. Abandoned Uranium Mines and the Navajo Nation. Navajo Nation AUM Screening Assessment Report and Atlas with Geospatial Data. Prepared for U.S. Environmental Agency, Region 9 through an Interagency Agreement with U.S. Army Corps of Engineers. Prepared by TerraSpectra Geomatics in cooperation with Navajo Nation Environmental Protection Agency and Navajo Abandoned Mine Lands Reclamation Program. August.

USEPA, 2007b. Technologically Enhanced Naturally Occurring Radioactive Materials From Uranium Mining, Volumes I and II (EPA 402-R-05-007).

USEPA, 2013. Federal Actions to Address Impacts of Uranium Contamination in the Navajo Nation – Five Year Plan Summary Report, January.

USEPA, 2015. ProUCL Version 5.1 Technical Guide, Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations, September. https://www.epa.gov/sites/production/files/2016-05/documents/proucl_5.1_tech-guide.pdf

USEPA, 2016a. "Table of Regulated Drinking Water Contaminants", Groundwater and Drinking Water. 7 June 2016. Web 6 June 2016. https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants. Accessed 2016 June 7.

USEPA, 2016b. "Table of Secondary Drinking Water Standards", Secondary Drinking Water Standards: Guidance for Nuisance Chemicals. https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals. Accessed 7 June.

USEPA, 2016c. ProUCL 5.1.00 Software.

USEPA, 2017. Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM). [Webpage] located at https://www.epa.gov/radiation/technologically-enhanced-naturally-occurring-radioactive-materials-tenorm. Accessed July19, 2017

US Fish and Wildlife Service (USFWS). 1996. Guidelines for Conducting and Reporting Botanical Inventories for Federally Listed, Proposed, and Candidate Plants. Sacramento Fish and Wildlife Office, Sacramento, California.

USFWS, 1998. Final Endangered Species Act (ESA) Section 7 Consultation Handbook, March 1998. https://www.fws.gov/endangered/esalibrary/ pdf/esa_section7_handbook.pdf

USFWS, 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

US Geological Survey (USGS), 1967. *Petrology of the Morrison Formation in the Colorado Plateau Region.* Geological Survey Professional Paper 556.

USGS, 1984. Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States. US Geological Survey Professional Paper 1270.

USGS, 2003. Flow Origin, Drainage Area, and Hydrologic Characteristics for Headwater Streams in the Mountain top Coal-Mining Region of Southern West Virginia, 2000-01.

USGS, 2016. [Webpage] located at https://geomaps.wr.usgs.gov/parks/province/coloplat.html. Accessed January 2016.

Western Regional Climate Center, 2017. [Webpage] located at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?az1634. Accessed 2017 January 23.

Weston Solutions, Inc., 2010. Tsosie 1 AUM Site Navajo Abandoned Uranium Mine Site Screen Report. August.

World Heritage Encyclopedia, 2017. [Webpage] located at http://www.worldheritage.org/article/WHEBN0014241395/Mineralization%20(geology) Accessed December 28. 2017.

TABLES

Table 3-1
Identified Potential Water Features
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Identified Water Feature	Source of Identified Water Feature	Water Feature Identification	Field Sample Identification	Field Personnel Observations
No Water Feature	2007 AUM Atlas[1], NNDWR	09T-551	NA	No surface water or windmill well observed at this location during RSE activities. Field personnel did observe an oil derrick and four 20 foot tall oil tanks at this location. Location is also listed as "oil producing" in NNDWR database.
No Water Feature	2007 AUM Atlas[1], NNDWR	09T-545	NA	No surface water or windmill well observed at this location during RSE activities. Field personnel did observe piping that ran from the approximate area of the location to the area of 09T-551. Location is listed as "oil producing" in NNDWR database.
Seep	2007 AUM Atlas[1], NNDWR	09-6-14	S055-WS-001	A water seep was present at this location. The seep daylighted along a geologic contact located on a bedrock sidewall and was approximately 50 feet long. A rock drain was constructed downgradient of the seep, and it drained into a PVC pipe that gravity feed to a cement vault approximately 170 feet northwest of the seep. The cement vault was approximately 4 feet square and had a hole on top where large livestock (horses) could access water. A water sample ID S055-WS-001 was collected from the cement vault on May 24, 2017. A cement water trough with a shutoff valve was present approximately 70 feet northwest of the vault.
Seep	Stantec/Trust	S055-Seep-1/Donkey Spring	S055-WS-002	A water seep was present at this location. The seep was located in a drainage approximately 0.33 miles southeast of the Site. The seep was along a contact between sandstone beds.
Drainage Channel	2007 AUM Atlas[1], NNDWR	TSE TAH 5	NA	No surface water observed at this location during RSE activities. NNDWR database indicates NAML staff identified the location as a natural spring in the past.
Drainage Channel	2007 AUM Atlas[1], NNDWR	09-6-10	NA	No well or surface water observed in this area.
Drainage Channel	2007 AUM Atlas[1], NNDWR	TSE TAH 4	NA	No surface water observed at this location during RSE activities. NNDWR database indicates in the past NAML staff identified the location as a natural spring .
Drainage Channel, Potential Seep	2007 AUM Atlas[1], NNDWR	Sah Tah Spring/ RV990317TNS001	NA	No surface water or metal pipe observed at this location during RSE activities. 2007 AUM Atlas indicates in the past a sample was collected from a metal pipe at a spring.
Drainage Channel	2007 AUM Atlas[1], NNDWR	TSE TAH 1	NA	No surface water observed at this location during RSE activities. NNDWR database indicates in the past NAML staff identified the location as a natural spring .
Drainage Channel	2007 AUM Atlas[1], NNDWR	TSE TAH 2	NA	No surface water observed at this location during RSE activities. NNDWR database indicates in the past NAML staff identified the location as a natural spring .
Drainage Channel	2007 AUM Atlas[1], NNDWR	09B-9	NA	No surface water observed at this location during RSE activities. NNDWR database indicates in the past NAML staff identified the location as a natural spring.
Drainage Channel	2007 AUM Atlas[1], NNDWR	TSE TAH 3	NA	No surface water observed at this location during RSE activities. NNDWR database indicates in the past NAML staff identified the location as a natural spring.

Notes
NA - Water feature not sampled
ID - identification
PVC - polyvinyl chloride
NAML - Navajo Abandoned Mines Reclamation Department
NNDWR - Navajo Nation Department of Water Resources
RSE - Removal Site Evaluation
[1] USEPA, 2007a

Table 3-2
Soil and Sediment Sampling Summary
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Sample Location	Sample Depth (ft bgs)	Sample Media	Sample Category	Sample Collection Method	Survey Area	Sample Date	Easting ¹	Northing ¹	Sample Types: Metals, Total	Sample Types: Ra-226	Sample Types: Thorium
Background Reference Area Study - Background Area 1											
S055-BG1-001	0 - 0.5	soil	SF	grab	NA	6/24/2017	653308.27	4082957.03	N;FD	N;FD	--
S055-BG1-002	0 - 0.5	soil	SF	grab	NA	6/24/2017	653307.18	4082962.46	N	N	--
S055-BG1-003	0 - 0.5	soil	SF	grab	NA	6/24/2017	653312.95	4082964.50	N	N	--
S055-BG1-004	0 - 0.5	soil	SF	grab	NA	6/24/2017	653310.61	4082964.74	N	N	--
S055-BG1-005	0 - 0.5	soil	SF	grab	NA	6/24/2017	653313.17	4082969.71	N	N	--
S055-BG1-006	0 - 0.5	soil	SF	grab	NA	6/24/2017	653310.14	4082968.51	N	N	--
S055-BG1-007	0 - 0.5	soil	SF	grab	NA	6/24/2017	653307.02	4082969.70	N	N	--
S055-BG1-008	0 - 0.5	soil	SF	grab	NA	6/24/2017	653303.39	4082964.64	N	N	--
S055-BG1-009	0 - 0.5	soil	SF	grab	NA	6/24/2017	653303.39	4082968.36	N	N	--
S055-BG1-010	0 - 0.5	soil	SF	grab	NA	6/24/2017	653311.33	4082973.71	N	N	--
S055-BG1-011	0 - 0.5	soil	SF	grab	NA	6/26/2017	653306.99	4082966.99	N	N	--
S055-BG1-011	0.5 - 1	soil	SB	grab	NA	6/26/2017	653306.99	4082966.99	N	N	--
S055-BG1-011	1 - 2	soil	SB	grab	NA	6/26/2017	653306.99	4082966.99	N	N	--
Background Reference Area Study - Background Area 2											
S055-BG2-001	0 - 0.5	soil	SF	grab	NA	6/24/2017	653335.04	4082919.50	N;FD	N;FD	--
S055-BG2-002	0 - 0.5	soil	SF	grab	NA	6/24/2017	653336.95	4082921.41	N	N	--
S055-BG2-003	0 - 0.5	soil	SF	grab	NA	6/24/2017	653335.37	4082922.38	N	N	--
S055-BG2-004	0 - 0.5	soil	SF	grab	NA	6/24/2017	653339.69	4082922.85	N	N	--
S055-BG2-005	0 - 0.5	soil	SF	grab	NA	6/24/2017	653338.87	4082925.00	N	N	--
S055-BG2-006	0 - 0.5	soil	SF	grab	NA	6/24/2017	653341.73	4082926.05	N	N	--
S055-BG2-007	0 - 0.5	soil	SF	grab	NA	6/24/2017	653343.65	4082924.78	N	N	--
S055-BG2-008	0 - 0.5	soil	SF	grab	NA	6/24/2017	653346.45	4082928.38	N	N	--
S055-BG2-009	0 - 0.5	soil	SF	grab	NA	6/24/2017	653344.66	4082925.98	N;MS;MSD	N	--
S055-BG2-010	0 - 0.5	soil	SF	grab	NA	6/24/2017	653348.01	4082929.31	N	N	--
S055-BG2-011	0 - 0.8	soil	SB	grab	NA	6/26/2017	653343.69	4082926.27	N	N	--
S055-BG2-011	0.8 - 1.75	soil	SB	grab	NA	6/26/2017	653343.69	4082926.27	N	N	--
Correlation											
S055-C01-001	0 - 0.5	soil	SF	5-point composite	NA	6/26/2017	653200.83	4082808.87	N;FD	N;FD	N;FD
S055-C02-001	0 - 0.5	soil	SF	5-point composite	NA	6/26/2017	653036.37	4082645.24	N	N	N
S055-C03-001	0 - 0.5	soil	SF	5-point composite	NA	6/26/2017	653150.67	4082635.85	N	N	N
S055-C04-001	0 - 0.5	soil	SF	5-point composite	NA	6/26/2017	653130.70	4082636.80	N	N	N
S055-C05-001	0 - 0.5	soil	SF	5-point composite	NA	6/26/2017	653176.26	4082593.12	N;MS;MSD	N	N
Characterization											
S055-CX-001	0 - 0.5	soil	SF	grab	B	6/23/2017	653141.07	4082548.69	N	N	--
S055-CX-002	0 - 0.5	soil	SF	grab	B	6/23/2017	653179.28	4082600.20	N	N	--
S055-CX-003	0 - 0.5	soil	SF	grab	B	6/23/2017	653282.44	4082630.01	N;FD	N;FD	--
S055-CX-004	0 - 0.5	soil	SF	grab	B	6/23/2017	653219.68	4082671.35	N	N	--
S055-CX-005	0 - 0.5	soil	SF	grab	B	6/23/2017	653158.79	4082634.90	N;MS;MSD	N	--
S055-CX-006	0 - 0.5	soil	SF	grab	B	6/23/2017	653134.83	4082634.24	N	N	--
S055-CX-007	0 - 0.5	soil	SF	grab	A	6/23/2017	653092.41	4082652.54	N	N	--
S055-CX-008	0 - 0.5	soil	SF	grab	A	6/23/2017	653154.88	4082717.17	N	N	--
S055-CX-009	0 - 0.5	soil	SF	grab	A	6/23/2017	653109.02	4082776.35	N	N	--
S055-CX-010	0 - 0.5	soil	SF	grab	A	6/23/2017	653218.83	4082878.46	N	N	--
S055-CX-011	0 - 0.5	soil	SF	grab	B	6/24/2017	653189.50	4082637.16	N	N	--
S055-SCX-001	0 - 0.5	soil	SF	grab	B	6/23/2017	653186.33	4082628.66	N;MS;MSD	N	--
S055-SCX-001	0.5 - 0.9	soil	SB	grab	B	6/23/2017	653186.33	4082628.66	N	N	--
S055-SCX-002	0 - 0.5	sediment	SF	grab	A	6/23/2017	653174.77	4082688.27	N	N	--
S055-SCX-002	0.5 - 1	sediment	SB	grab	A	6/23/2017	653174.77	4082688.27	N	N	--

Notes

--	Not Sampled
N	Normal
FD	Field Duplicate
MS	Matrix Spike
MSD	Matrix Spike Duplicate
Ra-226	Radium 226
NA	Not Applicable
SB	Subsurface Sample
SF	Surface Sample
ft bgs	feet below ground surface

¹ Coordinate System: NAD 1983 UTM Zone 12N

Sample Location	Sample Depth (ft bgs)	Sample Media	Sample Category	Sample Collection Method	Survey Area	Sample Date	Easting [1]	Northing [1]	Sample Types Metals, Total	Ra-226	Thorium
Characterization continued											
S055-SCX-003	0 - 0.5	soil	SF	grab	B	6/23/2017	653213.47	4082671.02	N	N	--
S055-SCX-003	0.5 - 1.5	soil	SB	grab	B	6/23/2017	653213.47	4082671.02	N	N	--
S055-SCX-003	1.5 - 1.75	soil	SB	grab	B	6/23/2017	653213.47	4082671.02	N	N	--
S055-SCX-004	0 - 0.5	sediment	SF	grab	B	6/24/2017	653165.67	4082651.72	N	N	--
S055-SCX-004	0.5 - 1	sediment	SB	grab	B	6/24/2017	653165.67	4082651.72	N	N	--
S055-SCX-005	0 - 0.5	soil	SF	grab	A	6/24/2017	653122.59	4082767.21	N;FD	N;FD	--
S055-SCX-005	0.5 - 2	soil	SB	composite	A	6/24/2017	653122.59	4082767.21	N	N	--
S055-SCX-005	2 - 3	soil	SB	grab	A	6/24/2017	653122.59	4082767.21	N	N	--
S055-SCX-006	0 - 0.5	soil	SF	grab	A	6/24/2017	653072.75	4082710.22	N	N	--
S055-SCX-006	0.5 - 1.75	soil	SB	composite	A	6/24/2017	653072.75	4082710.22	N	N	--
S055-SCX-007	0 - 0.5	sediment	SF	grab	A	6/24/2017	653142.85	4082718.30	N	N	--
S055-SCX-007	0.5 - 1	sediment	SB	grab	A	6/24/2017	653142.85	4082718.30	N	N	--
S055-SCX-007	1 - 1.8	sediment	SB	grab	A	6/24/2017	653142.85	4082718.30	N	N	--
S055-SCX-008	0 - 0.5	soil	SF	grab	A	6/24/2017	653183.38	4082735.40	N;MS;MSD	N	--
S055-SCX-008	0.5 - 2.5	soil	SB	composite	A	6/24/2017	653183.38	4082735.40	N	N	--
S055-SCX-008	2.5 - 3.9	soil	SB	composite	A	6/24/2017	653183.38	4082735.40	N	N	--
S055-SCX-009	0 - 0.5	soil	SF	grab	A	6/24/2017	653221.49	4082745.91	N	N	--
S055-SCX-009	0.5 - 2.1	soil	SB	composite	A	6/24/2017	653221.49	4082745.91	N	N	--
S055-SCX-010	0 - 0.5	soil	SF	grab	A	6/24/2017	653200.14	4082807.20	N	N	--
S055-SCX-010	0.5 - 0.9	soil	SB	grab	A	6/24/2017	653200.14	4082807.20	N	N	--
S055-SCX-011	0 - 0.7	soil	SB	grab	A	6/26/2017	653201.13	4082876.04	N;FD	N;FD	--

Notes

--	Not Sampled
N	Normal
FD	Field Duplicate
MS	Matrix Spike
MSD	Matrix Spike Duplicate
Ra-226	Radium 226
NA	Not Applicable
SB	Subsurface Sample
SF	Surface Sample
ft bgs	feet below ground surface
[1] Coordinate System:	NAD 1983 UTM Zone 12N

Table 3-3
Mine Feature Samples and Area
Tsosie 1
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Mine Feature	Surface Samples	Subsurface Samples	Area (sq. ft)	Volume of TENORM exceeding ILs (yd^3)
Waste Pile	2	2	844	15
Reclaimed Area	2	1	6,914	979
Temporary Ponding Area	2	2	55,988	3,235
Potential Haul Roads	0	1	*	1,046
Drainages	2	3	**	--

Notes

sq.ft - square feet

yd^3 - cubic yards

ILs - investigation levels

TENORM - technologically enhanced naturally occurring radioactive material

* Area not determined because the width of the potential haul roads vary throughout the Site

** Area not determined because the width of the drainages vary throughout the Site

-- Discrete volume was not identified for feature.

Table 3-4
Water Sampling Summary
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Field Sample Identification	Water Feature Identification	Sample Date	Easting [1]	Northing [1]	Sample Types: Ra-226	Ra-228	Gross Alpha	Metals, Dissolved[2]	Metals, Total	TDS	Anions	Cations
Surface Water												
S055-WS-001	09-16-14	5/24/2017	652377.50	4081700.66	N;FD	N;FD	N;FD	N;FD;MS;MSD	N;FD;MS;MSD	N;FD	N;FD	N;FD

Notes

N	Normal
FD	Field Duplicate
MS	Matrix Spike
MSD	Matrix Spike Duplicate
Ra-226	Radium 226
Ra-228	Radium 228
TDS	Total Dissolved Solids

[1] Coordinate System: NAD 1983 UTM Zone 12N

[2] Metals total mercury analysis also included laboratory MS/MSD, all other total metals analyses did not include laboratory MS/MDS

Table 4-1
Background Reference Area Soil Sample Analytical Results
Tsosie 1
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Navajo Nation AUM Environmental Response Trust - First Phase

Location Identification	S055-BG1-001 Dup	S055-BG1-001	S055-BG1-002	S055-BG1-003	S055-BG1-004	S055-BG1-005	S055-BG1-006	S055-BG1-007	S055-BG1-008	S055-BG1-009	S055-BG1-010	S055-BG1-011
Date Collected	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/26/2017
Depth (feet)	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5
Analyte (Units)												
Metals[1] (mg/kg)												
Arsenic	1.5	1.8	2.4	1.1	1.3	1	1.4	1.5	1.4	1.6	0.82	1.7
Molybdenum	<0.2	<0.19	0.22	<0.2	<0.19	<0.2	<0.19	<0.2	<0.2	<0.2	<0.2	<0.21
Selenium	<1	<0.95	<0.98	<0.99	<0.96	<1	<0.96	<0.99	<1	<0.99	<1	<1.1
Uranium	0.95	1.2	1.3	0.65	0.81	0.5	0.84	0.84	0.9	1	0.54	0.96
Vanadium	6.2	5.7	6.7	4.7	5.1	4.5	5.3	5.9	6.1	5.7	3.4	6.1
Radionuclides (pCi/g)												
Radium-226	0.6 ± 0.18	1.29 ± 0.27	0.8 ± 0.23	0.79 ± 0.23	0.87 ± 0.21	0.63 ± 0.21	1 ± 0.24	1.18 ± 0.27	1.12 ± 0.24	1.07 ± 0.26	0.57 ± 0.21	1.45 ± 0.28

Notes
Bold Bolded result indicates positively identified compound
mg/kg milligrams per kilogram
pCi/g picocuries per gram
[1] Analysis required a standard sample dilution of 10 times; reported values have been converted to non-dilute value
< Result not detected above associated laboratory reporting limit

Location Identification	S055-BG1-011	S055-BG1-011	S055-BG2-001	S055-BG2-001 Dup	S055-BG2-002	S055-BG2-003	S055-BG2-004	S055-BG2-005	S055-BG2-006	S055-BG2-007	S055-BG2-008	S055-BG2-009
Date Collected	6/26/2017	6/26/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017
Depth (feet)	0.5 - 1	1 - 2	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5
Analyte (Units)												
Metals[1] (mg/kg)												
Arsenic	1.9	1.7	8.8	6.5	5.8	5	12	7.1	5.4	4.8	3.7	4.4
Molybdenum	<0.2	<0.2	0.62	0.77	0.65	0.66	0.63	0.58	0.37	0.31	0.26	0.37
Selenium	<0.98	<1	<0.99	<0.99	<0.95	<0.95	<0.98	<0.99	<0.97	<0.98	<0.94	<0.98
Uranium	1.3	1.2	6.6	5.3	4.9	4	5.5	6	5.8	5.9	5.1	5.6
Vanadium	5.8	5.6	8.1	6.7	6.7	7	9.2	11	6.6	4	7	6.2
Radionuclides (pCi/g)												
Radium-226	0.97 ± 0.28	1.06 ± 0.24	6.83 ± 0.92	6.2 ± 0.86	5.12 ± 0.69	4.56 ± 0.67	6.12 ± 0.82	6.59 ± 0.87	5.89 ± 0.81	4.56 ± 0.63	5.2 ± 0.73	4.81 ± 0.66

Notes
Bold Bolded result indicates positively identified compound
mg/kg milligrams per kilogram
pCi/g picocuries per gram
[1] Analysis required a standard sample dilution of 10 times; reported values have been converted to non-dilute value
< Result not detected above associated laboratory reporting limit

Location Identification	S055-BG2-010	S055-BG2-011	S055-BG2-011
Date Collected	6/24/2017	6/26/2017	6/26/2017
Depth (feet)	0 - 0.5	0 - 0.8	0.8 - 1.75
Analyte (Units)			
Metals[1] (mg/kg)			
Arsenic	9.2	4.4	12
Molybdenum	0.24	0.24	0.35
Selenium	<0.95	<1.1	1.1
Uranium	4.8	5.2	11
Vanadium	14	5.6	16
Radionuclides (pCi/g)			
Radium-226	5.94 ± 0.84	5.06 ± 0.69	9.6 ± 1.3

Notes
Bold Bolded result indicates positively identified compound
mg/kg milligrams per kilogram
pCi/g picocuries per gram
[1] Analysis required a standard sample dilution of 10 times; reported values have been converted to non-dilute value
< Result not detected above associated laboratory reporting limit

Table 4-2
Static Gamma Measurement Summary
Tsosie 1
Removal Site Evaluation Report - Final
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Sample Location	Survey Area	Subsurface Static Gamma Investigation Level (cpm)	Sample Depth (ft bgs)	Media	Static Gamma Measurement (cpm)
S055-BG1-011	Background Area 1	*	0.0	soil	9,821
S055-BG1-011	Background Area 1	*	0.5	soil	11,204
S055-BG1-011	Background Area 1	*	1.0	soil	12,719
S055-BG1-011	Background Area 1	*	1.5	soil	13,219
S055-BG1-011	Background Area 1	*	2.0	soil	12,865
S055-BG1-011	Background Area 1	*	2.4	soil	13,219**
S055-BG2-011	Background Area 2	*	0.0	soil	20,024
S055-BG2-011	Background Area 2	*	0.5	soil	30,739
S055-BG2-011	Background Area 2	*	1.0	soil	45,615
S055-BG2-011	Background Area 2	*	1.5	soil	49,324
S055-BG2-011	Background Area 2	*	1.8	soil	51,193**
S055-SCX-002	A	--	0.0	sediment	14,693
S055-SCX-002	A	12,719	0.5	sediment	18,621
S055-SCX-002	A	12,719	1.0	sediment	19,924**
S055-SCX-005	A	--	0.0	soil	9,569
S055-SCX-005	A	12,719	0.5	soil	13,116
S055-SCX-005	A	12,719	1.0	soil	13,198
S055-SCX-005	A	12,719	1.5	soil	12,058
S055-SCX-005	A	12,719	2.0	soil	12,230
S055-SCX-005	A	12,719	2.5	soil	11,978
S055-SCX-005	A	12,719	3.0	soil	12,667
S055-SCX-006	A	--	0.0	soil	9,724
S055-SCX-006	A	12,719	0.5	soil	11,771
S055-SCX-006	A	12,719	1.0	soil	12,434
S055-SCX-006	A	12,719	1.5	soil	13,329**
S055-SCX-007	A	--	0.0	sediment	8,496
S055-SCX-007	A	12,719	0.5	sediment	9,600
S055-SCX-007	A	12,719	1.0	sediment	12,408
S055-SCX-007	A	12,719	1.5	sediment	14,937
S055-SCX-007	A	12,719	1.8	sediment	16,142**
S055-SCX-008	A	--	0.0	soil	14,866
S055-SCX-008	A	12,719	1.0	soil	17,665
S055-SCX-008	A	12,719	2.0	soil	16,612
S055-SCX-008	A	12,719	3.0	soil	16,422
S055-SCX-008	A	12,719	3.9	soil	18,573**

Notes

Bold	Bolded result indicates measurement exceeds subsurface gamma investigation level
*	The subsurface gamma investigation levels are derived from the background area measurements, refer to Section 4.1 of the RSE report
**	Measurement collected at interface of unconsolidated material and refusal material (e.g., bedrock)
--	The subsurface gamma investigation level does not apply to surface static gamma measurements
IL	Investigation Level
RSE	Removal Site Investigation
cpm	counts per minute
ft bgs	feet below ground surface

Table 4-2
Static Gamma Measurement Summary
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Sample Location	Survey Area	Subsurface Static Gamma Investigation Level (cpm)	Sample Depth (ft bgs)	Media	Static Gamma Measurement (cpm)
S055-SCX-009	A	--	0.0	soil	12,904
S055-SCX-009	A	12,719	0.5	soil	17,001
S055-SCX-009	A	12,719	1.0	soil	17,019
S055-SCX-009	A	12,719	1.5	soil	16,767
S055-SCX-009	A	12,719	2.0	soil	15,143
S055-SCX-010	A	--	0.0	soil	11,116
S055-SCX-010	A	12,719	0.5	soil	14,984
S055-SCX-010	A	12,719	0.9	soil	15,789**
S055-SCX-011	A	--	0.0	soil	11,914
S055-SCX-011	A	12,719	0.7	soil	14,981**
S055-SCX-001	B	--	0.0	soil	22,661
S055-SCX-001	B	45,615	0.5	soil	73,318
S055-SCX-001	B	45,615	0.8	soil	116,500
S055-SCX-003	B	--	0.0	soil	19,753
S055-SCX-003	B	45,615	0.5	soil	26,595
S055-SCX-003	B	45,615	1.0	soil	33,768
S055-SCX-003	B	45,615	1.5	soil	38,866
S055-SCX-003	B	45,615	1.8	soil	39,355**
S055-SCX-004	B	--	0.0	sediment	12,514
S055-SCX-004	B	45,615	0.5	sediment	14,029
S055-SCX-004	B	45,615	1.0	sediment	14,440**

Notes

Bold	Bolded result indicates measurement exceeds subsurface gamma investigation level
*	The subsurface gamma investigation levels are derived from the background area measurements, refer to Section 4.1 of the RSE report
**	Measurement collected at interface of unconsolidated material and refusal material (e.g., bedrock)
--	The subsurface gamma investigation level does not apply to surface static gamma measurements
IL	Investigation Level
RSE	Removal Site Investigation
cpm	counts per minute
ft bgs	feet below ground surface

Table 4-3
Gamma Correlation Study Soil Sample Analytical Results
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Location Identification	S055-C01-001 Dup	S055-C01-001	S055-C02-001	S055-C03-001	S055-C04-001	S055-C05-001
Date Collected	6/26/2017	6/26/2017	6/26/2017	6/26/2017	6/26/2017	6/26/2017
Depth (feet)	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5
Analyte (Units)						
Metals [1] (mg/kg)						
Arsenic	1.4	1.4	31	5.8	14	3.2
Molybdenum	0.2	0.23	1.4	0.65	1.9	0.32
Selenium	<0.93	<0.95	1.4	<0.98	<0.96	<0.99
Uranium	0.83	0.87	30	6.6	17	7.5
Vanadium	8.1	8	18	6	10	6.8
Radionuclides (pCi/g)						
Radium-226	1.33 ± 0.3	1.43 ± 0.29	30.5 ± 3.7 J+	5.43 ± 0.76	32.7 ± 4	6.66 ± 0.88
Thorium-228	0.52 ± 0.1	0.467 ± 0.099	1.1 ± 0.2	0.394 ± 0.088	0.55 ± 0.11	0.48 ± 0.1
Thorium-230	1.01 ± 0.18	1.08 ± 0.2	15.4 ± 2.4	5.1 ± 0.81	26.1 ± 4.1	4.78 ± 0.76
Thorium-232	0.468 ± 0.092	0.444 ± 0.091	1.09 ± 0.19	0.336 ± 0.073	0.53 ± 0.1	0.386 ± 0.082

Notes
Bold Bolded result indicates positively identified compound
pCi/g picocuries per gram
mg/kg milligrams per kilogram.
J+ Data are estimated and are potentially biased high due to associated quality control data
1 The correlation soil samples were inadvertently analyzed for arsenic, molybdenum, selenium, uranium, and vanadium as the result of laboratory error. These composite samples were not used for direct comparison to the ILs and no further evaluation was completed on

Table 4-4a
Site Characterization Soil and Sediment Sample Analytical Results for Survey Area A
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

	Location Identification	S055-CX-007	S055-CX-008	S055-CX-009	S055-CX-010	S055-SCX-002	S055-SCX-002	S055-SCX-005	S055-SCX-005	S055-SCX-005	S055-SCX-005 Dup	S055-SCX-006
	Date Collected	6/23/2017	6/23/2017	6/23/2017	6/23/2017	6/23/2017	6/23/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017
	Depth (feet)	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0.5 - 1.0	0 - 0.5	0.5 - 2.0	2.0 - 3.0	0 - 0.5	0 - 0.5
	Sample Category	surface	surface	surface	surface	surface	subsurface	surface	subsurface	subsurface	surface	surface
	Sample Collection Method	grab	grab	grab	grab	grab	grab	grab	grab	composite	grab	grab
	Media	soil	soil	soil	soil	sediment	sediment	soil	soil	soil	soil	soil
Analyte (Units)												
Metals[1] (mg/kg)	Investigation Level											
Arsenic	2.67	1.7	2.5	2.3	0.62	3.7	2.7	1.3	1.9	1.2	1.1	2.1
Molybdenum	NA	<0.19	0.23	0.25	<0.2	2.1	1.1	<0.2	0.24	<0.2	<0.19	1.2
Selenium	NA	<0.97	<0.94	<0.92	<1	<1.1	<1.1	<1	<1	<1	<0.96	<1
Uranium	1.57	1.3	1.1	0.75	0.61	4.5	3.6	0.37	0.57	0.33	0.34	0.95
Vanadium	7.98	5.5	10	10	3.8	35	27	5.7	8	7.5	5.5	6.3
Radionuclides (pCi/g)												
Radium-226	1.75	1.38 ± 0.28	1.79 ± 0.32	0.99 ± 0.29	0.59 ± 0.18	6.06 ± 0.87 J+	4.73 ± 0.73 J+	0.81 ± 0.24	0.6 ± 0.2	0.6 ± 0.19	0.45 ± 0.2	0.85 ± 0.27

Notes

Bold	Bolded result indicates positively identified compound
Shaded	Shaded result indicates result greater than or equal to the investigation level
Shaded	Shaded result indicates analyte detected, where that analyte does not have an investigation level
mg/kg	milligrams per kilogram
pCi/g	picocuries per gram
NA	An investigation level is not identified because in BG-1 selenium sample results were all non-detect and molybdenum had only one detection
1	Analysis required a standard sample dilution of 10 times; reported values have been converted to non-diluted value
<	Result not detected above associated laboratory reporting limit
J-	Data are estimated and are potentially biased low due to associated quality control data
J+	Data are estimated and are potentially biased high due to associated quality control data

Table 4-4a
Site Characterization Soil and Sediment Sample Analytical Results for Survey Area A
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

	Location Identification	S055-SCX-006	S055-SCX-007	S055-SCX-007	S055-SCX-007	S055-SCX-008	S055-SCX-008	S055-SCX-008	S055-SCX-009	S055-SCX-009	S055-SCX-010	S055-SCX-010
	Date Collected	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017	6/24/2017
	Depth (feet)	0.5 - 1.75	0 - 0.5	0.5 - 1.0	1.0 - 1.8	0 - 0.5	0.5 - 2.5	2.5 - 3.9	0 - 0.5	0.5 - 2.1	0 - 0.5	0.5 - 0.9
	Sample Category	subsurface	surface	subsurface	subsurface	surface	subsurface	subsurface	surface	subsurface	surface	subsurface
	Sample Collection Method	composite	grab	grab	grab	grab	composite	composite	grab	composite	grab	grab
	Media	soil	sediment	sediment	sediment	soil	soil	soil	soil	soil	soil	soil
Analyte (Units)												
Metals[1] (mg/kg)	Investigation Level											
Arsenic	2.67	1.6	1.3	1.7	3.3	4.7	2.2	2.2	7.5	3.9	1.9	0.77
Molybdenum	NA	0.47	0.3	0.25	0.3	0.89 J-	0.33	0.24	0.88	0.35	0.29	<0.21
Selenium	NA	<1	<1.1	<0.95	<0.97	<1	<1	<0.99	<0.98	<0.99	<1	<1.1
Uranium	1.57	1.1	0.31	0.48	2.9	4.1	1.1	2.1	3.5	2.7	1.2	0.5
Vanadium	7.98	5.6	9.6	8.1	14	25	11	6.5	10	10	9.2	3
Radionuclides (pCi/g)												
Radium-226	1.75	1.11 ± 0.25	0.61 ± 0.25	0.7 ± 0.25	1.99 ± 0.34	4.28 ± 0.72 J+	1.28 ± 0.29	1.72 ± 0.35	2.4 ± 0.39	2.76 ± 0.47	1.84 ± 0.36 J+	2.01 ± 0.39 J+

Notes

Bold	Bolded result indicates positively identified compound
Shaded	Shaded result indicates result greater than or equal to the investigation level
Shaded	Shaded result indicates analyte detected, where that analyte does not have an investigation level
mg/kg	milligrams per kilogram
pCi/g	picocuries per gram
NA	An investigation level is not identified because in BG-1 selenium sample results were all non-detect and molybdenum had only one detection
1	Analysis required a standard sample dilution of 10 times; reported values have been converted to non-diluted value
<	Result not detected above associated laboratory reporting limit
J-	Data are estimated and are potentially biased low due to associated quality control data
J+	Data are estimated and are potentially biased high due to associated quality control data

	Location Identification	S055-SCX-011	S055-SCX-011 Dup
	Date Collected	6/26/2017	6/26/2017
	Depth (feet)	0 - 0.7	0 - 0.7
	Sample Category	subsurface	subsurface
	Sample Collection Method	grab	grab
	Media	soil	soil
Analyte (Units)			
Metals[1] (mg/kg)	Investigation Level		
Arsenic	2.67	2.3	1.7
Molybdenum	NA	0.3	<0.2
Selenium	NA	<1.1	<0.99
Uranium	1.57	2.8	2.1
Vanadium	7.98	9.8	8.3
Radionuclides (pCi/g)			
Radium-226	1.75	4.65 ± 0.81 J+	2.34 ± 0.46 J+

Notes

Bold	Bolded result indicates positively identified compound
Shaded	Shaded result indicates result greater than or equal to the investigation level
Shaded	Shaded result indicates analyte detected, where that analyte does not have an investigation level
mg/kg	milligrams per kilogram
pCi/g	picocuries per gram
NA	An investigation level is not identified because in BG-1 selenium sample results were all non-detect and molybdenum had only one detection
1	Analysis required a standard sample dilution of 10 times; reported values have been converted to non-diluted value
<	Result not detected above associated laboratory reporting limit
J-	Data are estimated and are potentially biased low due to associated quality control data
J+	Data are estimated and are potentially biased high due to associated quality control data

Table 4-4b
Site Characterization Soil and Sediment Sample Analytical Results for Survey Area B
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Location Identification		S055-CX-001	S055-CX-002	S055-CX-003	S055-CX-003 Dup	S055-CX-004	S055-CX-005	S055-CX-006	S055-CX-011	S055-SCX-001	S055-SCX-001	S055-SCX-003
Date Collected		6/23/2017	6/23/2017	6/23/2017	6/23/2017	6/23/2017	6/23/2017	6/23/2017	6/24/2017	6/23/2017	6/23/2017	6/23/2017
Depth (feet)		0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0.5 - 0.9	0 - 0.5
Sample Category		surface	surface	surface	surface	surface	surface	surface	surface	surface	subsurface	surface
Sample Collection Method		grab	grab	grab	grab	grab	grab	grab	grab	grab	grab	grab
Media		soil	soil	soil	soil	soil	soil	soil	soil	soil	soil	soil
Analyte (Units)												
Metals[1] (mg/kg)	Investigation Level											
Arsenic	14.3	2.5	13	1.6	1.5	4.2	8.3 J+	140	9.3	2.6	21	2.5
Molybdenum	0.974	<0.19	1.7	0.97	0.79	0.36	1.7 J-	1.6	5.5	1	16	0.51
Selenium	NA	<0.96	1.1	<0.93	<0.96	<0.95	<0.92	1.3	<0.99	<1.1	2.3	<1
Uranium	7.57	0.84	21	1	0.67	5.7	5.9	37	28	3.7 J+	61	4.3
Vanadium	16.2	12	12	4.3	4.2	6.7	22 J+	14	190	30 J+	400	27
Radionuclides (pCi/g)												
Radium-226	7.96	0.8 ± 0.26 J+	31.3 ± 3.8	0.91 ± 0.21 J-	0.91 ± 0.24 J-	4.65 ± 0.66	7.7 ± 1	59.1 ± 7.1	23.5 ± 2.8 J-	5.45 ± 0.79 J+	56.2 ± 6.8 J+	8.2 ± 1.1 J+

Notes

Bold	Bolded result indicates positively identified compound
Shaded	Shaded result indicates result greater than or equal to the investigation level
Shaded	Shaded result indicates analyte detected, where that analyte does not have an investigation level
mg/kg	milligrams per kilogram
pCi/g	picocuries per gram
NA	An investigation level is not identified because selenium had only one detection in BG-2
1	Analysis required a standard sample dilution of 10 times; reported values have been converted to non-diluted value
<	Result not detected above associated laboratory reporting limit
J-	Data are estimated and are potentially biased low due to associated quality control data
J+	Data are estimated and are potentially biased high due to associated quality control data

Table 4-4b
Site Characterization Soil and Sediment Sample Analytical Results for Survey Area B
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

	Location Identification	S055-SCX-003	S055-SCX-003	S055-SCX-004	S055-SCX-004
	Date Collected	6/23/2017	6/23/2017	6/24/2017	6/24/2017
	Depth (feet)	0.5 - 1.5	1.5 - 1.75	0 - 0.5	0.5 - 1
	Sample Category	subsurface	subsurface	surface	subsurface
	Sample Collection Method	grab	grab	grab	grab
	Media	soil	soil	sediment	sediment
Analyte (Units)					
Metals[1] (mg/kg)	Investigation Level				
Arsenic	14.3	2.6	4	3.8	3.2
Molybdenum	0.974	0.65	1.3	1.1	0.6
Selenium	NA	<1.1	<1.1	<1	<0.98
Uranium	7.57	6.2	12	4.1	2.8
Vanadium	16.2	33	33	23	20
Radionuclides (pCi/g)					
Radium-226	7.96	7.7 ± 1.1 J+	8.6 ± 1.1	4.23 ± 0.63	3.11 ± 0.45

Notes
- Bold — Bolded result indicates positively identified compound
- Shaded — Shaded result indicates result greater than or equal to the investigation level
- Shaded — Shaded result indicates analyte detected, where that analyte does not have an investigation level
- mg/kg — milligrams per kilogram
- pCi/g — picocuries per gram
- NA — An investigation level is not identified because selenium had only one detection in BG-2
- [1] — Analysis required a standard sample dilution of 10 times; reported values have been converted to non-diluted value
- < — Result not detected above associated laboratory reporting limit
- J- — Data are estimated and are potentially biased low due to associated quality control data
- J+ — Data are estimated and are potentially biased high due to associated quality control data

Table 4-5
Summary of Investigation Level Exceedances in Soil at Borehole Locations
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Sample Location	Survey Area	Investigation Level Exceedances
S055-SCX-001[1]	B	As, Mo, Se, U, V, Ra-226, Static Gamma
S055-SCX-002[2]	A	As, Mo, U, V, Ra-226, Static Gamma
S055-SCX-003	B	Mo, U, V, Ra-226
S055-SCX-004	B	Mo, V
S055-SCX-005[2]	A	Mo, V, Static Gamma
S055-SCX-006[2]	A	Mo, Static Gamma
S055-SCX-007[2]	A	As, Mo, U, V, Ra-226, Static Gamma
S055-SCX-008[2]	A	As, Mo, U, V, Ra-226, Static Gamma
S055-SCX-009[2]	A	As, Mo, U, V, Ra-226, Static Gamma
S055-SCX-010[2]	A	Mo, V, Ra-226, Static Gamma
S055-SCX-011[2]	A	Mo, U, V, Ra-226, Static Gamma

Notes
[1] Detections of Se included for reference, no IL was established for Se
[2] Detections of Mo included for reference for locations in Survey Area A, no IL was established for Mo in Survey Area A

IL - Investigation Level
As - Arsenic
Mo - Molybdenum
Ra-226 - Radium 226
Se - Selenium
U - Uranium
V - Vanadium

Table 4-6a
Water Sampling Investigation Level Derivation
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Analyte (Units)	USEPA MCL [a]	USEPA Secondary Standard [b]	Navajo Nation Surface Water Quality Standards [c]	Navajo Nation Primary Drinking Water MCL[d]	Investigation Level
Radionuclides (pCi/L)					
Ra-226 [e]	5	*	5	5	5
Ra-228 [e]	5	*	5	5	5
Gross Alpha	15	*	15	15	15
Metals (ng/L)					
Mercury	2000	*	2000	2000	2000
Metals (µg/L)					
Antimony	6	*	5.6	6	5.6
Arsenic	10	*	10	10	10
Barium	2000	*	2000	2000	2000
Beryllium	4	*	4	4	4
Cadmium	5	*	5	5	5
Chromium, Total	100	*	100	100	100
Cobalt	*	*	*	*	*
Copper	1300	*	1300	*	1300
Lead	15	*	15	15	15
Molybdenum	*	*	*	*	*
Nickel	*	*	610	*	610
Selenium	50	*	50	50	50
Silver	*	100	35	*	35
Thallium	2	*	2	2	2
Uranium	30	*	30	30	30
Vanadium	*	*	*	*	*
Zinc	*	5000	2100	*	2100
General Chemistry Parameters (mg/L) [f]					
Bicarbonate	*	*	*	*	*
Calcium	*	*	*	*	*
Carbonate	*	*	*	*	*
Chloride	*	250	*	*	250
Sodium	*	*	*	*	*
Sulfate	*	250	*	*	250
TDS	*	500	*	*	500

Notes
Bold – indicates the most conservative value to be used for comparison.
[a] "Table of Regulated Drinking Water Contaminants", Groundwater and Drinking Water (USEPA, 2016a).
[b] "Table of Secondary Drinking Water Standards", Secondary Drinking Water Standards: Guidance for Nuisance Chemicals (USEPA, 2016b).
[c] Navajo Nation Surface Water Quality Standards (NNEPA, 2015)
[d] Maximum Contaminant Levels Navajo Nation Primary Drinking Water Regulations (NNPDWR, 2015)
[e] The MCL for Ra-226 and Ra-228 have a combined limit of 5 pCi/L, and are not individually 5pCi/L
[f] Collected data will be used for water quality analysis purposes

* USEPA primary (MCL), secondary standard, Navajo Nation Surface Water Quality Standards, or Navajo Drinking Water MCLs are not established for these analytes.

MCL - maximum contaminant level
µg/L - micrograms per liter
mg/L - milligrams per liter
ng/L - nanograms per liter
pCi/L - picocuries per liter
TDS - Total Dissolved Solids
Ra-226 - Radium 226
Ra-228 - Radium 228
USEPA - Unites States Environmental Protection Agency

Table 4-6b
Water Sampling Analytical Results
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Analyte (Units)	Water Feature Identification / Field Sample Identification / Date Collected / Matrix / Preparation	09-6-14	09-6-14	09-6-14	09-6-14	S055-Seep-1/Donkey Spring
	Field Sample Identification	S055-WS-001	S055-WS-001	S055-WS-001 Dup	S055-WS-001 Dup	S055-WS-002[4]
	Date Collected	5/24/2017	5/24/2017	5/24/2017	5/24/2017	4/23/2018
	Matrix	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
	Preparation	Dissolved	Total	Dissolved	Total	NS
Radionuclides (pCi/L)	Investigation Level					
Ra-226	5 [1]	NS	5.8 ± 1.5	NS	9.2 ± 2.4	NS
Ra-228	5 [1]	NS	0 ± 0.27	NS	0.74 ± 0.36	NS
Gross Alpha	--	NS	319 ± 51	NS	334 ± 54	NS
Adjusted Gross Alpha [2]	15	NS	14.9	NS	23.2	NS
Gross Beta	--	NS	51.2 ± 8.8	NS	54 ± 9.1	NS
Mercury (ng/L)						
Mercury	2000	<0.5 ; <0.5	<0.5 ; 0.2 F	NS	NS	NS
Metals [3] (µg/L)						
Antimony	5.6	<0.3	<0.3	0.32	<0.3	NS
Arsenic	10	<2	<2	<2	<2	NS
Barium	2000	18	18	17	18	NS
Beryllium	4	<0.5	<0.5	<0.5	<0.5	NS
Cadmium	5	<0.3	<0.3	<0.3	<0.3	NS
Chromium, Total	100	<10	<10	<10	<10	NS
Cobalt	--	<1	<1	<1	<1	NS
Copper	1300	<10	<10	<10	<10	NS
Lead	15	<0.5	<0.5	<0.5	<0.5	NS
Molybdenum	--	4.8	4.3	4.3	4.6	NS
Nickel	610	<5	<5	<5	<5	NS
Selenium	50	12	10	13	12	NS
Silver	35	<0.1	<0.1	<0.1	<0.1	NS
Thallium	2	<0.2	<0.2	<0.2	<0.2	NS
Uranium	30	470	450	460	460	NS
Vanadium	--	<1	<1	<1	<1	NS
Zinc	2100	<20	<20	<20	<20	NS
General Chemistry Parameters (mg/L)						
TDS	500	NS	950	NS	960	NS
Carbonate	--	NS	<20	NS	<20	NS
Bicarbonate	--	NS	220	NS	230	NS
Chloride	250	NS	19 D	NS	19 D	NS
Sulfate	250	NS	460 D	NS	470 D	NS
Calcium	--	190000	190000	200000	190000	NS
Sodium	--	53000	52000	54000	52000	NS
Field Parameters						
Oxidation Reduction Potential(millivolts)	--	NS	147.3	NS	NS	208.1
pH(pH units)	--	NS	7.29	NS	NS	7.71
Specific Conductivity(µS/cm)	--	NS	1286	NS	NS	1254
Temperature(°C)	--	NS	17.8	NS	NS	14.6
Turbidity(NTU)	--	NS	0.31	NS	NS	NS[5]

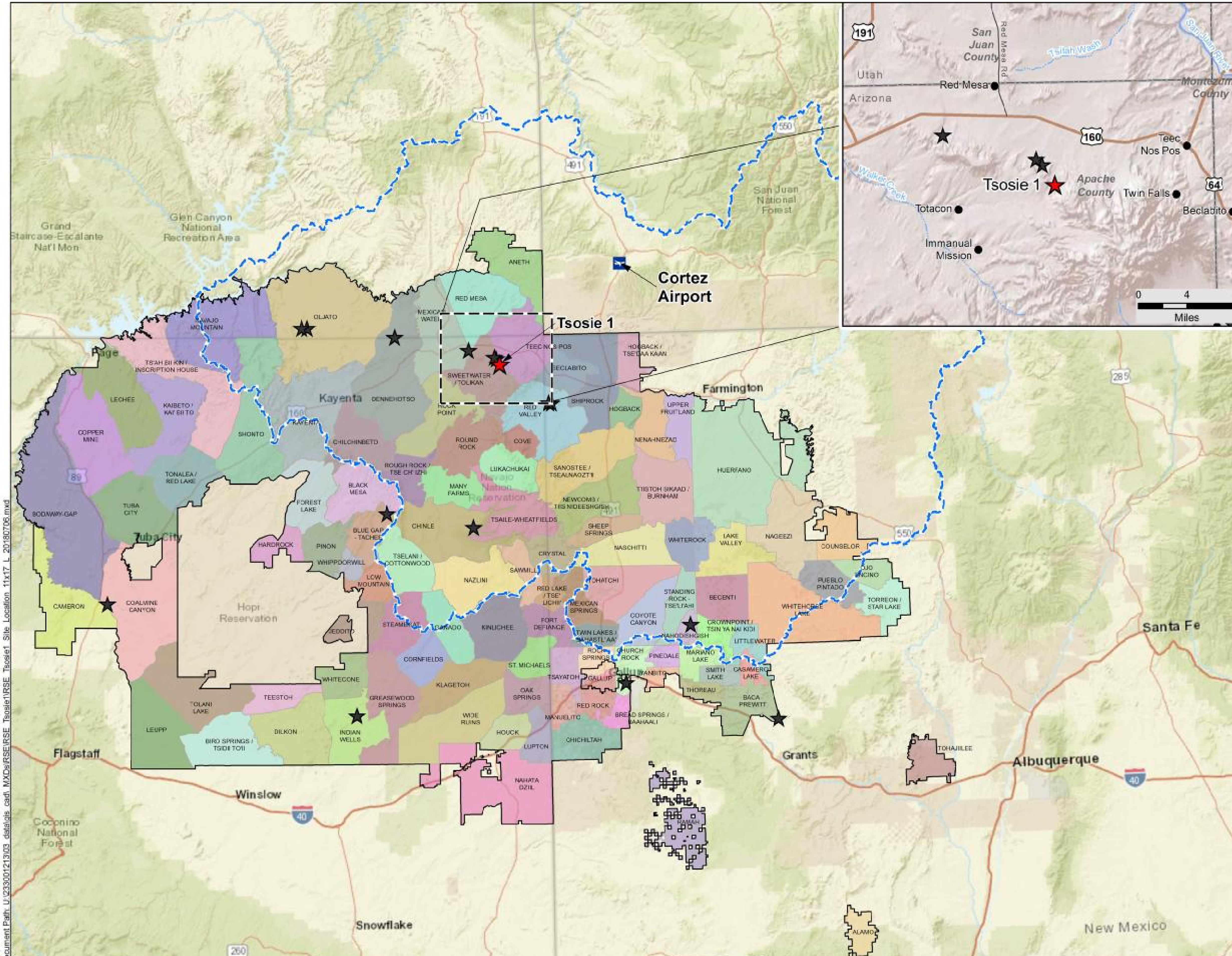
Notes

Bold	Bolded result indicates positively identified compound
Shaded	Shaded result indicates result or reporting limit greater than or equal to the investigation level
D	Analysis required non-standard dilution; reported values have been converted to non-dilute value
F	Analyte was positively identified but the reported concentration is estimated; reported concentration is less
°C	Degrees Celsius
µg/L	micrograms per liter
µS/cm	microSiemens per centimeter
mg/L	milligrams per liter
ng/L	nanograms per liter
NTU	nephelometric turbidity unit
pCi/L	picocuries per liter
PPTV	parts per trillion volume
--	Not established
NS	Not scheduled
Ra-226	Radium 226
Ra-228	Radium 228
TDS	Total Dissolved Solids
<	Result not detected above associated laboratory reporting limit
1	The Investigation Level for Ra-226 and Ra-228 have a combined limit of 5 pCi/L, and are not individually 5pCi/L
2	Adjusted Gross Alpha = Gross alpha concentration - uranium concentration, using the conversion factor of 0.6757 to convert uranium µg/L to pCi/L (U.S. Department of Energy, 2011)
3	Analysis required sample dilution of 10 times; reported values have been converted to non-diluted value
4	There was not enough water present at the seep location to collect an analytical sample, but there was enough water present to collect field parameters
5	Turbidity field parameter was not collected because of the amount of suspended sediment that was present in the limited water available to collect the field parameters

FIGURES

FIGURE ACRONYMS/ABBREVIATIONS

As	arsenic
BG	potential background reference area
bgs	below ground surface
cpm	counts per minute
ft	feet
IL	investigation level
mg/kg	milligrams per kilogram
Mo	molybdenum
NA	not applicable
NAD	North American Datum
pCi/g	picocuries per gram
Ra	radium-226
Ra-226	radium-226
Se	selenium
TENORM	Technologically Enhanced Naturally Occurring Radioactive Materials
uk	unknown
U	uranium
UTL	upper tolerance limit
UTM	Universal Transverse Mercator
V	vanadium



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Tsosie 1 Mine Site
- Priority Abandoned Uranium Mine (AUM) Site
- Populated Place
- US Highway
- State Highway
- Major Road
- Stream
- Intermittent Stream
- San Juan River Watershed
- Navajo Nation Boundary
- Navajo Nation Chapter

Cortez Airport, Colorado Wind Rose (KCEZ), 1996-2006

Windspeed (mph): >0 - 2; >2 - 4; >4 - 6; >6 - 8; >8

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap: ESRI World Street Map and World Shaded Relief accessed 07/2018.

Wind Rose: USEPA, 2007a

0 25 50
Miles

TITLE:
Site Location

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

DATE:	DOCUMENT NAME:	
7/6/2018	Removal Site Evaluation Report	
Stantec	AUTHOR: CBB	REVIEWER: EDZ
	FIGURE: 1-1	

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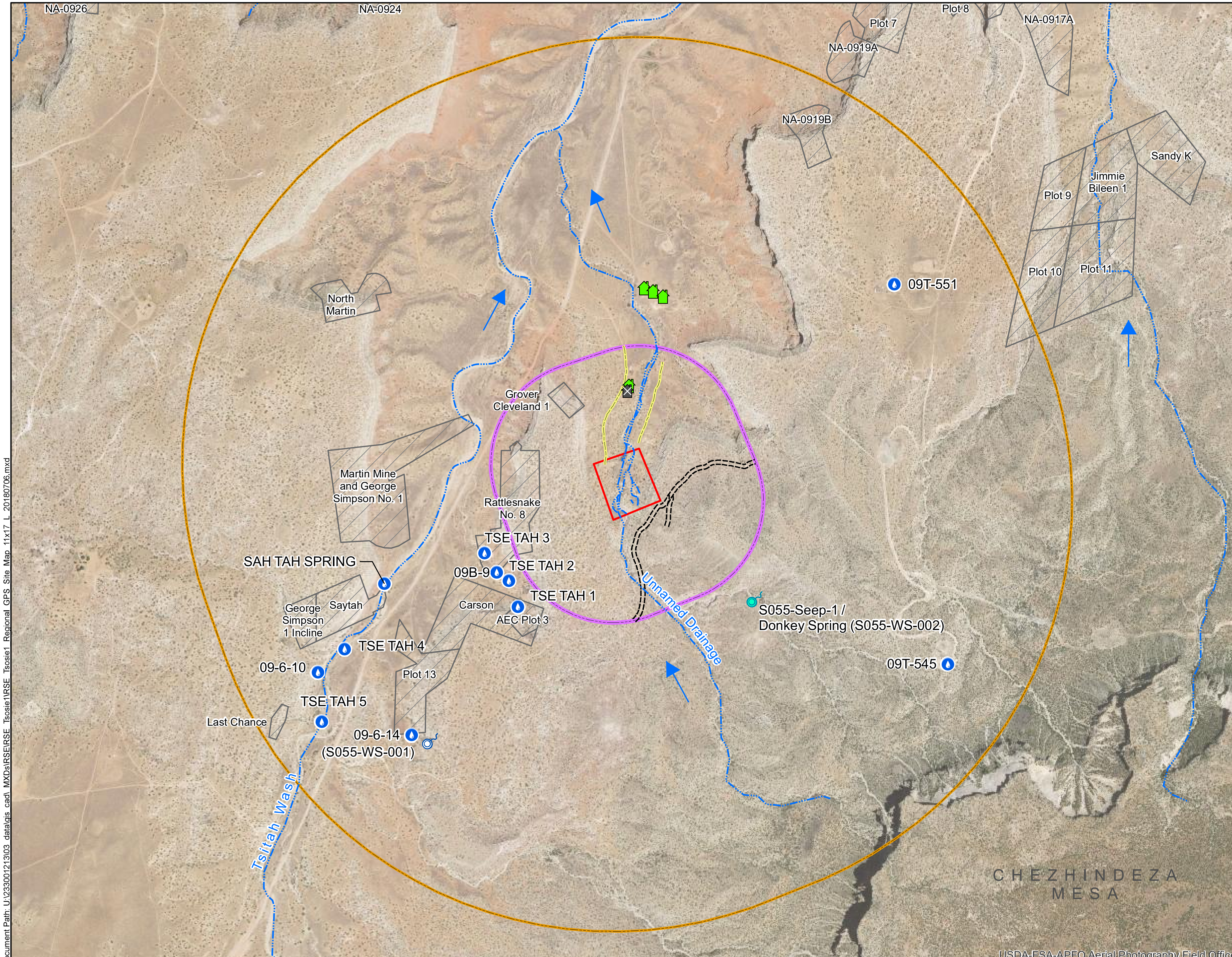

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NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Site Clearance Identified Potential Water Feature[1]
- Habitable Building
- Uninhabitable Building
- Seep
- Seep[2]
- Flow Direction
- Intermittent Stream/River
- Potential Haul Road
- Road
- Claim Boundary
- 1/4-Mile Claim Boundary Buffer
- 1-Mile Claim Boundary Buffer
- Other Claim Boundary

NOTES:

1. Potential water features and identification names identified in 2007 AUM Atlas and/or in database provided by the Navajo Nation Department of Water Resources.

2. S055-Seep-1 was identified with the help of residents that live near the Site.

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 7/6/2018

N W E S

0 1,250 2,500

Feet

TITLE: Site Features

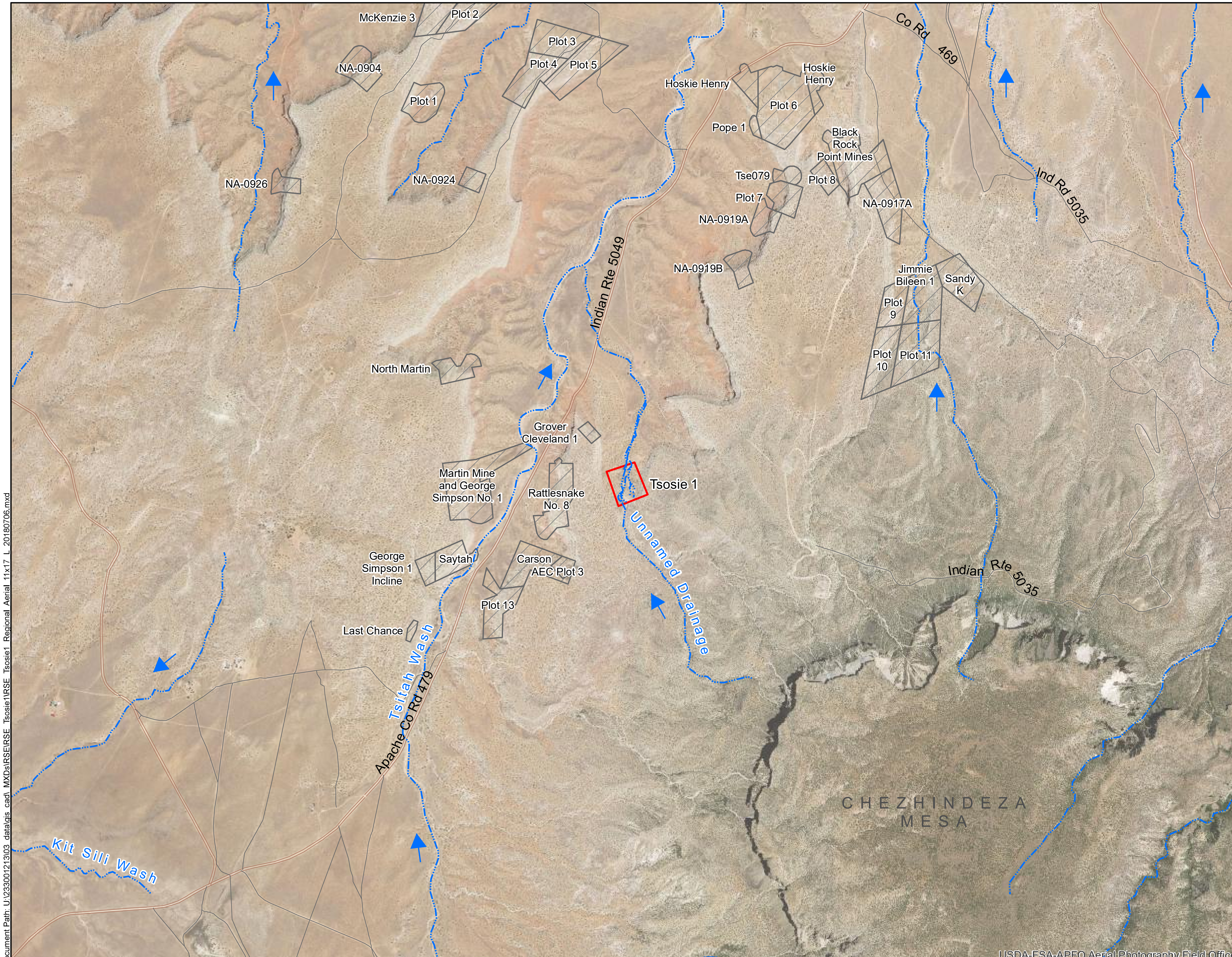
PROJECT: Removal Site Evaluation Tsosie 1 Mine Site

DATE:	DOCUMENT NAME:
7/6/2018	Removal Site Evaluation Report

Stantec

AUTHOR:	REVIEWER:
CBB	EDZ

FIGURE: 2-1



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Flow Direction
- Intermittent Stream/River
- Tribal Road
- County Road
- Local Road
- Claim Boundary
- Other Claim Boundary

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 7/6/2018

N W E S

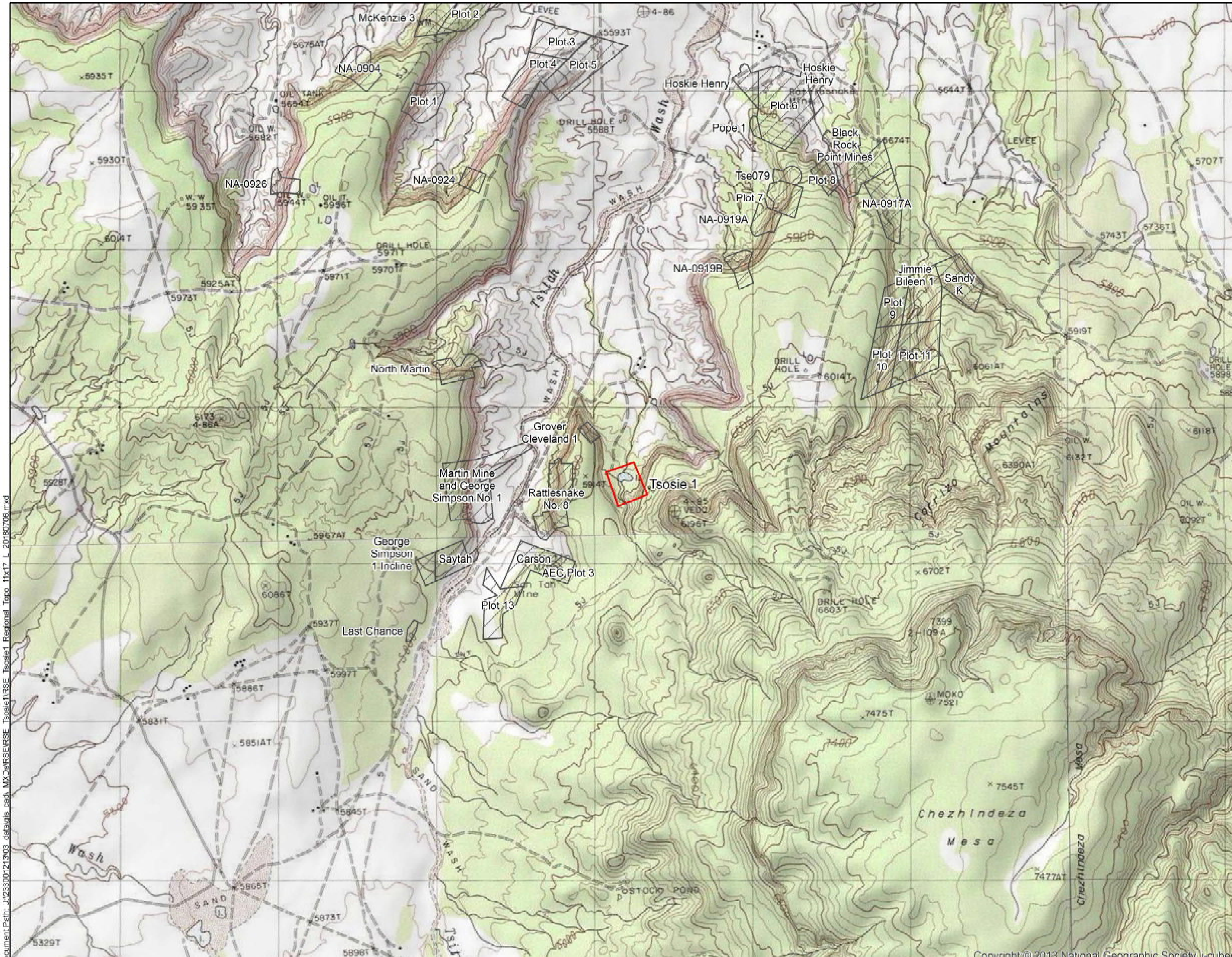
0 2,000 4,000
Feet

TITLE:
Regional Aerial Photograph

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

DATE:	DOCUMENT NAME:	
7/6/2018	Removal Site Evaluation Report	
Stantec	AUTHOR: CBB	REVIEWER: EDZ
	FIGURE: 2-2	

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Regional_Aerial_11x17_L_20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

Claim Boundary
Other Claim Boundary

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap: ESRI USA Topo Maps service accessed 07/2018.

0 2,000 4,000
Feet

TITLE: Regional Topographic Map

PROJECT: Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 7/6/2018

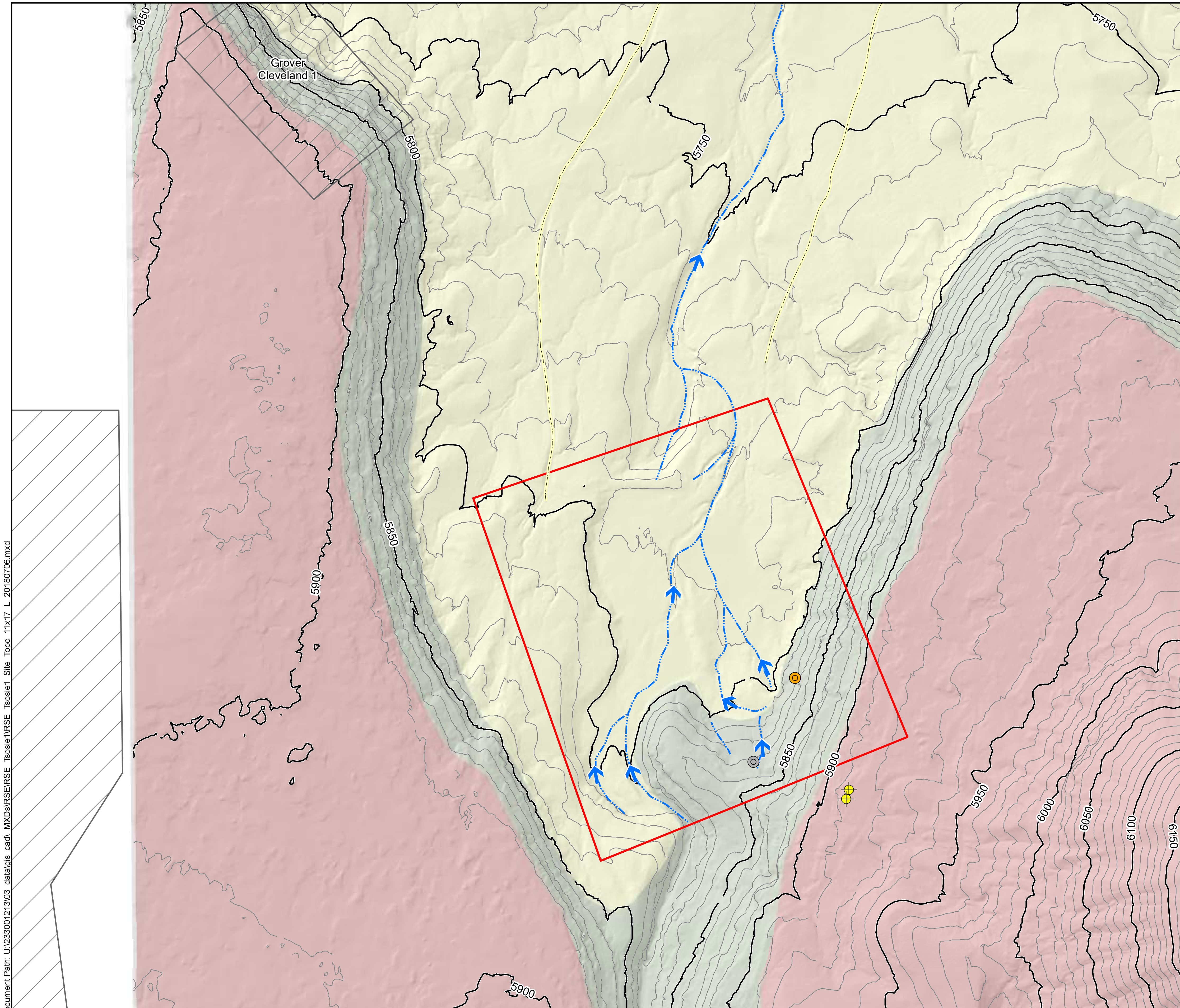
DOCUMENT NAME: Removal Site Evaluation Report

AUTHOR: CBB

REVIEWER: EDZ

FIGURE: 2-3

Stantec



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Historical Borehole
- Approximate Buried Portal Location
- Sealed Portal
- Flow Direction
- Drainage
- Potential Haul Road
- Index Contour (50 ft Interval)
- Index Contour (10 ft Interval)
- Claim Boundary
- Other Claim Boundary

Geomorphology Features

- Mesa Top
- Mesa Sidewall
- Plains

NOTE:
The extent of the basemap is based on the Cooper aerial surveys conducted on June 16, 2017.

REFERENCES:
Site-specific contours were generated as part of aerial surveys conducted on June 16, 2017.

Coordinate System: NAD 1983 UTM Zone 12N

N W E S

0 200 400
Feet

TITLE:
Site Topography

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 7/6/2018

DOCUMENT NAME: Removal Site Evaluation Report

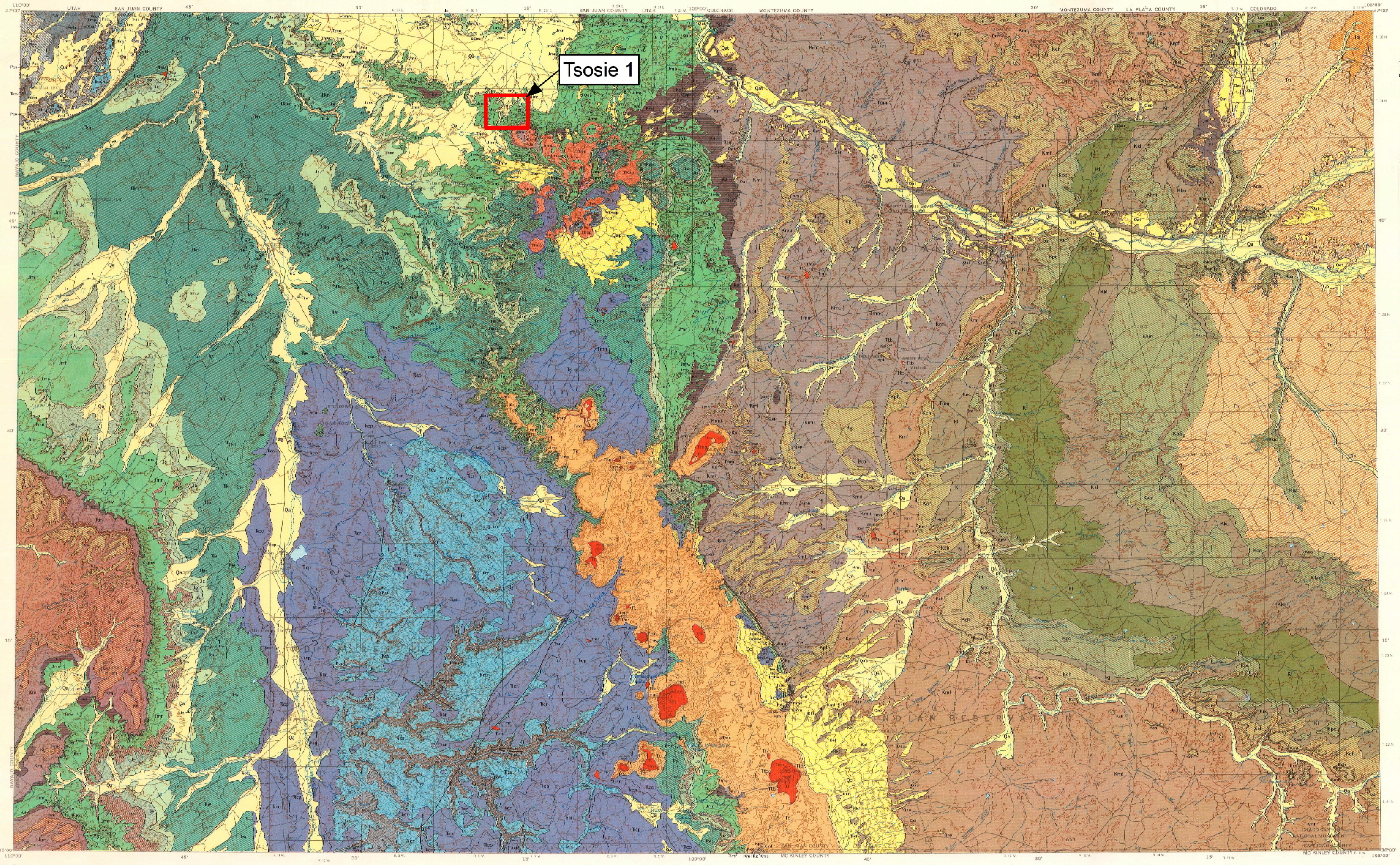
Stantec

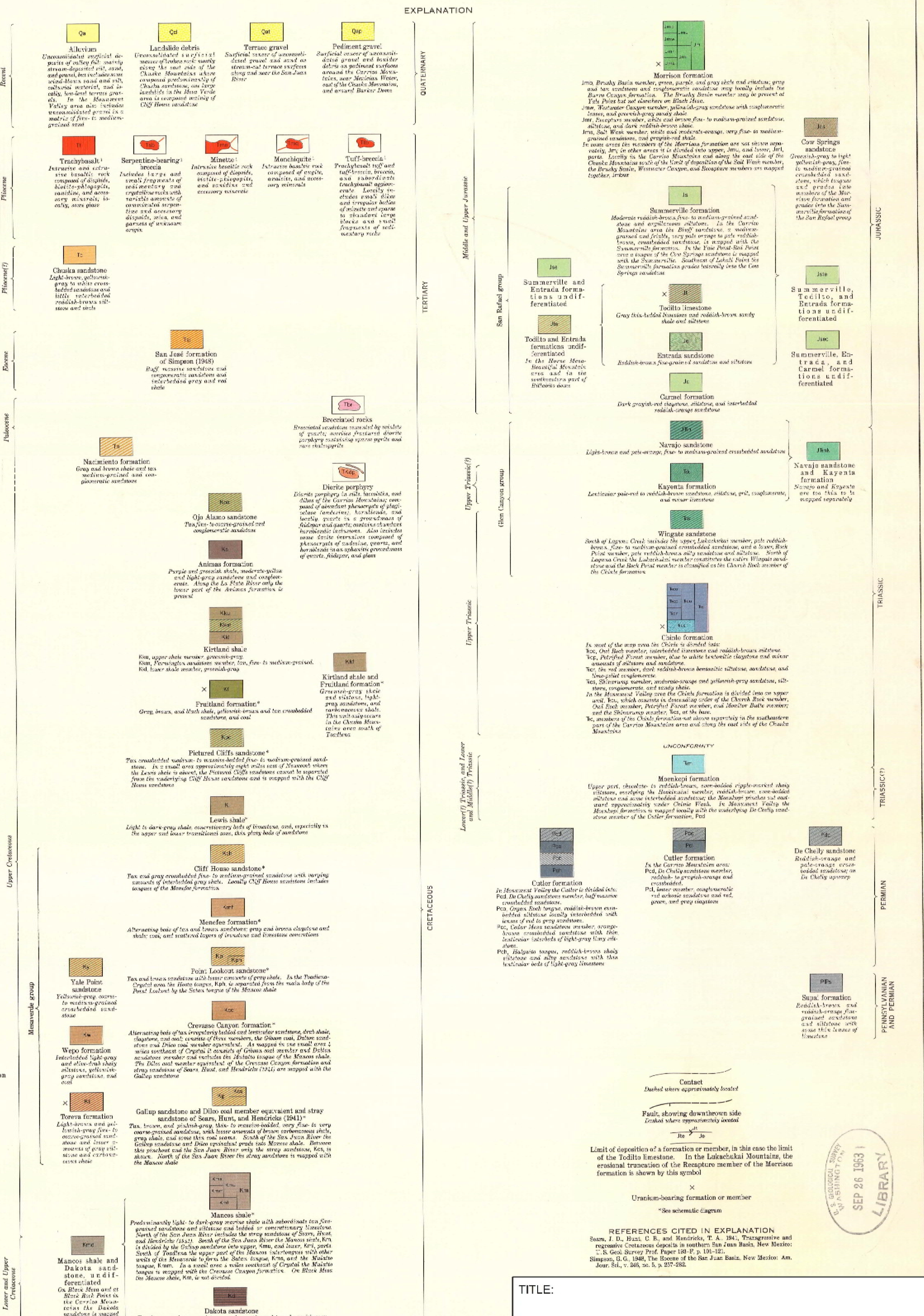
AUTHOR: EDZ

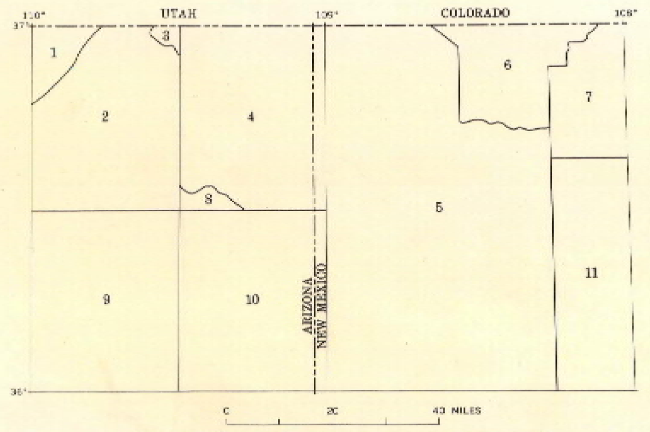
REVIEWER: CBB

FIGURE: 2-4

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Site_Topo_11x17_L_20180706.mxd

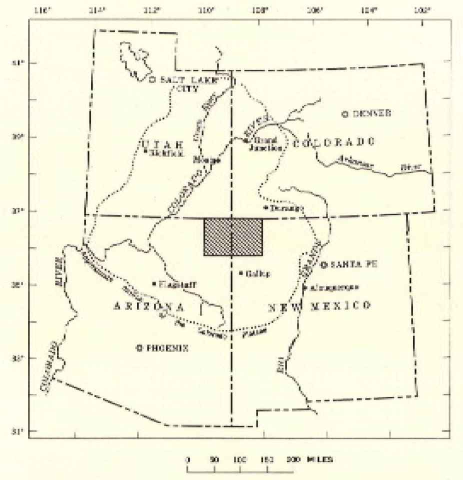




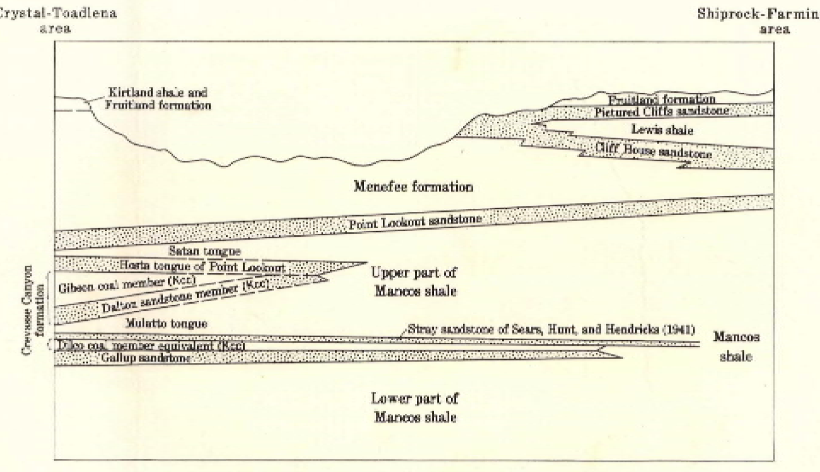


INDEX MAP SHOWING SOURCES OF GEOLOGIC DATA

GEOLOGIC SOURCES



INDEX MAP SHOWING AREA OF SHIPROCK QUADRANGLE



SCHEMATIC DIAGRAM SHOWING STRATIGRAPHIC RELATIONS OF MESAVERDE GROUP, EQUIVALENT FORMATIONS, AND THE MANCOS SHALE

GEOLOGY, STRUCTURE, AND URANIUM DEPOSITS OF THE SHIPROCK QUADRANGLE, NEW MEXICO AND ARIZONA

Compiled by
Robert B. O'Sullivan and Helen M. Beikman
1963

NAVAJO NATION
AUM Environmental
Response Trust-First Phase

TITLE:
Regional Geology

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

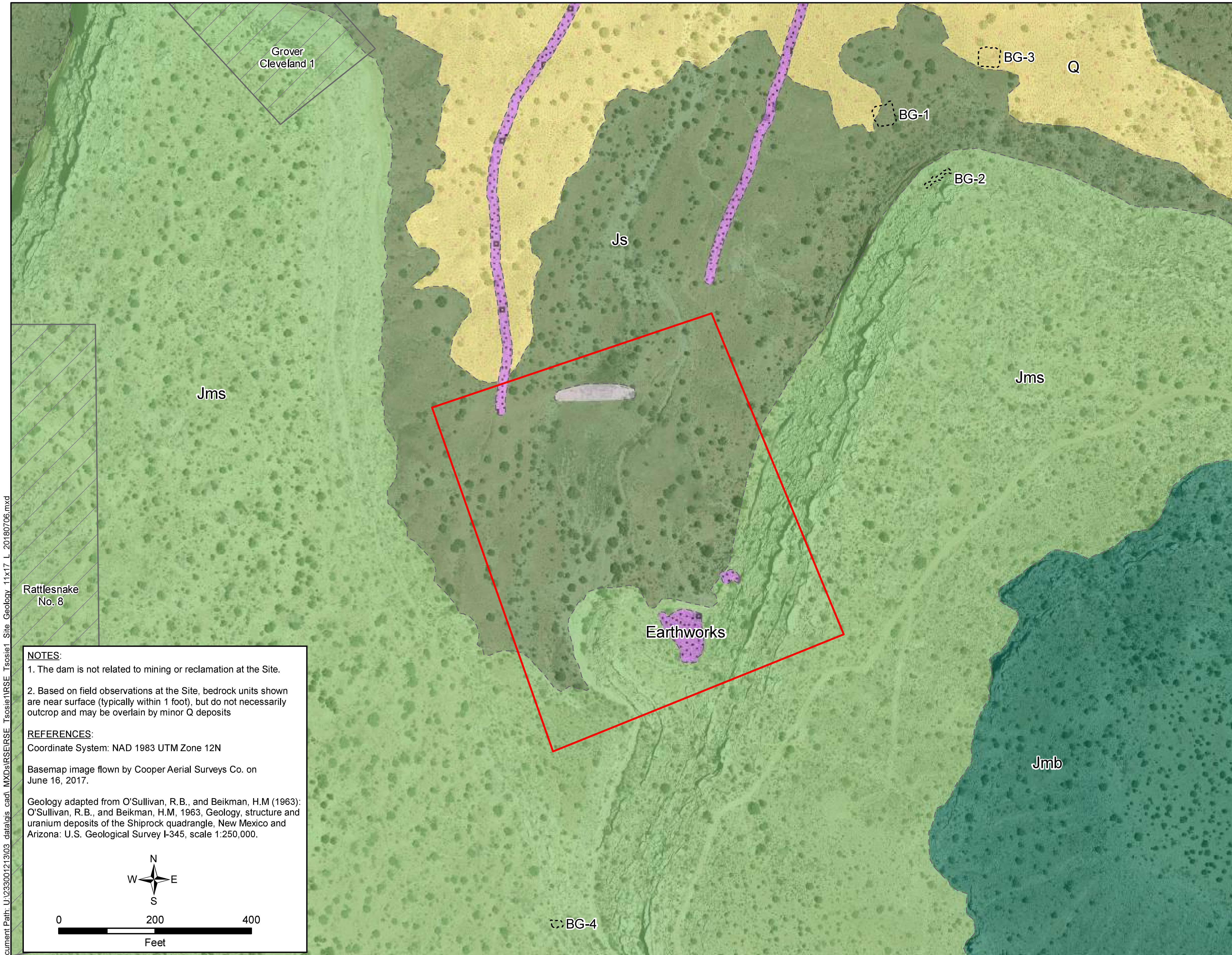
DATE: 7/6/2018

DOCUMENT NAME: Removal Site Evaluation Report

AUTHOR: CBB
REVIEWER: EDZ

Stantec

FIGURE: 2-5



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

Potential Background Reference Area
Claim Boundary
Other Claim Boundary
Geologic Contact (Inferred)

Site Geology

HOLOCENE

Approximate Dam Footprint[1]

Earthworks: Human-caused disturbance of the land surface potentially related to mining or reclamation.

Q: Quaternary Deposits – Undifferentiated (Pleistocene and Holocene) – includes sandy to gravelly colluvial and alluvial deposits, and eolian sand deposits.

JURASSIC

Jmb: Brushy Basin Member of the Morrison Formation (Upper Jurassic) - green, purple, and gray shale and siltstone, gray and tan sandstone, and conglomeritic sandstone, may locally include the Burrow Canyon formation.

Jms: Salt Wash Member of the Morrison Formation (Upper Jurassic) – Yellowish gray to greenish-gray cross-bedded very fine to medium-grained calcareous sandstone inter-bedded with greenish-gray and reddish-brown claystone.

Js: Summerville Formation (Upper Jurassic) – Reddish-brown to light-orange very fine- to fine-grained flat bedded silty sandstone and thin-bedded silty sandstone, claystone, and siltstone; forms banded steep slopes and cliffs.

NOTES:

1. The dam is not related to mining or reclamation at the Site.

2. Based on field observations at the Site, bedrock units shown are near surface (typically within 1 foot), but do not necessarily outcrop and may be overlain by minor Q deposits

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

Geology adapted from O'Sullivan, R.B., and Beikman, H.M (1963): O'Sullivan, R.B., and Beikman, H.M, 1963, Geology, structure and uranium deposits of the Shiprock quadrangle, New Mexico and Arizona: U.S. Geological Survey I-345, scale 1:250,000.

TITLE: Site Geology

PROJECT: Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 9/11/2018

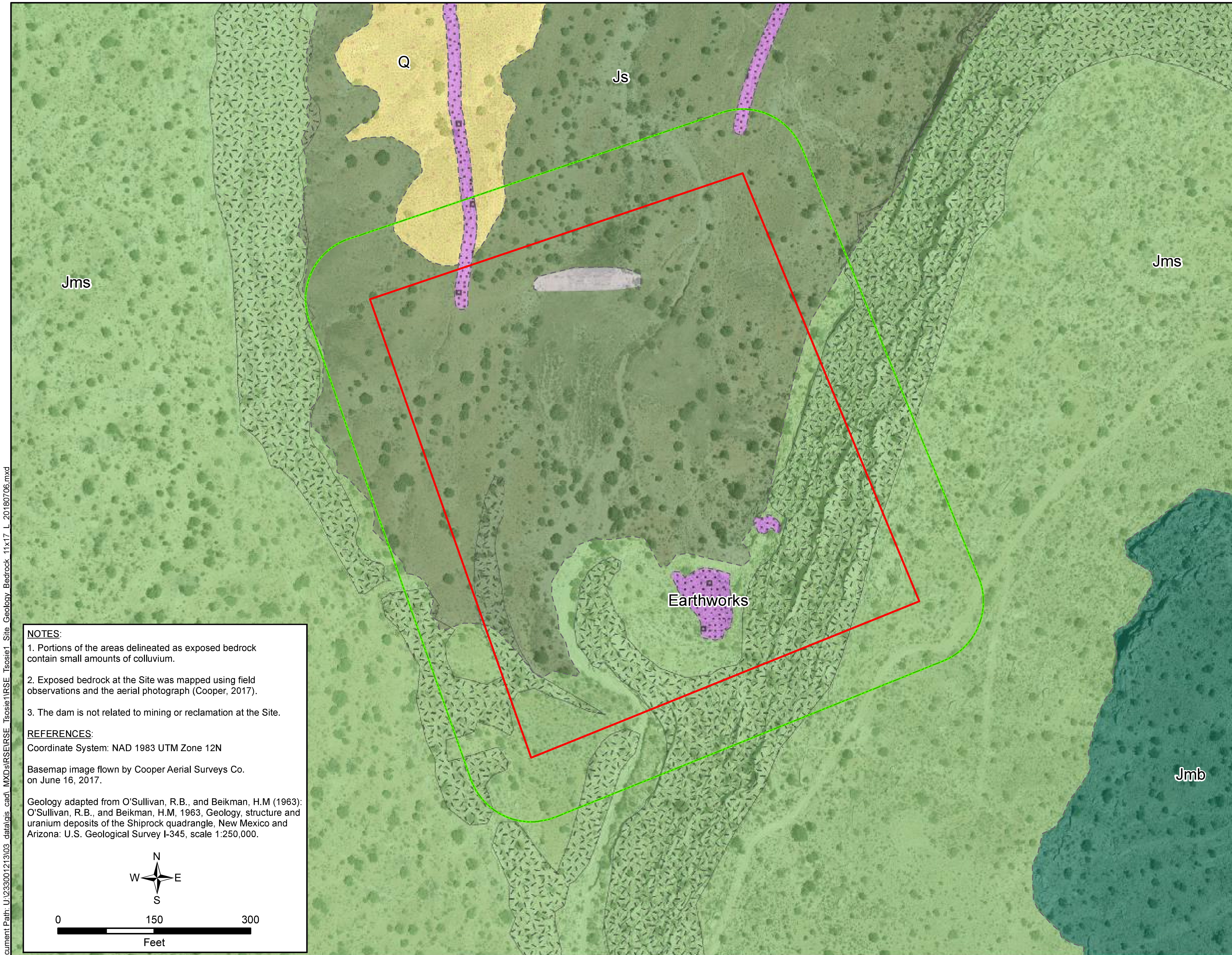
DOCUMENT NAME: Removal Site Evaluation Report

Stantec

AUTHOR: CBB

REVIEWER: EDZ

FIGURE: 2-6a



NOTES:

1. Portions of the areas delineated as exposed bedrock contain small amounts of colluvium.

2. Exposed bedrock at the Site was mapped using field observations and the aerial photograph (Cooper, 2017).

3. The dam is not related to mining or reclamation at the Site.

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

Geology adapted from O'Sullivan, R.B., and Beikman, H.M (1963): O'Sullivan, R.B., and Beikman, H.M, 1963, Geology, structure and uranium deposits of the Shiprock quadrangle, New Mexico and Arizona: U.S. Geological Survey I-345, scale 1:250,000.

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Claim Boundary
- 100-Foot Claim Buffer
- Geologic Contact (Inferred)
- Exposed Bedrock[1]

Site Geology

HOLOCENE

- Approximate Dam Footprint[3]
- Earthworks: Human-caused disturbance of the land surface potentially related to mining or reclamation.
- Q: Quaternary Deposits – Undifferentiated (Pleistocene and Holocene) – includes sandy to gravelly colluvial and alluvial deposits, and eolian sand deposits.

JURASSIC

- Jmb: Brushy Basin Member of the Morrison Formation (Upper Jurassic) - green, purple, and gray shale and siltstone, gray and tan sandstone, and conglomeritic sandstone, may locally include the Burrow Canyon formation.
- Jms: Salt Wash Member of the Morrison Formation (Upper Jurassic) – Yellowish gray to greenish-gray cross-bedded very fine to medium-grained calcareous sandstone inter-bedded with greenish-gray and reddish-brown claystone.
- Js: Summerville Formation (Upper Jurassic) – Reddish-brown to light-orange very fine- to fine-grained flat bedded silty sandstone and thin-bedded silty sandstone, claystone, and siltstone; forms banded steep slopes and cliffs.

TITLE: Site Exposed Bedrock

PROJECT: Removal Site Evaluation Tsosie 1 Mine Site

DATE: 7/18/2018

DOCUMENT NAME: Removal Site Evaluation Report

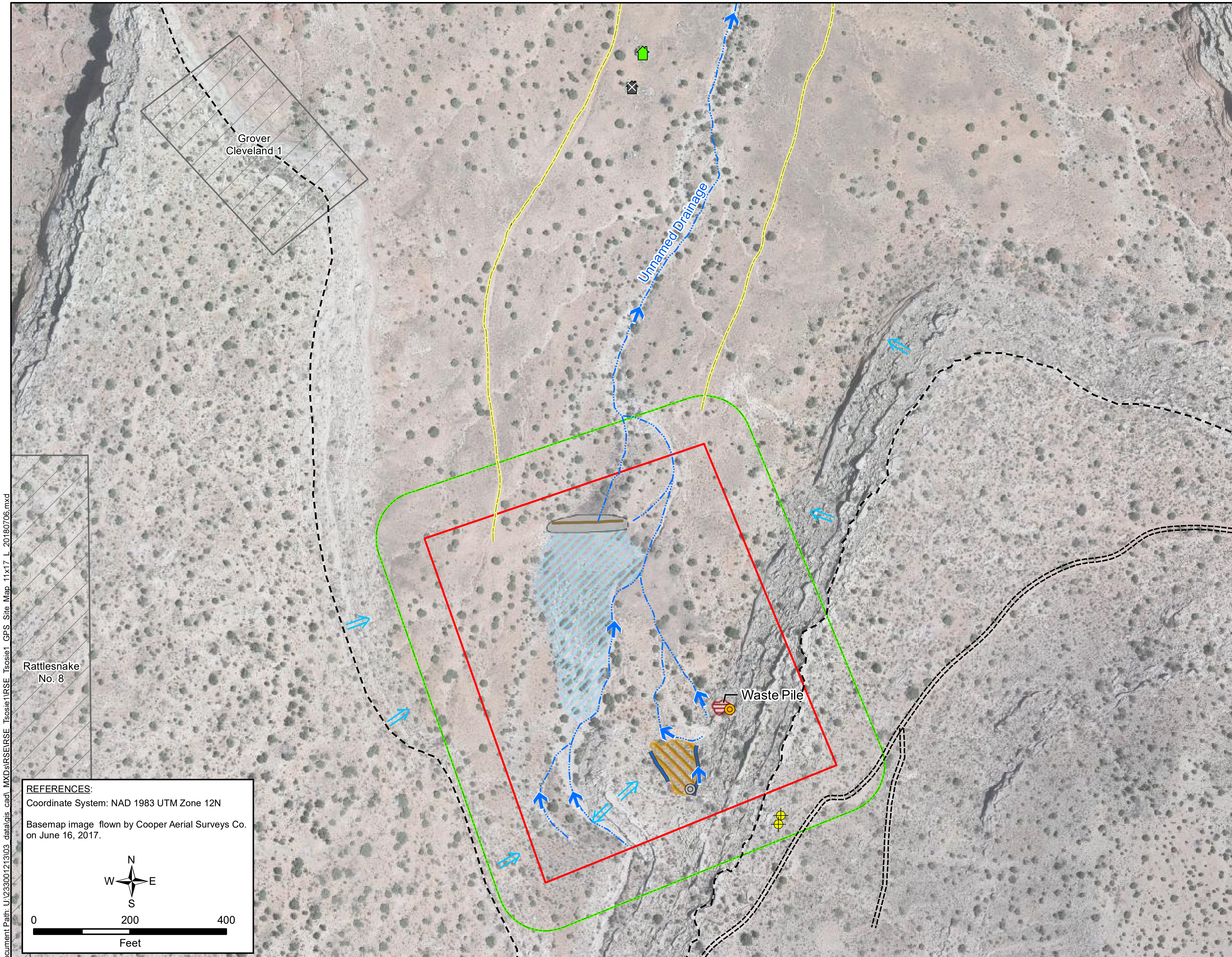
Stantec

AUTHOR: CBB

REVIEWER: EDZ

FIGURE: 2-6b

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Site_Geology_Bedrock_11x17_L_20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Historical Borehole
- Approximate Buried Portal Location
- Habitable Building
- Sealed Portal
- Uninhabitable Building
- Flow Direction
- Approximate Overland Water Flow Direction
- Dam Crest
- Potential Haul Road
- Drainage
- Road
- Drainage Armored with Riprap
- Approximate Edge of Mesa
- Approximate Dam Footprint
- Temporary Ponding Area
- Reclaimed Area
- Waste Pile
- Claim Boundary
- Other Claim Boundary
- 100-Foot Claim Buffer

TITLE:

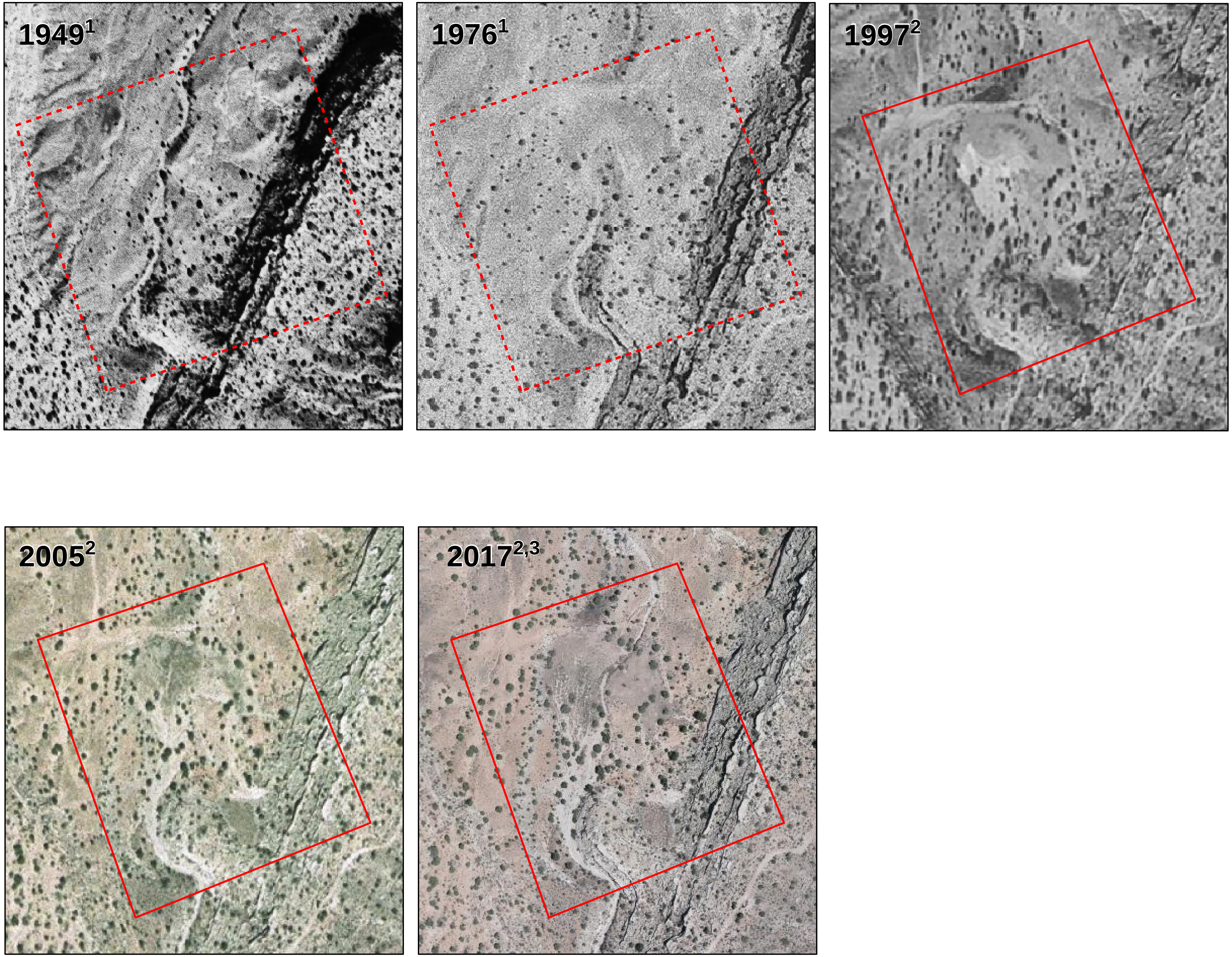
Site Map

PROJECT:

Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 7/18/2018	DOCUMENT NAME: Removal Site Evaluation Report
Stantec	AUTHOR: CBB
	REVIEWER: EDZ
	FIGURE: 2-7

Document Path: U:\233001213\03 data\gis cad\ MXDs\RSE\RSE Tsosie1\RSE Tsosie1 GPS Site Map 11x17 L 20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

Tsosie 1 Claim Boundary

Approximate Site Location, not georeferenced

NOTES:
1. Image is not georeferenced, scale not available.

2. Image is georeferenced. Scale bar applies to these image frames only.

3. Site-specific imagery flown by Cooper Aerial Surveys Co. on June 16, 2017.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Historical Aerial Imagery downloaded from https://earthexplorer.usgs.gov/ (01/2016)

N W E S

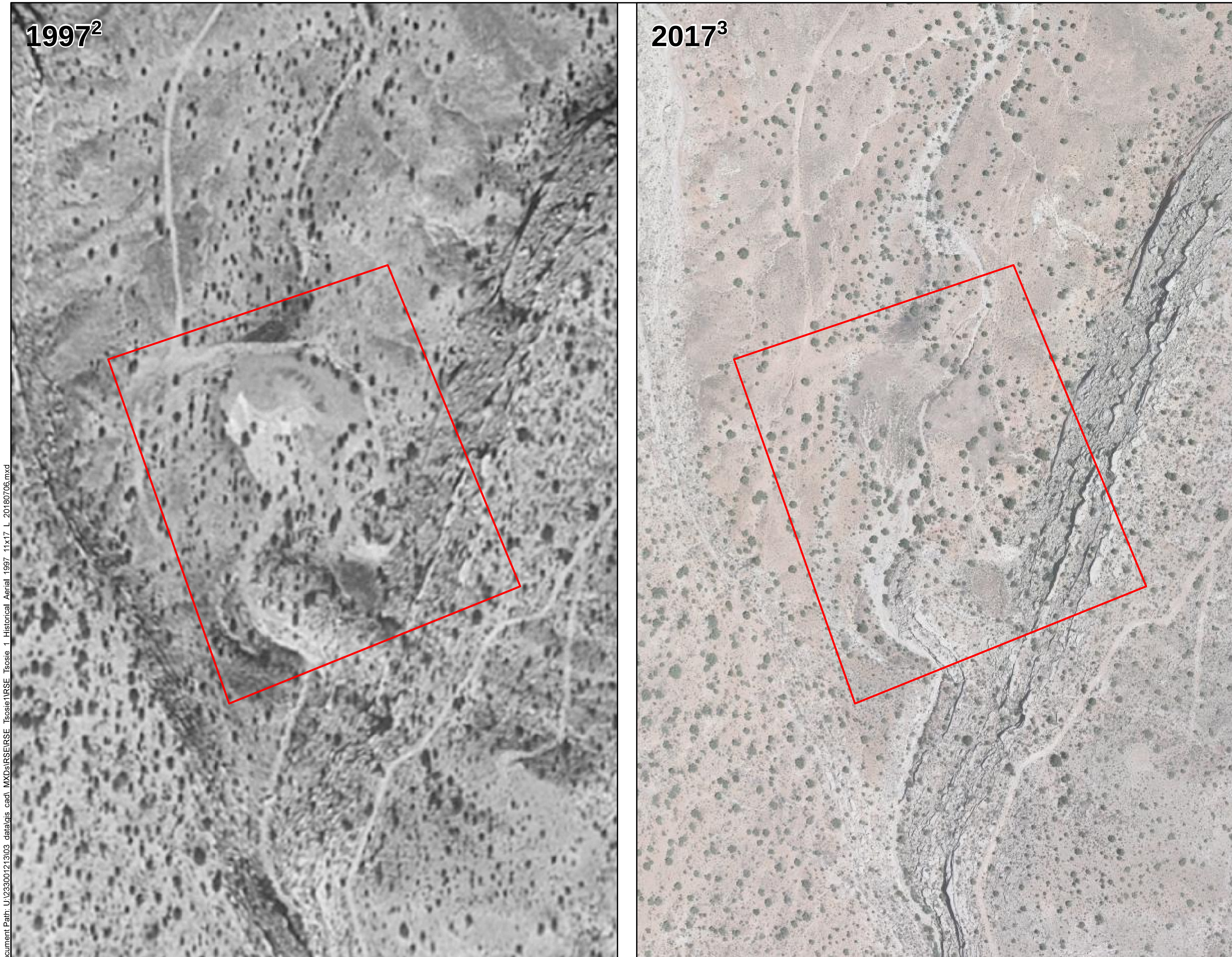
0 250 500
Feet

TITLE:
Historical Aerial Photograph Comparison

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 7/6/2018	DOCUMENT NAME: Removal Site Evaluation Report
Stantec	AUTHOR: CBB / REVIEWER: JP
	FIGURE: 3-1a

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Historical_Aerial_Compilation_11x17_L_20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

Claim Boundary

REFERENCES:
1. Coordinate System: NAD 1983 UTM Zone 12N

2. 1997 aerial image downloaded from https://earthexplorer.usgs.gov/ (01/2016) and georeferenced using current image from BING (03/2016).

3. Site-specific imagery flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

0 200 400
Feet

TITLE:
1997 Historical Aerial Photograph Comparison

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 7/6/2018	DOCUMENT NAME: Removal Site Evaluation Report
Stantec	AUTHOR: CBB / REVIEWER: EDZ
	FIGURE: 3-1b

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie_1_Historical_Aerial_1997_11x17_L_20180706.mxd

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

Potential Background Reference Area

Claim Boundary

Other Claim Boundary

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

0 200 400

Feet

TITLE:

Potential Background Reference Areas

PROJECT:

Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 9/11/2018

DOCUMENT NAME: Removal Site Evaluation Report

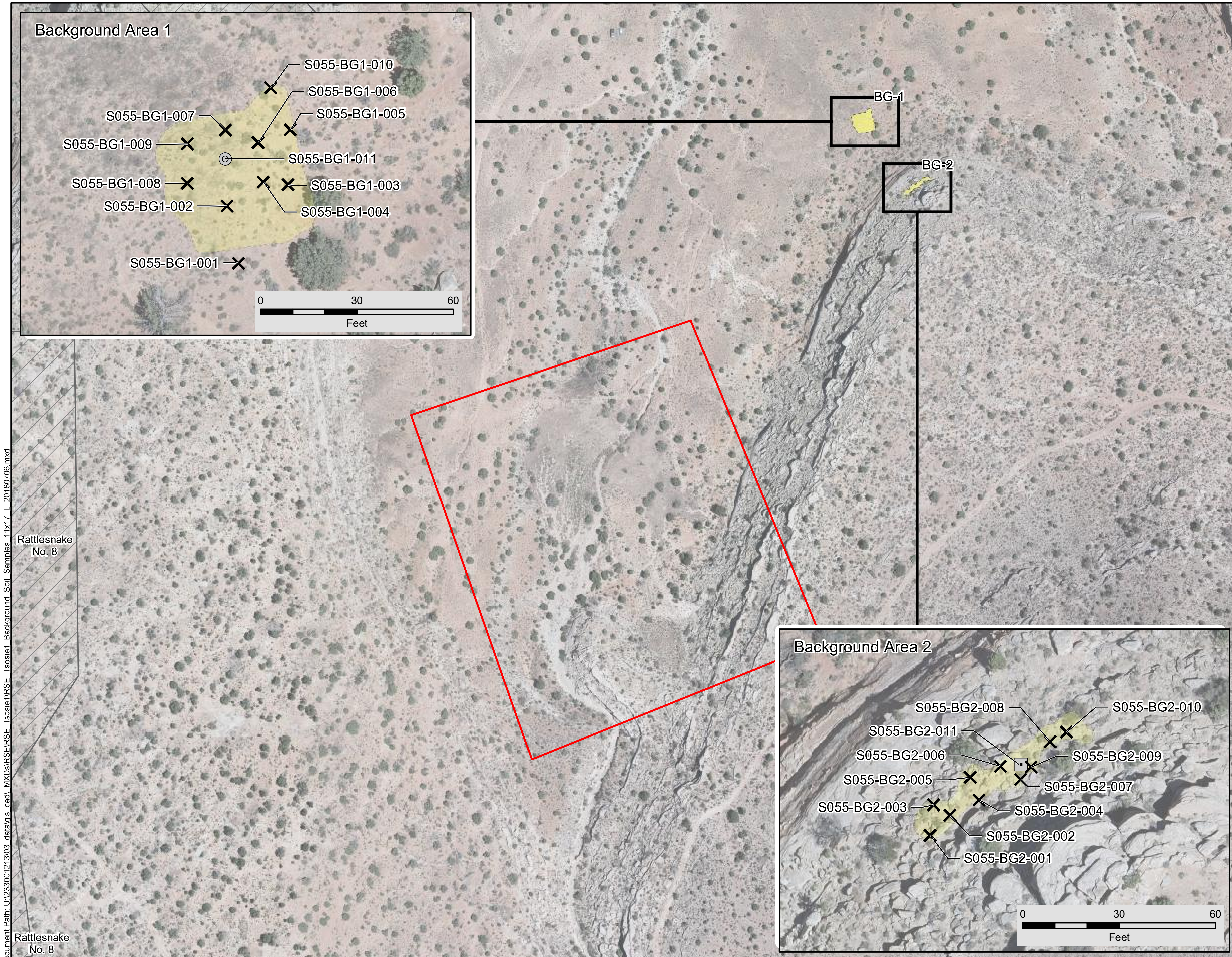
AUTHOR: CBB

REVIEWER: EDZ

FIGURE: 3-2

Stantec

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Background_Areas_11x17_L_20180706.mxd



Document Path: U:\233001213\03 data\gis cad\ MXDs\RSE\RSE Tsosie1\RSE Tsosie1 Background Soil Samples 11x17 L 20180706.mxd

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Sample Only
- Background Reference Area
- Claim Boundary
- Other Claim Boundary

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

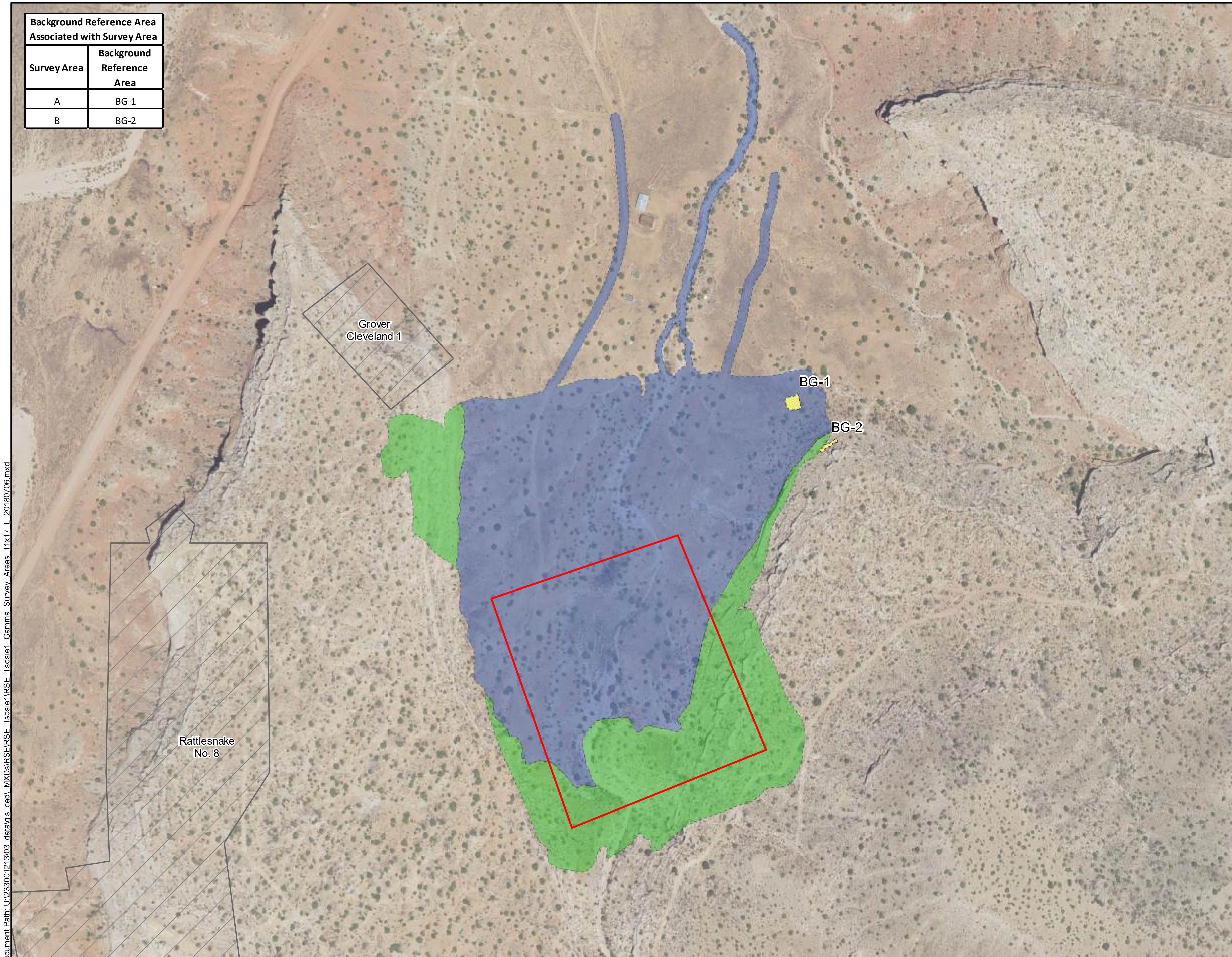
N W E S

0 200 400
Feet

TITLE:
Background Reference Areas - Sample Locations

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 9/11/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: CBB	REVIEWER: EDZ
	FIGURE: 3-3	



Background Reference Area Associated with Survey Area	
Survey Area	Background Reference Area
A	BG-1
B	BG-2

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Background Reference Area
- Survey Area A
- Survey Area B
- Claim Boundary
- Other Claim Boundary

NOTE:
Gamma survey area is approximately 35.0 acres.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/25/2018

N W E S

0 300 600
Feet

TITLE:
Gamma Radiation Survey Areas

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 9/25/2018

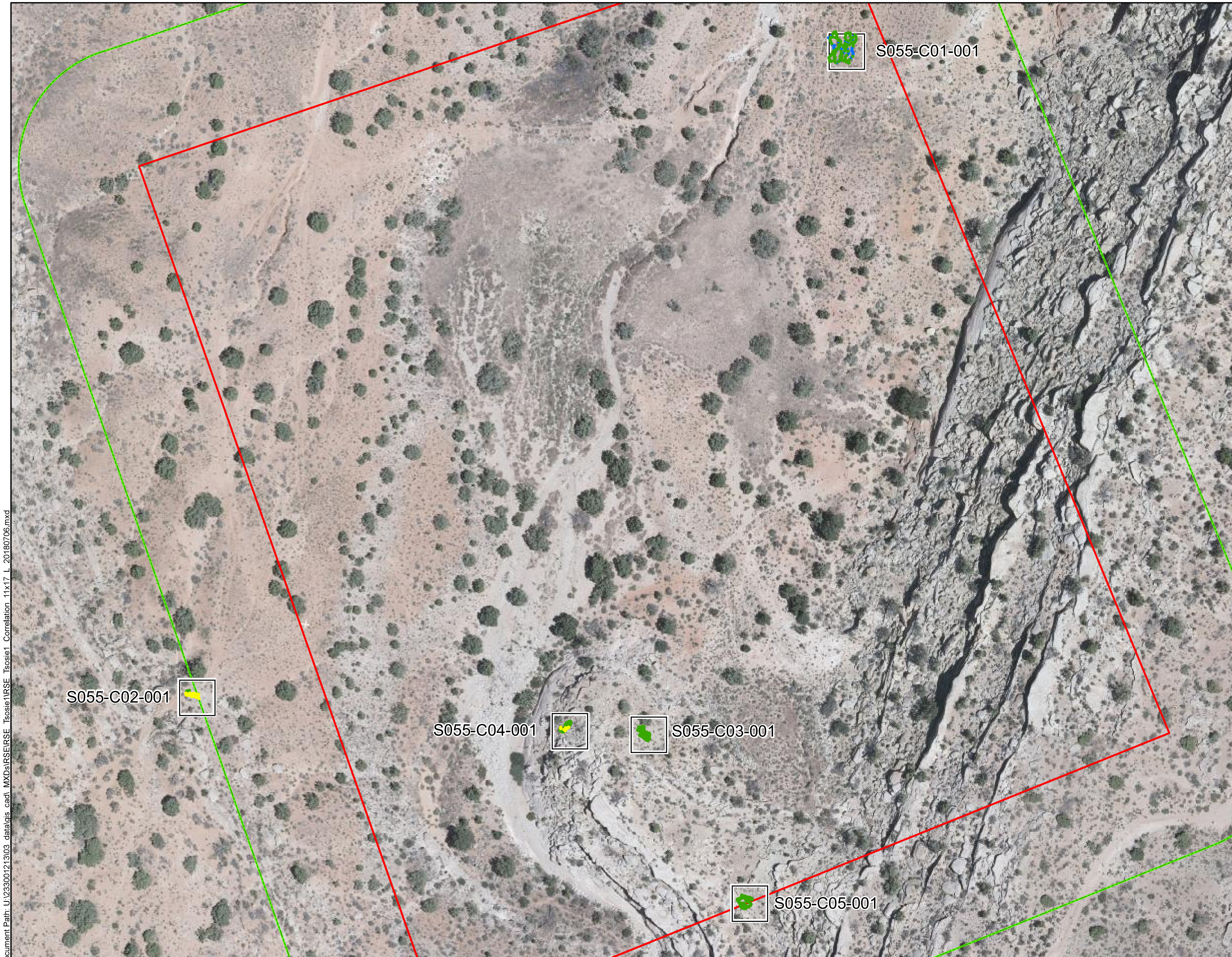
DOCUMENT NAME: Removal Site Evaluation Report

AUTHOR: WDC
REVIEWER: CBB

Stantec

FIGURE: 3-4

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Gamma_Survey_Areas_11x17_L_20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

S055-C01-001 Correlation Location (30' x 30')

Claim Boundary

100-Foot Claim Buffer

Gamma Survey

Counts per Minute (CPM)

8,868 - 10,273 (Minimum to BG-1 UTL)

10,274 - 29,861 (>BG-1 UTL to BG-2 UTL)

29,862 - 44,363 (>BG2 UTL to Maximum)

NOTE:
Each correlation sample consists of five grab samples collected from 0.0 - 0.5 feet below ground surface, composited together for laboratory analysis.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

0 80 160
Feet

TITLE: Gamma Correlation Study Locations

PROJECT: Removal Site Evaluation Tsosie1 Mine Site

DATE: 7/6/2018

DOCUMENT NAME: Removal Site Evaluation Report

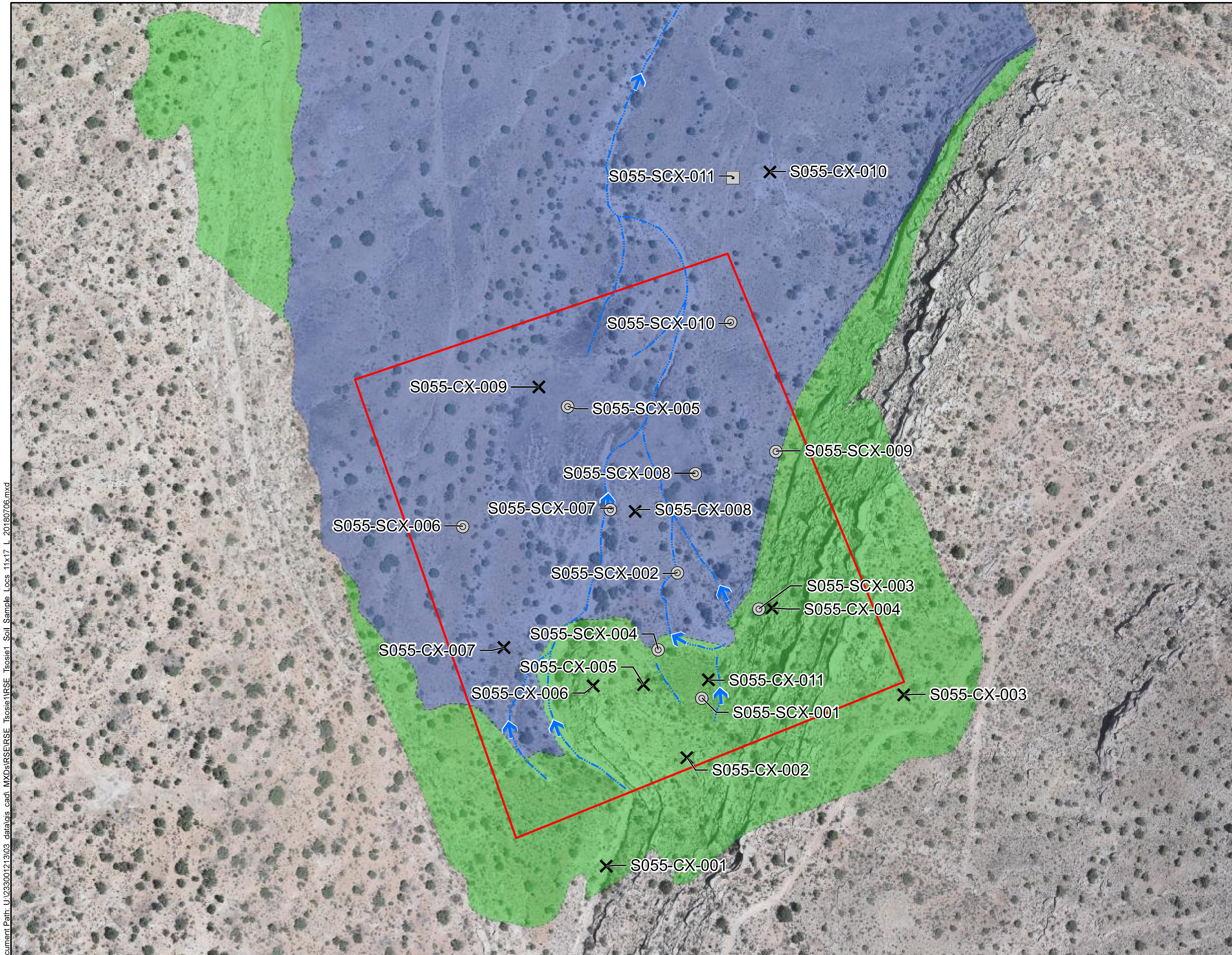
Stantec

AUTHOR: CBB

REVIEWER: EDZ

FIGURE: 3-5

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Correlation_11x17_L_20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- Flow Direction
- Drainage
- Survey Area A
- Survey Area B
- Claim Boundary

NOTES:
Surface and subsurface static gamma measurements were collected at all borehole locations.

Surface soil samples range from 0.0 - 0.5 feet below ground surface (ft bgs)

Subsurface soil samples range from 0.5 - 3.9 ft bgs

Static gamma measurements range from 0.0 - 3.9 ft bgs

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

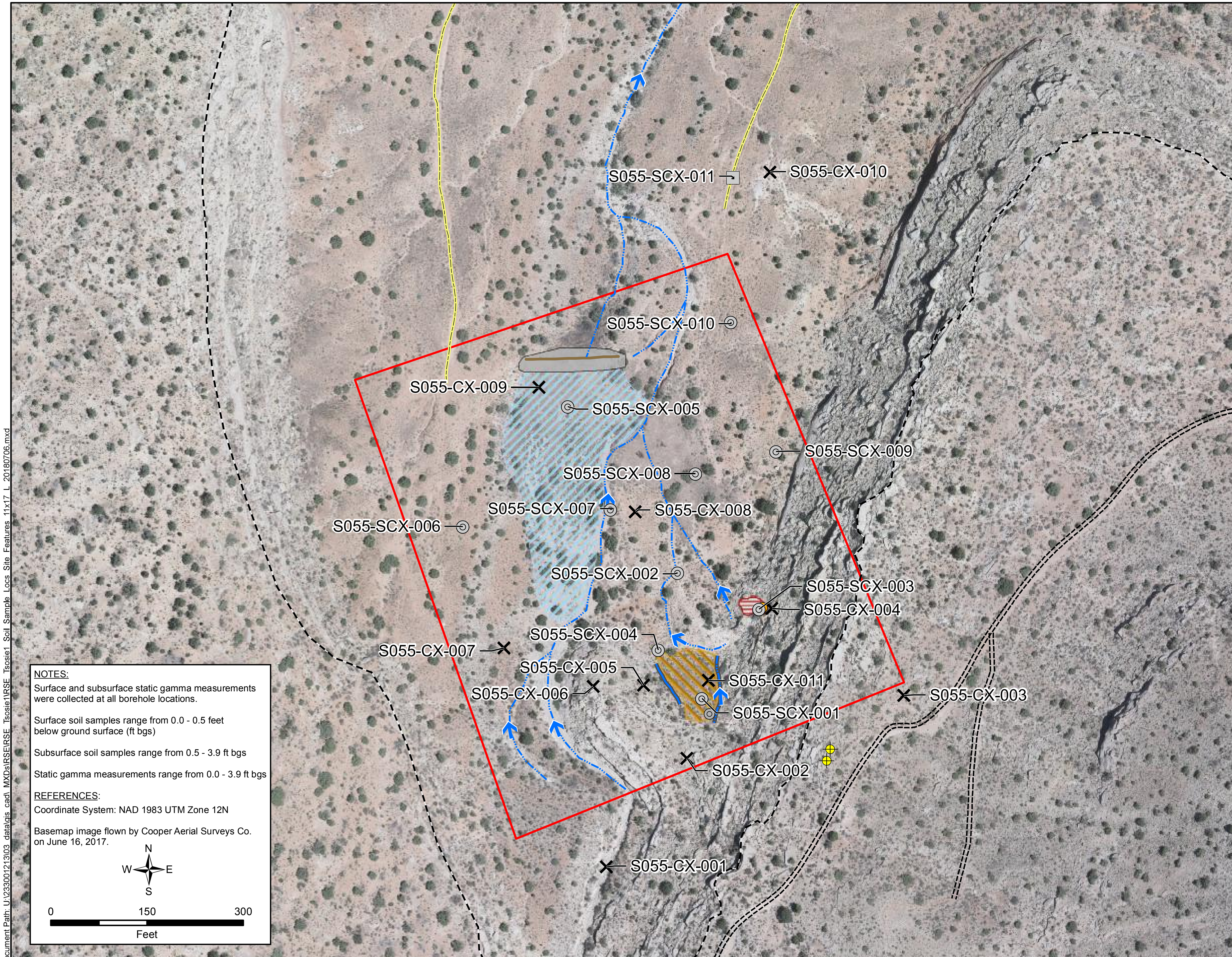
0 150 300
Feet

TITLE:
Site Characterization Surface and Subsurface Sample Locations

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/11/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: CBB	REVIEWER: EDZ
	FIGURE: 3-6a	

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Soil_Sample_Locs_11x17_L_20180706.mxd



NOTES:
Surface and subsurface static gamma measurements were collected at all borehole locations.

Surface soil samples range from 0.0 - 0.5 feet below ground surface (ft bgs)

Subsurface soil samples range from 0.5 - 3.9 ft bgs

Static gamma measurements range from 0.0 - 3.9 ft bgs

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N
W E
S

0 150 300
Feet

NAVAJO NATION
AUM Environmental Response Trust

LEGEND

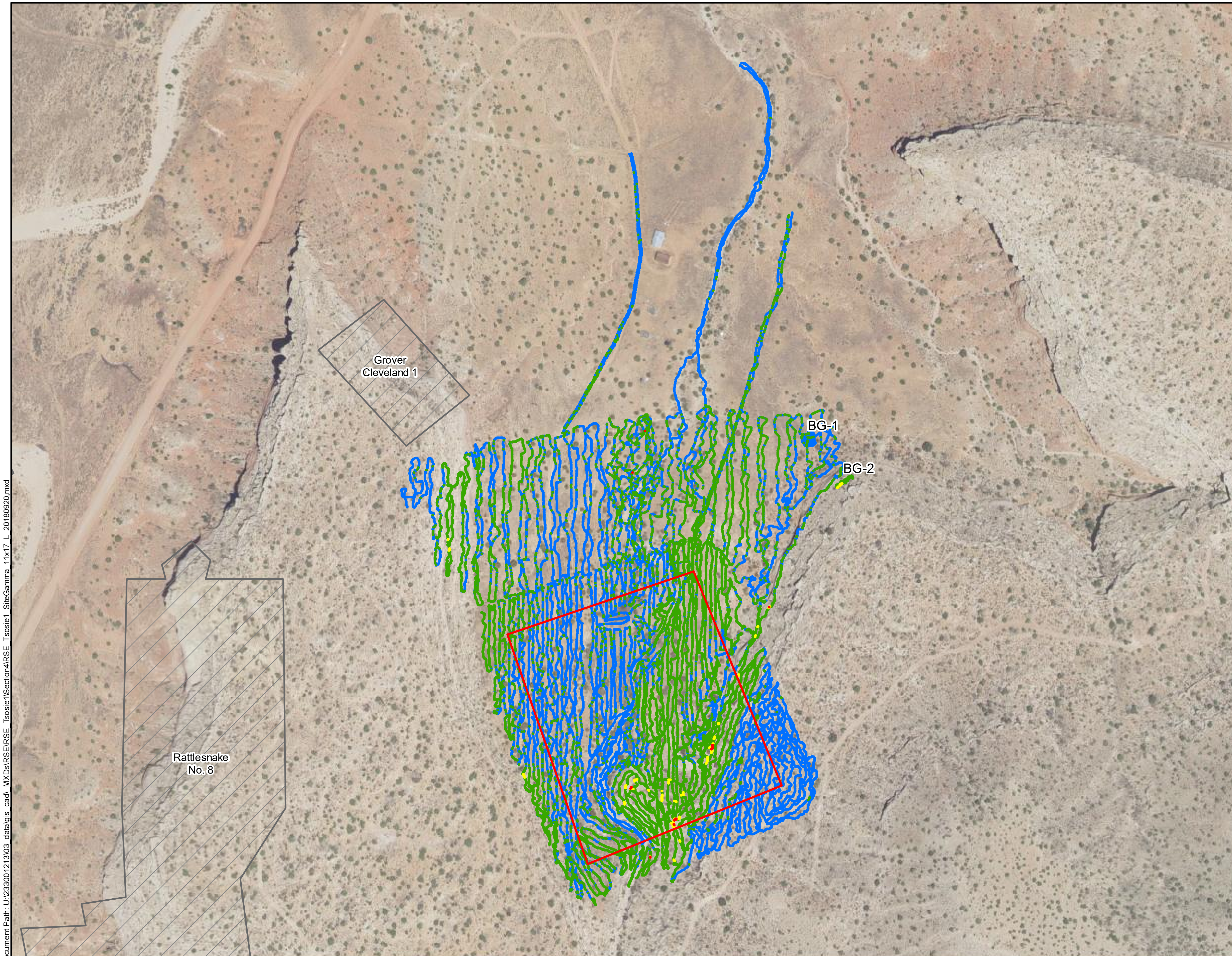
- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples Only
- Borehole Location - Subsurface Samples Only
- Historical Borehole
- Approximate Buried Portal Location
- Sealed Portal
- Flow Direction
- Drainage
- Dam Crest
- Potential Haul Road
- Road
- Drainage Armored with Riprap
- Approximate Edge of Mesa
- Approximate Dam Footprint
- Temporary Ponding Area
- Reclaimed Area
- Waste Pile
- Claim Boundary

TITLE:
Sample Locations Compared to Mining-Related Features

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE:	DOCUMENT NAME:	
9/11/2018	Removal Site Evaluation Report	
	AUTHOR: CBB	REVIEWER: EDZ
Stantec	FIGURE: 3-6b	

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_Soil_Sample_Locs_Site_Features_11x17_L_20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

Claim Boundary
Other Claim Boundary

Gamma Survey

Counts per Minute (CPM)

- 5,429 - 10,273 (Minimum to BG-1 IL)
- 10,274 - 29,861 (>BG-1 IL to BG-2 IL)
- 29,862 - 51,365 (>BG-2 IL to 5x BG-1 IL)
- 51,366 - 89,945 (>5x BG-1 IL to Maximum)

NOTE:
Refer to Figure 3-4 for Survey Area delineation.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/20/2018

N W E S

0 300 600
Feet

TITLE: Gamma Radiation Survey Results

PROJECT: Removal Site Evaluation Tsosie1 Mine Site

DATE: 9/20/2018

DOCUMENT NAME: Removal Site Evaluation Report

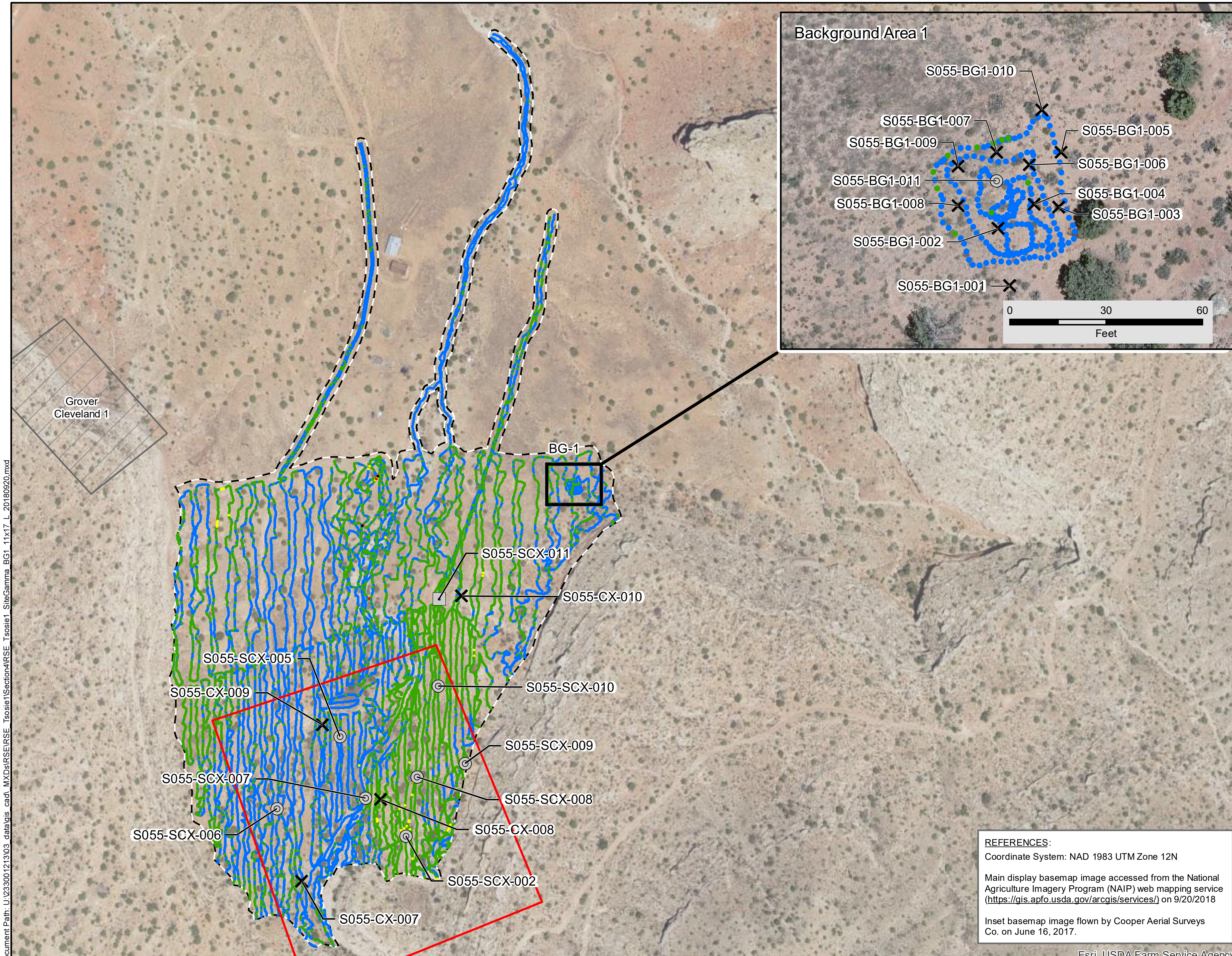
AUTHOR: CBB

REVIEWER: EDZ

Stantec

FIGURE: 4-1a

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_SiteGamma_11x17_L_20180920.mxd



REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Main display basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/20/2018

Inset basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

Esri, USDA Farm Service Agency

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- Survey Area A
- Claim Boundary
- Other Claim Boundary

Gamma Survey

Counts per Minute (CPM)

- 5,677 - 10,273 (Minimum to BG-1 IL)
- 10,274 - 15,410 (>BG-1 IL to 1.5x BG-1 IL)
- 15,411 - 20,546 (>1.5x BG-1 IL to 2x BG-1 IL)
- 20,547 - 51,365 (>2x BG-1 IL to 5x BG-1 IL)
- 51,366 - 68,902 (>5x BG-1 IL to Maximum)

N W E S

0 250 500
Feet

TITLE:
Gamma Radiation Survey Results for Survey Area A

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/20/2018

DOCUMENT NAME: Removal Site Evaluation Report

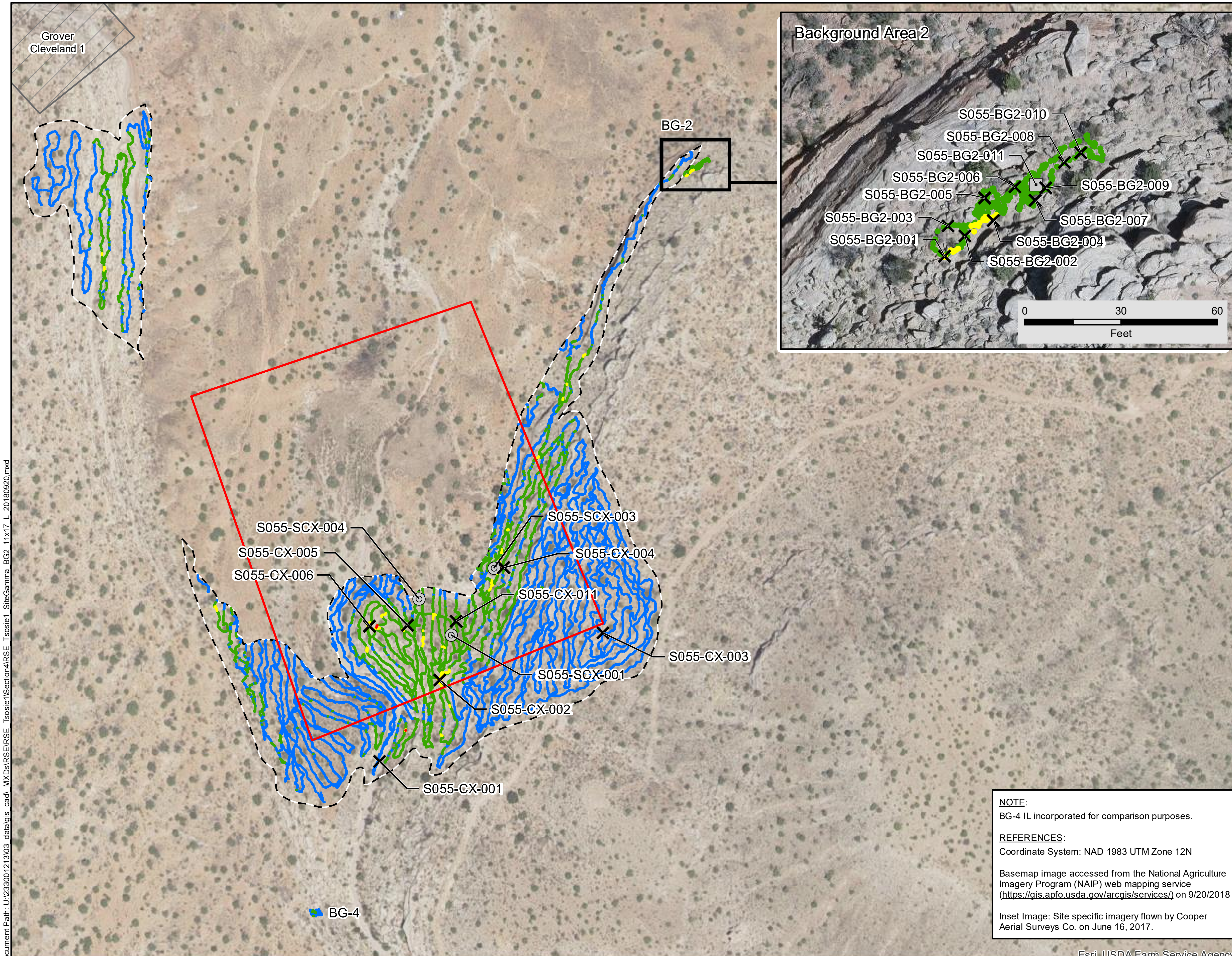
Stantec

AUTHOR: WDC

REVIEWER: CBB

FIGURE: 4-1b

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_SiteGamma_BG1_11x17_L_20180920.mxd



NOTE:
BG-4 IL incorporated for comparison purposes.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/20/2018

Inset Image: Site specific imagery flown by Cooper Aerial Surveys Co. on June 16, 2017.

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- Survey Area B
- Claim Boundary
- Other Claim Boundary

Gamma Survey

Counts per Minute (CPM)

- 5,429 - 12,391 (Minimum to BG-4 IL)
- 12,392 - 29,861 (>BG-4 IL to BG-2 IL)
- 29,862 - 59,722 (>BG-2 IL to BG-2 IL)
- 59,723 - 89,945 (>2x BG-2 IL to Maximum)

N W E S

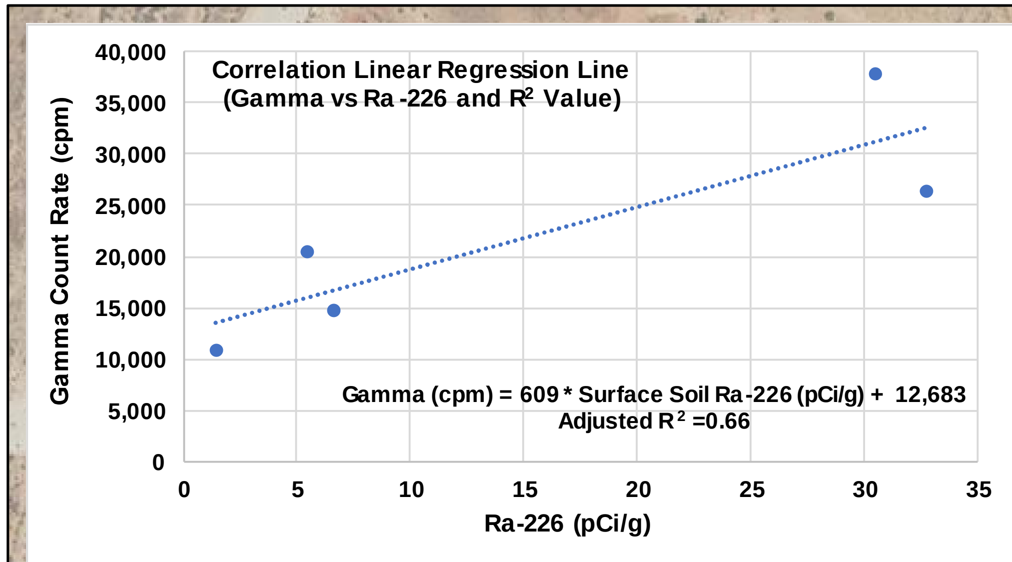
0 200 400
Feet

TITLE:
Gamma Radiation Survey Results for Survey Area B

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

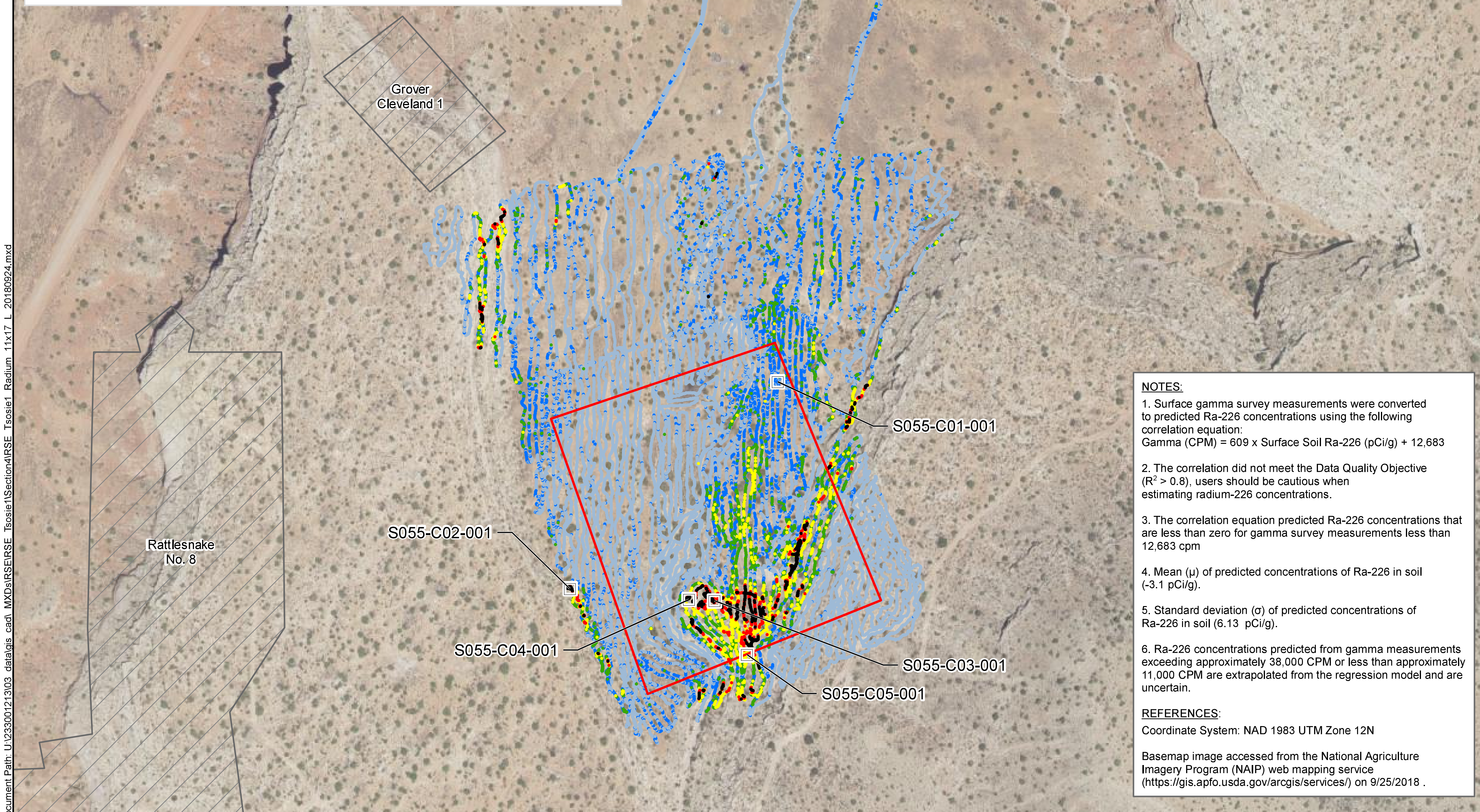
DATE: 9/20/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: WDC	REVIEWER: CBB
	FIGURE: 4-1c	

Document Path: U:\233001213\03_data\gis_cad\MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_SiteGamma_BG2_11x17_L_20180920.mxd



Correlation Data		
Sample ID	Ra-226 (pCi/g)	Mean Gamma Count Rate (cpm)[1]
S055-C01-001	1.43	10,854
S055-C01-002	30.5	37,736
S055-C01-003	5.43	20,487
S055-C01-004	32.7	26,310
S055-C01-005	6.66	14,716

[1] Average gamma count rate for a correlation



NOTES:

1. Surface gamma survey measurements were converted to predicted Ra-226 concentrations using the following correlation equation:
Gamma (CPM) = 609 x Surface Soil Ra-226 (pCi/g) + 12,683

2. The correlation did not meet the Data Quality Objective ($R^2 > 0.8$), users should be cautious when estimating radium-226 concentrations.

3. The correlation equation predicted Ra-226 concentrations that are less than zero for gamma survey measurements less than 12,683 cpm

4. Mean (μ) of predicted concentrations of Ra-226 in soil (-3.1 pCi/g).

5. Standard deviation (σ) of predicted concentrations of Ra-226 in soil (6.13 pCi/g).

6. Ra-226 concentrations predicted from gamma measurements exceeding approximately 38,000 CPM or less than approximately 11,000 CPM are extrapolated from the regression model and are uncertain.

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/25/2018 .

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- S055-C01-001 Correlation Location (30' x 30')
- Claim Boundary
- Other Claim Boundary

Predicted Ra-226 Concentration[1,2] (pCi/g)

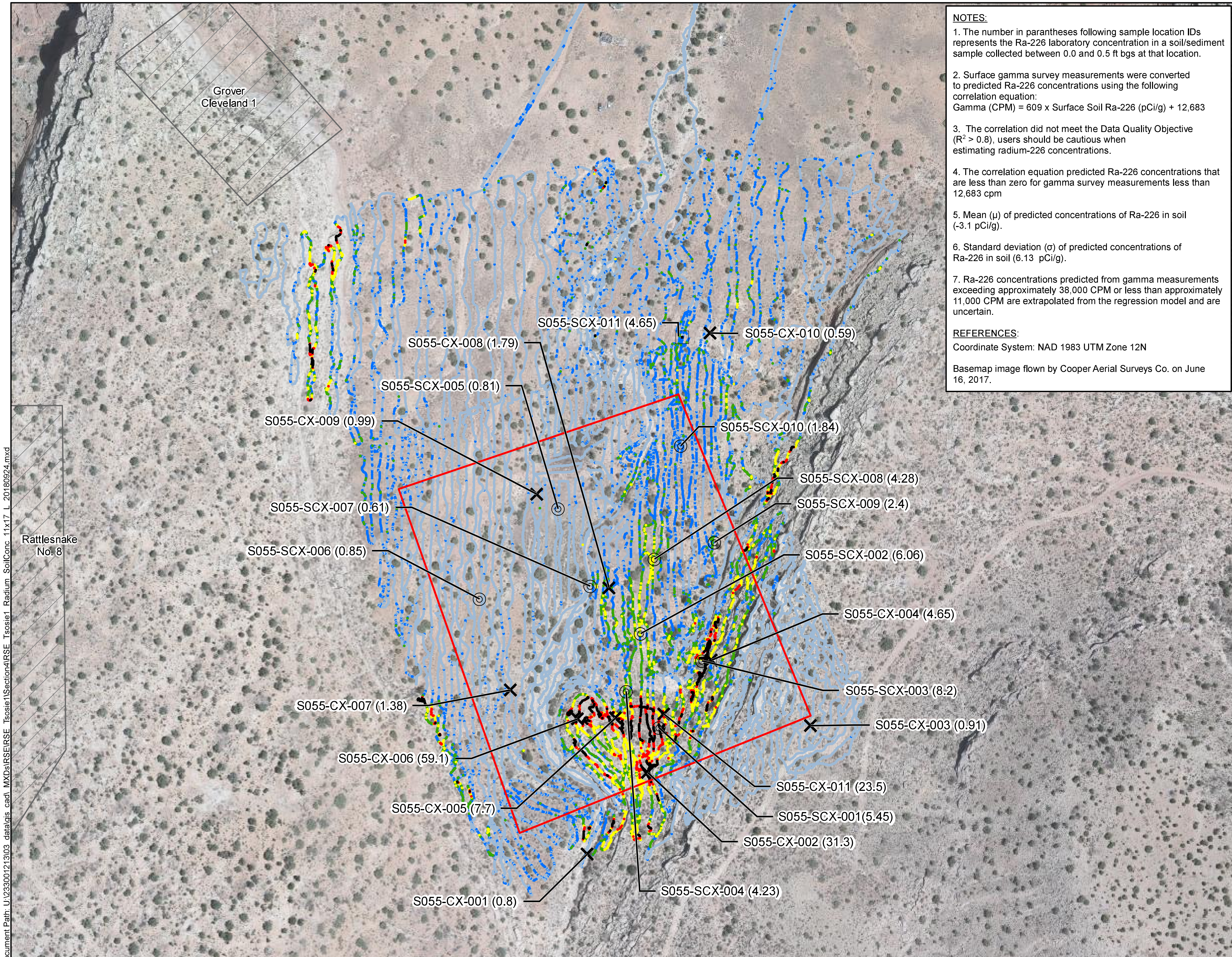
- -11.9 - -3.1 (μ)[3,4]
- -3.0 - 0[3]
- 0 - 3.0 (μ + 1σ[5])
- 3.1 - 9.1 (μ + 2σ)
- 9.2 - 15.2 (μ + 3σ)
- 15.2 -126.9

TITLE:
Predicted Ra-226 Concentrations in Soil Using the Correlation Equation

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/25/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: WDC	REVIEWER: CBB
	FIGURE: 4-2a	

Document Path: U:\233001213\03_data\gis_cad\MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Radium_11x17_L_20180924.mxd



NOTES:

1. The number in parantheses following sample location IDs represents the Ra-226 laboratory concentration in a soil/sediment sample collected between 0.0 and 0.5 ft bgs at that location.

2. Surface gamma survey measurements were converted to predicted Ra-226 concentrations using the following correlation equation:
Gamma (CPM) = 609 x Surface Soil Ra-226 (pCi/g) + 12,683

3. The correlation did not meet the Data Quality Objective (R^2 > 0.8), users should be cautious when estimating radium-226 concentrations.

4. The correlation equation predicted Ra-226 concentrations that are less than zero for gamma survey measurements less than 12,683 cpm

5. Mean (μ) of predicted concentrations of Ra-226 in soil (-3.1 pCi/g).

6. Standard deviation (σ) of predicted concentrations of Ra-226 in soil (6.13 pCi/g).

7. Ra-226 concentrations predicted from gamma measurements exceeding approximately 38,000 CPM or less than approximately 11,000 CPM are extrapolated from the regression model and are uncertain.

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- Claim Boundary
- Other Claim Boundary

Predicted Ra-226 Concentration[2,3] (pCi/g)

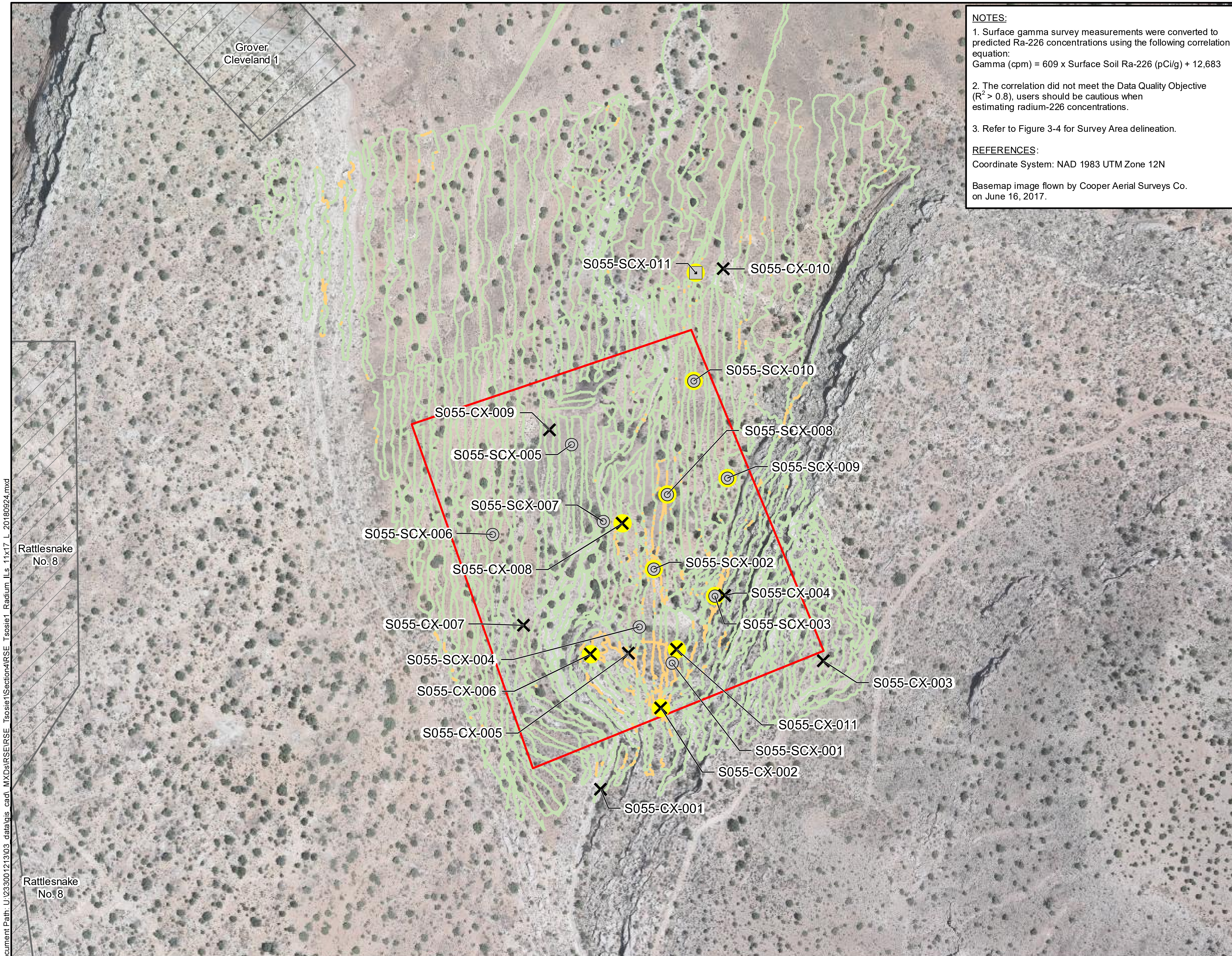
- -11.9 - -3.1 (μ)[4,5]
- -3.0 - 0[4]
- 0 - 3.0 (μ + 1σ[6])
- 3.1 - 9.1 (μ + 2σ)
- 9.2 - 15.2 (μ + 3σ)
- 15.2 -126.9

TITLE:
Predicted Ra-226 Concentrations in Soil Compared to Ra-226 Concentrations in Soil/Sediment

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/25/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: WDC	REVIEWER: CBB
	FIGURE: 4-2b	

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Radium_SoilConc_11x17_L_20180924.mxd



NOTES:

1. Surface gamma survey measurements were converted to predicted Ra-226 concentrations using the following correlation equation:
Gamma (cpm) = 609 x Surface Soil Ra-226 (pCi/g) + 12,683

2. The correlation did not meet the Data Quality Objective (R^2 > 0.8), users should be cautious when estimating radium-226 concentrations.

3. Refer to Figure 3-4 for Survey Area delineation.

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- Ra-226 IL Exceedance in Surface Soil
- Claim Boundary
- Other Claim Boundary

Predicted Ra-226 Concentrations (pCi/g)

IL Not Exceeded
Survey Area A: -11.5 - 1.75
Survey Area B: -11.9 - 7.96

IL Exceeded
Survey Area A: 1.76 - 92.3
Survey Area B: 7.97 - 126.9

N W E S

0 200 400
Feet

TITLE:
Predicted Ra-226 Concentrations in Surface Soil Compared to Ra-226 ILs

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/24/2018

DOCUMENT NAME: Removal Site Evaluation Report

AUTHOR: WDC

REVIEWER: CBB

Stantec

FIGURE: 4-2c

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Radium_ILs_11x17_L_20180924.mxd

Soil and Sediment Investigation Levels

Analyte (Units)	Investigation Level: Survey Area A	Investigation Level: Survey Area B
Metals (mg/kg)		
Arsenic	2.67	14.3
Molybdenum	NA[1]	0.974
Selenium	NA[2]	NA[2]
Uranium	1.57	7.57
Vanadium	7.98	16.2
Radionuclides (pCi/g)		
Radium-226	1.75	7.96

[1] No IL was established for Mo in Survey Area A because there was not enough detections in background reference area 1 (one detection) to establish an IL.

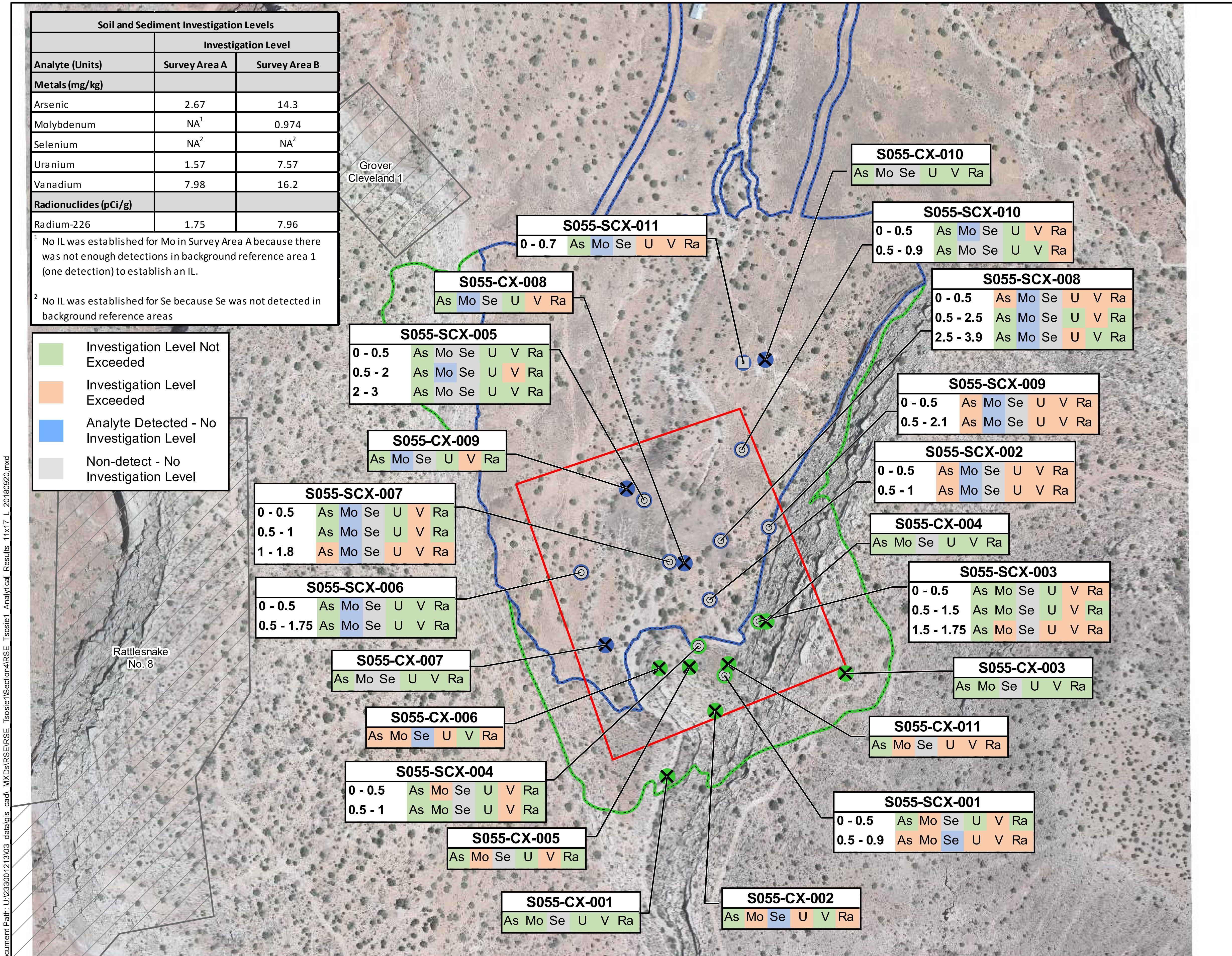
[2] No IL was established for Se because Se was not detected in background reference areas

Investigation Level Not Exceeded

Investigation Level Exceeded

Analyte Detected - No Investigation Level

Non-detect - No Investigation Level



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NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Survey Area A - Surface Sample Location
- Survey Area A - Borehole Surface and Subsurface Samples
- Survey Area A - Borehole Subsurface Samples Only
- Survey Area B - Surface Sample Location
- Survey Area B - Borehole Surface and Subsurface Samples
- Survey Area A
- Survey Area B
- Claim Boundary
- Other Claim Boundary

NOTE:
Sample Intervals (e.g., 0 - 0.5) are in ft bgs.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

0 250 500
Feet

TITLE:
Surface and Subsurface Metals and Ra-226 Analytical Results

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/20/2018

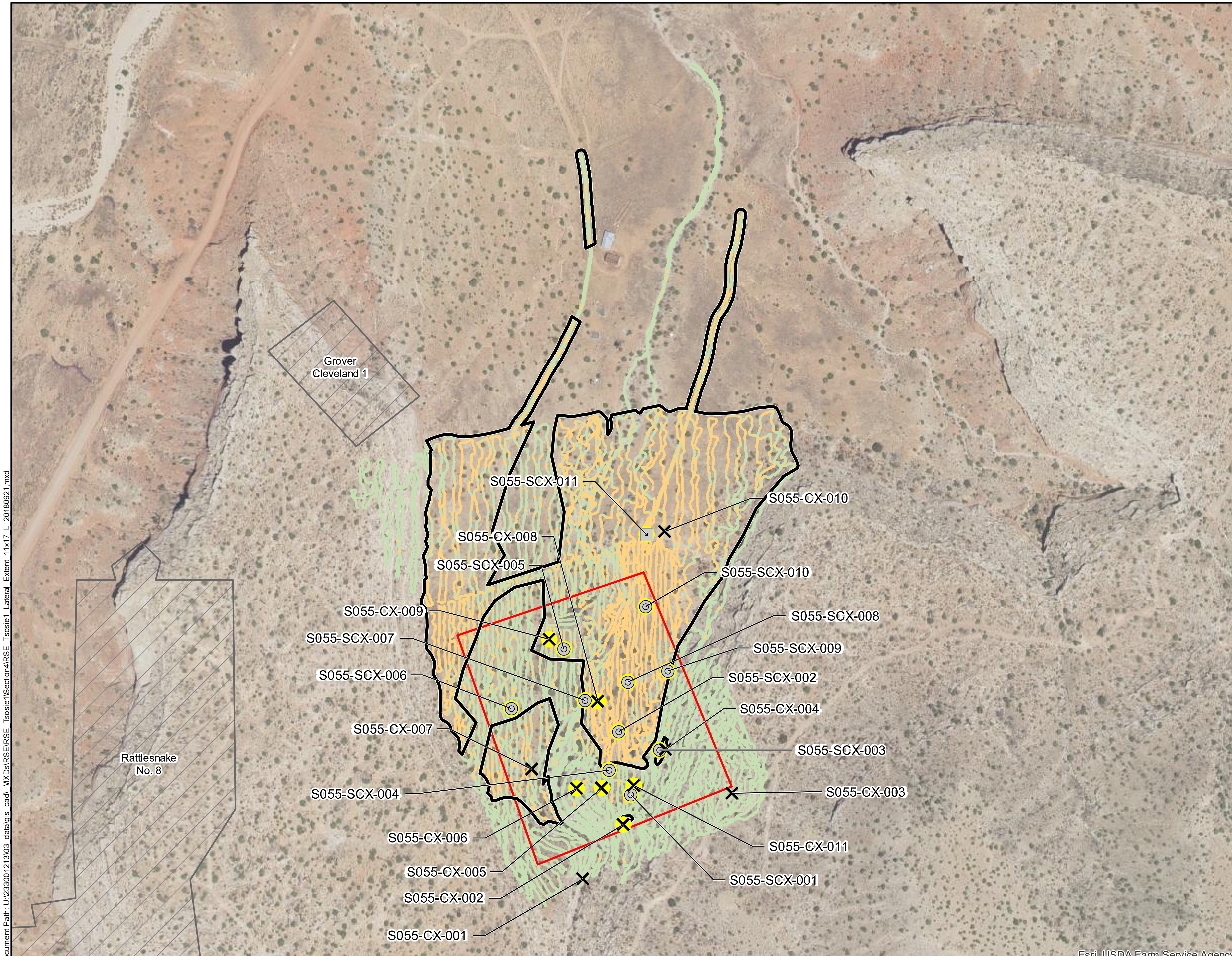
DOCUMENT NAME: Removal Site Evaluation Report

AUTHOR: WDC

REVIEWER: CBB

Stantec

FIGURE: 4-3



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- IL Exceedance in Unconsolidated Material at Location
- Approximate Area where Surface Gamma ILs are Exceeded (18.7 acres)
- Claim Boundary
- Other Claim Boundary

Gamma Survey

Counts per Minute (CPM)

IL Not Exceeded
Survey Area A: 5,677 - 10,273
Survey Area B: 5,429 - 29,861

IL Exceeded
Survey Area A: 10,274 - 68,902
Survey Area B: 29,862 - 89,945

NOTE:
Refer to Figure 3-4 for Survey Area delineation.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/21/2018

N W E S

0 300 600
Feet

TITLE: Lateral Extent of Surface and Subsurface IL Exceedances

PROJECT: Removal Site Evaluation Tsosie1 Mine Site

DATE: 9/21/2018

DOCUMENT NAME: Removal Site Evaluation Report

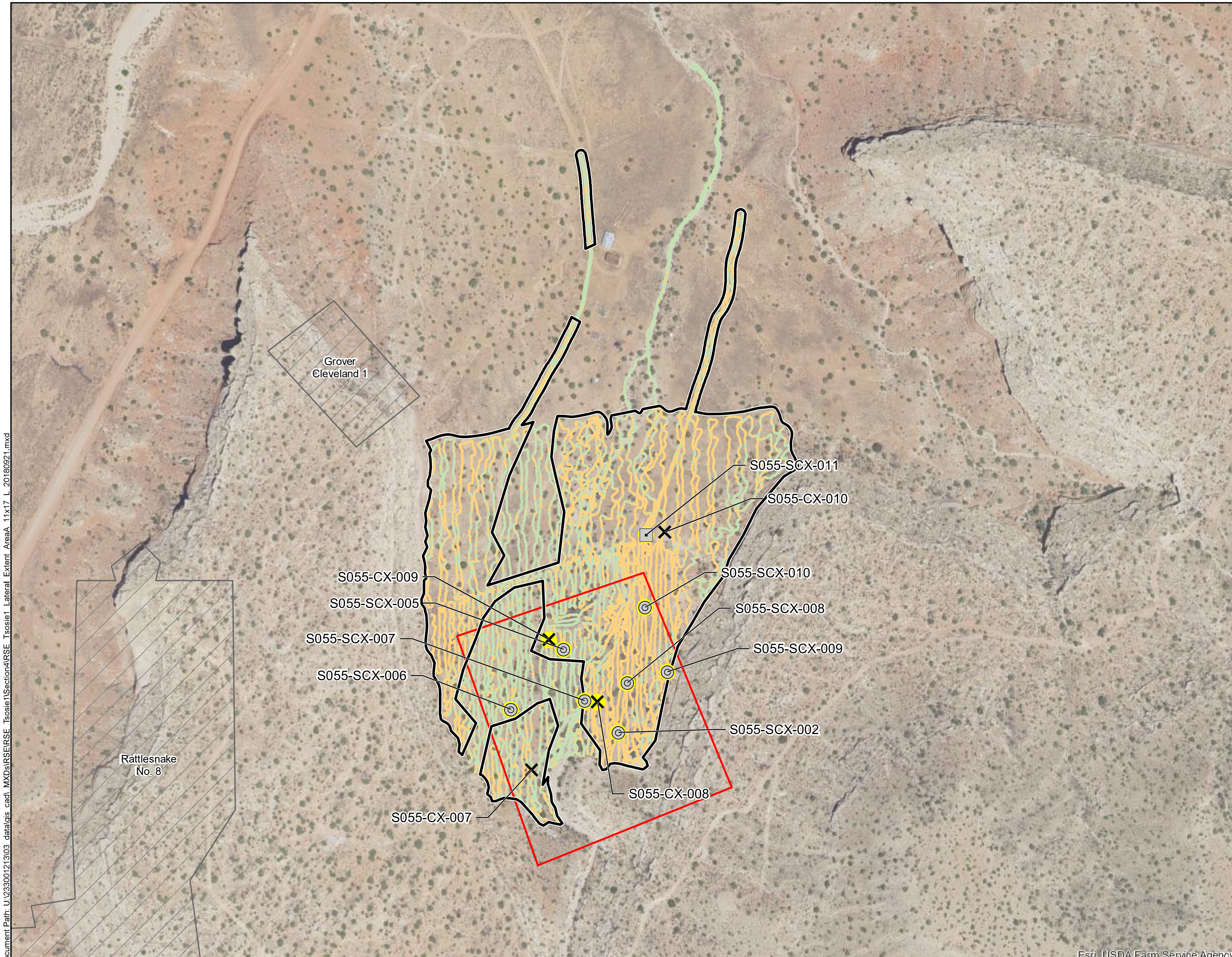
AUTHOR: WDC

REVIEWER: CBB

Stantec

FIGURE: 4-4a

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Lateral_Extent_11x17_L_20180921.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- IL Exceedance in Unconsolidated Material at Location
- Approximate Area where Suface Gamma IL is Exceeded (18.6 acres)
- Claim Boundary
- Other Claim Boundary

Gamma Survey

Counts per Minute (CPM)

- 5,677 - 10,273 (IL Not Exceeded)
- 10,274 - 68,902 (IL Exceeded)

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/25/2018

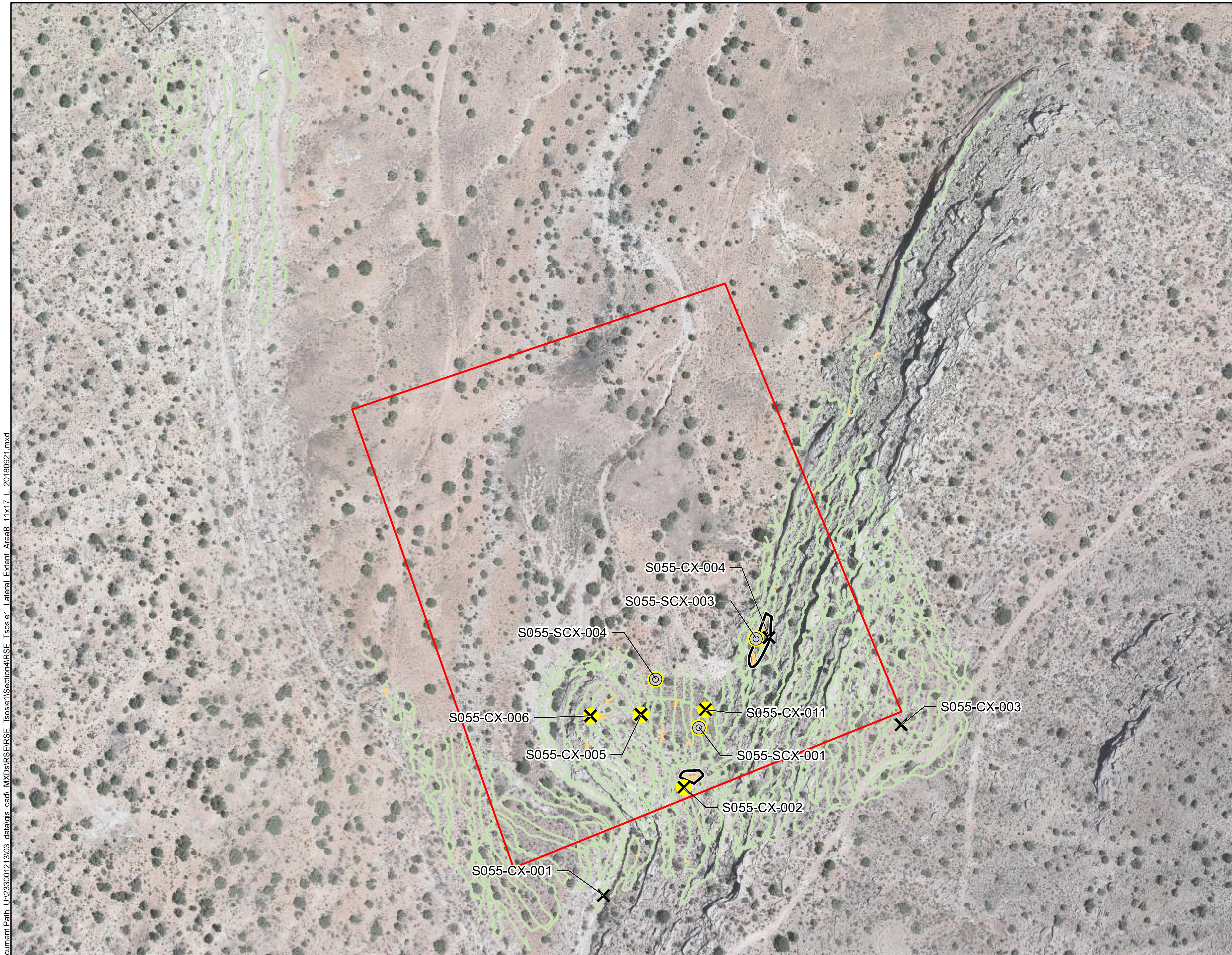
N W E S

0 300 600
Feet

TITLE: Survey Area A
Lateral Extent of Surface and Subsurface IL Exceedances

PROJECT: Removal Site Evaluation
Tsosie1 Mine Site

DATE:	DOCUMENT NAME:	
9/25/2018	Removal Site Evaluation Report	
Stantec	AUTHOR: WDC	REVIEWER: CBB
	FIGURE: 4-4b	



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- IL Exceedance in Unconsolidated Material at Location
- Approximate Area where Surface Gamma IL is Exceeded (0.04 acres)
- Claim Boundary
- Other Claim Boundary

Gamma Survey
Counts per Minute (CPM)
- 5,429 - 29,861 (IL Not Exceeded)
- 29,862 - 89,945 (IL Exceeded)

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

0 150 300
Feet

TITLE: Survey Area B Lateral Extent of Surface and Subsurface IL Exceedances

PROJECT: Removal Site Evaluation Tsosie1 Mine Site

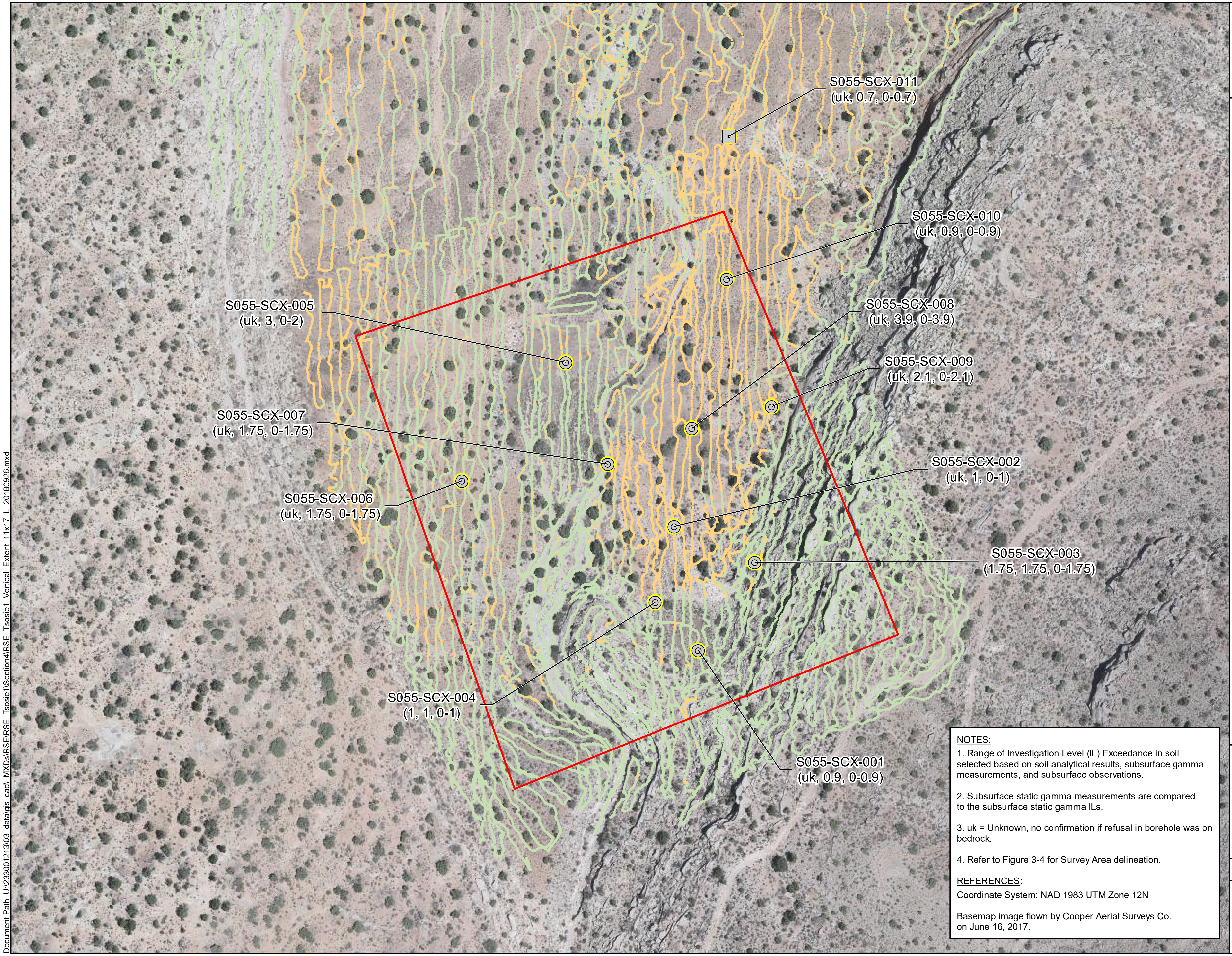
DATE:	DOCUMENT NAME:
9/25/2018	Removal Site Evaluation Report

Stantec

AUTHOR:	REVIEWER:
WDC	CBB

FIGURE: 4-4c

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Lateral_Extent_AreaB_11x17_L_20180921.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Borehole Location - Surface and Subsurface Sample Location (Depth of Bedrock, Borehole Depth, Depth Range of IL Exceedance in Unconsolidated Material [1])
- Borehole Location - Subsurface Sample Location (Depth of Bedrock, Borehole Depth, Depth Range of IL Exceedance in Unconsolidated Material [1])
- IL Exceedance in Unconsolidated Material at Location
- Claim Boundary
- Other Claim Boundary

Gamma Survey
Counts per Minute (CPM)

- IL Not Exceeded
  Survey Area A: 5,677 - 10,273
  Survey Area B: 5,429 - 29,861
- IL Exceeded
  Survey Area A: 10,274 - 68,902
  Survey Area B: 29,862 - 89,945

N
W E
S

0 150 300
Feet

NOTES:

1. Range of Investigation Level (IL) Exceedance in soil selected based on soil analytical results, subsurface gamma measurements, and subsurface observations.

2. Subsurface static gamma measurements are compared to the subsurface static gamma ILs.

3. uk = Unknown, no confirmation if refusal in borehole was on bedrock.

4. Refer to Figure 3-4 for Survey Area delineation.

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

TITLE: Vertical Extent of IL Exceedances in Soil

PROJECT: Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/25/2018

DOCUMENT NAME: Removal Site Evaluation Report

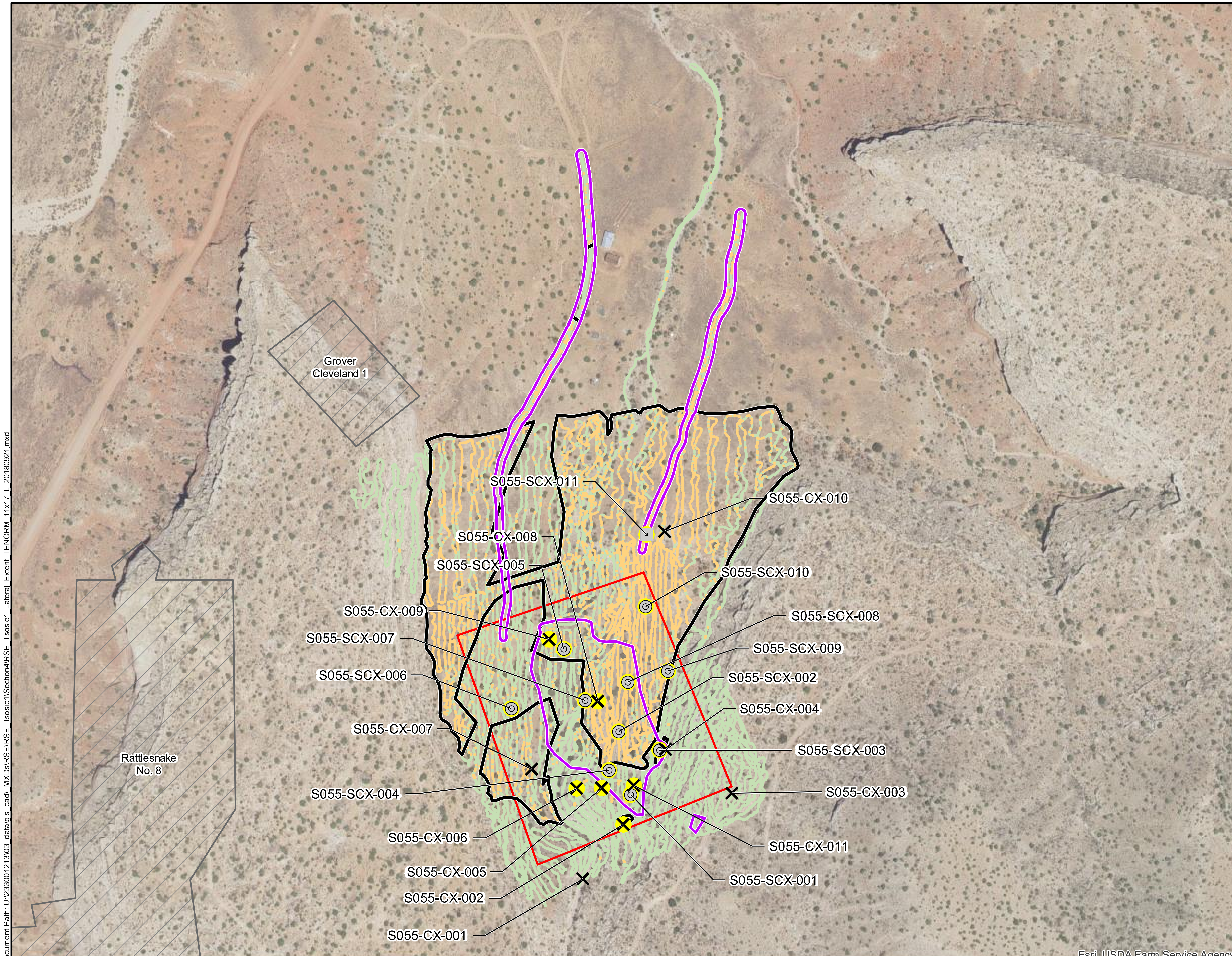
AUTHOR: WDC

REVIEWER: CBB

Stantec

FIGURE: 4-5

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Vertical_Extent_11x17_L_20180926.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- IL Exceedance in Unconsolidated Material at Location
- TENORM (5.2 acres)
- Approximate Area where Surface Gamma ILs are Exceeded (18.7 acres)
- Claim Boundary
- Other Claim Boundary

Gamma Survey

Counts per Minute (CPM)

IL Not Exceeded
Survey Area A: 5,677 - 10,273
Survey Area B: 5,429 - 29,861

IL Exceeded
Survey Area A: 10,274 - 68,902
Survey Area B: 29,862 - 89,945

NOTE:
Refer to Figure 3-4 for Survey Area delineation.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/21/2018

N
W E
S

0 300 600
Feet

TITLE:
TENORM Compared to Lateral Extent of IL Exceedances

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/21/2018

DOCUMENT NAME: Removal Site Evaluation Report

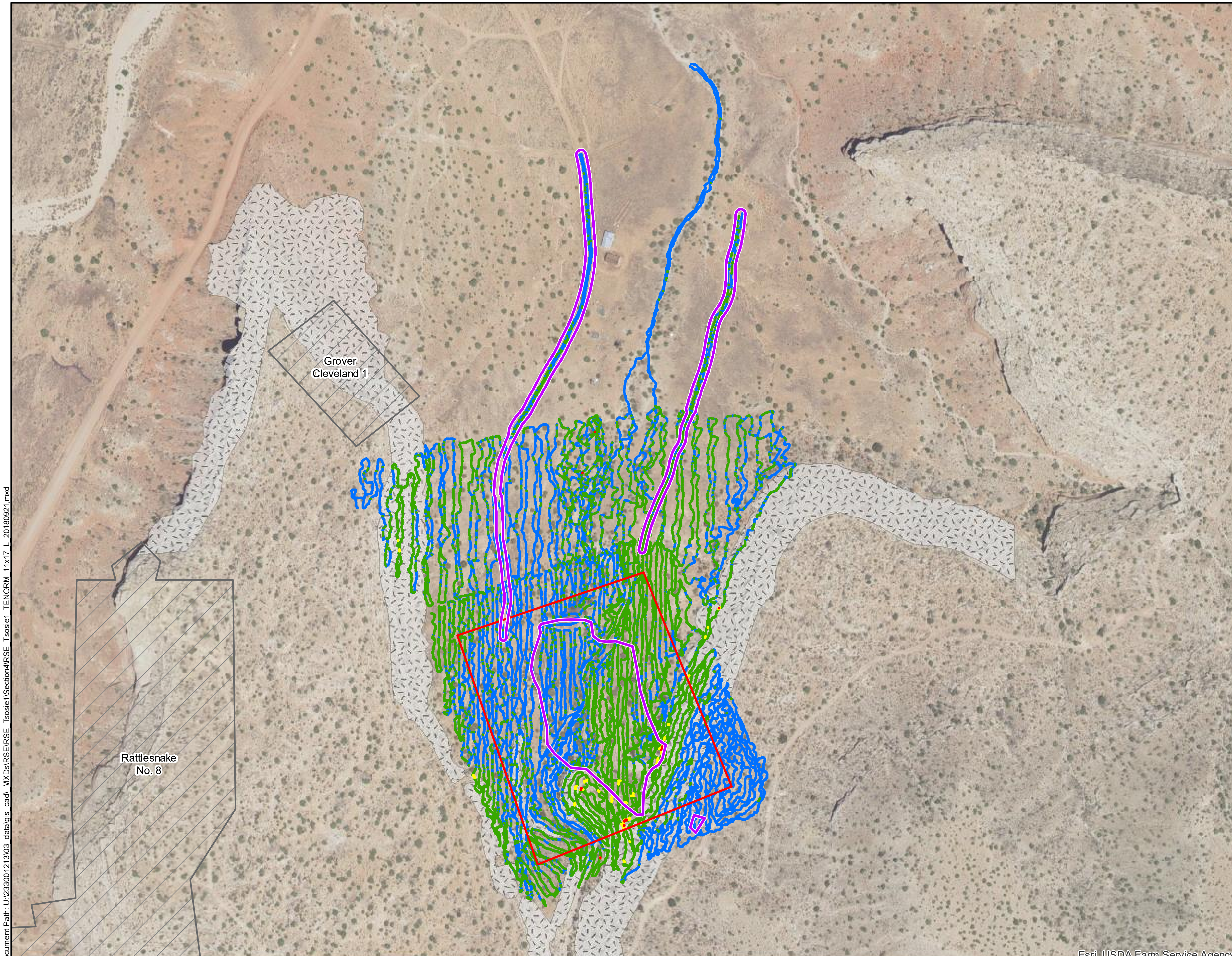
Stantec

AUTHOR: WDC

REVIEWER: CBB

FIGURE: 4-6

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Lateral_Extent_TENORM_11x17_L_20180921.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- TENORM (5.2 acres)
- Exposed Bedrock[1]
- Claim Boundary
- Other Claim Boundary

Gamma Survey

Counts per Minute (CPM)

- 5,429 - 10,273 (Minimum to BG-1 IL)
- 10,274 - 29,861 (>BG-1 IL to BG-2 IL)
- 29,862 - 51,365 (>BG2 IL to 5x BG-1 IL)
- 51,366 - 89,945 (>5x BG-1 IL to Maximum)

NOTE:
Portions of the areas delineated as exposed bedrock contain small amounts of colluvium.

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/21/2018

N W E S

0 300 600
Feet

TITLE:
TENORM Compared to Gamma Radiation Survey Results

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/21/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: CBB	REVIEWER: EDZ
	FIGURE: 4-7	

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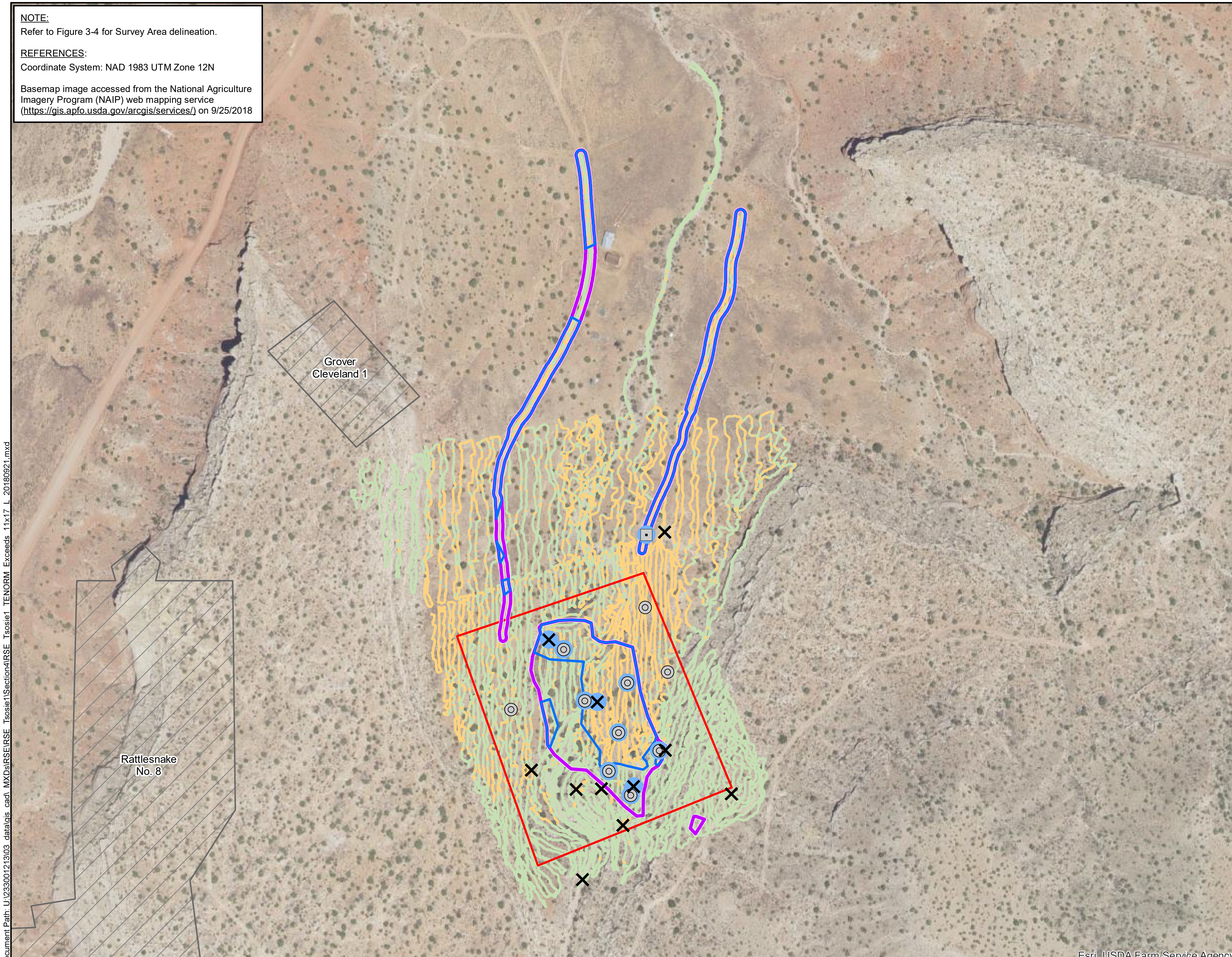


NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- TENORM Exceeding ILs in Unconsolidated Material at Location
- TENORM Area Exceeding Surface Gamma ILs (3.4 acres)
- TENORM (5.2 acres)
- Claim Boundary
- Other Claim Boundary

Gamma Survey
Counts per Minute (CPM)

IL Not Exceeded
Survey Area A: 5,677 - 10,273
Survey Area B: 5,429 - 29,861

IL Exceeded
Survey Area A: 10,274 - 68,902
Survey Area B: 29,862 - 89,945

N W E S

0 300 600
Feet

TITLE:
TENORM that Exceeds ILs

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/25/2018

DOCUMENT NAME: Removal Site Evaluation Report

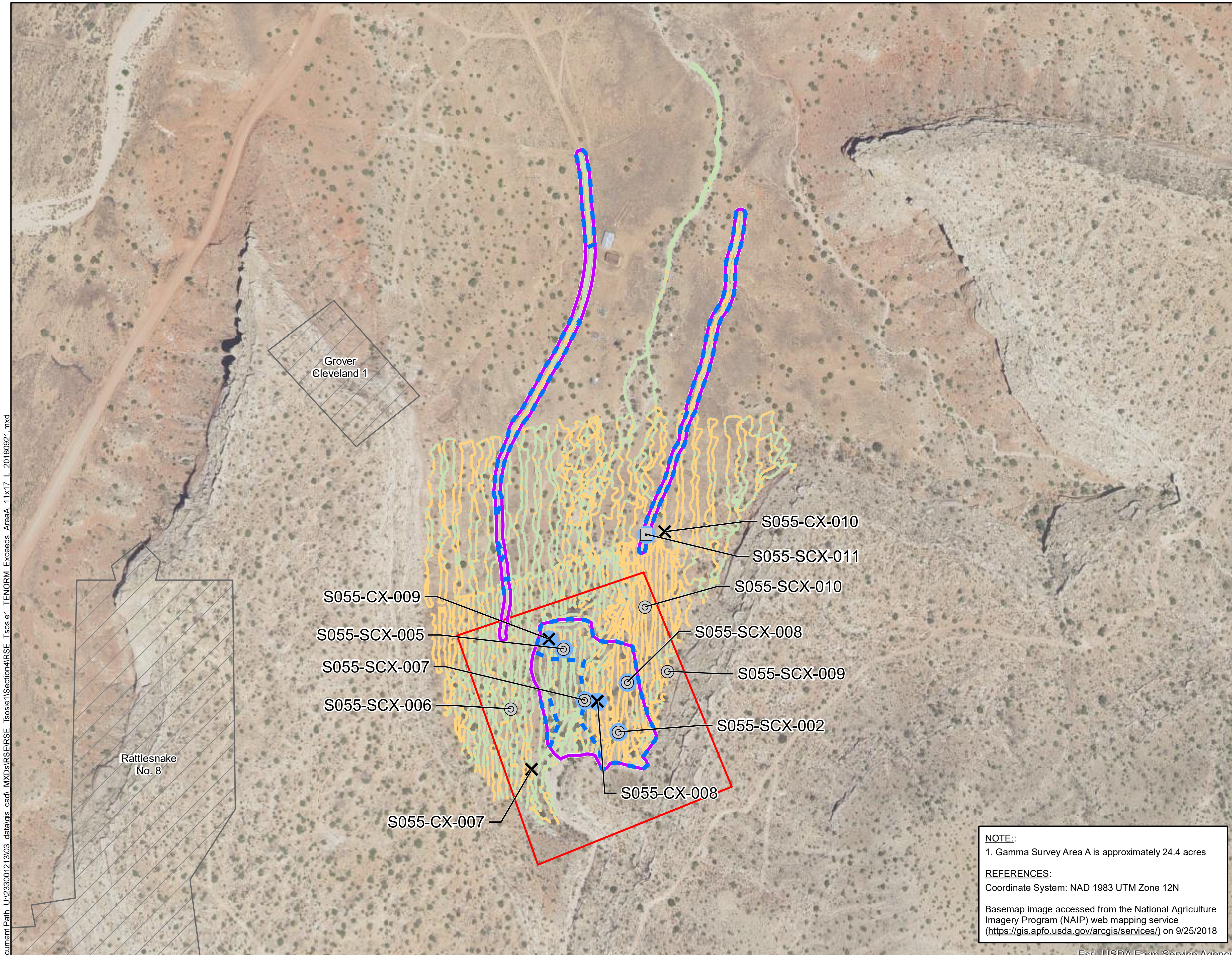
Stantec

AUTHOR: WDC

REVIEWER: CBB

FIGURE: 4-8a

Document Path: U:\233001213\03_data\gis_cad\MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_TENORM_Exceeds_11x17_L_20180921.mxd



NOTE::
1. Gamma Survey Area A is approximately 24.4 acres

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/25/2018

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- TENORM Exceeding ILs in Unconsolidated Material at Location
- TENORM Area Exceeding Surface Gamma IL (3.38 acres)
- TENORM (4.6 acres)
- Claim Boundary
- Other Claim Boundary

Gamma Survey[1]
Counts per Minute (CPM)

- IL Not Exceeded
  Survey Area A: 5,677 - 10,273
  Survey Area B: 5,429 - 29,861
- IL Exceeded
  Survey Area A: 10,274 - 68,902
  Survey Area B: 29,862 - 89,945

N W E S

0 300 600
Feet

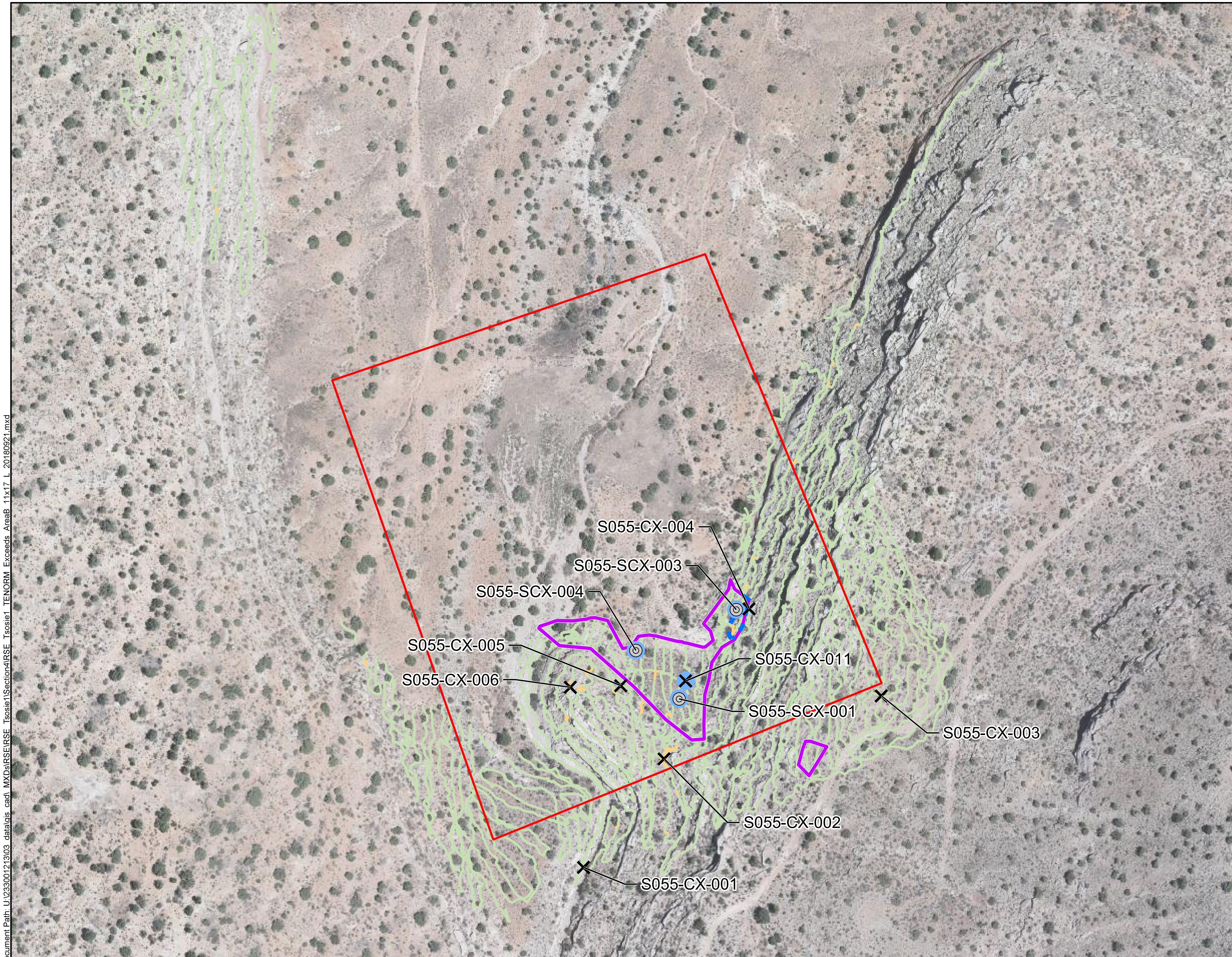
TITLE:
TENORM that Exceeds ILs for Survey Area A

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/25/2018
DOCUMENT NAME: Removal Site Evaluation Report
AUTHOR: WDC
REVIEWER: CBB
FIGURE: 4-8b

Stantec

Document Path: U:\2330012130\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_TENORM_Exceeds_AreaA_11x17_L_20180921.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- TENORM Exceeding ILs in Unconsolidated Material at Location
- TENORM Area Exceeding Surface Gamma IL (0.02 acres)
- TENORM (0.6 acres)
- Claim Boundary

Gamma Survey[1]
Counts per Minute (CPM)

IL Not Exceeded
Survey Area A: 5,677 - 10,273
Survey Area B: 5,429 - 29,861

IL Exceeded
Survey Area A: 10,274 - 68,902
Survey Area B: 29,862 - 89,945

NOTE::
1. Gamma Survey Area B is approximately 10.5 acres

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys on June 16, 2017.

N W E S

0 150 300
Feet

TITLE: TENORM that Exceeds ILs for Survey Area B

PROJECT: Removal Site Evaluation Tsosie1 Mine Site

DATE: 9/25/2018

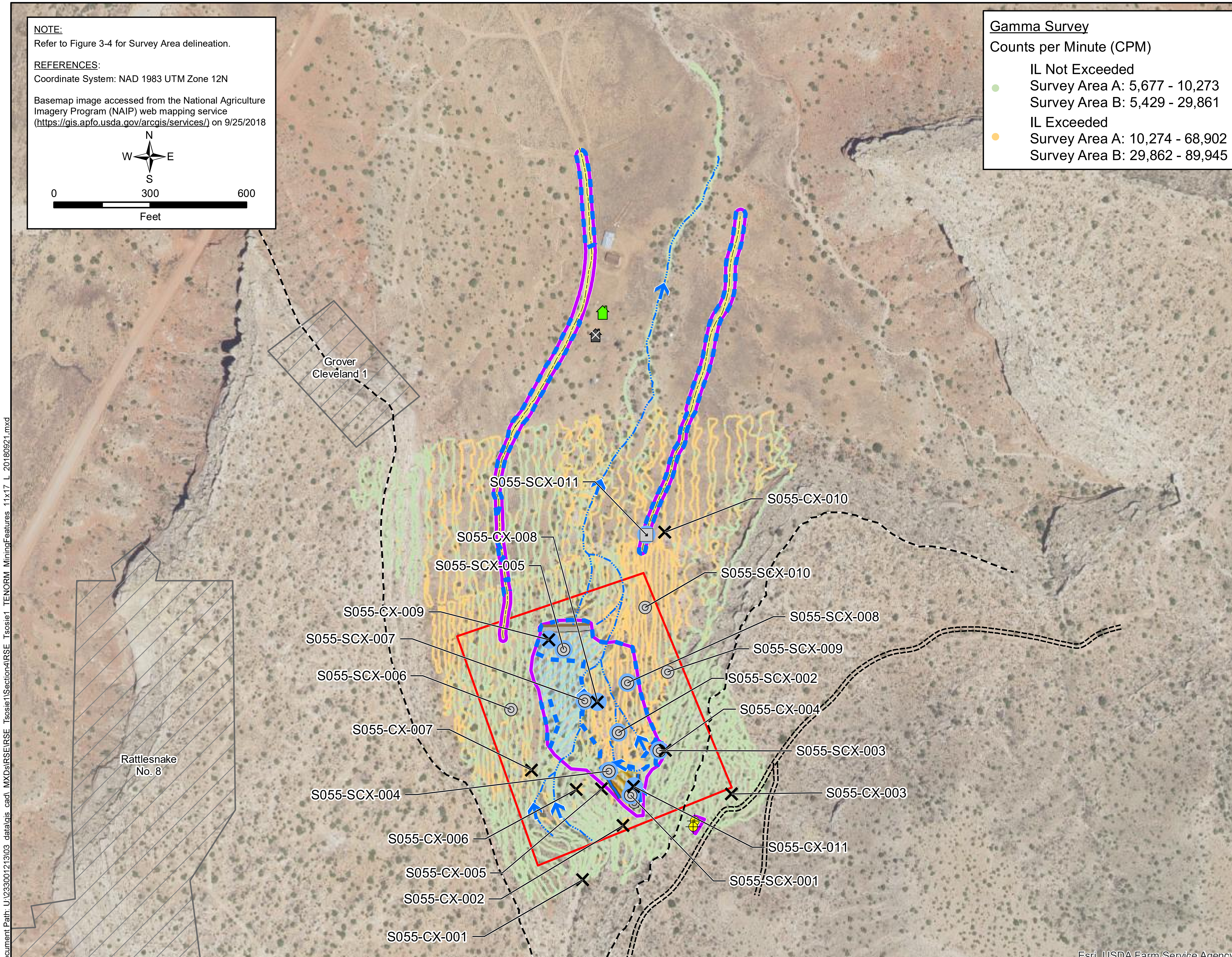
DOCUMENT NAME: Removal Site Evaluation Report

Stantec

AUTHOR: WDC

REVIEWER: CBB

FIGURE: 4-8c



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Surface Sample Location
- Borehole Location - Surface and Subsurface Samples
- Borehole Location - Subsurface Samples Only
- TENORM Exceeding ILs in Unconsolidated Material at Location
- TENORM Area Exceeding Surface Gamma ILs (3.4 acres)
- TENORM (5.2 acres)
- Historical Borehole
- Approximate Buried Portal Location
- Habitable Building
- Sealed Portal
- Uninhabitable Building
- Flow Direction
- Drainage
- Dam Crest
- Potential Haul Road
- Road
- Drainage Armored with Riprap
- Approximate Edge of Mesa
- Approximate Dam Footprint
- Temporary Ponding Area
- Reclaimed Area
- Waste Pile
- Claim Boundary
- Other Claim Boundary

TITLE:
TENORM that Exceeds IL Compared To Mining Related Features

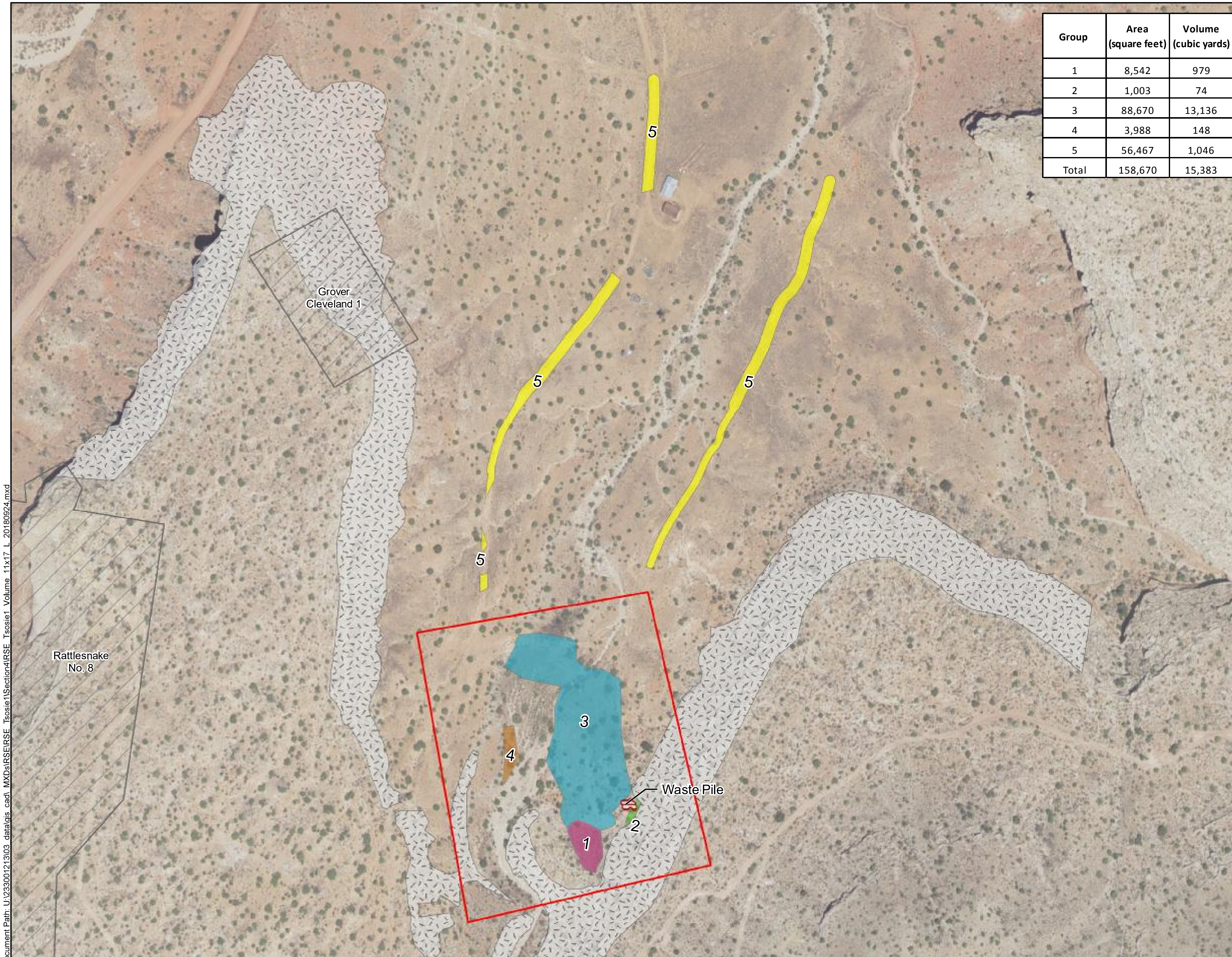
PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/25/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: WDC	REVIEWER: CBB
	FIGURE: 4-8d	

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_TENORM_MiningFeatures_11x17_L_20180921.mxd

NAVAJO NATION
AUM Environmental Response Trust-First Phase

Group	Area (square feet)	Volume (cubic yards)
1	8,542	979
2	1,003	74
3	88,670	13,136
4	3,988	148
5	56,467	1,046
Total	158,670	15,383



LEGEND

- Waste Pile
- Exposed Bedrock[1]
- Claim Boundary
- Other Claim Boundary

Average Depth by Group
(feet below ground surface)

- Group 1 - Variable[2]
- Group 2 - 2.0 ft
- Group 3 - 4.0 ft
- Group 4 - 1.0 ft
- Group 5 - 0.5 ft

NOTES:
1. Portions of the areas delineated as exposed bedrock contain small amounts of colluvium.

2. See Figure 4-9b

REFERENCES:
Coordinate System: USA Contiguous Albers Equal Area Conic

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 9/24/2018

N
W E
S

0 250 500
Feet

TITLE:
Volume Estimate of TENORM that Exceeds IL

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/24/2018

DOCUMENT NAME: Removal Site Evaluation Report

AUTHOR: CBB

REVIEWER: TL

Stantec

FIGURE: 4-9a

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\Section4\RSE_Tsosie1_Volume_11x17_L_20180924.mxd

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

Approximate Reclaimed Area Contour (thickness in feet)

Claim Boundary

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

0 30 60
Feet

TITLE:
Reclaimed Area Contours for Volume Estimates

PROJECT:
Removal Site Evaluation
Tsosie1 Mine Site

DATE: 9/11/2018

DOCUMENT NAME: Removal Site Evaluation Report

Stantec

AUTHOR: CBB
REVIEWER: TL

FIGURE: 4-9b

Document Path: U:\233001213\03 data\gis cad\ MXDs\RSE\RSE Tsosie1\Section4\RSE Tsosie1 Volume Contours 11x17 L 20180911.mxd

APPENDICES

Appendix A Radiological Characterization of the Tsosie 1 Abandoned Uranium Mine

Radiological Characterization of the Tsosie 1 Abandoned Uranium Mine

September 18, 2018

prepared for:

Stantec Consulting Services Inc.

2130 Resort Drive, Suite 350
Steamboat Springs, CO 80487

prepared by:

ERG

Environmental Restoration Group, Inc.

8809 Washington St. NE
Suite 150
Albuquerque, NM 87113

Contents

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Acronyms

ANSI	American National Standards Institute
AUM	abandoned uranium mine
BG1	Background Reference Area 1
BG2	Background Reference Area 2
cpm	counts per minute
DQOs	data quality objectives
ERG	Environmental Restoration Group, Inc.
ft	foot
GPS	global positioning system
MDC	minimum detectable concentration
µR/h	microRoentgens per hour
pCi/g	picocuries per gram
R^2	Pearson's Correlation Coefficient
RSE	removal site evaluation
σ	standard deviation
Stantec	Stantec Consulting Services Inc.

Executive Summary

This report addresses the radiological characterization of the Tsosie 1 abandoned uranium mine (AUM) located in the Teec Nos Pos Chapter of the Navajo Nation, Arizona. It documents part of the implementation of the Navajo Nation AUM Environmental Response Trust, First Phase, Removal Site Evaluation Work Plan (RSE Work Plan: MWH, 2016). The work was performed by Environmental Restoration Group, Inc. (ERG) of Albuquerque, New Mexico and Stantec Consulting Services Inc. (Stantec) on behalf of the Navajo Nation AUM Environmental Response Trust – First Phase.

This report provides 1) the results of a Global Positioning System (GPS)-based gamma radiation (gamma) survey, 2) comparisons of the gamma count rates at this AUM to exposure rates and concentrations of radium-226 in surface soils, and 3) an assessment of equilibrium in the uranium series. The field activities addressed in this report were conducted on October 5 and 6, 2016; June 23 and 26, and September 12, 2017. They included a GPS-based radiological survey of land surfaces over a Survey Area consisting of the mine claim area out to a 100-foot (ft) buffer, roads and drainages within a 0.25-mile radius of the 100-ft buffer, areas where the survey was extended; and correlation studies.

The discussion of the results of soil sampling in this report is limited to concentrations of radium-226 and isotopes of thorium in samples taken from surface soils, as part of correlation studies. The objective of the analysis of thorium isotopes was to 1) assess the potential effects of thorium-232 and thorium-228 on the correlation of gamma count rates to concentrations of radium-226 in surface soils; and 2) evaluate thorium-230 and radium-226 activities to indicate the status of equilibrium in the uranium decay series. These and additional results for the RSE are addressed in the "Tsosie 1 Removal Site Evaluation Report" (Stantec, 2018).

The findings of the RSE pertaining to these activities are:

- The horizontal extent and magnitude of mining-related materials were delineated sufficiently to support additional characterization of the subsurface.
- Elevated count rates were observed on 1) the walls of ridges on the west, east and southeast edges of the mine claim and 2) waste rock that was exposed in a disposal cell in the southeast corner of the mine claim.
- Two potential Background Reference Areas were established.
- The mean relationship between gamma count rates and concentrations of radium-226 in surface soils (0 to 0.5 ft below ground surface) is described by a linear model:

  Gamma Count Rate (cpm) = 609 x [radium-226 (pCi/g)] + 12683

- The distribution of concentrations of radium-226 in surface soils predicted using this model is rightward tailed. The values in the Survey Area range from -11.9 to 126.9, with a central tendency (median) of -4.5 pCi/g.

- The thorium series radionuclides do not appear to affect the prediction of concentrations of radium-226 in surface soil from gamma count rates.

- There is evidence that the uranium series radionuclides are in equilibrium, but not secular equilibrium.

- The relationship between gamma count rates and exposure rates is described by a linear regression model:

  Exposure Rate (microRoentgens per hour [µR/h]) = Gamma Count Rate (cpm) x $3x10^{-4}$ + 10.553

- The distribution of exposure rates predicted using this model is rightward tailed. The values in the Survey Area range from 12.2 to 37.6, with a central tendency (median) of 13.6 µR/h.

1.0 Introduction

This report addresses the radiological characterization of the Tsosie 1 abandoned uranium mine (AUM) located in the Teec Nos Pos Chapter of the Navajo Nation, Arizona. It documents part of the implementation of the Navajo Nation AUM Environmental Response Trust, First Phase, Removal Site Evaluation Work Plan (RSE Work Plan: MWH, 2016). The work was performed by Environmental Restoration Group, Inc. (ERG) of Albuquerque, New Mexico and Stantec Consulting Services Inc. (Stantec) on behalf of the Navajo Nation AUM Environmental Response Trust – First Phase.

This report provides 1) the results of a Global Positioning System (GPS)-based gamma radiation (gamma) survey, 2) comparisons of the gamma count rates at this AUM to exposure rates and concentrations of radium-226 in surface soils, and 3) an assessment of equilibrium in the uranium series.

The objective of the correlation between field gamma count rate and surface soil concentrations of radium-226 was to use field instrumentation to predict surface soil concentrations of radium-226. The objective of the correlation between field gamma count rate and exposure rate was to use field instrumentation to predict exposure rates.

The field activities addressed in this report were conducted on October 5 and 6, 2016; June 23 and 26, and September 12, 2017. They included a GPS-based radiological survey of land surfaces over an approximately 35-acre Survey Area consisting of the mine claim area out to a 100-foot (ft) buffer, roads and drainages within a 0.25-mile radius of the 100-ft buffer, areas where the survey was extended; and correlation studies. Section 3.0 of the RSE Work Plan provides the data quality objectives (DQOs) for the project.

The discussion of the results of soil sampling in this report is limited to concentrations of radium-226 and isotopes of thorium in samples taken from surface soils, as part of correlation studies. The objective of the analysis of thorium isotopes was to 1) assess the potential effects of thorium-232 and thorium-228 on the correlation of gamma count rates to concentrations of radium-226 in surface soils; and 2) evaluate thorium-230 and radium-226 activities to indicate the status of equilibrium in the uranium decay series. These and additional results for the RSE are addressed in the "Tsosie 1 Removal Site Evaluation Report" (Stantec, 2018).

Figure 1 shows the location of the AUM. Background information that is pertinent to the characterization of this AUM is presented in the "Tsosie 1 Removal Site Evaluation Report" (Stantec, 2018).

2.0 GPS-Based Gamma Surveys

This section addresses the GPS-based surveys conducted in two potential Background Reference Areas and the Survey Area. The survey was extended to bound areas in which elevated count rates were observed. Table 1 lists the detection systems used in the survey. Pursuant to the approved RSE Work Plan, detectors were function checked each day to ensure the instruments were stable to the limits prescribed by the Work Plan. Detector normalization was not performed as it was not addressed by the RSE Work Plan. Appendix A presents the completed function check forms and calibration certificates for the instruments. Standard operating procedures (SOPs) are discussed in Section 4.2 of the RSE Work Plan and are provided in Appendix E therein. ERG followed the quality assurance and control requirements stipulated in the approved workplan.

The 2x2 sodium iodide (NaI) detectors used in this investigation are sensitive to sub-surface radium-226 decay products and other gamma emitting radionuclides. The purpose of the gamma correlation was to estimate radium-226 concentrations in the upper 15 cm of soil. ERG selected correlation plots based on the range of gamma radiation levels observed. If subsurface soil concentrations of gamma emitting radionuclides were variable between correlation locations, this variability would be included in the regression model, and if the magnitude of the effect were sufficiently large, it would result in failure of the DQOs related to the regression analysis.

Table 1. Detection systems used in the GPS-Based gamma surveys.

Survey Area	Ludlum Model 44-10	Ludlum Model 2221 Ratemeter/Scaler
Potential Background Reference Areas	PR303727	254772
Survey Area	PR303727	254772
	PR295014[a]	196086[a]
	PR320678	282971
	PR154615	138638
	PR355763[a]	138368[a]
	PR292690	254757

Notes:
[a] Detection system used in the correlation studies described in Section 3.0.

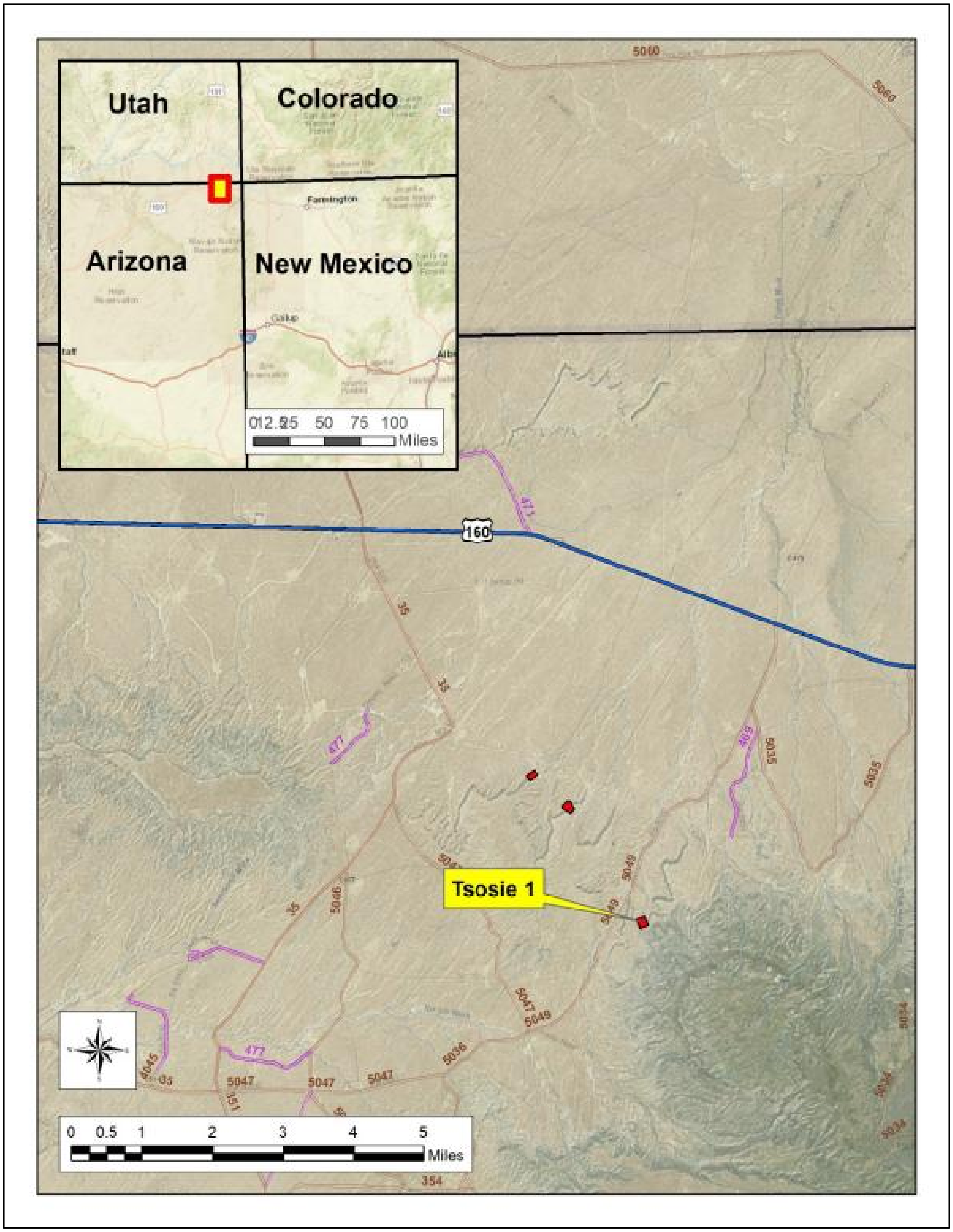


Figure 1. Location of the Tsosie 1 Abandoned Uranium Mine

2.1 Potential Background Reference Areas

Two potential Background Reference Areas were surveyed, the locations and results of which are depicted on Figure 2. BG1 and BG2 in the figure are Background Reference Areas 1 and 2, respectively. Table 2 lists a summary of the gamma count rates, which in:

- BG1 ranged from 6,744 to 11,218 counts per minute (cpm), with a mean and median of 8,822 and 8,837 cpm, respectively.

- BG2 ranged from 12,454 to 36,929 cpm, with a mean and median of 20,105 and 18,526 cpm, respectively.

Figure 3 depicts histograms of the gamma count rates in the Background Reference Areas. The red and green lines on the figure are theoretical normal and lognormal distributions, respectively. They are presented to show what could be expected if the distributions were normal or lognormal.

Table 2. Summary statistics for gamma count rates in the potential Background Reference Areas.

	Gamma Count Rate (cpm)					
Potential Background Reference Area	**n**	**Minimum**	**Maximum**	**Mean**	**Median**	**Standard Deviation**
1	232	6,744	11,218	8,822	8,837	797
2	325	12,454	36,929	20,105	18,526	5,443

Notes:
cpm = counts per minute

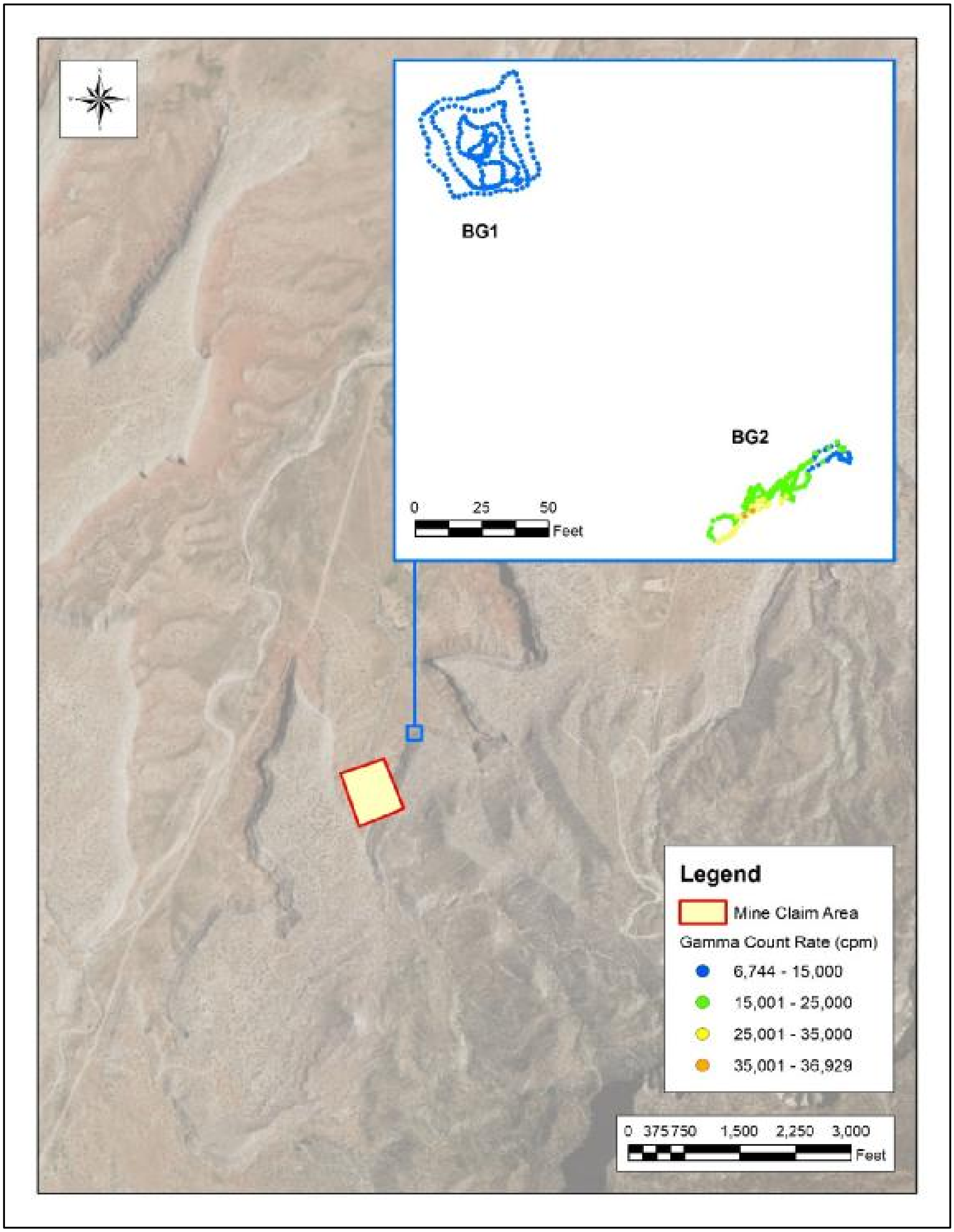
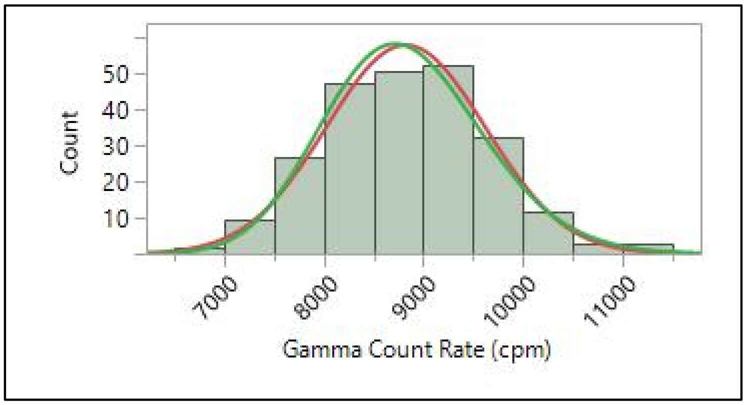
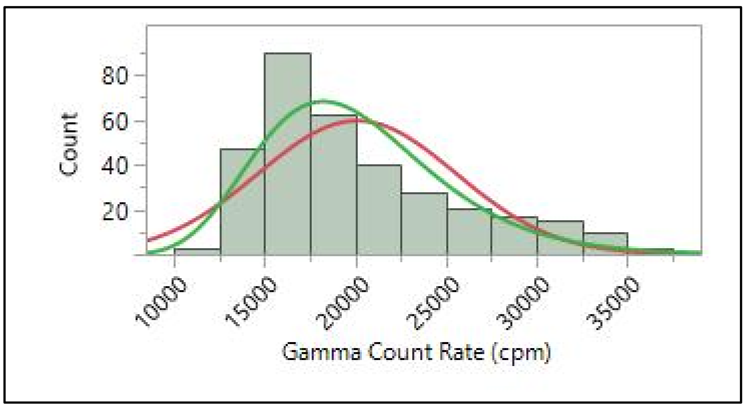


Figure 2. Gamma count rates in the potential Background Reference Areas.



a. Background Reference Area 1



b. Background Reference Area 2

Figure 3. Histograms of gamma count rates in the Background Reference Areas.

2.2 Survey Area

The gamma count rates observed in the Survey Area are depicted in Figure 4. Elevated count rates were observed on 1) the walls of ridges on the west, east and southeast edges of the mine claim and 2) waste rock that was exposed in a disposal cell in the southeast corner of the mine claim.

Figure 5 is a histogram of the gamma count rate measurements made in the Survey Area, including the area surveyed outside the 100-ft buffer. As stated in Section 2.1, the red and green lines on the figure are theoretical normal and lognormal distributions, respectively. They are presented to show what could be expected if the distributions were normal or lognormal. The distribution of the right-tailed set of measurements, evaluated using U.S. Environmental Protection Agency software ProUCL (version

5.1.002), is not defined. The box plot in Figure 6 depicts cutoffs as horizontal bars, from bottom to top, for the following values or percentiles: minimum, 0.5, 2.5, 10, 25, 50, 75, 90, 97.5, 99.5, and maximum. The 25th, 50th, and 75th percentiles (the three horizontal lines of the box inside the box plot) are 8,915, 9,931, and 11,420 cpm, respectively.

Table 3 is a statistical summary of the measurements, which range from 5,429 to 89,945 cpm and have a central tendency (median) of 9,931 cpm.

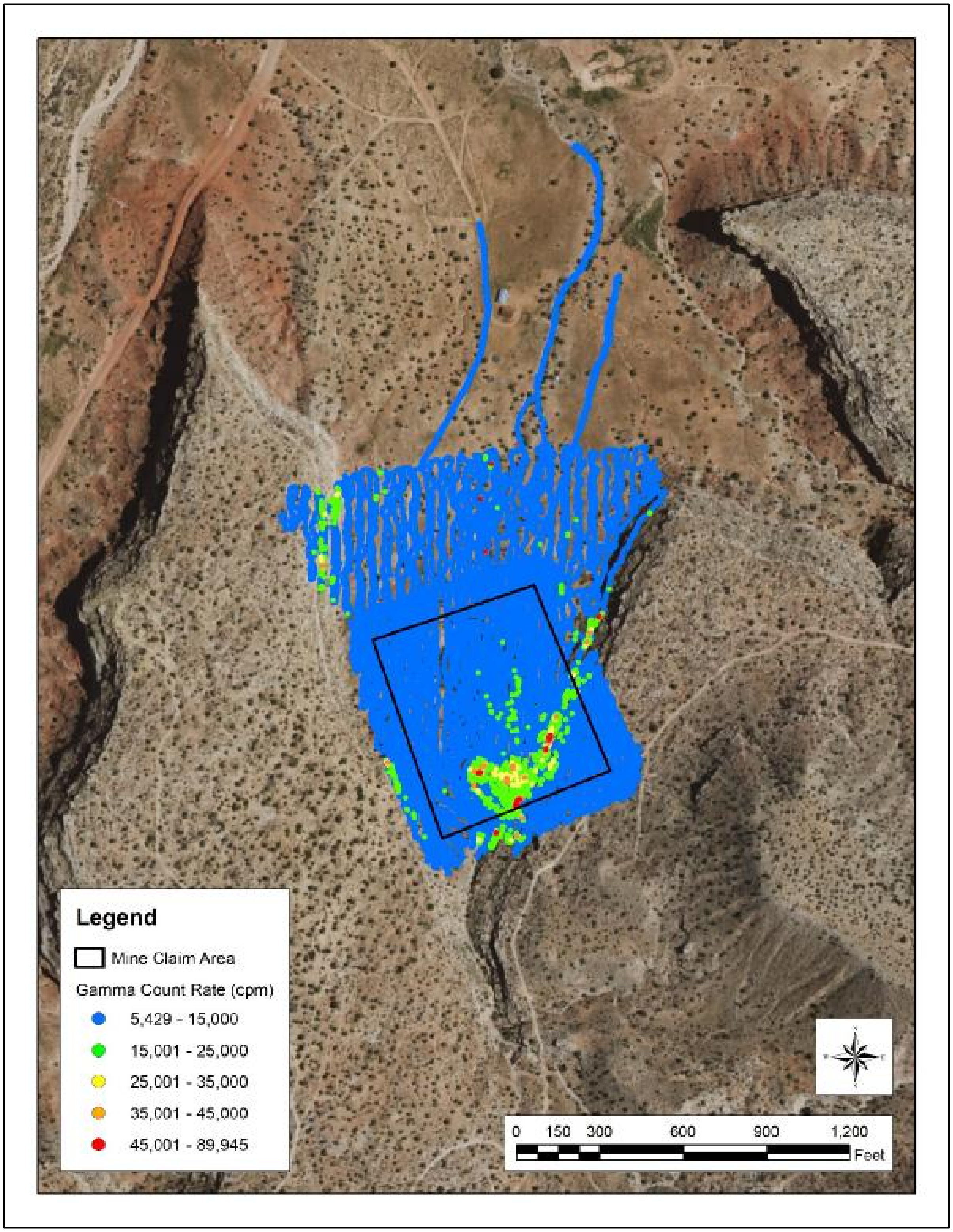


Figure 4. Gamma count rates in the Survey Area.

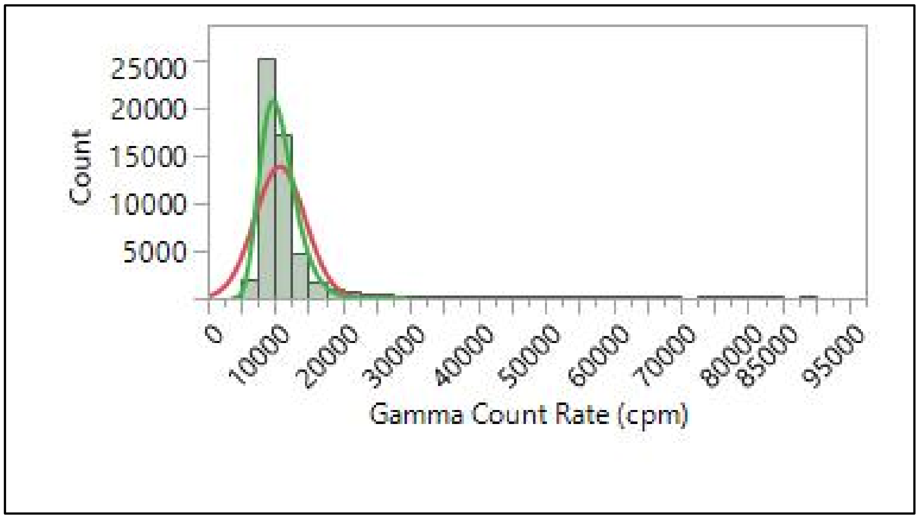


Figure 5. Histogram of gamma count rates in the Survey Area.

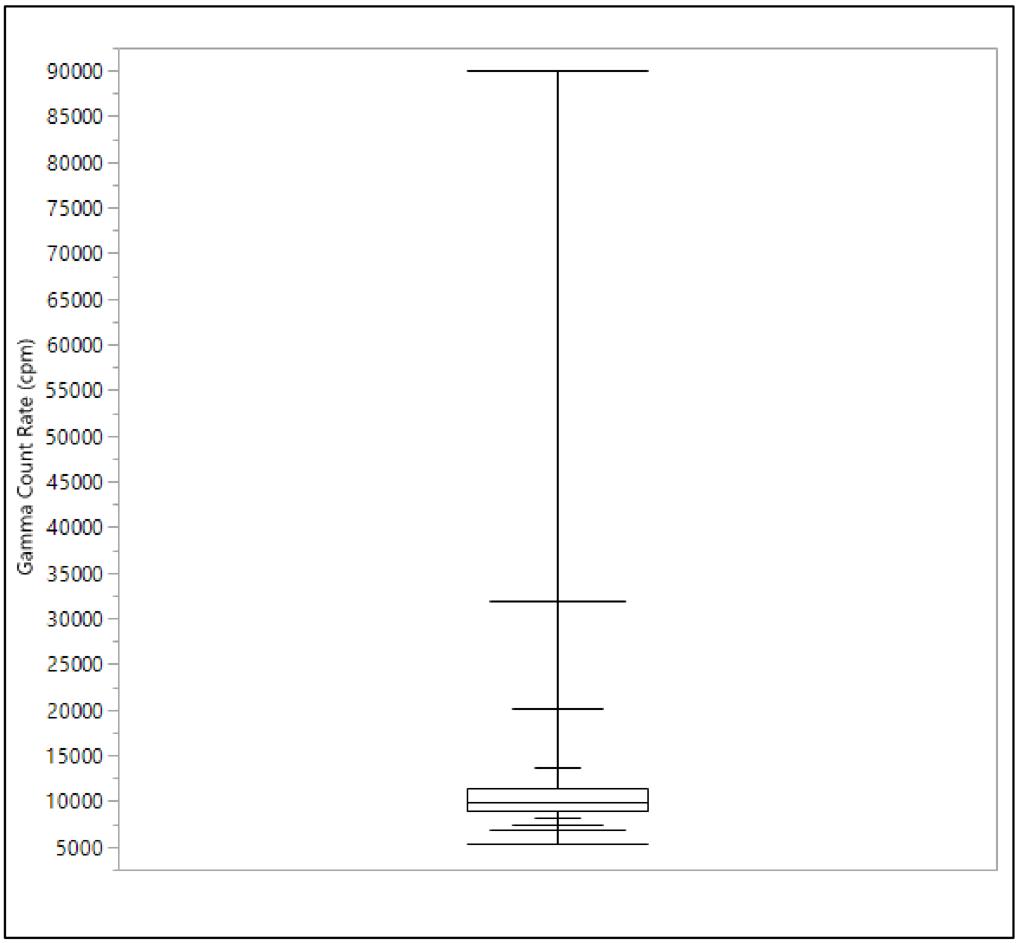


Figure 6. Box plot of gamma count rates in the Survey Area.

Table 3. Summary statistics for gamma count rates in the Survey Area.

Parameter	Gamma Count Rate (cpm)
n	52,004
Minimum	5,429
Maximum	89,945
Mean	10,778
Median	9,931
Standard Deviation	3,730

Notes:
cpm = counts per minute

3.0 Correlation Studies

The following sections address the activities under two types of correlation studies outlined in the RSE Work Plan: comparisons of 1) radium-226 concentrations in surface soils and gamma count rates and 2) exposure rates and gamma count rates. GPS-based gamma count rate measurements were made over small areas for the former study. The means of the measurements were used in this case. Static gamma count rate measurements, co-located with exposure rate measurements, were used in the latter study.

3.1 Radium-226 concentrations in surface soils and gamma count rates

On October 12, 2016 field personnel made GPS-based gamma count rates measurements and collected five-point composite samples of surface soils in each of five areas at the AUM. These areas were selected using criteria established in the RSE Work Plan. No DQO was established for homogeneity of the correlation plots and as described in Section 4.3 and Appendix E of the RSE Work Plan, homogeneity of the correlation plots was evaluated qualitatively. Sub-samples were collected from the correlation plot centroid and at each corner of the plot. The activities were performed contemporaneously, by area and all on the same day, such that variations in the gamma count rate measurements could be limited largely to those posed by the soils and rocks at the locations. Figure 7 shows the GPS-based gamma count rate measurements in the five areas (labeled with location identifiers). The gamma count rate measurements were repeated on September 12, 2017 because some of the measurements made on October 12, 2016 were not recorded in the GPS datalogger. The soil samples were not re-collected, because the radium-226 concentrations at the locations were not expected to change.

The soil samples were analyzed by ALS Laboratories in Ft Collins, CO for radium-226 and isotopic thorium. The latter analysis was included to assess the potential effects of thorium series isotopes on the correlation and evaluate thorium-230 and radium-226 activities to indicate the status of equilibrium in the uranium decay series. Table 4 lists the results of the gamma count rate measurements and radium-226 concentrations in the soil samples. The means of the gamma count rate measurements range from 10,854 to 37,736 cpm. The concentrations of radium-226 in the soil samples range from 1.43 to 32.7 picocuries per gram (pCi/g).

Table 5 lists the concentrations of isotopes of thorium (thorium-228, -230, and -232) in the same soil samples. Laboratory analyses are presented in Appendix F.2, Laboratory Analytical Data and Data Validation Report, in the "Tsosie 1 Removal Site Evaluation Report" (Stantec, 2018).

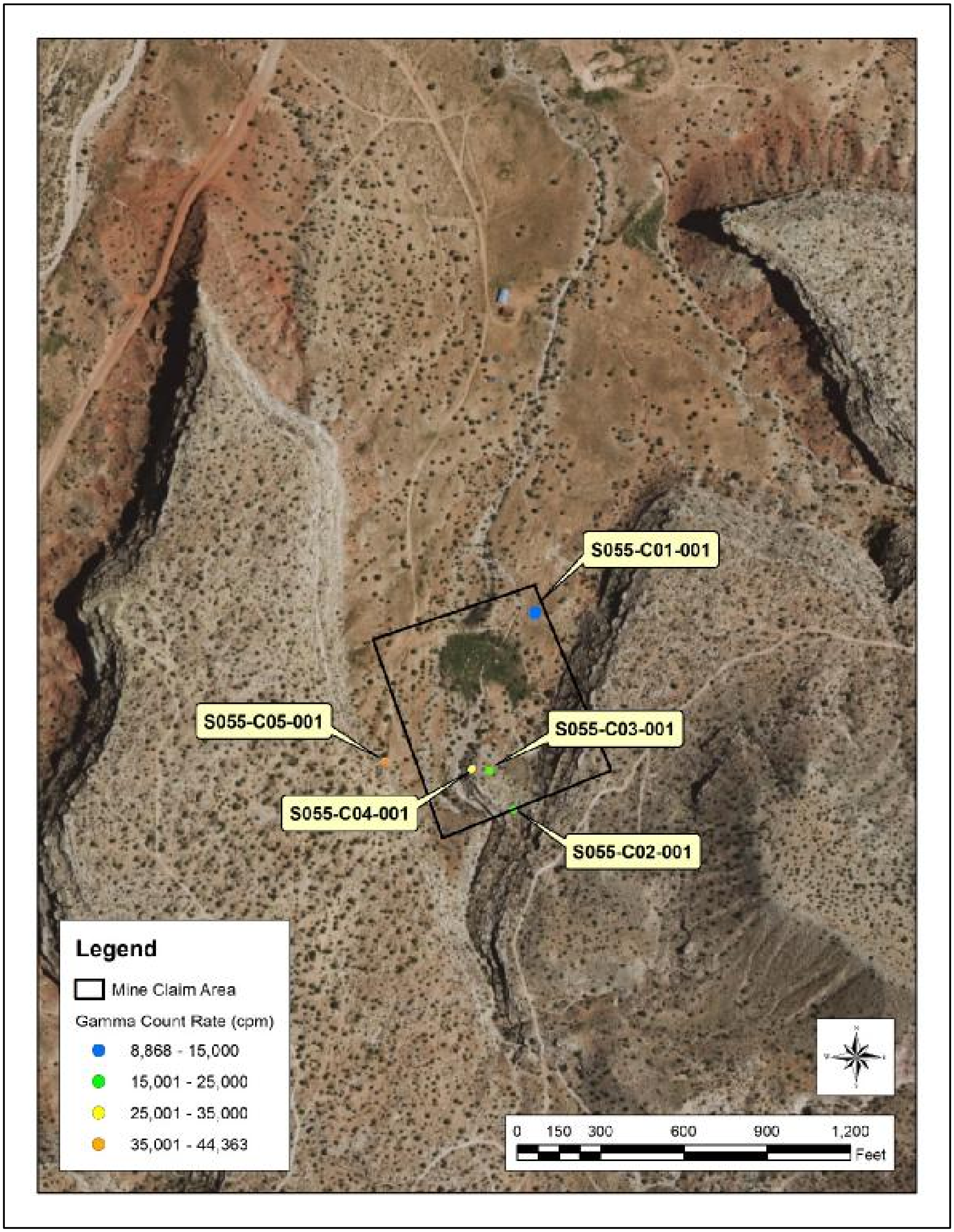


Figure 7. GPS-based gamma count rate measurements made for the correlation study.

Table 4. Gamma count rates and associated concentrations of radium-226 in samples of surface soils obtained in the correlation study.

		Gamma Count Rate (cpm)				Ra-226 (pCi/g)		
Location	Area (m^2)	Mean	Minimum	Maximum	σ	Result	Error ±2σ	MDC
S055-C01-001	59.6	10,854	8,868	12,974	745	1.43	0.29	0.36
S055-C02-001	6.7	37,736	24,200	44,363	4,231	30.5	3.7	0.9
S055-C03-001	9.8	20,487	17,582	24,115	1,564	5.43	0.76	0.61
S055-C04-001	6.2	26,310	19,176	32,028	3,285	32.7	4	1.1
S055-C05-001	10.9	14,716	12,851	17,043	843	6.66	0.88	0.48

Notes:
cpm = counts per minute
MDC = minimum detectable concentration
m^2 =square meters
pCi/g = picocuries per gram
σ = standard deviation

Table 5. Concentrations of isotopes of thorium in samples of surface soils obtained in the correlation study.

	Thorium-228 (pCi/g)			Thorium-230 (pCi/g)			Thorium-232 (pCi/g)		
Sample ID	Result	Error ± 2 σ	MDC	Result	Error ± 2 σ	MDC	Result	Error ± 2 σ	MDC
S055-C01-001	0.467	0.099	0.047	1.08	0.2	0.08	0.444	0.091	0.019
S055-C02-001	1.1	0.2	0.06	15.4	2.4	0.1	1.09	0.19	0.02
S055-C03-001	0.394	0.088	0.053	5.1	0.81	0.07	0.336	0.073	0.021
S055-C04-001	0.55	0.11	0.05	26.1	4.1	0.1	0.53	0.1	0.01
S055-C05-001	0.48	0.1	0.07	4.78	0.76	0.07	0.386	0.082	0.021

Notes:
MDC = minimum detectable concentration
pCi/g = picocuries per gram
σ = standard deviation

A model was made of the results in Table 4, predicting the concentrations of radium-226 in surface soils from the mean gamma count rate in each area. The mean relationship between the measurements, shown in Figure 8, is a linear function with an adjusted Pearson's Correlation Coefficient (adjusted R^2) of 0.66, as expressed in the equation:

Gamma Count Rate (cpm) = 609 x [radium-226 (pCi/g)] + 12683

The root mean square error and p-value for the model are $6.1\text{x}10^3$ and 0.059, respectively; these parameters are not data quality objectives (DQOs) and are included only as information. The R^2 value for this model does not meet the project DQO of 0.8. The model could be improved with additional correlation data collected in the future.

This equation was used to convert the gamma count rate measurements observed in the gamma surveys to predicted concentrations of radium-226. Table 6 presents summary statistics for the predicted concentrations of radium-226 in the Survey Area. The range of the predicted concentrations of radium-226 in the Survey Area is -11.9 to 126.9 pCi/g, with a mean and median of -3.1 and -4.5 pCi/g, respectively. Note that the radium-226 concentrations predicted from gamma count rate measurements exceeding approximately 38,000 cpm are extrapolated from the regression model and are outside of the correlation dataset and therefore inherently uncertain. While the gamma correlation equation can be used to convert gamma count rates to concentrations of Ra-226 in soil, the resulting radium concentrations are highly uncertain estimates, as the wide prediction interval bands illustrated in Figure 8 demonstrate. Users of the regression equation should be aware of the limitations of the dataset and be cautious when estimating radium-226 concentrations.

Figure 9 shows the predicted concentrations of radium-226, the spatial and numerical distribution of which mirror those depicted in Figure 4.

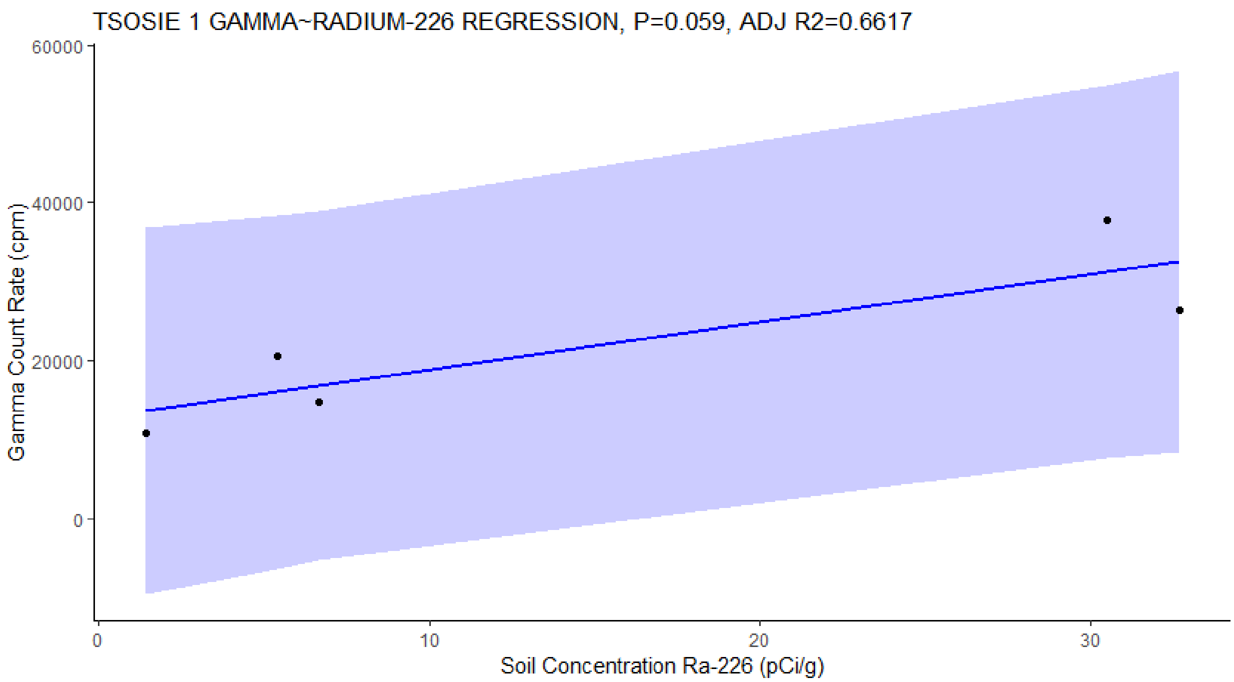


Figure 8. Correlation of gamma count rates and concentrations of radium-226 in surface soils (blue line) with 95% upper prediction level bands plotted (shaded area).

Table 6. Predicted concentrations of radium-226 in the Survey Area.

Parameter	Radium-226 (pCi/g)
n	52,004
Minimum	-11.9
Maximum	126.9
Mean	-3.1
Median	-4.5
Standard Deviation	6.1

Notes:
pCi/g = picocuries per gram

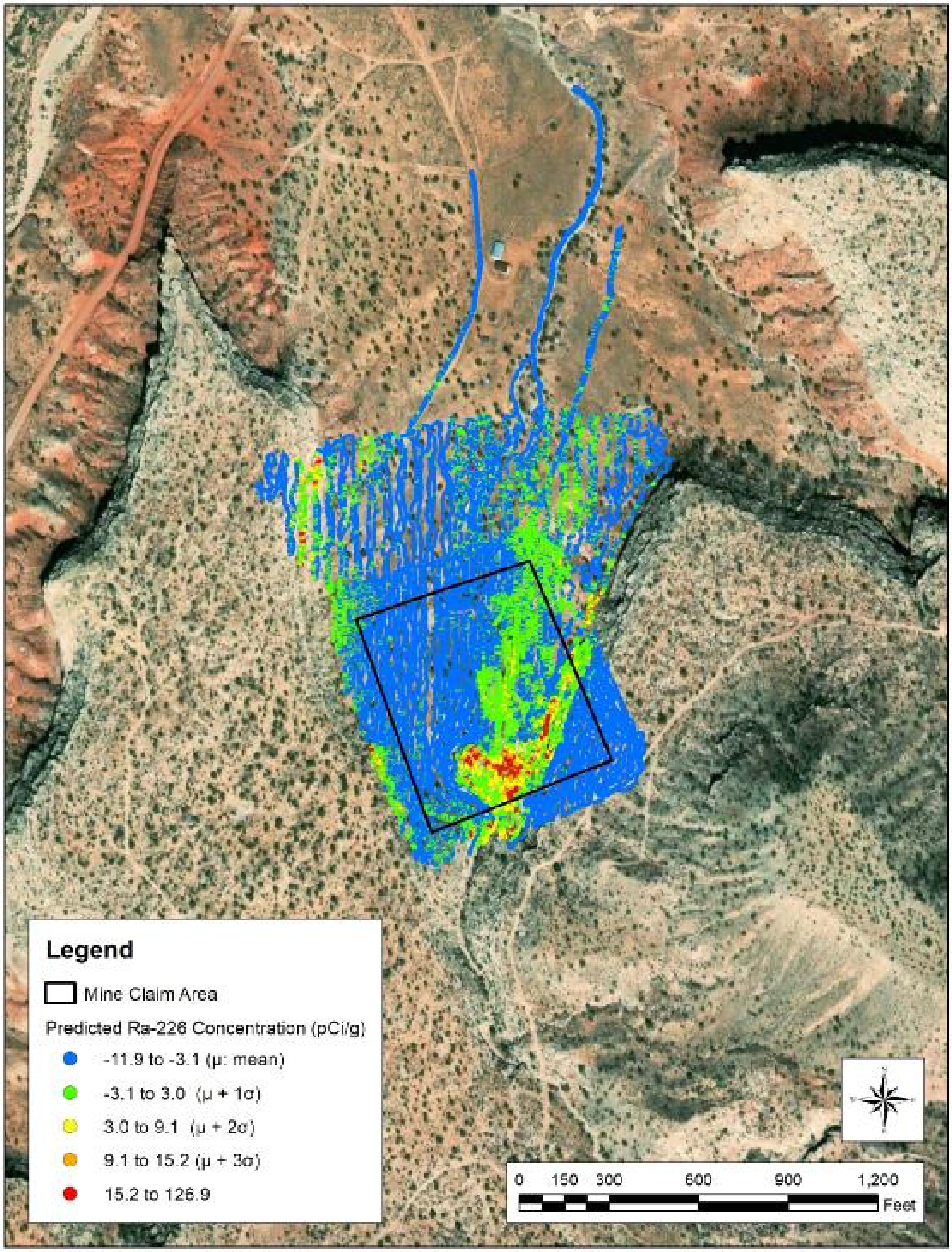


Figure 9. Predicted concentrations of radium-226 in the Survey Area.

Soil concentrations of potassium-40 (K-40) were not expected to be spatially variable within the site, and therefore this radionuclide was not separately accounted for in the RSE Work Plan. If K-40 concentrations did vary, this variability would be included in the regression model and, if the magnitude of the effect were sufficiently large, would result in failure of DQOs related to the regression analysis.

A multivariate linear regression (MLR) was used to evaluate the influence of thorium-232 and thorium-228, isotopes in the thorium series, on the average gamma count rate in the correlation locations. The MLR model was first run using radium-226, thorium-232, and thorium-228 as predictors of gamma count rate. The model failed to produce results because thorium-232 and thorium-228 are colinear. The MLR model was subsequently run without thorium-228. For the second model, the p-values for radium-226 and thorium-232 were both greater than 0.05 (0.28 and 0.29 respectively) and therefore not significant predictors of gamma count rate collectively. Thorium-232 and radium-226 were then each modelled individually as a predictor of gamma count rate. The p-value for thorium-232 coefficient was 0.063 with an adjusted R^2 of 0.65. The thorium-232 coefficient is not significant and the R^2 value does not meet the project DQO. Subsequently we conclude that thorium-232 and thorium-228 concentrations in soil are not significant predictors of gamma count rate. Finally, the p-value for radium-226 as a predictor of gamma count rate was also not significant ($p = 0.059$), as described above, and the adjusted R^2 value (0.66) did not meet the applicable project DQO ($R^2 > 0.8$).

The depletion of radon-222 in surface soil due to environmental factors is assumed to be relatively constant across the correlation locations (i.e., the loss is a fixed fraction of the available source). Provided this is the case, any loss of radon-222 in surface soil is unimportant and accounted for within the statistical model. If the loss is not a consistent fraction at each correlation location, it is one of many potential correlation confounders that are all linked to spatial heterogeneity of the environmental conditions, and especially spatial heterogeneity of the soil matrix.

The presence of heterogeneous concentrations of gamma emitting radionuclides in sub-surface soil can affect the gamma correlation model. If subsurface soil concentrations of gamma emitting radionuclides were variable between correlation locations, this variability would be included in the regression model, and if the magnitude of the effect were sufficiently large, it would result in failure of the DQOs related to the regression analysis.

3.2 Equilibrium in the uranium series

Secular equilibrium is a condition that occurs when the half-life of a decay-product nuclide is significantly shorter than that of its parent nuclide. After a period of ingrowth equal to approximately seven times the half-life of the decay product, the two nuclides effectively decay with the half-life of the parent. When two radionuclides are in secular equilibrium, their activities are equal.

Equilibrium, for the purpose of this report, is defined as a condition whereby a parent nuclide and its decay product are present in the environment at a fixed ratio, but this ratio – for whatever reason – is not a one-to-one relationship indicative of secular equilibrium. Most commonly, an equilibrium condition results from an environmental process which chemically selects for and transports one nuclide (parent or decay product) away from the other nuclide. Because a consistent fraction of one nuclide has been removed, the two nuclides are present at a fixed ratio other than one-to-one.

Determination of secular equilibrium for an AUM can be an important part of the risk assessment process, as the assumed fraction of radium-226 decay products present in the environment greatly influences a hypothetical receptor's radiation dose and mortality risk. However, it is also acceptable and conservative to assume secular equilibrium between radium-226 and its decay products for the purpose of risk assessment, and therefore to avoid the need to conclusively determine the secular equilibrium status of an AUM. Thus, an inconclusive result regarding secular equilibrium is not a study data gap, as the risk assessment phase may still proceed, provided that conservative assumptions are included regarding equilibrium concentrations of radium-226 decay products.

Regardless, the RSE Work Plan specified that an evaluation of secular equilibrium would be made at each of the 16 Trust AUMs, and so a robust statistical examination of secular equilibrium status for thorium-230 and radium-226 was conducted. The RSE Work Plan did not require an evaluation of equilibrium condition of uranium -238 and uranium-234 because the natural activity abundance for these isotopes is expected and therefore assumed. Likewise, thorium-234 and protactinium-234m were not evaluated since their half-lives are sufficiently short that secular equilibrium can be assumed. Uranium-235 is not in the uranium-238 decay therefore it wasn't evaluated. The ratio of thorium-230 to radium-226 can be evaluated even though different analytical methods were used to measure activity concentrations. Radium-226 was measured by EPA method 901.1m, which is a total activity method and thorium-230 was measured by alpha spectroscopy following digestion with hydrofluoric acid, which is also a total-activity method. Thus, it is appropriate to compare the two results.

Evaluation of secular equilibrium for each mine site proceeded as follows:

1. Construction of a figure that depicts soil concentrations of Th-230 plotted against soil concentrations of Ra-226.
2. Simple linear regression is performed on the dataset; the p-value and the adjusted R^2 are recorded. The resulting linear model and the 95% UCL bands are plotted on the figure generated in step 1.
3. The line y=x is added to the figure generated in step 2 (this line represents a perfect 1:1 ratio between Th-230 to Ra-226, indicative of secular equilibrium).
4. An examination of the model and the figure is made sequentially:
    a. If the p-value for the regression slope is insignificant (i.e., $p > 0.05$) or the adjusted R^2 does not meet the study's data quality objective (Adjusted $R^2 > 0.8$), ERG concludes that there is insufficient evidence to conclude that Ra-226 and Th-230 are in equilibrium (secular or otherwise).

b. If the p-value for the regression slope is significant (i.e., $p < 0.05$) and the adjusted R^2 meets the DQO (Adjusted $R^2 > 0.8$) there are two possible conditions, which are evaluated via visual examination of the figure generated in step 3.

   i. If the y=x line falls fully within the bounds of the 95% UCL bands on the regression, ERG concludes that there is evidence that Ra-226 and Th-230 are in secular equilibrium at the site.

   ii. If the y=x line falls partially or completely outside the bounds of the 95% UCL bands on the regression, ERG concludes that there is evidence that Ra-226 and Th-230 are in equilibrium, but not secular equilibrium at the site.

Based on this method, ERG concludes there is evidence that thorium-230 and radium-226 are in equilibrium, but not secular equilibrium (Figure 10).

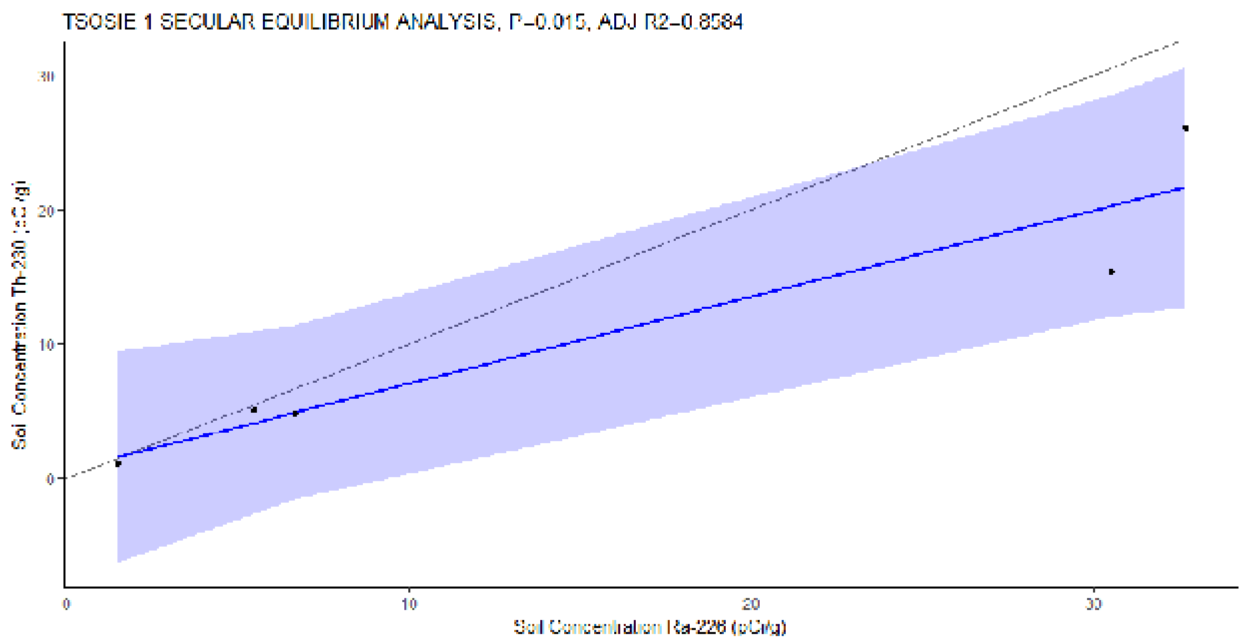


Figure 10. Evaluation of secular equilibrium in the uranium decay series.

3.3 Exposure rates and gamma count rates

Field personnel made co-located one-minute static count rate and exposure rate measurements at five locations within the Survey Area, representing the range of gamma count rates obtained in the GPS-based gamma survey. Figure 7 shows the locations of the co-located measurements, which were made in the centers of the areas.

The gamma count rate and exposure rate measurements were made on June 26, 2017 at 0.5 m and 1 m above the ground surface, respectively. The gamma count rate measurements were made using one of the sodium iodide detection systems used in the GPS-based gamma survey of the AUM (Serial Numbers

PR295014/196086). The exposure rate measurements were made using a Reuter Stokes Model RS-S131-200-ER000 (Serial Number 1000992) high pressure ionization chamber (HPIC) at 1-second intervals for about 10 minutes. The HPIC output the 1-second measurements as 1-minute averages. The exposure rate used in the comparison was the mean of these measurements, less those occurring in initial instrument warm-ups. The HPIC was in current calibration and function-checked before and after use. A correction factor of 1.02 was applied to the measured value per the manufacturer's recommendation by the software of the unit. Calibration forms for the HPIC are provided in Appendix A. Table 7 presents the results for the two types of measurements made at each of the five locations. Appendix B presents the individual (one minute) exposure rate measurements.

The best predictive relationship between the measurements is linear with a R^2 of 0.9597. The root mean square error and p-value for the model are 0.972256 and 0.0035, respectively; these parameters are not DQOs and are included only as information.

The following equation is the linear regression shown in Figure 11 between the mean exposure rate and gamma count rate results in Table 7 that was generated using MS Excel:

Exposure Rate (microRoentgens per hour [μR/h]) = $3\text{x}10^{-4}$ x Gamma Count Rate (cpm) + 10.553

Figure 12 presents the exposure rates predicted from the gamma count rate measurements, the spatial and numerical distribution of which mirror those depicted in Figure 4.

Tables 8 and 9 present summary statistics for the predicted exposure rates in the two Background Reference Areas and AUM, respectively.

The range of predicted exposure rates at:

- BG1 is 12.6 to 13.9 μR/h, with a mean and median of 13.2 μR/h
- BG2 is 14.3 to 21.6 μR/h, with a mean and median of 16.6 and 16.1 μR/h, respectively

The range of predicted exposure rates at the AUM is 12.2 to 37.6 μR/h, with a mean and median of 13.8 and 13.6 μR/h, respectively.

Table 7. Co-located gamma count rate and exposure rate measurements.

Location	Gamma Count Rate (cpm)	Exposure Rate (μR/h)
S055-C01-001	10,958	13.1
S055-C02-001	43,051	23.2
S055-C03-001	20,990	18.1
S055-C04-001	31,309	21.0
S055-C05-001	14,150	14.9

Notes:
cpm = counts per minute
μR/h = microRoentgens per hour

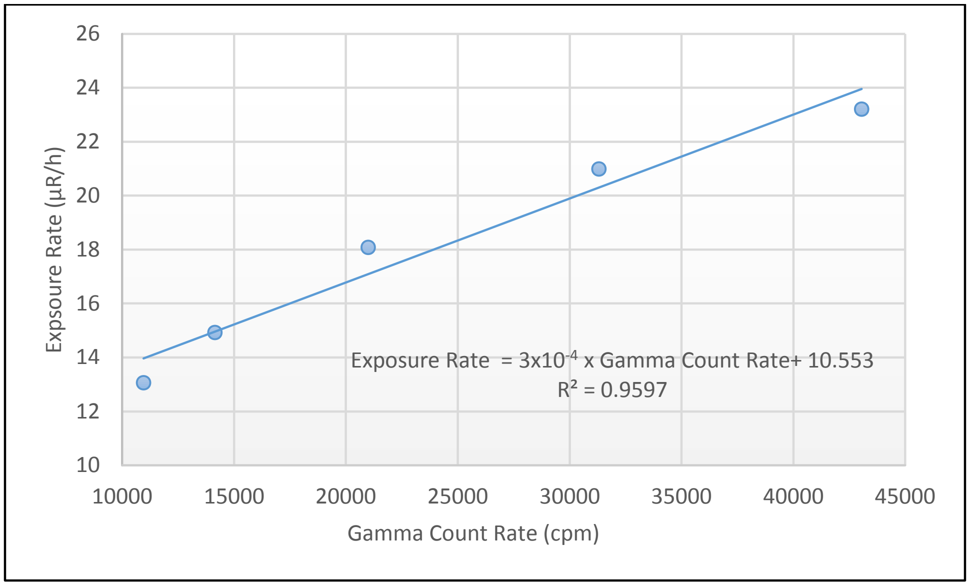


Figure 11. Correlation of gamma count rates and exposure rates.

Table 8. Predicted exposure rates in the potential Background Reference Areas.

Potential Background Reference Area	BG1	BG2
Parameter	Exposure Rate (µR/h)	
n	232	325
Minimum	12.6	14.3
Maximum	13.9	21.6
Mean	13.2	16.6
Median	13.2	16.1
Standard Deviation	0.2	1.6

Notes:
BG1 = Background Reference Area 1
BG2 = Background Reference Area 2
µR/h = microRoentgens per hour

Table 9. Predicted exposure rates in the Survey Area.

Parameter	Exposure Rate (µR/h)
n	52,004
Minimum	12.2
Maximum	37.6
Mean	13.8
Median	13.6
Standard Deviation	1.1

Notes:
µR/h = microRoentgens per hour

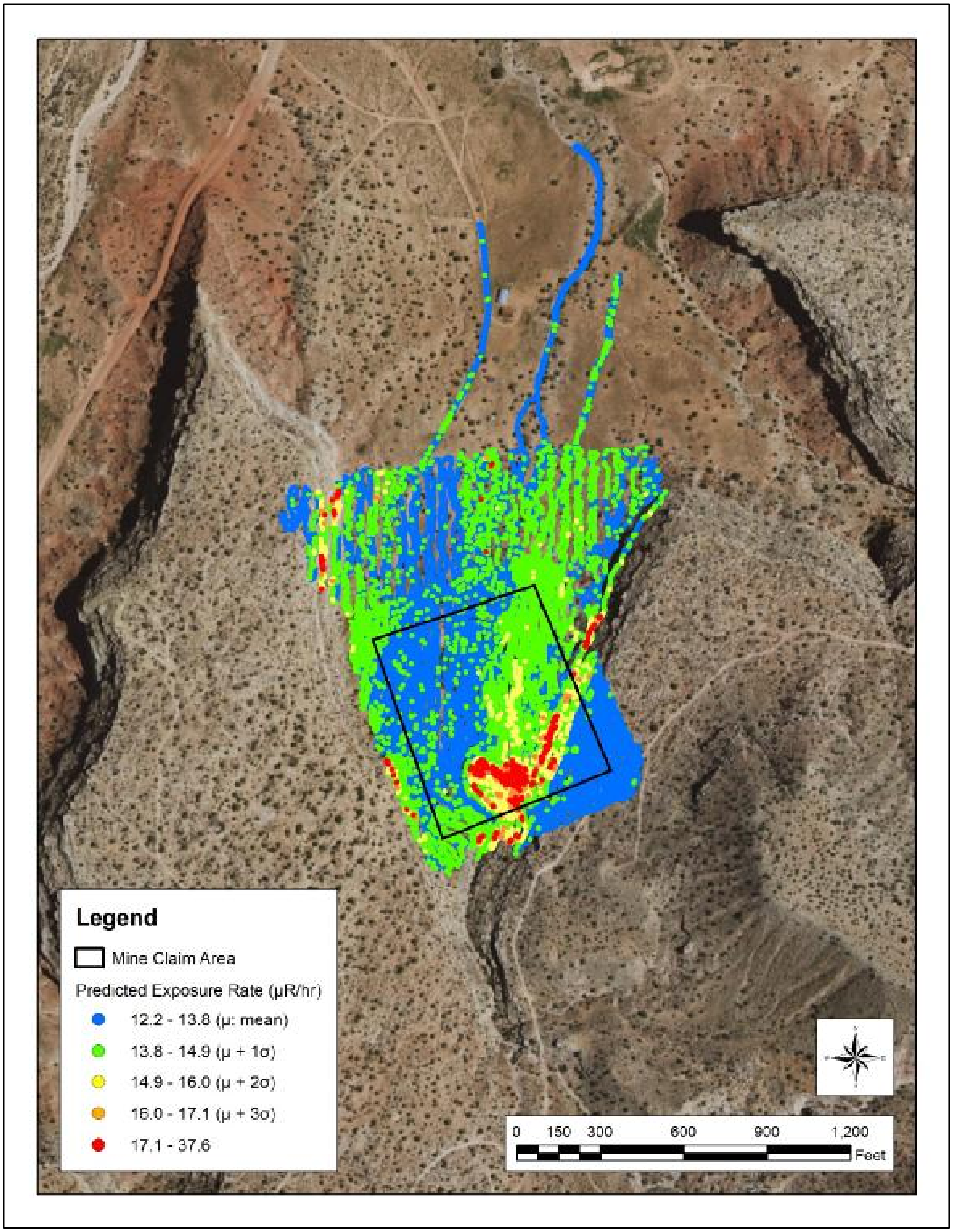


Figure 12. Predicted exposure rates in the Survey Area.

4.0 Deviations to RSE Work Plan

The RSE Work Plan specifies that the comparison of gamma count rates and radium concentrations in surface soils was to occur in 900 square foot areas. Field personnel adjusted the areas as necessary, to minimize the variability of gamma count rates observed, particularly where the spatial distribution of waste rock was heterogeneous.

5.0 Conclusions

The findings of the RSE pertaining to these activities are:

- The horizontal extent and magnitude of mining-related materials were delineated sufficiently to support additional characterization of the subsurface.
- Elevated count rates were observed on 1) the walls of ridges on the west, east and southeast edges of the mine claim and 2) waste rock that was exposed in a disposal cell in the southeast corner of the mine claim.
- Two potential Background Reference Areas were established.
- The relationship between gamma count rates and concentrations of radium-226 in surface soils (0 to 0.5 ft below ground surface) is described by a linear model:

$$\text{Gamma Count Rate (cpm)} = 609 \times [\text{radium-226 (pCi/g)}] + 12683$$

- The distribution of concentrations of radium-226 in surface soils predicted using this model is rightward tailed. The values in the Survey Area range from -11.9 to 126.9 pCi/g, with a central tendency (median) of -4.5 pCi/g.
- The thorium series radionuclides do not appear to affect the prediction of concentrations of radium-226 from gamma count rates.
- There is evidence that the uranium series radionuclides are in equilibrium, but not secular equilibrium.
- The relationship between gamma count rates and exposure rates is described by a linear regression model:

$$\text{Exposure Rate } (\mu\text{R/h}) = \text{Gamma Count Rate (cpm)} \times 3\text{x}10^{-4} + 10.553$$

- The distribution of exposure rates predicted using this model resembles a right-tailed distribution. The values in the Survey Area range from 12.2 to 37.6, with a central tendency (median) of 13.6 μR/h.
- Further work is recommended to support a robust gamma correlation.

6.0 References

MWH, 2016. Navajo Nation AUM Environmental Response Trust, First Phase, Removal Site Evaluation Work Plan, October 24, 2016.

Stantec, 2018. Tsosie 1 Removal Site Evaluation Report, September 2018.

Appendix A Instrument calibration and completed function check forms

ERG

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Certificate of Calibration

Calibration and Voltage Plateau

Meter:	Manufacturer: Ludlum	Model Number:	2221r	Serial Number:	254772
Detector:	Manufacturer: Ludlum	Model Number:	44-10	Serial Number:	PR303727

✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V

✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch Other:

✔ Geotropism ✔ Audio Check

✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC)

Source Distance: ☐ Contact ✔ 6 inches ☐ Other:

Source Geometry: ✔ Side ☐ Below ☐ Other:

Threshold: 10 mV

Window:

Barometric Pressure: 24.75 inches Hg

Temperature: 74 °F

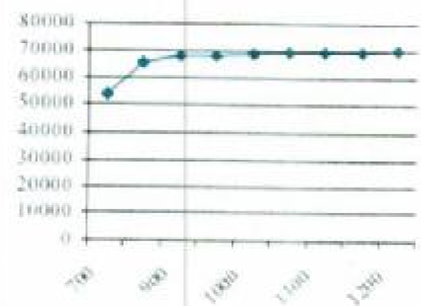
Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	398857	400
x 1000	100	100	100		100
x 100	400	400	400	39913	400
x 100	100	100	100		100
x 10	400	400	400	3992	400
x 10	100	100	100		100
x 1	400	400	400	399	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	53620	
800	64979	
900	67955	
950	67795	
1000	68536	9542
1050	69153	
1100	69331	
1150	69346	
1200	69492	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1000

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932

☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03

☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03

Fluke multimeter serial number: ☐ 87490128

✔ Gamma Source: Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03

☐ Other Source:

Calibrated By: Calibration Date: 7-6-16 Calibration Due: 7-6-17

Reviewed By: Date: 7/20/16

ERG

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	196086
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR295014

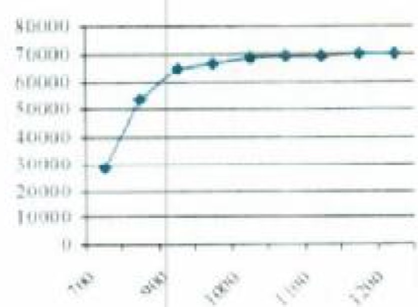
✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V
✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch Other:
✔ Geotropism ✔ Audio Check
✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC) Barometric Pressure: 24.78 inches Hg
Source Distance: ☐ Contact ✔ 6 inches ☐ Other: Threshold: 10 mV Temperature: 74 °F
Source Geometry: ✔ Side ☐ Below ☐ Other: Window: Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	399802	400
x 1000	100	100	100		100
x 100	400	400	400	39989	400
x 100	100	100	100		100
x 10	400	400	400	3999	400
x 10	100	100	100		100
x 1	400	400	400	400	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	28456	
800	53330	
900	64430	
950	66209	
1000	68333	
1050	69077	
1100	69121	8924
1150	69973	
1200	70155	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1100

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932
☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03
☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03

Fluke multimeter serial number: ☐ 87490128
✔ Gamma Source: Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Other Source:

Calibrated By: [signature] Calibration Date: 7 [illegible] 16 Calibration Due: 7-[illegible]-17

Reviewed By: [signature] Date: 7/20/16

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

ERG

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
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Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	196086
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR295014

✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V
✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch ☐ Other:
✔ Geotropism ✔ Audio Check
✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC)

Source Distance: ☐ Contact ✔ 6 inches ☐ Other:
Source Geometry: ✔ Side ☐ Below ☐ Other:

Threshold: 10 mV
Window:

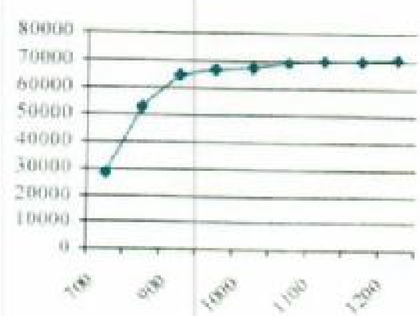
Barometric Pressure: 24.27 inches Hg
Temperature: 78 °F
Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	399386	400
x 1000	100	100	100		100
x 100	400	400	400	39949	400
x 100	100	100	100		100
x 10	400	400	400	3995	400
x 10	100	100	100		100
x 1	400	400	400	399	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	28235	
800	52834	
900	64481	
950	66468	
1000	67321	
1050	69009	
1100	69981	9079
1150	69564	
1200	70538	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1100

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932
☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03
☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03

Fluke multimeter serial number: ☐ 87490128
✔ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Other Source:

Calibrated By:
Reviewed By:

Calibration Date: ~~1 March 17~~ 2/28/17
Calibration Due: ~~1 March 18~~ 2/28/18
Date: 3/1/17

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	138368
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR355763

☑ Mechanical Check ☑ THR/WIN Operation
☑ F/S Response Check ☑ Reset Check
☑ Geotropism ☑ Audio Check
☑ Meter Zeroed ☑ Battery Check (Min 4.4 VDC)

HV Check (+/- 2.5%): ☑ 500 V ☑ 1000 V ☑ 1500 V
Cable Length: ☐ 39-inch ☑ 72-inch ☐ Other:

Source Distance: ☐ Contact ☑ 6 inches ☐ Other:
Source Geometry: ☑ Side ☐ Below ☐ Other:

Threshold: 10 mV
Window:

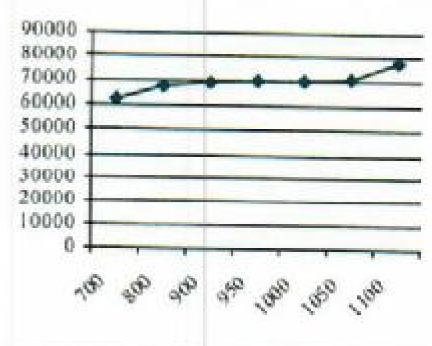
Barometric Pressure: 24.75 inches Hg
Temperature: 76 °F
Relative Humidity: 20 %

Instrument found within tolerance: ☑ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	398875	400
x 1000	100	100	100		100
x 100	400	400	400	39883	400
x 100	100	100	100		100
x 10	400	400	400	3988	400
x 10	100	100	100		100
x 1	400	400	400	398	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	62275	
800	68049	
900	69726	
950	70112	9509
1000	70068	
1050	71042	
1100	77619	

Voltage Plateau



Comments: Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 950

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ☑ 201932
Fluke multimeter serial number: ☐ 87490128
☐ Alpha Source: Th-230 sn: 4098-03@12,800dpm/6,520 cpm (1/4/12)
☑ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Beta Source: Tc-99 sn: 4099-03@17,700dpm/11,100cpm(1/4/12)
☐ Other Source:

Calibrated By: [signature] Calibration Date: 9/7-17 Calibration Due: 9-17-18

Reviewed By: T.Tck— Date: 09/08/17

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This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
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Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	138368
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR154615

✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V

✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch ☐ Other:

✔ Geotropism ✔ Audio Check

✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC) Barometric Pressure: 24.78 inches Hg

Source Distance: ☐ Contact ✔ 6 inches ☐ Other: Threshold: 10 mV Temperature: 74 °F

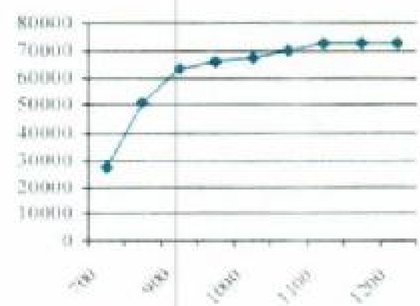
Source Geometry: ✔ Side ☐ Below ☐ Other: Window: Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	398436	400
x 1000	100	100	100		100
x 100	400	400	400	39845	400
x 100	100	100	100		100
x 10	400	400	400	3984	400
x 10	100	100	100		100
x 1	400	400	400	399	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	26998	
800	51037	
900	63340	
950	65550	
1000	67410	
1050	70113	
1100	72217	
1150	72561	9216
1200	72337	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1150

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932 Fluke multimeter serial number: ☐ 87490128

☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03 ✔ Gamma Source: Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03

☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03 ☐ Other Source:

Calibrated By: Calibration Date: 7-6-16 Calibration Due: 7-6-17

Reviewed By: Date: 7/20/16

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A-1997

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Environmental Restoration Group, Inc
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Certificate of Calibration

Calibration and Voltage Plateau

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	282971
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR320678

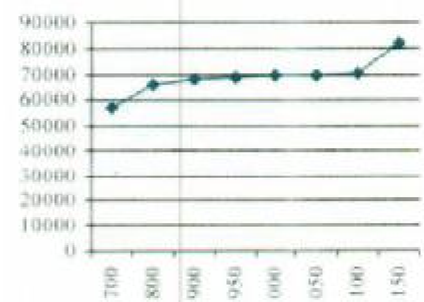
✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V
✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch ☐ Other:
✔ Geotropism ✔ Audio Check
✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC) Barometric Pressure: 24.63 inches Hg
Source Distance: ☐ Contact ✔ 6 inches ☐ Other: Threshold: 10 mV Temperature: 75 °F
Source Geometry: ✔ Side ☐ Below ☐ Other: Window: Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	399936	400
x 1000	100	100	100		100
x 100	400	400	400	39984	400
x 100	100	100	100		100
x 10	400	400	400	3998	400
x 10	100	100	100		100
x 1	400	400	400	400	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	57641	
800	65850	
900	68414	
950	68639	
1000	69410	9773
1050	69358	
1100	70301	
1150	81822	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1000

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932 Fluke multimeter serial number: ☐ 87490128
☐ Alpha Source: Th-230 sn: 4098-03 @ 12,800dpm/6,520 cpm (1/4/1 ☐ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Beta Source: Tc-99 sn: 4099-03 @ 17,700dpm/11,100cpm (1/4/12 ☐ Other Source:

Calibrated By: [signature] Calibration Date: 3-13-17 Calibration Due: 3-13-18

Reviewed By: [signature] Date: 14 March 2017

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

ERG

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer: Ludlum	Model Number: 2221r	Serial Number: 254757
Detector:	Manufacturer: Ludlum	Model Number: 44-10	Serial Number: PR292690

☐ Mechanical Check ☐ THR/WIN Operation HV Check (+/- 2.5%): ☐ 500 V ☐ 1000 V ☐ 1500 V
☐ F/S Response Check ☐ Reset Check Cable Length: ☐ 39-inch ☑ 72-inch ☐ Other:
☐ Geotropism ☐ Audio Check
☐ Meter Zeroed ☐ Battery Check (Min 4.4 VDC)

Source Distance: ☐ Contact ☑ 6 inches ☐ Other:
Source Geometry: ☑ Side ☐ Below ☐ Other:

Threshold: 10 mV
Window:

Barometric Pressure: 24.75 inches Hg
Temperature: 75 °F
Relative Humidity: 26 %

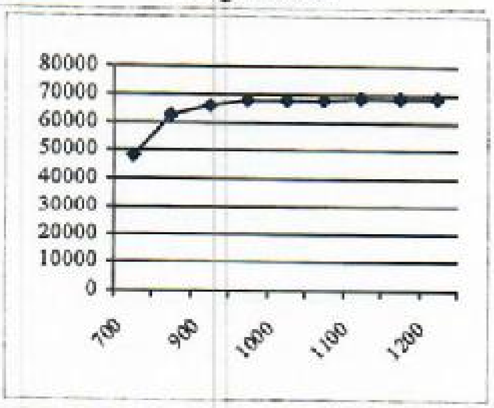
Instrument found within tolerance: ☑ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400				
x 1000	100				
x 100	400				
x 100	100				
x 10	400				
x 10	100				
x 1	400				
x 1	100				

See Ludlum Cal Sheet

High Voltage	Source Counts	Background
700	48461	
800	62632	
900	66021	
950	67593	
1000	67720	9478
1050	67893	
1100	68340	
1150	68592	
1200	68684	

Voltage Plateau



Comments: Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1000

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ☑ 201932
Fluke multimeter serial number: ☐ 87490128
☐ Alpha Source: Th-230 sn: 4098-03@12,800dpm/6,520 cpm (1/4/12)
☑ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Beta Source: Tc-99 sn: 4099-03@17,700dpm/11,100cpm(1/4/12)
☐ Other Source:

Calibrated By: [signature] Calibration Date: 5-21-17 Calibration Due: 5-21-18

Reviewed By: T. [signature] Date: 08/21/17

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

www.ludlums.com

Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

ACCREDITED CERT # 4084.01

Customer ERG

ORDER NO. 20315528/452181

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 254757

Mfg. ______ Model ______ Serial No. ______

Cal. Date 25-Jul-17 Cal Due Date 25-Jul-18 Cal. Interval 1 Year Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 74 °F RH 47 % Alt 706.0 mm Hg

☐ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☑ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck.
☑ Calibrated in accordance with LMI SOP 14.8 ☐ Calibrated in accordance with LMI SOP 14.9

Instrument Volt Set 1500 V Input Sens. 10 mV Det. Oper. ______ V at ______ mV Threshold Dial Ratio 100 = 10 mV

☐ HV Readout (2 points) Ref./Inst. 500 / 500 V Ref./Inst. 1500 / 1502 V

COMMENTS:

Calibrated with 39" cable.
Calibrated with Window in "OUT" position.
Firmware: 261027

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1000	400 Kcpm	N/A	400
X 1000	100 Kcpm		100
X 100	40 Kcpm		400
X 100	10 Kcpm		100
X 10	4 Kcpm		400
X 10	1 Kcpm		100
X 1	400 cpm		400
X 1	100 cpm		100

*Uncertainty within ± 10% C.F. within ± 20%

ALL Range(s) Calibrated Electronically

Digital Readout REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	Log Scale REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
400 Kcpm	N/A	39956 (0)	500 Kcpm	N/A	500 Kcpm
40 Kcpm		3995	50 Kcpm		50
4 Kcpm		400	5 Kcpm		5
400 cpm		40	500 cpm		500 cpm
40 cpm		4	50 cpm		50

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 ISO/IE 17025:2005(E) State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 009 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 2324/2521 ☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ 2169CP ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be ☐ T-304 Ra-226 ☐ Y982

☐ Alpha S/N ______ ☐ Beta S/N ______ ☐ Other ______

☑ m 500 S/N 201934 ☐ Oscilloscope S/N ______ ☑ Multimeter S/N 92780460

Calibrator Josie Ruiz Josie Ruiz Title Technician Date 25 July 17

QC'd By [signature] Title Service Dept QC Date 26 Jul 17

FORM SC22A 12/12/2016 Page 1 of 1

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed: ______

Reuter-Stokes

Calibration Certificate

Reuter-Stokes certifies that the Environmental Radiation Monitor, identified below, has been calibrated for output using the shadow shield technique*, and calibrated with radiation sources traceable to the National Institute of Standards and Technology.

Sensor Type:	100 R/Hr
Serial Number:	1000992
Calibration Date:	03/16/2017
Sensitivity:	-2.281E-8 A/R/h

Richard J. Bitley
Authorized Signature

*Calibration Procedure: RS-SOP 238.1

Reuter-Stokes

Calibration Data

Sensor Type:	100 R/Hr	Source (CS-137):	BB-400
Serial Number:	1000992	Date of Certification:	12/01/1994
Calibration Date:	03/16/2017	Exposure Rate at 1 meter:	4.226 mR/h

Customer Name: STOCK

Sensitivity (Ra-226): -2.281E-8 A/R/h

Distance		Exposure Rate	P+S+A	S+A	P	k(CS-137)
Feet	cm	μR/h	A	A	A	A/R/h
12	366	185.323	-5.403E-12	-1.164E-12	-4.239E-12	-2.287E-08
14	427	135.592	-4.135E-12	-1.012E-12	-3.123E-12	-2.303E-08
16	488	103.384	-3.294E-12	-9.029E-13	-2.391E-12	-2.313E-08
18	549	81.348	-2.708E-12	-8.209E-13	-1.887E-12	-2.319E-08

k(CS-137) = -2.306E-8 A/R/h

$\bar{k}$ = -2.306E-8 A/R/h

k(Ra-226) = 0.9892 k(CS-137)

σ = 1.39E-10 A/R/h

k(Ra-226) = -2.281E-8 A/R/h

$V = \frac{\sigma}{\bar{k}} =$ -0.603%

By: John Lak

Date: 3-17-17

ERG

Single-Channel Function Check Log

Environmental Restoration Group Inc
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	254772
Cal. Due Date:	7-19-17

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR303727
Cal. Due Date:	7-19-17

Comments:
NNERT

Source: Cs-137 Activity: 5.12 uCi Source Date: 6-6-94 Distance to Source: 6 Inches

Serial No.: 333-94 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s): Project reference points
10-4-16	0925	5.7	1003	99	45635	6378	39254	NW	Tsosie 1
10-4-16	1720	5.6	1008	99	46987	6720	40267	NW	Comfort Suites Parking lot
10-5-16	0620	5.7	1007	99	47335	6804	40531	NW	Comfort Suites Parking lot
10-5-16	1542	5.5	999	99	45375	6342	39033	NW	Tsosie 1
10-6-16	0900	5.5	1003	99	43705	6364	37341	NW	Tsosie 1
10-6-16	1713	5.5	1000	99	44279	6053	38226	NW	Comfort Suites Parking Lot
10-7-16	0902	5.5	1006	99	44457	6003	38404	NW	Oak 124/125
10-7-16	1627	5.5	999	99	46103	6751	39352	NW	Comfort Suites Parking Lot
10-8-16	0903	5.6	1003	99	45434	6365	39069	NW	Red Valley Intersection
10-8-16	1653	5.5	999	99	45195	6467	38718	NW	Comfort Suites Parking Lot
10-10-16	0958	5.5	1004	100	42755	5579	37176	NW	Oak 124/125
10-10-16	1919	5.5	959	99	51651	6930	44721	NW	Oak 124/125

Reviewed by: MP Review Date: 11/29/16

(2)

ERG

Single-Channel Function Check Log

Environmental Restoration Group Inc
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	196086
Cal. Due Date:	7-9-17

DETECTOR	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	PR 295014
Cal. Due Date:	7-9-17

Comments:
NNEAT

Source: Cs-137 Activity: 5.12 uCi Source Date: 6-16-94 Distance to Source: 6 Inches

Serial No.: 333-94 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
10-4-16	0936	5.5	1102	100	46804	6042	40762	NW	Project Reference Points
10-4-16	1720	5.4	1106	100	46032	6898	39134	NW	Tsosie 1
10-5-16	0622	5.4	1109	101	45794	6834	38960	NW	Comfort Suites Parking Lot
10-5-16	1748	5.3	1097	99	46608	6021	40587	NW	Comfort Suites Parking Lot
10-6-16	0904	5.4	1103	100	44521	6273	38248	NW	Tsosie 1
10-6-16	1718	5.3	1099	100	45178	6311	38867	NW	Comfort Suites Parking Lot
10-7-16	0859	5.4	1104	100	44101	5226	38875	NW	Comfort Suites Parking Lot
10-7-16	1633	5.4	1098	99	44930	6832	38098	NW	Oak 124/125
10-8-16	0908	5.4	1104	100	45110	6201	38909	NW	Comfort Suites Parking Lot
10-8-16	1658	5.3	1098	99	45810	6196	39614	NW	Red Valley Intersection
10-12-16	1331	5.4	1099	99	46496	6519	39977	NW	Comfort Suites Parking Lot
10-12-16	1614	5.4	1097	100	44509	6060	38449	NW	Barton 3
									Comfort Suites Parking Lot

Reviewed by: MH Review Date: 11/29/16

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	138638
Cal. Due Date:	7-9-17

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR154615
Cal. Due Date:	7-9-17

Comments:
NNERF

Source: Cs-137 Activity: 5.12 uCi Source Date: 6-6-94 Distance to Source: 6 Inches

Serial No.: 333-94 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
10-5-16	0900	5.9	1184	165	46216	7136	39080	NW	TSosie 1
10-5-16	1546	5.7	1198	185	45357	6266	39091	NW	TSosie 1
10-8-16	0833	5.7	1182	164	45202	6004	39198	NW	Intersection to Oak 124 @ Red Valley
10-8-16	1702	5.6	1128	112	49505	6399	43106	NW	Comfort Suites Farmington
10-12-16	1334	5.7	1139	122	46929	6807	40122	NW	Barton 3
10-12-16	1610	5.6	1130	115	44390	6093	38297	NW	Comfort Suites Farmington
10-13-16	0917	5.6	1129	110	44223	7099	37124	NW	Alonzo
10-13-16	1910	DID NOT USE						NW	Comfort Suites Farmington
10-15-16	0929	5.7	1173	160	47369	7023	40346	NW	Harvey Blackwater
10-15-16	1821	5.7	1173	163	42767	5169	37598	NW	Hat Rock Inn lot
10-26-16	0755	5.7	1223	202	50474	8000	42474	NW	Boyd Tsosie
10-26-16	1540	5.6	1152	138	45033	6331	38702	NW	Boyd Tsosie

Reviewed by: [signature] Review Date: 11/29/16

ERG Form ITC.201.A

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	282971
Cal. Due Date:	3-13-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR320678
Cal. Due Date:	3-13-18

Comments:
NNZRT - Soils Characterization

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
6-20-17	1334	5.7	1046	100	37108	6411	30697	NW	Charles Keith
6-20-17	1651	5.6	1038	98	36894	5907	30987	NW	Charles Keith
6-21-17	0720	5.7	1045	100	38258	6568	31690	NW	Charles Keith
6-21-17	1400	5.5	1035	99	36426	5473	30953	NW	Charles Keith
6-22-17	0732	5.6	1044	100	37058	5300	31758	NW	Charles Keith
6-22-17	1710	5.5	1042	99	37441	6708	30733	NW	Tsosie 1
6-24-17	0901	5.6	1047	100	38218	7111	31107	NW	Tsosie 1
6-24-17	1655	5.5	1041	99	36728	6080	30648	NW	Tsosie 1
6-26-17	0852	5.6	1048	100	38982	7442	31540	NW	Tsosie 1
6-26-17	1632	5.4	1040	99	38932	7627	31305	NW	Tsosie 1
6-27-17	1238	5.5	1047	100	36268	5913	30355	NW	Eunice Becenti
6-27-17	1403	5.5	1044	100	36016	5567	30449	NW	Eunice Becenti

Reviewed by: [signature] Review Date: 6/29/17

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum Stokes
Model:	RS-S131-200-ER000U
Serial No.:	100092
Cal. Due Date:	3-16-18

DETECTOR	
Manufacturer:	Reuter Stokes
Model:	RS-S131-200-ER000U
Serial No.:	1000992
Cal. Due Date:	3-16-18

Comments:
NMERS - HPIC

Source: Cs-137 Activity: 4 uCi Source Date: 4-12-96 Distance to Source: Contact housing

Serial No.: 544-96 Emission Rate: NA cpm/emissions

← μR/h →

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
6-26-17	0630	8.18	401.2	NA	~14.2	~8.5	~5.7	NW	Home2 Suites room: Farmington
6-26-17	2100	7.93	401.1	NA	~14.5	~8.6	~5.9	NW	Hilton Garden Inn room: Gallup
6-29-17	0850	8.25	401.3	NA	~18	~12.5	~5.5	NW	Section 26
6-30-17	0740	8.21	401.3	NA	~19	~13.4	~5.6	NW	ERG office

NW 6-30-17

Reviewed by: MM Review Date: 10/9/17

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	196086
Cal. Due Date:	2-28-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR295014
Cal. Due Date:	2-28-18

Comments:
NNERT

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
6-26-17	0900	6.2	1109	101	38088	6806	31282	NW	Tsosie 1
6-26-17	1619	6.0	1095	99	38337	6166	32171	NW	Tsosie 1
6-27-17	1247	6.1	1108	100	36994	5161	31833	NW	Eunice Becenti
6-27-17	1358	6.0	1102	101	36293	5017	31276	NW	Eunice Becenti
6-28-17	0730	6.1	1111	101	36814	5111	31703	NW	Eunice Becenti
6-28-17	1752	5.9	1101	100	37391	5304	32087	NW	Gallup Garden Inn lot
6-29-17	0908	5.9	1106	100	35972	6002	29970	NW	Section 26
6-30-17	0855	5.9	1107	100	40749	9057	31692	NW	ERG office
						7-5-17			

Reviewed by: [signature] Review Date: 10/19/17

ERG Form ITC.201.A

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	138368
Cal. Due Date:	9-7-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR355763
Cal. Due Date:	9-7-18

Comments:
NNERT

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 Inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
9-12-17	0914	5.4	950	101	36935	6331	30604	NW	Barton 3
9-12-17	1432	5.3	944	99	38043	6468	31575	NW	Tsosie 1
9-13-17	0906	5.4	951	99	37146	6538	30608	NW	Alonzo
9-13-17	1600	5.3	944	99	35587	5991	29596	NW	Barton 3
9-14-17	0909	5.4	950	100	36080	6176	29904	NW	NA-0904
9-14-17	1255	5.3	948	100	36099	5764	30335	NW	NA-0904
9-15-17	0920	5.4	954	101	35208	5551	29657	NW	Eunice Becenti
9-15-17	1729	5.3	957	109	35937	5261	30676	NW	Eunice Becenti
9-19-17	0831	5.4	958	105	36467	6034	30433	NW	Section 26 @ trailer
9-19-17	1453	5.3	946	99	44454	14748	29706	NW	Section 26 @ corral
9-20-17	0736	5.3	953	102	37676	6987	30689	NW	Mexican Hat
9-20-17	1611	5.2	947	100	36842	6252	30590	NW	Mexican Hat

Reviewed by: [signature] Review Date: 10/9/17

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	254757
Cal. Due Date:	~~8-21-18~~ NW 7-25-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR292690
Cal. Due Date:	8-21-18

Comments:
UNEAT

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
9-12-17	0930	5.8	1008	114	37751	6287	31464	NW	Barton 3
9-12-17	1433	5.8	1003	111	37908	6408	31500	NW	Tsosie 1
9-13-17	0914	5.8	1007	110	37894	6629	31265	NW	Alongo
9-13-17	1603	5.7	993	101	36184	5750	30434	NW	Barton 3
9-14-17	0903	5.8	1000	102	37308	6025	31283	NW	NA-0904
9-14-17	1250	5.8	996	102	36293	6018	30275	NW	NA-0904
9-15-17	0925	5.9	1002	104	35475	5289	30186	NW	Eunice Becenti
9-15-17	1725	5.8	959	105	36724	4764	31960	NW	Eunice Becenti
9-16-17	0908	5.8	1005	104	36645	5582	31063	NW	Eunice Becenti
9-16-17	1258	5.7	1001	106	37099	5588	31511	NW	Eunice Becenti @ asphalt road

Reviewed by: MM Review Date: 10/9/17

Appendix B Exposure Rate Measurements

Date and Time	Exposure Rate (mR/h)[a]	Location
06/26/2017 10:09	0.0126	Correlation Location 1
06/26/2017 10:10	0.0127	Correlation Location 1
06/26/2017 10:11	0.0132	Correlation Location 1
06/26/2017 10:12	0.0130	Correlation Location 1
06/26/2017 10:13	0.0128	Correlation Location 1
06/26/2017 10:14	0.0131	Correlation Location 1
06/26/2017 10:15	0.0134	Correlation Location 1
06/26/2017 10:16	0.0134	Correlation Location 1
06/26/2017 10:17	0.0132	Correlation Location 1
06/26/2017 10:18	0.0132	Correlation Location 1
06/26/2017 10:53	0.0229	Correlation Location 2
06/26/2017 10:54	0.0231	Correlation Location 2
06/26/2017 10:55	0.0230	Correlation Location 2
06/26/2017 10:56	0.0236	Correlation Location 2
06/26/2017 10:57	0.0236	Correlation Location 2
06/26/2017 10:58	0.0231	Correlation Location 2
06/26/2017 10:59	0.0233	Correlation Location 2
06/26/2017 11:00	0.0231	Correlation Location 2
06/26/2017 11:01	0.0232	Correlation Location 2
06/26/2017 11:43	0.0173	Correlation Location 3
06/26/2017 11:44	0.0179	Correlation Location 3
06/26/2017 11:45	0.0185	Correlation Location 3
06/26/2017 11:46	0.0177	Correlation Location 3
06/26/2017 11:47	0.0179	Correlation Location 3
06/26/2017 11:48	0.0182	Correlation Location 3
06/26/2017 11:49	0.0183	Correlation Location 3
06/26/2017 11:50	0.0181	Correlation Location 3
06/26/2017 11:51	0.0185	Correlation Location 3
06/26/2017 11:52	0.0185	Correlation Location 3
06/26/2017 12:20	0.0197	Correlation Location 4
06/26/2017 12:21	0.0210	Correlation Location 4
06/26/2017 12:22	0.0208	Correlation Location 4
06/26/2017 12:23	0.0211	Correlation Location 4
06/26/2017 12:24	0.0214	Correlation Location 4
06/26/2017 12:25	0.0211	Correlation Location 4
06/26/2017 12:26	0.0209	Correlation Location 4
06/26/2017 12:27	0.0211	Correlation Location 4
06/26/2017 12:28	0.0214	Correlation Location 4
06/26/2017 12:29	0.0215	Correlation Location 4
06/26/2017 13:13	0.0141	Correlation Location 5
06/26/2017 13:14	0.0151	Correlation Location 5
06/26/2017 13:15	0.0148	Correlation Location 5
06/26/2017 13:16	0.0151	Correlation Location 5
06/26/2017 13:17	0.0154	Correlation Location 5
06/26/2017 13:18	0.0146	Correlation Location 5
06/26/2017 13:19	0.0148	Correlation Location 5
06/26/2017 13:20	0.0147	Correlation Location 5
06/26/2017 13:21	0.0147	Correlation Location 5
06/26/2017 13:22	0.0152	Correlation Location 5

Tsosie 1 Exposure Rate Measurements for Correlation

a. Results reported are averages of 60, 1-second measurements

Appendix C Technical Memo from ERG to Stantec. "Statistical Analysis of the Navajo Trustee Mines Dataset: Multivariate Linear Regression for Evaluation of Gamma Correlation with Ra-226 and Evaluation of Secular Equilibrium Between Ra-226 and Th-230"

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113

ph: (505) 298-4224
fax: (505) 797-1404
www.ERGoffice.com

Memo

To: Kirsty Woods, Program Director, Stantec

From: Liz Ruedig, PhD, CHP, and Mike Schierman, CHP, Environmental Restoration Group

Date: 7/31/2018

Re: Statistical Analysis of the Navajo Trustee Mines Dataset: Multivariate Linear Regression for Evaluation of Gamma Correlation with Ra-226 and Evaluation of Secular Equilibrium Between Ra-226 and Th-230

Multivariate Linear Regression for Evaluation of Gamma Count Rate with Ra-226 Concentrations in Surface Soil

Due to a large number of reviewer comments at the sixteen Navajo Trust Abandoned Uranium Mines (AUMs) concerning the influence of gamma-emitting radionuclides not within the uranium-238 decay series on the correlation between dynamic gamma count rate and soil concentration of radium-226, Environmental Restoration Group has performed multivariate linear regression (MLR), relating gamma count rate to multiple soil radionuclides simultaneously. MLR models the influence of a set of predictor variables (in this case, soil concentrations of several gamma-emitting radionuclides, or surrogates for these radionuclides) on a single response variable (in this case, dynamic gamma count rate), accounting for the influence of each predictor variable upon the response variable independently of the other predictor variables within the set.

In a MLR, it is possible to distinguish from a large set of variables the subset that significantly predicts a response variable. This is done by evaluating potential models on a number of criteria:

1. **The multi-collinearity of predictor variables.**

   Predictor variables that are linearly related to each other (i.e., variables y and x, where y may also be mathematically expressed as some multiple of x) produce a condition known as multicollinearity, where the matrix math used to solve the multivariate linear regression becomes irreducible. A physical example of multicollinearity occurs when modelling the influence of two radionuclides in equilibrium with each other (e.g., Th-230 and Ra-226) on a single response variable (e.g., gamma count rate). In order to compute a mathematical solution to the regression model, one of the multicollinear variables must be removed from the regression matrix. The multicollinear variables are identifiable by a large variance inflation factor (VIF), typically greater than 7, but in cases of near-perfect multicollinearity, often much greater than this value (e.g., > 100).

   It is also possible to identify multicollinear predictor variables by regressing two suspect variables upon each other. A high degree of correlation (i.e., $p < 0.05$ and high adjusted R^2) between the two variables suggests that the predictor variables are multicollinear, and that one variable should be eliminated from the multivariate regression prior to analysis.

2. **The p-value of predictor variables**

   For a variable to be considered a significant predictor of the response variable, the p-value of its slope (as calculated in an ANOVA table) must be significant (i.e., $p < 0.05$). In a MLR, the adjusted R^2 value for individual predictor variables is not indicative of overall model quality.

For the Navajo Trust AUMs there are three potential gamma-contributing radionuclides (defined as radionuclides that emit gamma radiation, or whose short-lived decay products emit gamma radiation) present in soil: thorium-232, radium-226 and, thorium-228. Thorium-230, which does not emit gamma radiation, was excluded as a potentially significant gamma-contributing radionuclide.

A MLR model: gamma = radium-226 + thorium-228 + thorium-232 was run for each AUM. For 15 of the 16 mines, thorium-232 and thorium-228 were multicollinear. On this basis, thorium-228 was excluded from the MLR. No multicollinearity was detected at Barton 3. However, none of the predictor variables was a significant predictor of gamma count rate ($p > 0.05$) for the complete model. As such, analysis for all 16 AUMs proceeded by removing thorium-228 from the set of predictor variables and running a new MLR model: gamma = radium-226 + thorium-232. None of the 16 models exhibited multicollinearity with the reduced model. After accounting for the effect of radium-226, thorium-232 was not a significant predictor of gamma count rate at any of the 16 AUMs. Radium-226 was a significant predictor ($p < 0.05$) of gamma count rate (after accounting for the influence of thorium-232 and thorium-228) at some of the AUMs (six of 16 AUMs).

Since neither predictor variable (thorium-232 or radium-226) was unambiguously a predictor in the MLR, two univariate regression models were performed as a final step: gamma = radium-226 and gamma = thorium-232. Thorium-232 was a significant predictor of gamma count rate ($p < 0.05$) only at Standing Rock, which is not unexpected given the geological conditions at this AUM. At all other sites, thorium-232 (and thorium-228 by association) were not significant predictors of gamma count rate ($p > 0.05$). By way of contrast, radium-226 was a significant predictor of the gamma count rate ($p < 0.05$) at 13 of the 16 AUMs. At three AUMs (Mitten, NA-0928, and Tsosie 1) none of the measured radionuclides significantly predicted the gamma count rate. Additionally, the adjusted R^2 values for the correlation models at the three AUMs, plus Claim 28, fail to meet the specified data quality objective (DQO) of greater than 0.8.

The failure to construct statistically defensible correlation models at four AUMs has been identified as a data gap in the relevant AUM report. The unsatisfactory correlation result at these locations is likely due to the small number of correlation locations, or environmental conditions at the AUMs (e.g., spatial heterogeneity in radionuclide concentration in soil, topographic features influencing gamma count rate, etc.), or some combination thereof.

Note that while the statistical measures (i.e., conformance with the study DQO of $R^2 > 0.8$) associated with these regressions can be improved by fitting a power curve to the data, and reporting unadjusted R^2 values, with only five data points at each AUM, ERG does not believe that any statistical correlation model is sufficiently robust to make meaningful inferences concerning soil radium-226 concentration from the gamma scanning data. ERG believes that linear functions – not power curves – best mimic the conceptual model for the physical processes governing the observed data. Fitting any other function in an effort to achieve the study DQO for R^2 is not a statistically rigorous approach, and improving R^2 does not commensurately improve a statistical model's predictive ability. Figure *1* compares the result of fitting a linear versus a power function to the available correlation data for one AUM (Hoskie Tso); the other AUM results are similar.

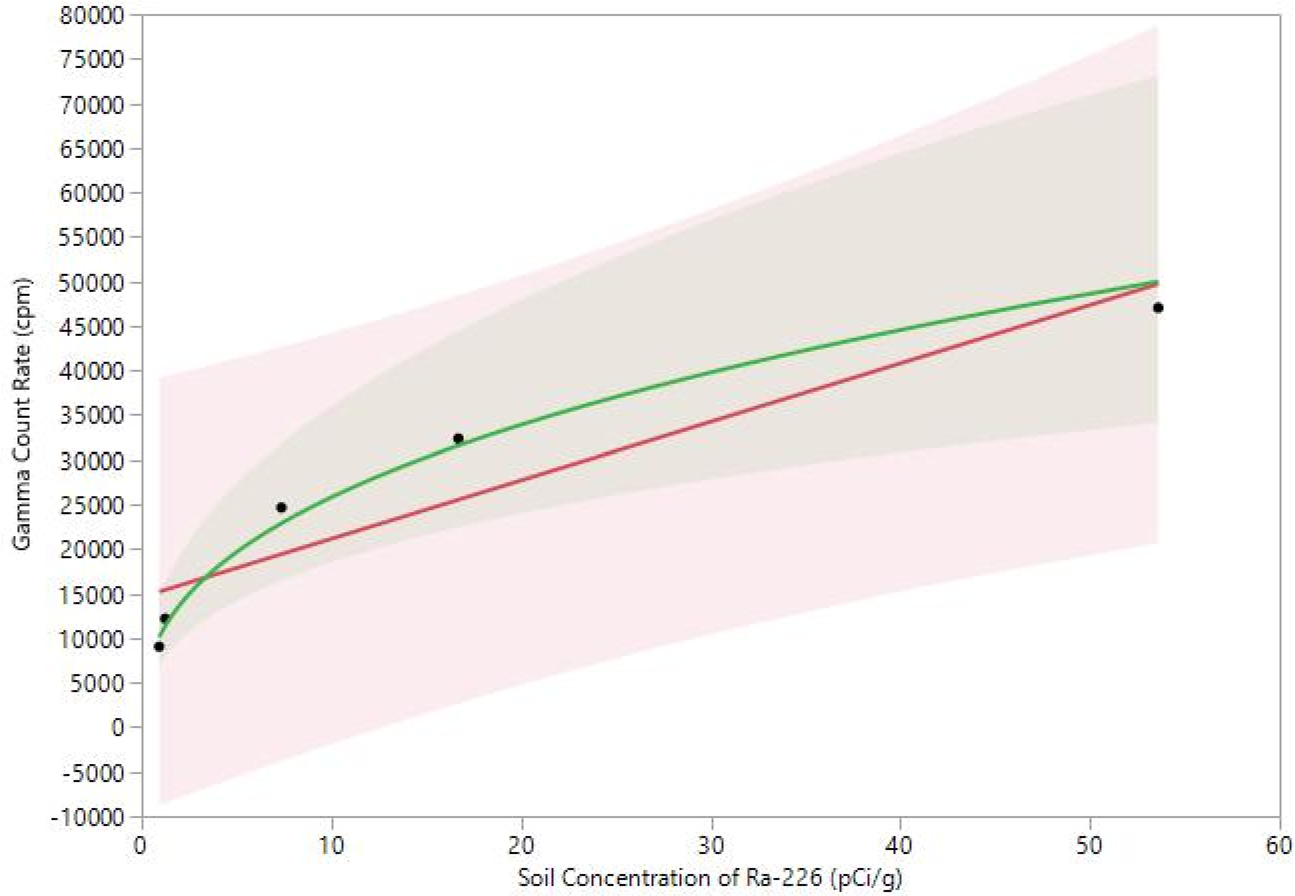


Figure 1. Regression models (linear versus power curve) for gamma count rate regressed on radium-226 showing 95% UPLs (upper prediction limits). Both models meet the study DQO for adjusted R^2 (greater than 0.8). Gamma count rate is not an especially strong predictor of soil concentration of radium-226 for either function.

ERG has updated the individual AUM reports with linear correlation functions and reported the more robust measures of statistical performance described in this memo.

Evaluation of Secular Equilibrium Between Ra-226 and Th-230

Secular equilibrium is a condition that occurs when the half-life of a decay-product nuclide is significantly shorter than that of its parent nuclide. After a period of ingrowth equal to approximately seven times the half-life of the decay product, the two nuclides effectively decay with the half-life of the parent. When two radionuclides are in secular equilibrium, their activities are equal.

Equilibrium, for the purpose of this report, is defined as a condition whereby a parent nuclide and its decay product are present in the environment at a fixed ratio, but this ratio – for whatever reason – is not a one-to-one relationship indicative of secular equilibrium. Most commonly, an equilibrium condition results from an environmental process which chemically selects for and transports one nuclide (parent or decay product) away from the other nuclide. Because a consistent fraction of one nuclide has been removed, the two nuclides are present at a fixed ratio other than one-to-one.

Determination of secular equilibrium for an AUM can be an important part of the risk assessment process, as the assumed fraction of radium-226 decay products present in the environment greatly influences a hypothetical receptor's radiation dose and mortality risk. However, it is also acceptable and conservative to assume secular equilibrium between radium-226 and its decay products for the purpose of risk assessment, and therefore to avoid the need to conclusively determine the secular equilibrium status of an AUM. Thus, an inconclusive result regarding secular equilibrium is not a study data gap, as the risk assessment phase may still proceed, provided that conservative assumptions are included regarding equilibrium concentrations of radium-226 decay products.

Regardless, the Navajo Nation AUM Environmental Response Trust RSE workplan specified that an evaluation of secular equilibrium would be made at each of the 16 Trust AUMs, and so a robust statistical examination of secular equilibrium status for radium-226 and its decay products at each AUM was conducted. One method of evaluating equilibrium between Ra-226 and Th-230 is to calculate the ratio (φ) between the two nuclides for each soil sample location, i.e.,

$$\varphi = \frac{\left[{}^{226}Ra\right]}{\left[{}^{230}Th\right]}$$

When φ is unity, the two nuclides may be said to be in secular equilibrium. Sometimes, φ is averaged over a number of locations, and if the average is unity, the population of measurement locations is said to be in secular equilibrium. Similarly, if φ is consistently some number other than one, it may be concluded that the measured population is in equilibrium. This approach does not account for the statistical uncertainty associated with making inferences across a population, nor the bias introduced into the measurement by averaging a potentially large number of ratios. It is also difficult to establish defensible cutoffs for whether Ra-226 and Th-230 are in secular equilibrium at a particular site using a ratio approach, as there is no objective basis for concluding, e.g., that φ must be between 0.8 and 1.2 (versus any other range of values for φ) for secular equilibrium to occur.

Due to a large number of reviewer comments concerning secular equilibrium within the RSE reports, Environmental Restoration Group opted to re-evaluate equilibrium at each mine site using a more robust statistical method: simple linear regression. This was done after confirming the methods to analyze Ra-226 (EPA Method 901.1) and Th-230 (alpha spectroscopy following sample digestion with hydrofluoric acid) are both total-activity methods with comparable results (L. Steere, ALS personal email communication, July 25, 2018). Evaluation of secular equilibrium for each mine site proceeded as follows:

1. Construction of a figure that depicts soil concentrations of Th-230 plotted against soil concentrations of Ra-226.

2. Simple linear regression is performed on the dataset; the p-value and the adjusted R^2 are recorded. The resulting linear model and the 95% UCL (upper confidence limit) bands are plotted on the figure generated in step 1.

3. The line y=x is added to the figure generated in step 2 (this line represents a perfect 1:1 ratio between Th-230 to Ra-226, indicative of secular equilibrium).

4. An examination of the model and the figure is made sequentially:

   a. If the p-value for the regression slope is insignificant (i.e., $p > 0.05$) or the adjusted R^2 does not meet the study's data quality objective (Adjusted $R^2 > 0.8$), ERG concludes that there is insufficient evidence to conclude that Ra-226 and Th-230 are in equilibrium (secular or otherwise) therefore, it is listed as inconclusive (no equilibrium). Figure *2* depicts the regression result for an AUM (Mitten) that failed to meet the p-value and adjusted R^2 criteria.

   b. If the p-value for the regression slope is significant (i.e., $p < 0.05$) and the adjusted R^2 meets the DQO (Adjusted $R^2 > 0.8$) there are two possible conditions, which are evaluated via visual examination of the figure generated in step 3.

      i. If the y=x line falls fully within the bounds of the 95% UCL bands on the regression, ERG concludes that there is evidence that Ra-226 and Th-230 are in secular equilibrium at the site. Figure *3* depicts the regression result for an AUM (Harvey Blackwater) where there is evidence that Ra-226 and Th-230 are in secular equilibrium.

      ii. If the y=x line falls partially or completely outside the bounds of the 95% UCL bands on the regression, ERG concludes that there is evidence that Ra-226 and Th-230 are in equilibrium, but not secular equilibrium at the site. Figure *4* depicts the regression result for an AUM (Alongo Mines) where there is evidence that Ra-226 and Th-230 are in equilibrium, but not secular equilibrium.

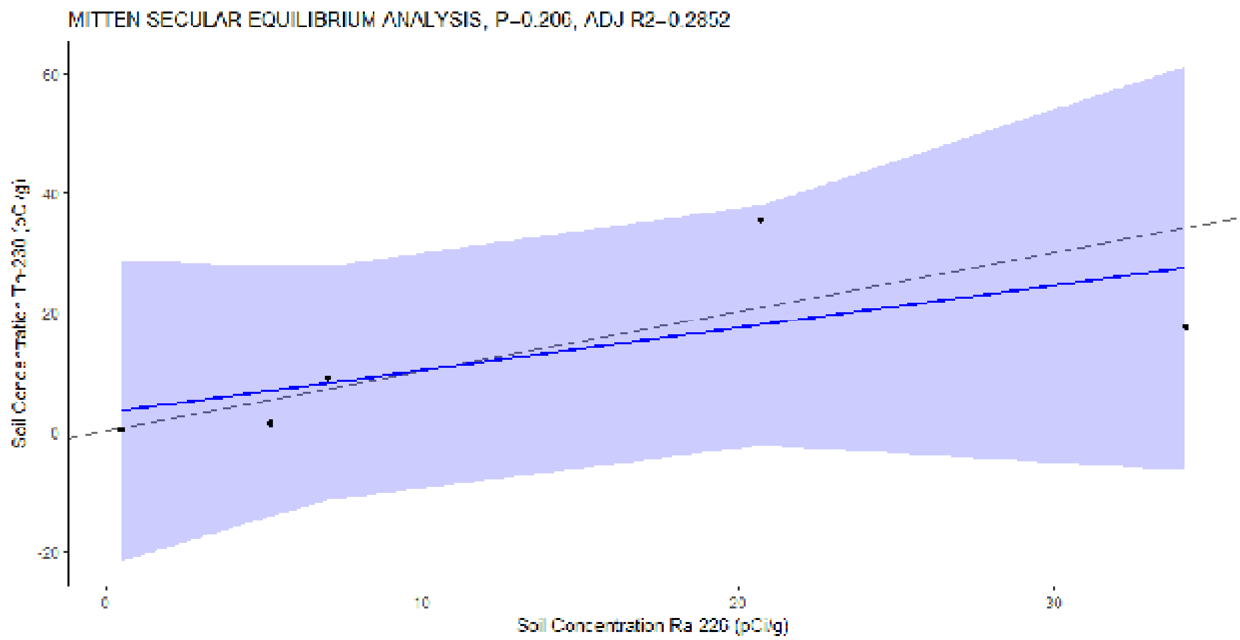


Figure 2. Result for Mitten secular equilibrium analysis, showing failure to meet p-value and adjusted R^2 criteria, i.e., the data are poorly correlated.

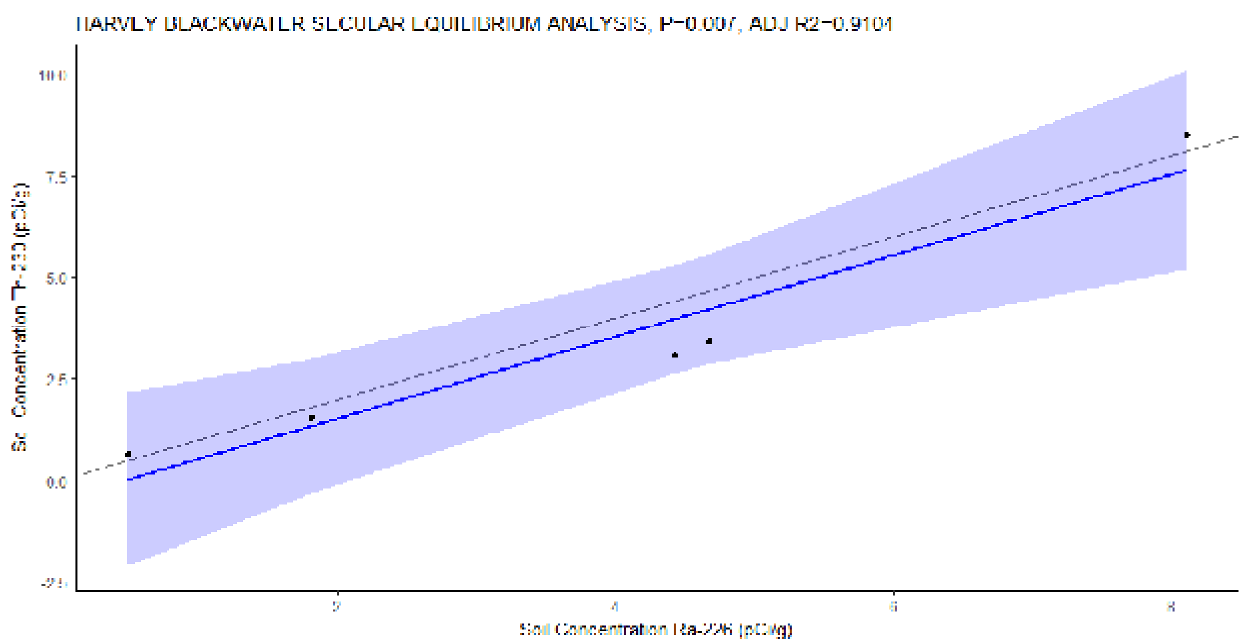


Figure 3. Result for Harvey Blackwater secular equilibrium analysis, showing excellent correlation between the data and the y=x line, i.e., Th-230 and Ra-226 are in secular equilibrium.

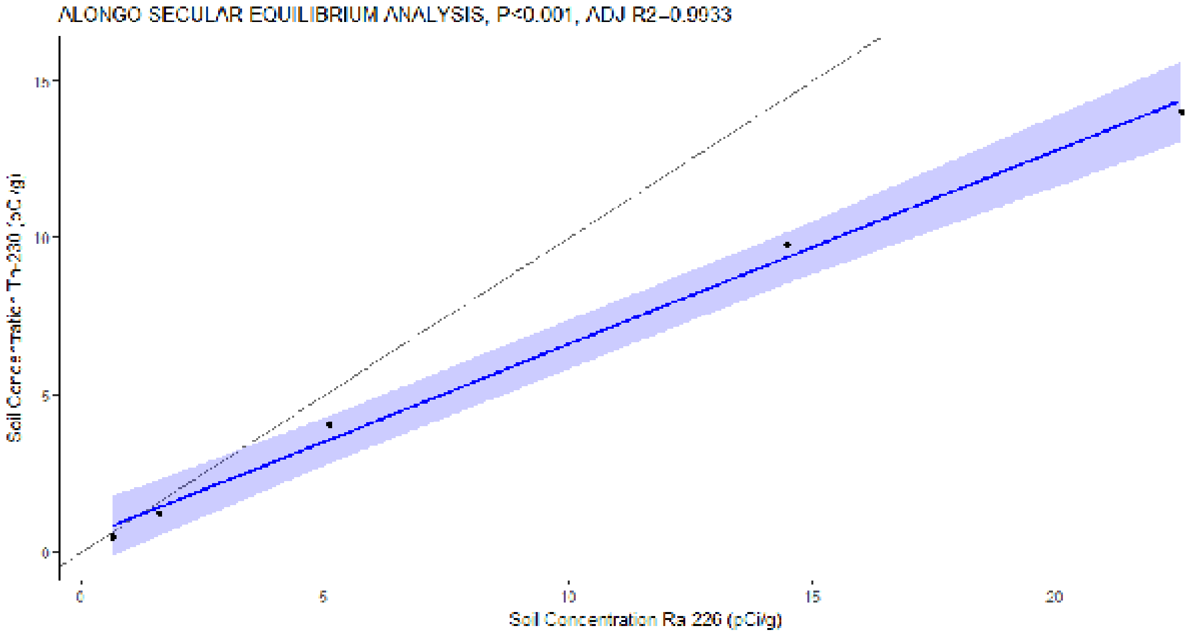


Figure 4. Result for Alongo Mines secular equilibrium analysis, showing excellent correlation between the data, but poor agreement with the y=x line, i.e., Th-230 and Ra-226 are in equilibrium, but not secular equilibrium.

ERG tested for secular equilibrium at each of the 16 Navajo AUMs using the process described above. The results are summarized in Table 1 and in the RSE report for each AUM, respectively. ERG concluded that the data provide evidence that that Ra-226 and Th-230 are in secular equilibrium in soils at two mines (Harvey Blackwater and NA-0928). At one mine (Mitten) there was insufficient evidence to draw any conclusions regarding equilibrium. At the remaining sites, there is evidence that Ra-226 and Th-230 are in equilibrium.

Table 1. Results of secular equilibrium analysis for each of the 16 Navajo Trust AUMs.

Mine	p-value	Adjusted R^2	Conclusion
Alongo Mine	<0.001	0.99	Equilibrium
Barton 3	<0.001	0.98	Equilibrium
Boyd Tisi	<0.001	0.99	Equilibrium
Charles Keith	<0.001	0.99	Equilibrium
Claim 28	<0.001	0.99	Equilibrium
Eunice Becenti	<0.001	0.99	Equilibrium
Harvey Blackwater	0.008	0.91	Secular Equilibrium
Hoskie Tso	<0.001	0.99	Equilibrium
Mitten	0.2	0.29	No Equilibrium
NA-0904	0.001	0.98	Equilibrium
NA-0928	0.002	0.97	Secular Equilibrium
Oak 124-125	<0.001	0.99	Equilibrium
Occurrence B	<0.001	0.98	Equilibrium
Section 26	0.002	0.96	Equilibrium
Standing Rock	0.008	0.91	Equilibrium
Tsosie 1	0.02	0.86	Equilibrium

Appendix D Preliminary Report "Tsosie 1 Abandoned Uranium Mine"

Disclaimer: Data and analytical methods used in this Preliminary Report are superseded by the Final Report.

Radiological Characterization of the Tsosie 1 Abandoned Uranium Mine

Preliminary

January 24, 2018

prepared for:

Stantec Consulting Services Inc.

2130 Resort Drive, Suite 350
Steamboat Springs, CO 80487

prepared by:

Environmental Restoration Group, Inc.

8809 Washington St. NE
Suite 150
Albuquerque, NM 87113

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Acronyms

ANSI	American National Standards Institute
AUM	abandoned uranium mine
BG1	Background Reference Area 1
BG2	Background Reference Area 2
cpm	counts per minute
DQOs	data quality objectives
ERG	Environmental Restoration Group, Inc.
ft	foot
GPS	global positioning system
MDL	method detection limit
µR/h	microRoentgens per hour
pCi/g	picocuries per gram
R^2	Pearson's Correlation Coefficient
RSE	removal site evaluation
σ	standard deviation
Stantec	Stantec Consulting Services Inc.

Executive Summary

This report addresses the radiological characterization of the Tsosie 1 abandoned uranium mine (AUM) located in the Sweetwater Chapter of the Navajo Nation near Red Mesa, Arizona. It documents part of the implementation of the Navajo Nation AUM Environmental Response Trust, First Phase, Removal Site Evaluation Work Plan (RSE Work Plan: MWH, 2016). The work was performed by Environmental Restoration Group, Inc. of Albuquerque, New Mexico and Stantec Consulting Services Inc. (Stantec) on behalf of the Navajo Nation AUM Environmental Response Trust – First Phase.

This report provides 1) the results of a Global Positioning System (GPS)-based gamma radiation (gamma) survey, 2) comparisons of the gamma count rates at this AUM to exposure rates and concentrations of radium-226 in surface soils, and 3) an assessment of equilibrium in the uranium series. The field activities addressed in this report were conducted on October 5 and 6, 2016; June 23 and 26, and September 12, 2017. They included a GPS-based radiological survey of land surfaces over a Survey Area consisting of the mine claim area out to a 100-foot (ft) buffer, roads and drainages within a 0.25-mile radius of the 100-ft buffer, areas where the survey was extended; and correlation studies.

The discussion of the results of soil sampling in this report is limited to concentrations of radium-226 and isotopes of thorium in samples taken from surface soils, as part of correlation studies. The objective of the analysis of thorium isotopes was to 1) assess the potential effects of thorium-232 and thorium-228 on the correlation of gamma count rates to concentrations of radium-226 in surface soils; and 2) evaluate thorium-230 and radium-226 activities to indicate the status of equilibrium in the uranium decay series. These and additional results for the RSE are addressed in “Tsosie 1 Removal Site Evaluation Report” (Stantec, 2018).

The findings of the RSE pertaining to these activities are:

- The horizontal extent and magnitude of mining-related materials were delineated sufficiently to support additional characterization of the subsurface.
- Elevated count rates were observed on 1) the walls of ridges on the west, east and southeast edges of the mine claim and 2) waste rock that was exposed in a disposal cell in the southeast corner of the mine claim.
- Two potential Background Reference Areas were established.
- The relationship between gamma count rates and concentrations of radium-226 in surface soils (0 to 0.5 ft below ground surface) is described by a power regression model:

$$\text{Radium-226 Concentration (picocuries per gram [pCi/g])} = 2\text{x}10^{-10}\,(\text{Gamma Count Rate}^{2.4886}\text{ in counts per minute [cpm]})$$

- The distribution of concentrations of radium-226 in surface soils predicted using this model resembles a lognormal distribution. The values in the Survey Area range from 0.4 to 426.1, with a central tendency (median) of 2.8 pCi/g.

- The thorium series radionuclides do not appear to affect the prediction of concentrations of radium-226 from gamma count rates.

- The uranium series radionuclides appear not to be in secular equilibrium.

- The relationship between gamma count rates and exposure rates is described by a linear regression model:

  Exposure Rate (microRoentgens per hour [μR/h]) = Gamma Count Rate (cpm) x $3x10^{-4}$ + 10.553

- The distribution of exposure rates predicted using this model resembles a lognormal distribution. The values in the Survey Area range from 12.2 to 37.6, with a central tendency (median) of 13.6 μR/h.

1.0 Introduction

This report addresses the radiological characterization of the Tsosie 1 abandoned uranium mine (AUM) located in the Sweetwater Chapter of the Navajo Nation near Red Mesa, Arizona. It documents part of the implementation of the Navajo Nation AUM Environmental Response Trust, First Phase, Removal Site Evaluation Work Plan (RSE Work Plan: MWH, 2016). The work was performed by Environmental Restoration Group, Inc. of Albuquerque, New Mexico and Stantec Consulting Services Inc. (Stantec) on behalf of the Navajo Nation AUM Environmental Response Trust – First Phase.

This report provides 1) the results of a Global Positioning System (GPS)-based gamma radiation (gamma) survey, 2) comparisons of the gamma count rates at this AUM to exposure rates and concentrations of radium-226 in surface soils, and 3) an assessment of equilibrium in the uranium series. The field activities addressed in this report were conducted on October 5 and 6, 2016; June 23 and 26, and September 12, 2017. They included a GPS-based radiological survey of land surfaces over an approximately 31-acre Survey Area consisting of the mine claim area out to a 100-foot (ft) buffer, roads and drainages within a 0.25-mile radius of the 100-ft buffer, areas where the survey was extended; and correlation studies.

The discussion of the results of soil sampling in this report is limited to concentrations of radium-226 and isotopes of thorium in samples taken from surface soils, as part of correlation studies. The objective of the analysis of thorium isotopes was to 1) assess the potential effects of thorium-232 and thorium-228 on the correlation of gamma count rates to concentrations of radium-226 in surface soils; and 2) evaluate thorium-230 and radium-226 activities to indicate the status of equilibrium in the uranium decay series. These and additional results for the RSE are addressed in “Tsosie 1 Removal Site Evaluation Report” (Stantec, 2018).

Figure 1 shows the location of the AUM. Background information that is pertinent to the characterization of this AUM is presented in “Tsosie 1 Removal Site Evaluation Report” (Stantec, 2018).

2.0 GPS-Based Gamma Surveys

This section addresses the GPS-based surveys conducted in two potential Background Reference Areas and the Survey Area. The survey was extended to bound areas in which elevated count rates were observed. Table 1 lists the detection systems used in the survey, which were function-checked before and after each day of use and within calibration, in accordance with American National Standards Institute (ANSI) Standard N232A (ANSI, 1997). Appendix A presents the completed function check forms and calibration certificates for the instruments.

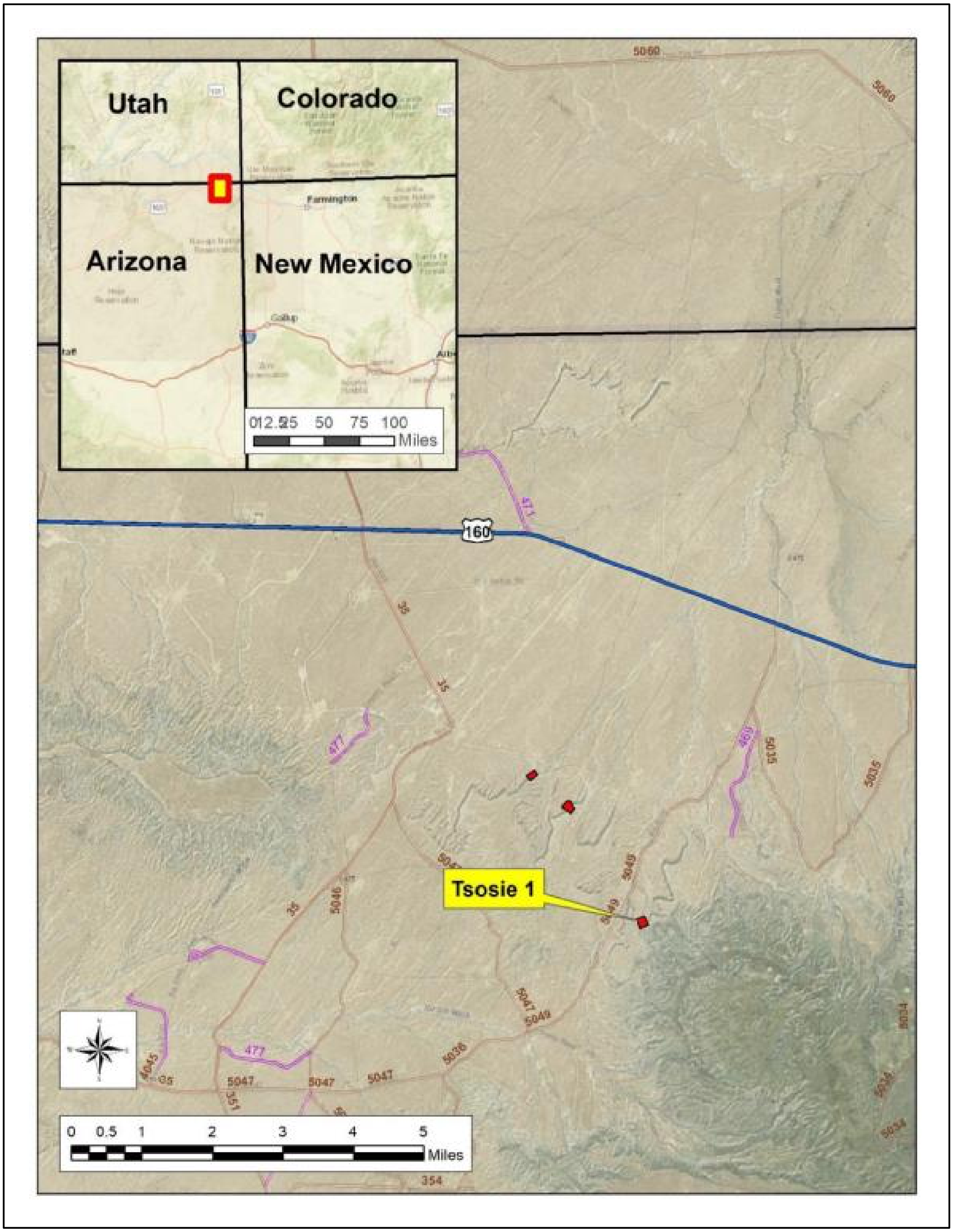


Figure 1. Location of the Tsosie 1 Abandoned Uranium Mine

Table 1. Detection systems used in the GPS-Based gamma surveys.

Survey Area	Ludlum Model 44-10	Ludlum Model 2221 Ratemeter/Scaler
Potential Background Reference Areas	PR303727	254772
Survey Area	PR303727	254772
	PR295014[a]	196086[a]
	PR320678	282971
	PR154615	138638
	PR355763[a]	138368[a]
	PR292690	254757

Notes:
[a]Detection systems used in the correlation studies described in Section 3.0.

2.1 Potential Background Reference Areas

Two potential Background Reference Areas were surveyed, the locations and results of which are depicted on Figure 2. BG1 and BGS in the figure are Background Reference Areas 1 and 2, respectively. Table 2 lists a summary of the gamma count rates, which in:

- BG1 ranged from 6,744 to 11,218 counts per minute (cpm), with a mean and median of 8,822 and 8,837 cpm, respectively.

- BG2 ranged from 12,454 to 36,929 cpm, with a mean and median of 20,105 and 18,526 cpm, respectively.

Figure 3 depicts histograms of the gamma count rates in in the Background Reference Areas. The red and green lines on the figure are theoretical normal and lognormal distributions, respectively. They are presented to show what could be expected if the distributions were normal or lognormal.

Table 2. Summary statistics for gamma count rates in the potential Background Reference Areas.

	Gamma Count Rate (cpm)					
Potential Background Reference Area	**n**	**Minimum**	**Maximum**	**Mean**	**Median**	**Standard Deviation**
1	232	6,744	11,218	8,822	8,837	797
2	325	12,454	36,929	20,105	18,526	5,443

Notes:
cpm = counts per minute

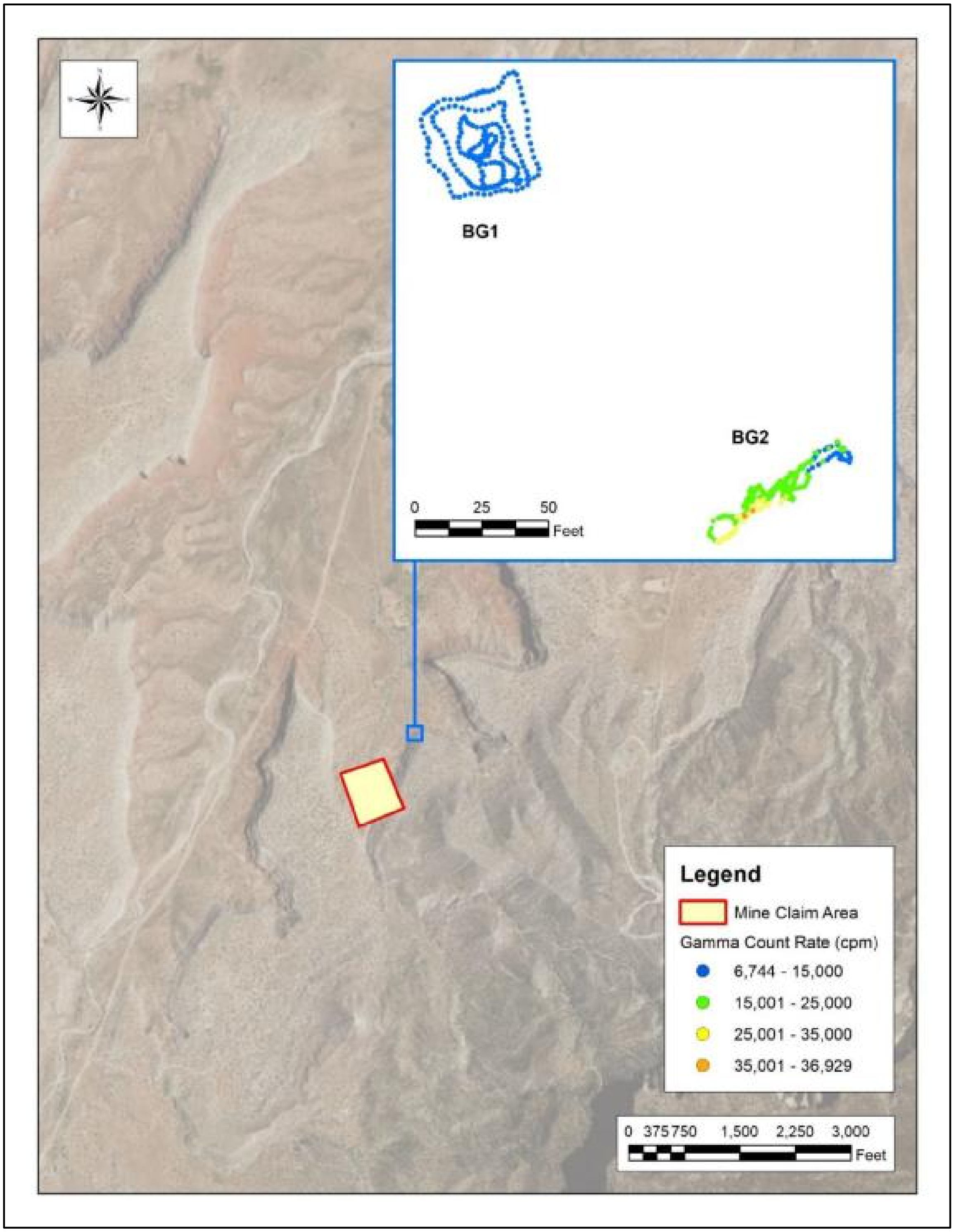
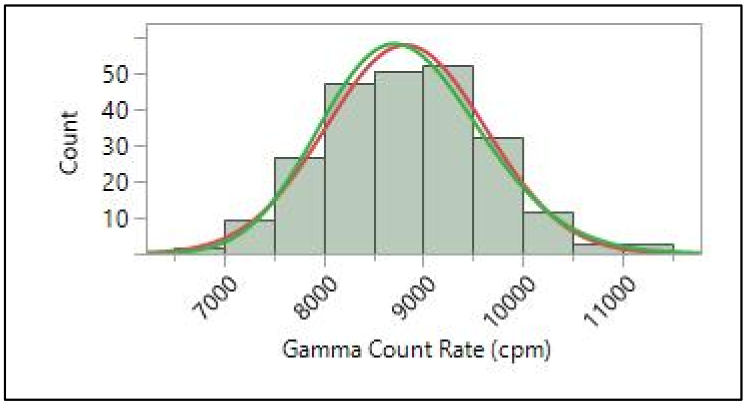
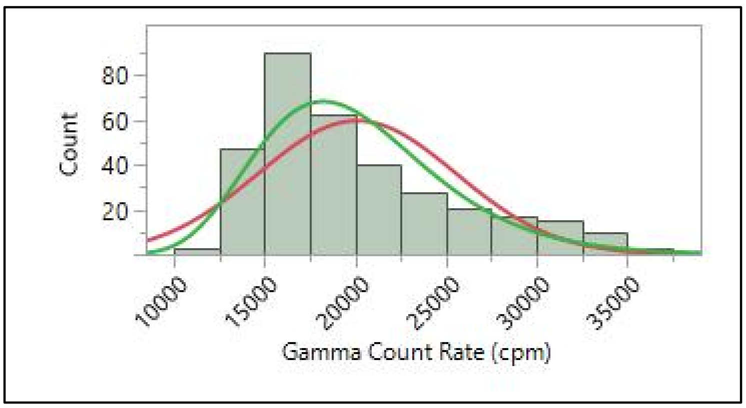


Figure 2. Gamma count rates in the potential Background Reference Areas.



a. Background Reference Area 1



b. Background Reference Area 2

Figure 3. Histograms of gamma count rates in the Background Reference Areas.

2.2 Survey Area

The gamma count rates observed in the Survey Area are depicted in Figure 4. Elevated count rates were observed on 1) the walls of ridges on the west, east and southeast edges of the mine claim and 2) waste rock that was exposed in a disposal cell in the southeast corner of the mine claim.

Figure 5 is a histogram of the gamma count rate measurements made in the Survey Area, including the area surveyed outside the 100-ft buffer. As stated in Section 2.1, the red and green lines on the figure are theoretical normal and lognormal distributions, respectively. They are presented to show what could be expected if the distributions were normal or lognormal. The distribution of the right-tailed set of measurements, evaluated using U.S. Environmental Protection Agency software ProUCL (version

5.1.002), is not defined; i.e., neither normal or logarithmic. The box plot in Figure 6 depicts cutoffs as horizontal bars, from bottom to top, for the following values or percentiles: minimum, 0.5, 2.5, 10, 25, 50, 75, 90, 97.5, 99.5, and maximum. The 25th, 50th, and 75th percentiles (the three horizontal lines of the box inside the box plot) are 8,915, 9,931, and 11,420 cpm, respectively.

Table 3 is a statistical summary of the measurements, which range from 5,429 to 89,945 cpm and have a central tendency (median) of 9,931 cpm.

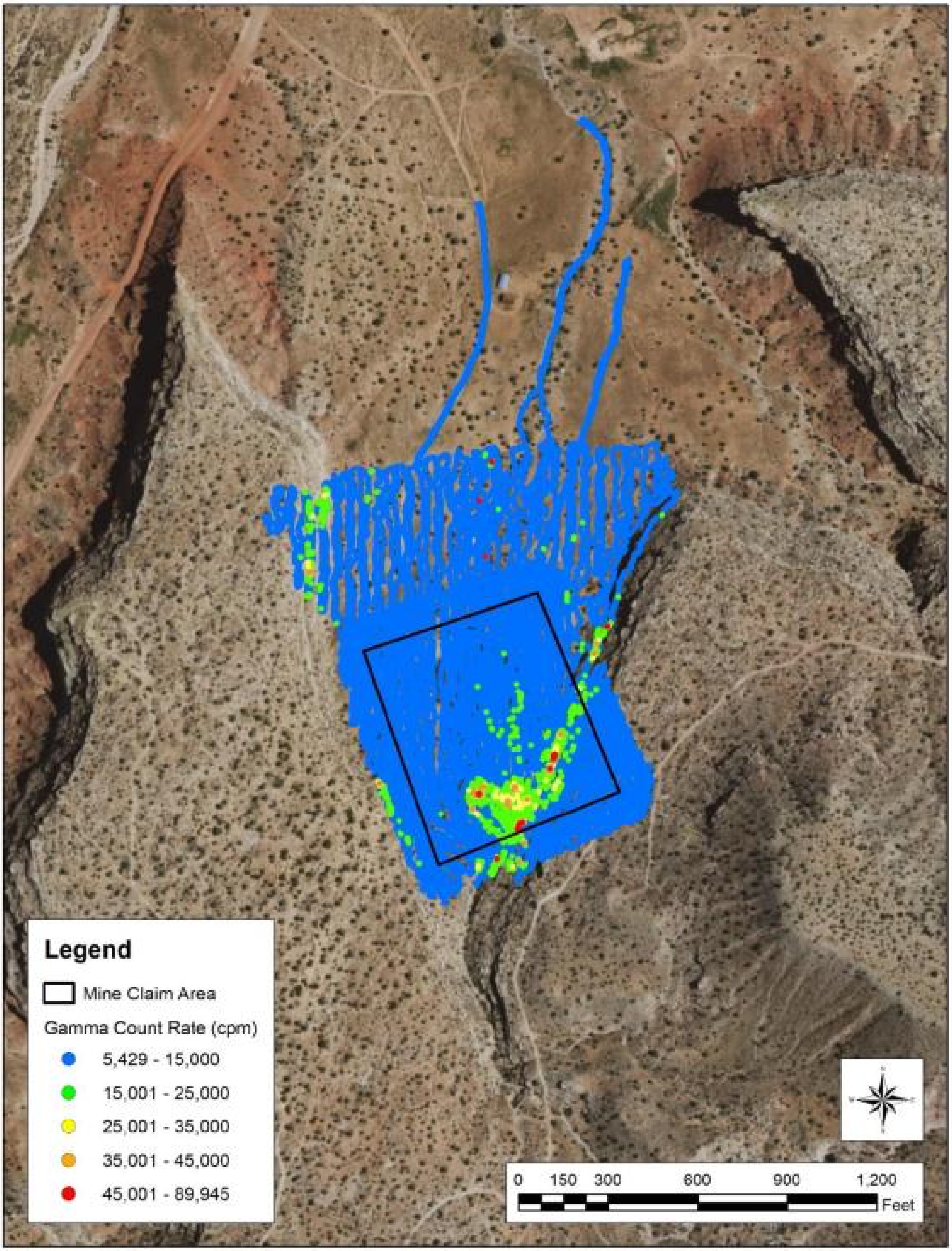


Figure 4. Gamma count rates in the Survey Area.

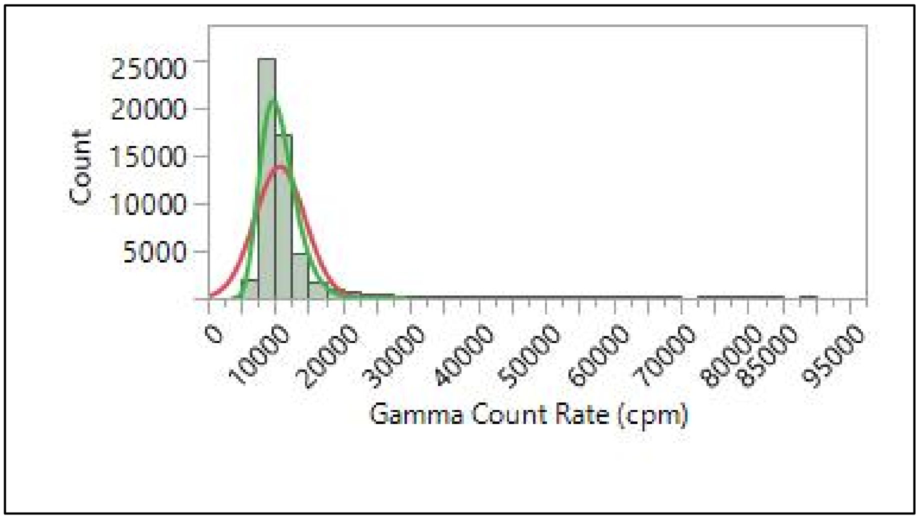


Figure 5. Histogram of gamma count rates in the Survey Area.

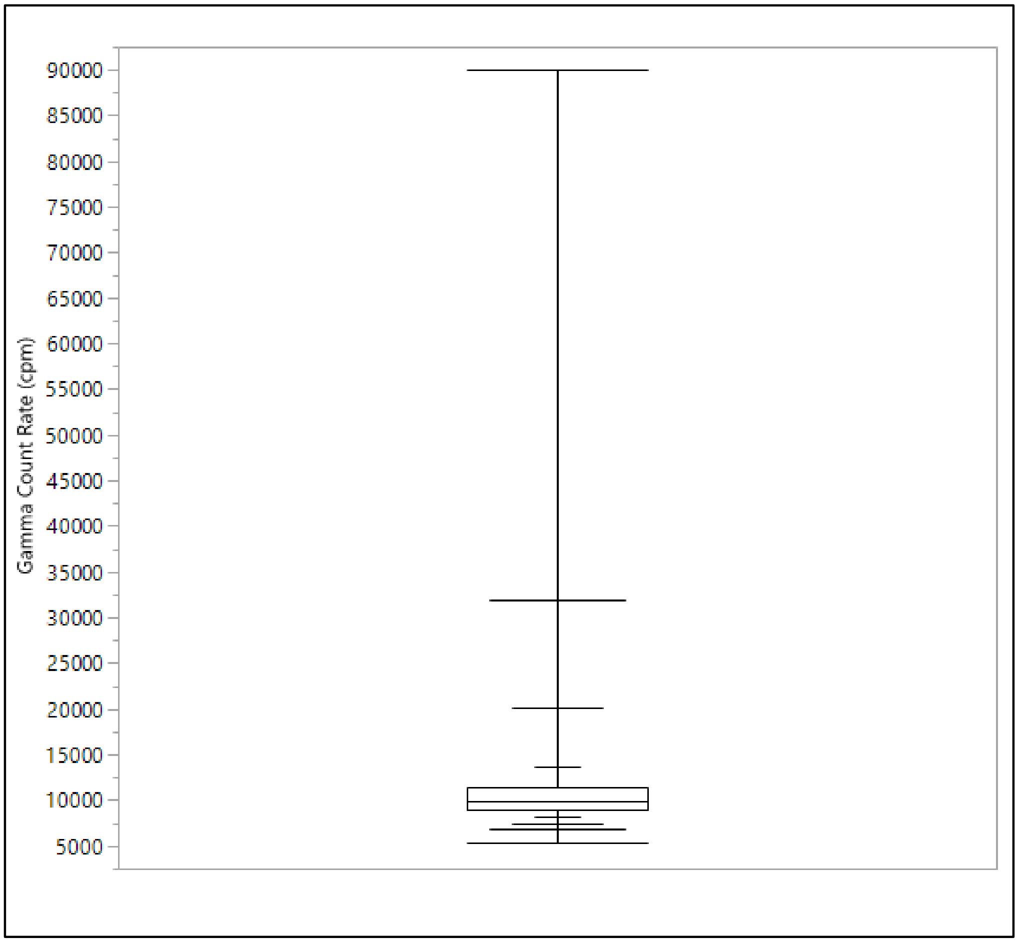


Figure 6. Box plot of gamma count rates in the Survey Area.

Table 3. Summary statistics for gamma count rates in the Survey Area.

Parameter	Gamma Count Rate (cpm)
n	52,004
Minimum	5,429
Maximum	89,945
Mean	10,778
Median	9,931
Standard Deviation	3,730

Notes:
cpm = counts per minute

3.0 Correlation Studies

The following sections address the activities under two types of correlation studies outlined in the RSE Work Plan: comparisons of 1) radium-226 concentrations in surface soils and gamma count rates and 2) exposure rates and gamma count rates. GPS-based gamma count rate measurements were made over small areas for the former study. The means of the measurements were used in this case. Static gamma count rate measurements, co-located with exposure rate measurements, were used in the latter study.

3.1 Radium-226 concentrations in surface soils and gamma count rates

On October 12, 2016 field personnel made GPS-based gamma count rates measurements and collected five-point composite samples of surface soils in each of five areas at the AUM. The activities were performed contemporaneously, by area and all on the same day, such that variations in the gamma count rate measurements could be limited largely to those posed by the soils and rocks at the locations. Figure 7 shows the GPS-based gamma count rate measurements in the five areas (labeled with location identifiers). The gamma count rate measurements were repeated on September 12, 2017 because some of the measurements made on October 12, 2016 were not recorded in the GPS datalogger. The soil samples were not re-collected, because the radium-226 concentrations at the locations were not expected to change.

The soil samples were analyzed by ALS Laboratories in Ft Collins, CO for radium-226 and isotopic thorium. The latter analysis was included to assess the potential effects of thorium series isotopes on the correlation and evaluate thorium-230 and radium-226 activities to indicate the status of equilibrium in the uranium decay series. Table 4 lists the results of the gamma count rate measurements and radium-226 concentrations in the soil samples. The means of the gamma count rate measurements range from 10,854 to 37,736 cpm. The concentrations of radium-226 in the soil samples range from 1.38 to 32.7 picocuries per gram (pCi/g).

Table 5 lists the concentrations of isotopes of thorium (thorium-228, -230, and -232) in the same soil samples. Laboratory analyses are presented in Appendix D, Laboratory Analytical Data and Data Usability Report, in “Tsosie 1 Removal Site Evaluation Report” (Stantec, 2018).

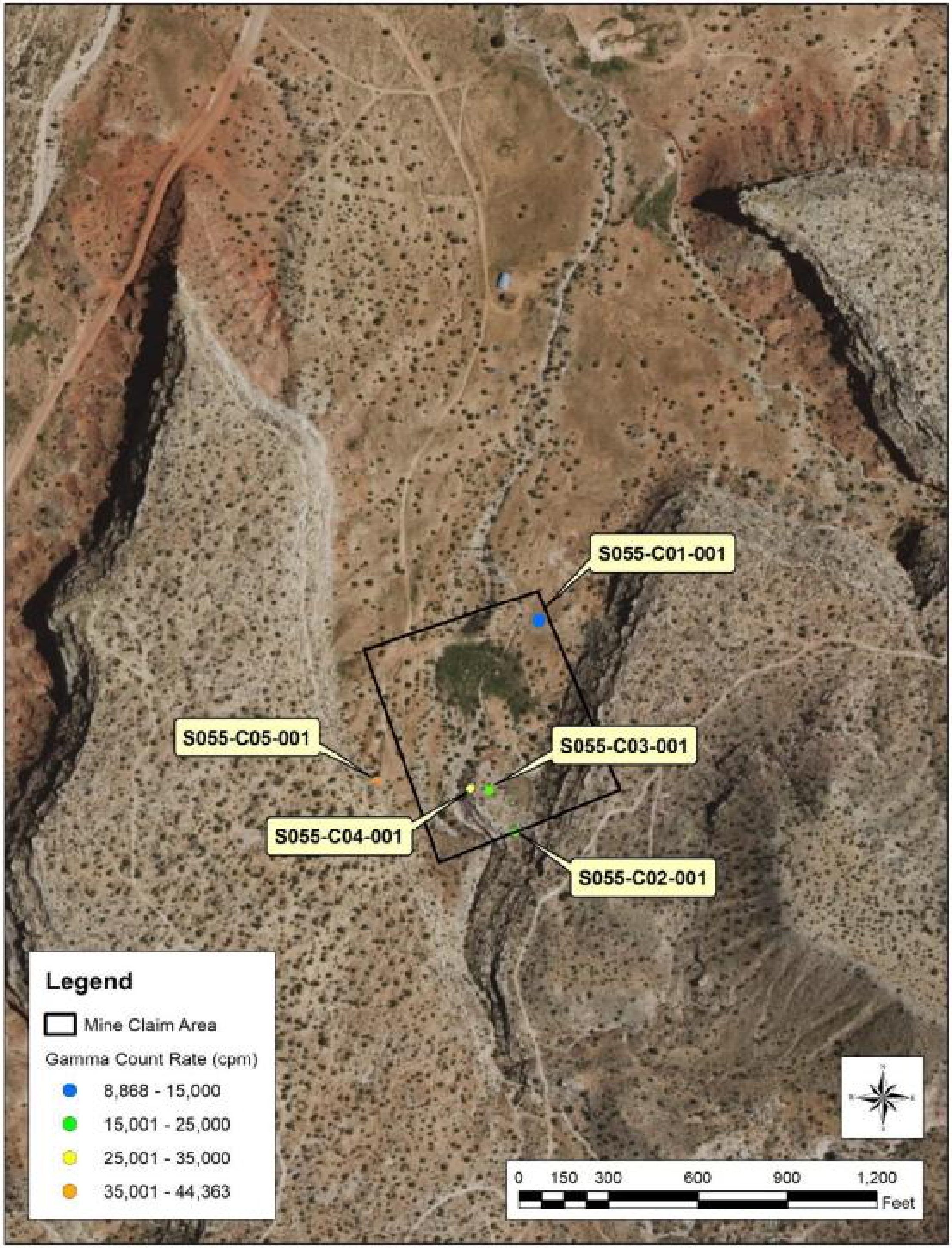


Figure 7. GPS-based gamma count rate measurements made for the correlation study.

Table 4. Gamma count rates and associated concentrations of radium-226 in samples of surface soils obtained in the correlation study.

	Gamma Count Rate (cpm)				Ra-226 (pCi/g)		
Location	Mean	Minimum	Maximum	σ	Result	Error ±1σ	MDL
S055-C01-001	10,854	8,868	12,974	745	1.38	0.3	0.38
S055-C02-001	37,736	24,200	44,363	4,231	30.5	3.7	0.9
S055-C03-001	20,487	17,582	24,115	1,564	5.43	0.76	0.61
S055-C04-001	26,310	19,176	32,028	3,285	32.7	4	1.1
S055-C05-001	14,716	12,851	17,043	843	6.66	0.88	0.48

Notes:
cpm = counts per minute
MDL = method detection limit
pCi/g = picocuries per gram
σ = standard deviation

Table 5. Concentrations of isotopes of thorium in samples of surface soils obtained in the correlation study.

	Thorium-228 (pCi/g)			Thorium-230 (pCi/g)			Thorium-232 (pCi/g)		
Sample ID	Result	Error ± 1 σ	MDL	Result	Error ± 1 σ	MDL	Result	Error ± 1 σ	MDL
S055-C01-001	0.467	0.099	0.047	1.08	0.2	0.08	0.444	0.091	0.019
S055-C02-001	1.1	0.2	0.06	15.4	2.4	0.1	1.09	0.19	0.02
S055-C03-001	0.394	0.088	0.053	5.1	0.81	0.07	0.336	0.073	0.021
S055-C04-001	0.55	0.11	0.05	26.1	4.1	0.1	0.53	0.1	0.01
S055-C05-001	0.44	0.1	0.07	4.78	0.76	0.07	0.386	0.082	0.021

Notes:
MDL = method detection limit
pCi/g = picocuries per gram
σ = standard deviation

A model was made of the results in Table 4, predicting the concentrations of radium-226 in surface soils from the mean gamma count rate in each area. The best predictive relationship between the measurements, shown Figure 8, is a strong, power function with a Pearson's Correlation Coefficient (R^2) of 0.8362, as expressed in the equation:

$$\text{Radium-226 concentration (pCi/g)} = 2 \times 10^{-10} \times \text{Gamma Count Rate (cpm)}^{2.4886}$$

R^2 is a measure of the dependence between two variables, and is expressed as a value between -1 and +1 where +1 is a positive correlation, 0 is no correlation, and -1 is a negative correlation. The root mean square error and p-value for the model are 0.618723 and 0.0297, respectively; these parameters are not data quality objectives (DQOs) and are included only as information.

The concentrations of thorium-232 and thorium-228, isotopes in the thorium series, in the correlation samples are similar and at most 1.1 pCi/g. Given these low concentrations and the high R^2 of the polynomial function, the thorium series radionuclides do not appear to affect the prediction of concentrations of radium-226, using gamma count rates.

This equation was used to convert the gamma count rate measurements observed in the gamma surveys to predicted concentrations of radium-226. Table 6 presents summary statistics for the predicted concentrations of radium-226 in the Survey Area. The range of the predicted concentrations of radium-226 in the Survey Area is 0.4 to 426.1 pCi/g, with a mean and median of 2.8 and 1.8 pCi/g, respectively. Note that the radium-226 concentrations predicted from gamma count rate measurements exceeding approximately 38,000 cpm are extrapolated from the regression model and are uncertain.

Figure 9 shows the predicted concentrations of radium-226, the spatial and numerical distribution of which mirror those depicted in Figure 4.

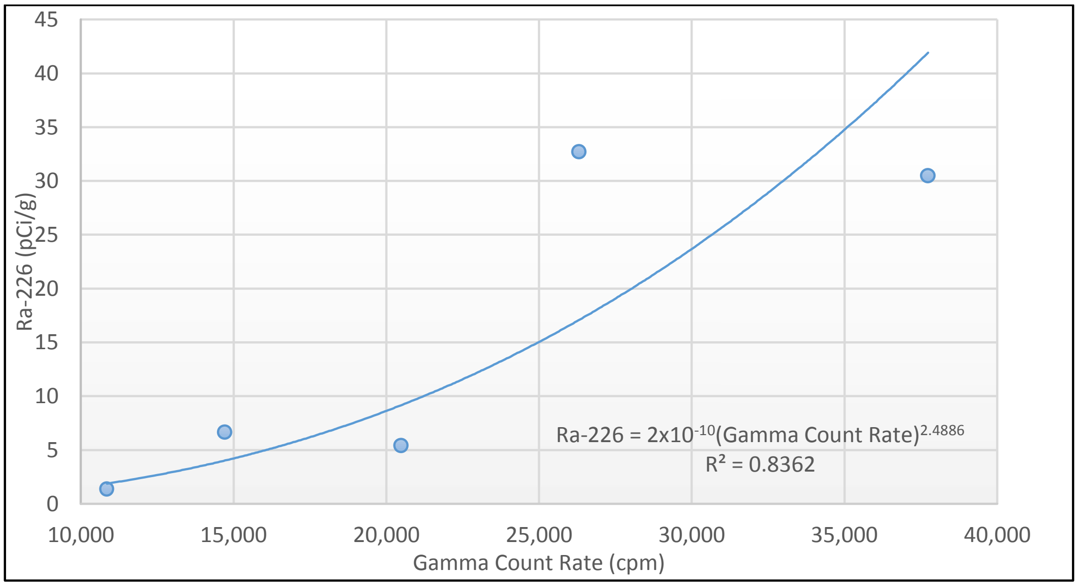


Figure 8. Correlation of gamma count rates and concentrations of radium-226 in surface soils.

Table 6. Predicted concentrations of radium-226 in the Survey Area.

Parameter	Radium-226 (pCi/g)
n	52,004
Minimum	0.4
Maximum	426.1
Mean	2.8
Median	1.8
Standard Deviation	7.0

Notes:
pCi/g = picocuries per gram

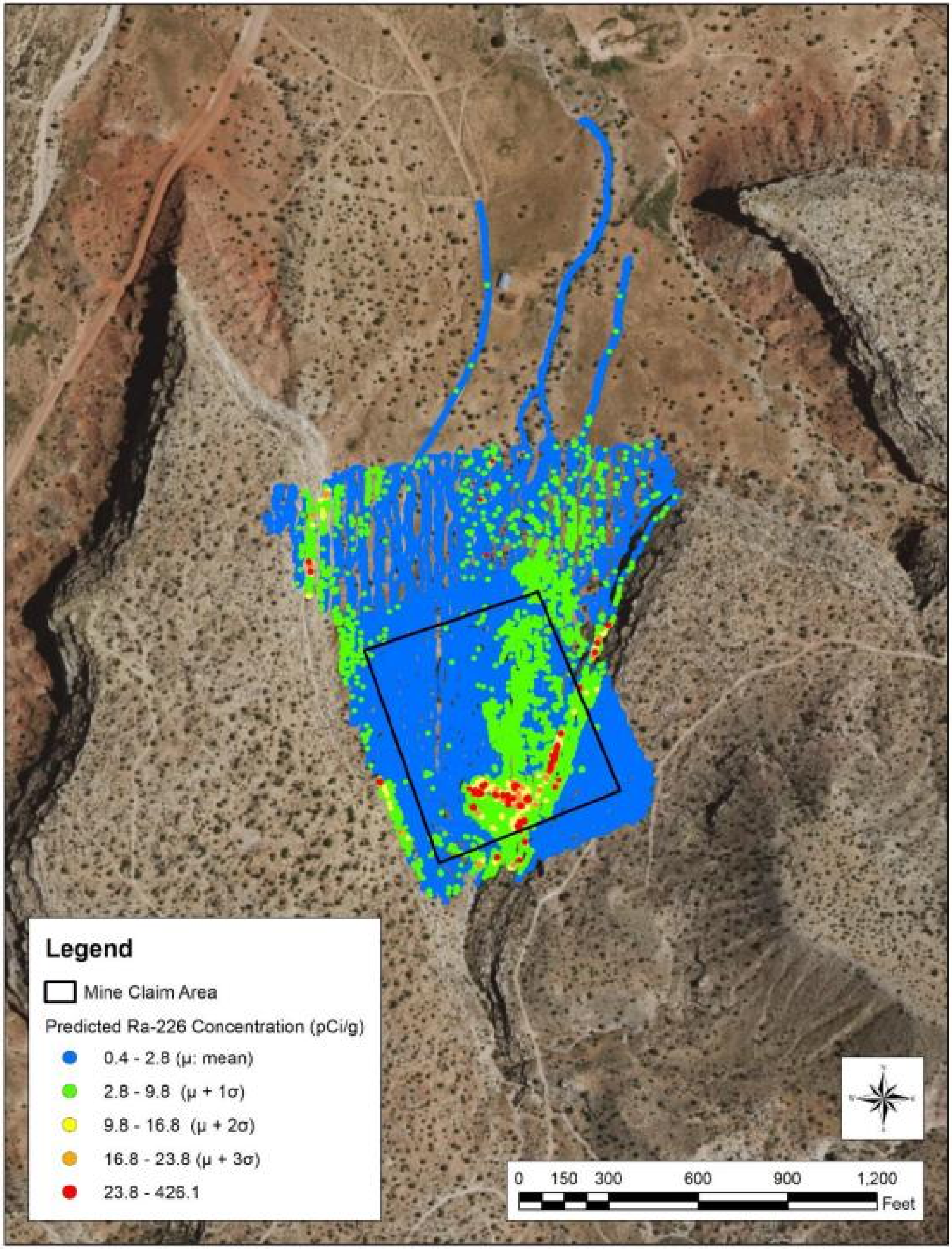


Figure 9. Predicted concentrations of radium-226 in the Survey Area.

3.2 Equilibrium in the uranium series

Secular equilibrium occurs when the activities of a parent radionuclide and its decay product are equal. This can occur in a closed system, when the half-life of the parent radionuclide is much larger than that of the decay product.

The ratio of the concentrations of radium-226 to thorium-230 can be used as an indicator of the status of equilibrium in the uranium series. The half-lives of thorium-230 and radium-226 are 77,000 and 1,600 years, respectively. The ratios in the five correlation samples are 1.3 (Sample S055-C01-001), 2.0 (Sample S055-C02-001), 1.1 (Sample S055-C03-001), 1.3 (Sample S055-C04-001), and 1.4 (Sample S055-C05-001) indicating that thorium-230 is depleted in relation to radium-226 and, by extrapolation, the uranium series itself is not in secular equilibrium.

Note this observation is based on the results of five samples, subject to differing analytical methods. Gamma spectroscopy, the method used to determine the concentration of radium-226, assesses an intact portion of the whole sample as it was collected. The concentration of thorium-230 was determined by alpha spectroscopy of an acid-leached aliquot of the sample.

This evaluation is not related to the correlation of radium-226 concentrations in surface soils and gamma count rates. It may be used for a future risk assessment.

3.3 Exposure rates and gamma count rates

Field personnel made co-located one-minute static count rate and exposure rate measurements at five locations within the Survey Area, representing the range of gamma count rates obtained in the GPS-based gamma survey. Figure 7 shows the locations of the co-located measurements, which were made in the centers of the areas.

The gamma count rate and exposure rate measurements were made on June 26, 2017 at 0.5 m and 1 m above the ground surface, respectively. The gamma count rate measurements were made using one of the sodium iodide detection systems used in the GPS-based gamma survey of the AUM (Serial Numbers PR295014/196086). The exposure rate measurements were made using a Reuter Stokes Model RS-S131-200-ER000 (Serial Number 1000992) high pressure ionization chamber (HPIC) at 1-second intervals for about 10 minutes. The HPIC output the 1-second measurements as 1-minute averages. The exposure rate used in the comparison was the mean of these measurements, less those occurring in initial instrument warm-ups. The HPIC was in current calibration and function-checked before and after use. Calibration forms for the HPIC are provided in Appendix A. Table 7 presents the results for the two types of measurements made at each of the five locations. Appendix B presents the individual (one minute) exposure rate measurements.

The best predictive relationship between the measurements is linear with a R^2 of 0.9597 indicating a strong, positive correlation. The root mean square error and p-value for the model are 0.972256 and 0.0035, respectively; these parameters are not DQOs and are included only as information.

The following equation is the linear regression (shown in Figure 10) between the mean exposure rate and gamma count rate results in Table 7 that was generated using MS Excel:

Exposure Rate (microRoentgens per hour [µR/h]) = 3×10^{-4} x Gamma Count Rate (cpm) + 10.553

Figure 11 presents the exposure rates predicted from the gamma count rate measurements, the spatial and numerical distribution of which mirror those depicted in Figure 4.

Tables 8 and 9 present summary statistics for the predicted exposure rates in the two Background Reference Areas and AUM, respectively.

The range of predicted exposure rates at:

- BG1 is 12.6 to 13.9 µR/h, with a mean and median of 13.2 µR/h
- BG2 is 14.3 to 21.6 µR/h, with a mean and median of 16.6 and 16.1 µR/h, respectively

The range of predicted exposure rates at the AUM is 12.2 to 37.6 µR/h, with a mean and median of 13.8 and 13.6 µR/h, respectively.

Table 7. Co-located gamma count rate and exposure rate measurements.

Location	Gamma Count Rate (cpm)	Exposure Rate (µR/h)
S055-C01-001	10,958	13.1
S055-C02-001	43,051	23.2
S055-C03-001	20,990	18.1
S055-C04-001	31,309	21.0
S055-C05-001	14,150	14.9

Notes:
cpm = counts per minute
µR/h = microRoentgens per hour

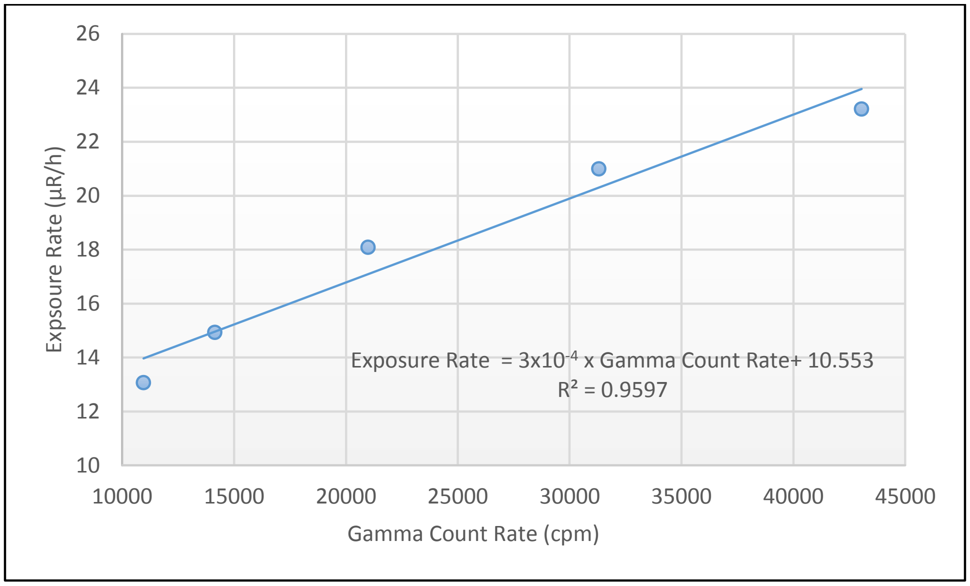


Figure 10. Correlation of gamma count rates and exposure rates.

Table 8. Predicted exposure rates in the potential Background Reference Areas.

Potential Background Reference Area	BG1	BG2
Parameter	**Exposure Rate (µR/h)**	
n	232	325
Minimum	12.6	14.3
Maximum	13.9	21.6
Mean	13.2	16.6
Median	13.2	16.1
Standard Deviation	0.2	1.6

Notes:
BG1 = Background Reference Area 1
BG2 = Background Reference Area 2
µR/h = microRoentgens per hour

Table 9. Predicted exposure rates in the Survey Area.

Parameter	Exposure Rate (µR/h)
n	52,004
Minimum	12.2
Maximum	37.6
Mean	13.8
Median	13.6
Standard Deviation	1.1

Notes:
µR/h = microRoentgens per hour

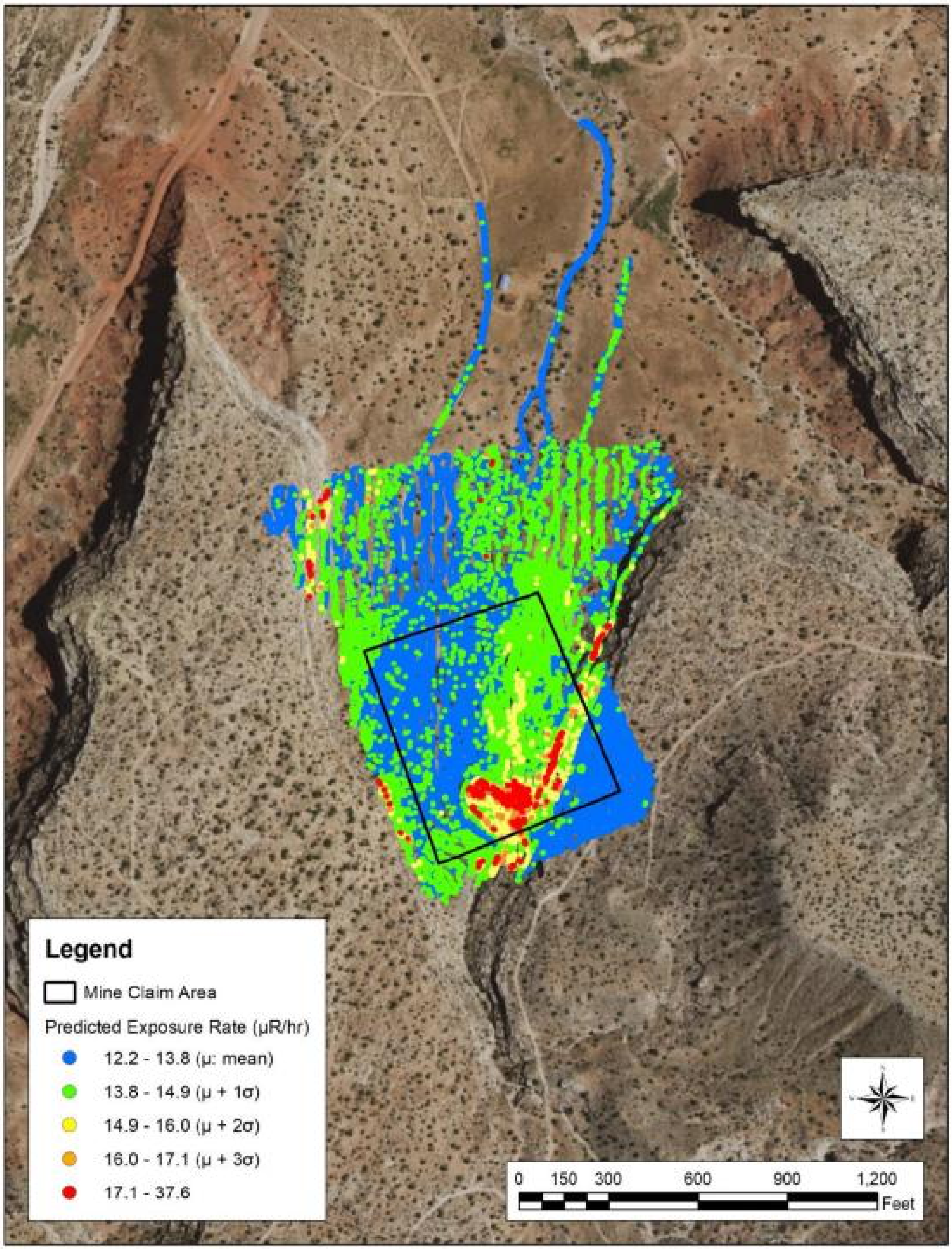


Figure 11. Predicted exposure rates in the Survey Area.

4.0 Deviations to RSE Work Plan

The RSE Work Plan specifies that the comparison of gamma count rates and radium concentrations in surface soils was to occur in 900 square foot areas. Field personnel adjusted the areas as necessary, to minimize the variability of gamma count rates observed, particularly where the spatial distribution of waste rock was heterogeneous.

5.0 Conclusions

The findings of the RSE pertaining to these activities are:

- The horizontal extent and magnitude of mining-related materials were delineated sufficiently to support additional characterization of the subsurface.

- Elevated count rates were observed on 1) the walls of ridges on the west, east and southeast edges of the mine claim and 2) waste rock that was exposed in a disposal cell in the southeast corner of the mine claim.

- Two potential Background Reference Areas were established.

- The relationship between gamma count rates and concentrations of radium-226 in surface soils (0 to 0.5 ft below ground surface) is described by a power regression model:

  Radium-226 Concentration (pCi/g) = $2\text{x}10^{-10}$ (Gamma Count Rate$^{2.4886}$ in cpm)

- The distribution of concentrations of radium-226 in surface soils predicted using this model resembles a lognormal distribution. The values in the Survey Area range from 0.4 to 426.1, with a central tendency (median) of 2.8 pCi/g.

- The thorium series radionuclides do not appear to affect the prediction of concentrations of radium-226 from gamma count rates.

- The uranium series radionuclides appear not to be in secular equilibrium.

- The relationship between gamma count rates and exposure rates is described by a linear regression model:

  Exposure Rate (µR/h) = Gamma Count Rate (cpm) x $3\text{x}10^{-4}$ + 10.553

- The distribution of exposure rates predicted using this model resembles a lognormal distribution. The values in the Survey Area range from 12.2 to 37.6, with a central tendency (median) of 13.6 µR/h.

6.0 References

ANSI, 1997. Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments, American National Standards Institute (ANSI) Standard N232A. June 20, 2014.

MWH, 2016. Navajo Nation AUM Environmental Response Trust, First Phase, Removal Site Evaluation Work Plan, October 24, 2016.

Stantec, 2018. Tsosie 1 Removal Site Evaluation Report, January 2018.

Appendix A Instrument calibration and completed function check forms

ERG

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	254772
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR303727

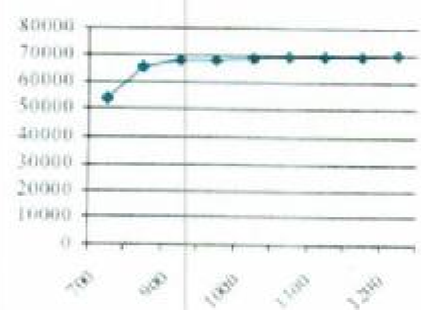
✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V
✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch Other:
✔ Geotropism ✔ Audio Check
✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC) Barometric Pressure: 24.75 inches Hg
Source Distance: ☐ Contact ✔ 6 inches ☐ Other: Threshold: 10 mV Temperature: 74 °F
Source Geometry: ✔ Side ☐ Below ☐ Other: Window: Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	398857	400
x 1000	100	100	100		100
x 100	400	400	400	39913	400
x 100	100	100	100		100
x 10	400	400	400	3992	400
x 10	100	100	100		100
x 1	400	400	400	399	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	53620	
800	64979	
900	67955	
950	67795	
1000	68536	9542
1050	69153	
1100	69331	
1150	69346	
1200	69492	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1000

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932
Fluke multimeter serial number: ☐ 87490128
☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03
✔ Gamma Source: Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03
☐ Other Source:

Calibrated By: [signature] Calibration Date: 7-6-16 Calibration Due: 7-6-17

Reviewed By: [signature] Date: 7/20/16

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

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Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	196086
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR295014

✔ Mechanical Check ✔ THR/WIN Operation
✔ F/S Response Check ✔ Reset Check
✔ Geotropism ✔ Audio Check
✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC)

HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V
Cable Length: ☐ 39-inch ✔ 72-inch Other:

Source Distance: ☐ Contact ✔ 6 inches ☐ Other:
Source Geometry: ✔ Side ☐ Below ☐ Other:

Threshold: 10 mV
Window:

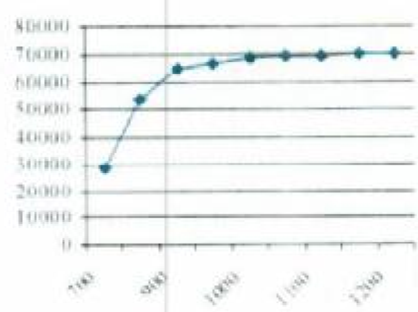
Barometric Pressure: 24.78 inches Hg
Temperature: 74 °F
Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	399802	400
x 1000	100	100	100		100
x 100	400	400	400	39989	400
x 100	100	100	100		100
x 10	400	400	400	3999	400
x 10	100	100	100		100
x 1	400	400	400	400	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	28456	
800	53330	
900	64430	
950	66209	
1000	68333	
1050	69077	
1100	69121	8924
1150	69973	
1200	70155	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1100

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932
☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03
☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03

Fluke multimeter serial number: ☐ 87490128
✔ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Other Source:

Calibrated By: [signature] Calibration Date: 7 [illegible] 16 Calibration Due: 7-[illegible]-17

Reviewed By: [signature] Date: 7/20/16

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

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Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	196086
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR295014

- ✔ Mechanical Check
- ✔ F/S Response Check
- ✔ Geotropism
- ✔ Meter Zeroed
- ✔ THR/WIN Operation
- ✔ Reset Check
- ✔ Audio Check
- ✔ Battery Check (Min 4.4 VDC)

HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V

Cable Length: ☐ 39-inch ✔ 72-inch ☐ Other:

Source Distance: ☐ Contact ✔ 6 inches ☐ Other:

Source Geometry: ✔ Side ☐ Below ☐ Other:

Threshold: 10 mV

Window:

Barometric Pressure: 24.27 inches Hg

Temperature: 78 °F

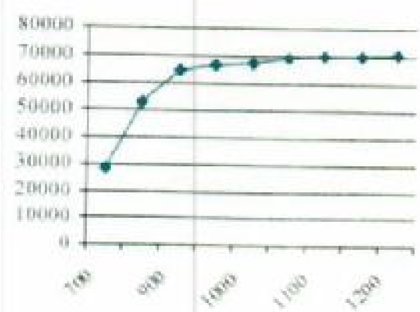
Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	399386	400
x 1000	100	100	100		100
x 100	400	400	400	39949	400
x 100	100	100	100		100
x 10	400	400	400	3995	400
x 10	100	100	100		100
x 1	400	400	400	399	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	28235	
800	52834	
900	64481	
950	66468	
1000	67321	
1050	69009	
1100	69981	9079
1150	69564	
1200	70538	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1100

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932

☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03

☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03

Fluke multimeter serial number: ☐ 87490128

✔ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03

☐ Other Source:

Calibrated By:

Reviewed By:

Calibration Date: 3/28/17 ~~1 March 17~~

Calibration Due: 2/28/18 ~~2 March 18~~

Date: 3-1-17

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

	Manufacturer:		Model Number:		Serial Number:
Meter:	Manufacturer: Ludlum		Model Number: 2221r		Serial Number: 138368
Detector:	Manufacturer: Ludlum		Model Number: 44-10		Serial Number: PR355763

☑ Mechanical Check ☑ THR/WIN Operation HV Check (+/- 2.5%): ☑ 500 V ☑ 1000 V ☑ 1500 V
☑ F/S Response Check ☑ Reset Check Cable Length: ☐ 39-inch ☑ 72-inch ☐ Other:
☑ Geotropism ☑ Audio Check
☑ Meter Zeroed ☑ Battery Check (Min 4.4 VDC)
Source Distance: ☐ Contact ☑ 6 inches ☐ Other:
Source Geometry: ☑ Side ☐ Below ☐ Other:

Threshold: 10 mV
Window:

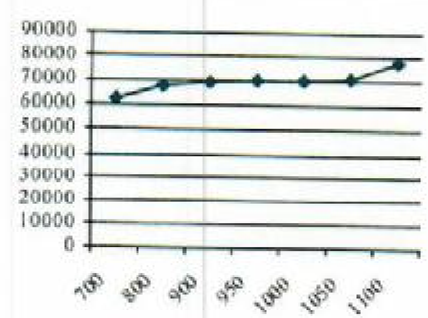
Barometric Pressure: 24.75 inches Hg
Temperature: 76 °F
Relative Humidity: 20 %

Instrument found within tolerance: ☑ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	398875	400
x 1000	100	100	100		100
x 100	400	400	400	39883	400
x 100	100	100	100		100
x 10	400	400	400	3988	400
x 10	100	100	100		100
x 1	400	400	400	398	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	62275	
800	68049	
900	69726	
950	70112	9509
1000	70068	
1050	71042	
1100	77619	

Voltage Plateau



Comments: Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 950

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ☑ 201932
Fluke multimeter serial number: ☐ 87490128
☐ Alpha Source: Th-230 sn: 4098-03@12,800dpm/6,520 cpm (1/4/12)
☑ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Beta Source: Tc-99 sn: 4099-03@17,700dpm/11,100cpm(1/4/12)
☐ Other Source:

Calibrated By: [signature] Calibration Date: 9/7-17 Calibration Due: 9-17-18

Reviewed By: T.TK Date: 09/08/17

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

ERG

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	138368
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR154615

✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V

✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch ☐ Other:

✔ Geotropism ✔ Audio Check

✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC) Barometric Pressure: 24.78 inches Hg

Source Distance: ☐ Contact ✔ 6 inches ☐ Other: Threshold: 10 mV Temperature: 74 °F

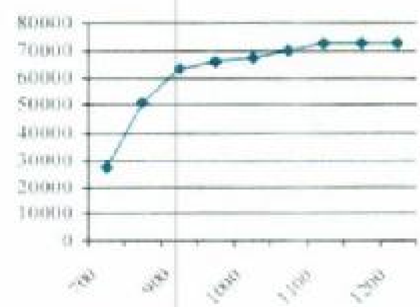
Source Geometry: ✔ Side ☐ Below ☐ Other: Window: Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	398436	400
x 1000	100	100	100		100
x 100	400	400	400	39845	400
x 100	100	100	100		100
x 10	400	400	400	3984	400
x 10	100	100	100		100
x 1	400	400	400	399	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	26998	
800	51037	
900	63340	
950	65550	
1000	67410	
1050	70113	
1100	72217	
1150	72561	9216
1200	72337	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1150

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932 Fluke multimeter serial number: ☐ 87490128

☐ Alpha Source: Th-230 @ 12,800 dpm (1/4/12) sn: 4098-03 ✔ Gamma Source: Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03

☐ Beta Source: Tc-99 @ 17,700 dpm (1/4/12) sn: 4099-03 ☐ Other Source:

Calibrated By: Calibration Date: 7-6-16 Calibration Due: 7-6-17

Reviewed By: Date: 7/20/16

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A-1997

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	282971
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR320678

✔ Mechanical Check ✔ THR/WIN Operation HV Check (+/- 2.5%): ✔ 500 V ✔ 1000 V ✔ 1500 V

✔ F/S Response Check ✔ Reset Check Cable Length: ☐ 39-inch ✔ 72-inch ☐ Other:

✔ Geotropism ✔ Audio Check

✔ Meter Zeroed ✔ Battery Check (Min 4.4 VDC) Barometric Pressure: 24.63 inches Hg

Source Distance: ☐ Contact ✔ 6 inches ☐ Other: Threshold: 10 mV Temperature: 75 °F

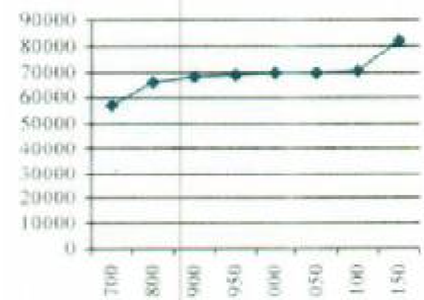
Source Geometry: ✔ Side ☐ Below ☐ Other: Window: Relative Humidity: 20 %

Instrument found within tolerance: ✔ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400	400	400	399936	400
x 1000	100	100	100		100
x 100	400	400	400	39984	400
x 100	100	100	100		100
x 10	400	400	400	3998	400
x 10	100	100	100		100
x 1	400	400	400	400	400
x 1	100	100	100		100

High Voltage	Source Counts	Background
700	57641	
800	65850	
900	68414	
950	68639	
1000	69410	9773
1050	69358	
1100	70301	
1150	81822	

Voltage Plateau



Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1000

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ✔ 201932 Fluke multimeter serial number: ☐ 87490128

☐ Alpha Source: Th-230 sn: 4098-03 @ 12,800dpm/6,520 cpm (1/4/1 ☐ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03

☐ Beta Source: Tc-99 sn: 4099-03 @ 17,700dpm/11,100cpm (1/4/12 ☐ Other Source:

Calibrated By: Calibration Date: 3-13-17 Calibration Due: 3-13-18

Reviewed By: Date: 14 March 2017

Certificate of Calibration

Calibration and Voltage Plateau

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

Meter:	Manufacturer:	Ludlum	Model Number:	2221r	Serial Number:	254757
Detector:	Manufacturer:	Ludlum	Model Number:	44-10	Serial Number:	PR292690

☐ Mechanical Check ☐ THR/WIN Operation HV Check (+/- 2.5%): ☐ 500 V ☐ 1000 V ☐ 1500 V
☐ F/S Response Check ☐ Reset Check Cable Length: ☐ 39-inch ☑ 72-inch ☐ Other:
☐ Geotropism ☐ Audio Check
☐ Meter Zeroed ☐ Battery Check (Min 4.4 VDC)

Source Distance: ☐ Contact ☑ 6 inches ☐ Other:
Source Geometry: ☑ Side ☐ Below ☐ Other:

Threshold: 10 mV
Window:

Barometric Pressure: 24.75 inches Hg
Temperature: 75 °F
Relative Humidity: 26 %

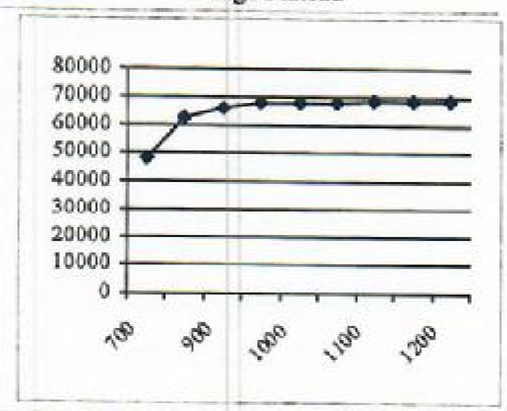
Instrument found within tolerance: ☑ Yes ☐ No

Range/Multiplier	Reference Setting	"As Found Reading"	Meter Reading	Integrated 1-Min. Count	Log Scale Count
x 1000	400				
x 1000	100				
x 100	400				
x 100	100				
x 10	400				
x 10	100				
x 1	400				
x 1	100				

See Ludlum Cal Sheet

High Voltage	Source Counts	Background
700	48461	
800	62632	
900	66021	
950	67593	
1000	67720	9478
1050	67893	
1100	68340	
1150	68592	
1200	68684	

Voltage Plateau



Comments: Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV = 1000

Reference Instruments and/or Sources:

Ludlum pulser serial number: ☐ 97743 ☑ 201932
Fluke multimeter serial number: ☐ 87490128
☐ Alpha Source: Th-230 sn: 4098-03@12,800dpm/6,520 cpm (1/4/12)
☑ Gamma Source Cs-137 @ 5.2 uCi (1/4/12) sn: 4097-03
☐ Beta Source: Tc-99 sn: 4099-03@17,700dpm/11,100cpm(1/4/12)
☐ Other Source:

Calibrated By: [signature] Calibration Date: 5-21-17 Calibration Due: 5-21-18

Reviewed By: T. [signature] Date: 08/21/17

ERG Form ITC. 101.A

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997

Scientific and Industrial Instruments
www.ludlums.com

CERTIFICATE OF CALIBRATION

501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

ACCREDITED
CERT # 4084.01

Customer ERG

ORDER NO. 20315528/452181

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 254757

Mfg. ______ Model ______ Serial No. ______

Cal. Date 25-Jul-17 Cal Due Date 25-Jul-18 Cal. Interval 1 Year Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 74 °F RH 47 % Alt 706.0 mm Hg

☐ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☑ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck.
☑ Calibrated in accordance with LMI SOP 14.8 ☐ Calibrated in accordance with LMI SOP 14.9

Instrument Volt Set 1500 V Input Sens. 10 mV Det. Oper. ______ V at ______ mV Threshold Dial Ratio 100 = 10 mV

☐ HV Readout (2 points) Ref./Inst. 500 / 500 V Ref./Inst. 1500 / 1502 V

COMMENTS:

Calibrated with 39" cable.
Calibrated with Window in "OUT" position.
Firmware: 261027

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1000	400 Kcpm	N/A	400
X 1000	100 Kcpm		100
X 100	40 Kcpm		400
X 100	10 Kcpm		100
X 10	4 Kcpm		400
X 10	1 Kcpm		100
X 1	400 cpm		400
X 1	100 cpm		100

*Uncertainty within ± 10% C.F. within ± 20%

ALL Range(s) Calibrated Electronically

Digital Readout REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	Log Scale REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
400 Kcpm	N/A	39956 (0)	500 Kcpm	N/A	500 Kcpm
40 Kcpm		3995	50 Kcpm		50
4 Kcpm		400	5 Kcpm		5
400 cpm		40	500 cpm		500 cpm
40 cpm		4	50 cpm		50

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques.
The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 ISO/IEC 17025:2005(E) State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 009 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 2324/2521 ☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ 2169CP ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be ☐ T-304 Ra-226 ☐ Y982

☐ Alpha S/N ______ ☐ Beta S/N ______ ☐ Other ______

☑ m 500 S/N 201934 ☐ Oscilloscope S/N ______ ☑ Multimeter S/N 92780460

Calibrator Josie Ruiz Josie Ruiz Title Technician Date 25 July 17

QC'd By [signature] Title Service Dept QC Date 26 Jul 17

FORM SC22A 12/12/2016 Page 1 of 1

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed: ______

Reuter-Stokes

Calibration Certificate

Reuter-Stokes certifies that the Environmental Radiation Monitor, identified below, has been calibrated for output using the shadow shield technique*, and calibrated with radiation sources traceable to the National Institute of Standards and Technology.

Sensor Type: 100 R/Hr

Serial Number: 1000992

Calibration Date: 03/16/2017

Sensitivity: -2.281E-8 A/R/h

Authorized Signature

*Calibration Procedure: RS-SOP 238.1

Reuter-Stokes

Calibration Data

Sensor Type:	100 R/Hr	Source (CS-137):	BB-400
Serial Number:	1000992	Date of Certification:	12/01/1994
Calibration Date:	03/16/2017	Exposure Rate at 1 meter:	4.226 mR/h

Customer Name: STOCK

Sensitivity (Ra-226): -2.281E-8 A/R/h

Distance		Exposure Rate	P+S+A	S+A	P	k(CS-137)
Feet	cm	μR/h	A	A	A	A/R/h
12	366	185.323	-5.403E-12	-1.164E-12	-4.239E-12	-2.287E-08
14	427	135.592	-4.135E-12	-1.012E-12	-3.123E-12	-2.303E-08
16	488	103.384	-3.294E-12	-9.029E-13	-2.391E-12	-2.313E-08
18	549	81.348	-2.708E-12	-8.209E-13	-1.887E-12	-2.319E-08

k(CS-137) = -2.306E-8 A/R/h

k(Ra-226) = 0.9892 k(CS-137)

k(Ra-226) = -2.281E-8 A/R/h

k = -2.306E-8 A/R/h

σ = 1.39E-10 A/R/h

$V = \frac{\sigma}{k} =$ -0.603%

By: John Lar

Date: 3-17-17

ERG

Single-Channel Function Check Log

Environmental Restoration Group Inc
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	254772
Cal. Due Date:	7-19-17

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR303727
Cal. Due Date:	7-19-17

Comments:
NNERT

Source: Cs-137
Serial No.: 333-94
Activity: 5.12 uCi
Emission Rate: NA cpm/emissions
Source Date: 6-6-94
Distance to Source: 6 Inches

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s): Project reference points
10-4-16	0925	5.7	1003	99	45635	6378	39254	NW	Tsosie 1
10-4-16	1720	5.6	1008	99	46987	6720	40267	NW	Comfort Suites Parking lot
10-5-16	0620	5.7	1007	99	47335	6804	40531	NW	Comfort Suites Parking lot
10-5-16	1542	5.5	999	99	45375	6342	39033	NW	Tsosie 1
10-6-16	0900	5.5	1003	99	43705	6364	37341	NW	Tsosie 1
10-6-16	1713	5.5	1000	99	44279	6053	38226	NW	Comfort Suites Parking Lot
10-7-16	0902	5.5	1006	99	44457	6003	38404	NW	Oak 124/125
10-7-16	1627	5.5	999	99	46103	6751	39352	NW	Comfort Suites Parking Lot
10-8-16	0903	5.6	1003	99	45434	6365	39069	NW	Red Valley Intersection
10-8-16	1653	5.5	999	99	45185	6467	38718	NW	Comfort Suites Parking Lot
10-10-16	0858	5.5	1004	100	42755	5579	37171	NW	Oak 124/125
10-10-16	1919	5.5	959	99	51651	6930	44721	NW	Oak 124/125

Reviewed by: MP

Review Date: 11/29/16

ERG

Single-Channel Function Check Log

Environmental Restoration Group Inc
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	196086
Cal. Due Date:	7-9-17

⟷

DETECTOR	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	PR 295014
Cal. Due Date:	7-9-17

Comments:
NNEAT

Source: Cs-137 | Activity: 5.12 uCi | Source Date: 6-16-94 | Distance to Source: 6 Inches

Serial No.: 333-94 | Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s): Project Reference Points
10-4-16	0936	5.5	1102	100	46804	6042	40762	NW	Tsosie 1
10-4-16	1720	5.4	1106	100	46032	6898	39134	NW	Comfort Suites Parking Lot
10-5-16	0622	5.4	1109	101	45794	6834	38960	NW	Comfort Suites Parking Lot
10-5-16	1748	5.3	1057	99	46608	6021	40587	NW	Tsosie 1
10-6-16	0904	5.4	1103	100	44521	6273	38248	NW	Comfort Suites Parking Lot
10-6-16	1718	5.3	1099	100	45178	6311	38867	NW	Comfort Suites Parking Lot
10-7-16	0859	5.4	1104	100	44101	5226	38875	NW	Oak 124/125
10-7-16	1633	5.4	1098	99	44930	6832	38098	NW	Comfort Suites Parking Lot
10-8-16	0908	5.4	1104	100	45110	6201	38909	NW	Red Valley Intersection
10-8-16	1658	5.3	1098	99	45810	6196	39614	NW	Comfort Suites Parking Lot
10-12-16	1331	5.4	1099	99	46496	6519	39977	NW	Barton 3
10-12-16	1614	5.4	1097	100	44509	6060	38449	NW	Comfort Suites Parking Lot

Reviewed by: [signature] Review Date: 11/29/16

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	138638
Cal. Due Date:	7-9-17

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR154615
Cal. Due Date:	7-9-17

Comments:
NNERT

Source: Cs-137 Activity: 5.12 uCi Source Date: 6-6-94 Distance to Source: 6 Inches

Serial No.: 333-94 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
10-5-16	0700	5.9	1184	165	46216	7136	39080	NW	Tsosie 1
10-5-16	1546	5.7	1198	185	45357	6266	39091	NW	Tsosie 1
10-8-16	0837	5.7	1182	164	45202	6004	39198	NW	Intersection to Oak 124 @ Red Valley
10-8-16	1702	5.6	1128	112	49505	6399	43106	NW	Comfort Suites Farmington
10-12-16	1334	5.7	1139	122	46929	6807	40122	NW	Barton 3
10-12-16	1610	5.6	1130	115	44390	6093	38297	NW	Comfort Suites Farmington
10-13-16	0917	5.6	1129	110	44223	7099	37124	NW	Alonzo
10-13-16	1910	—	—	—	DID NOT	USE	—	NW	Comfort Suites Farmington
10-15-16	0929	5.7	1173	160	47369	7023	40346	NW	Harvey Blackwater
10-15-16	1821	5.7	1173	163	42767	5169	37598	NW	Hat Rock Inn lot
10-26-16	0755	5.7	1223	202	50474	8000	42474	NW	Boyd Tisi
10-26-16	1540	5.6	1152	138	45033	6331	38702	NW	Boyd Tisi

Reviewed by: [signature] Review Date: 11/29/16

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	282971
Cal. Due Date:	3-13-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR320678
Cal. Due Date:	3-13-18

Comments:
NWERT - Soils Characterization

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
6-20-17	1334	5.7	1046	100	37108	6411	30697	NW	Charles Keith
6-20-17	1651	5.6	1038	98	36694	5907	30787	NW	Charles Keith
6-21-17	0720	5.7	1045	100	38258	6568	31690	NW	Charles Keith
6-21-17	1400	5.5	1035	99	36426	5473	30953	NW	Charles Keith
6-22-17	0732	5.6	1044	100	37058	5300	31758	NW	Charles Keith
6-22-17	1710	5.5	1042	99	37441	6708	30733	NW	Tsosie 1
6-24-17	0901	5.6	1047	100	38218	7111	31107	NW	Tsosie 1
6-24-17	1655	5.5	1041	99	36728	6080	30648	NW	Tsosie 1
6-26-17	0852	5.6	1048	100	38982	7442	31540	NW	Tsosie 1
6-26-17	1632	5.4	1040	99	38932	7627	31305	NW	Tsosie 1
6-27-17	1238	5.5	1047	100	36268	5913	30355	NW	Eunice Becenti
6-27-17	1403	5.5	1044	100	36016	5567	30449	NW	Eunice Becenti

Reviewed by: [signature] Review Date: 6/29/17

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE. Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Reuter Stokes
Model:	RS-S131-200-ER000U
Serial No.:	1000992
Cal. Due Date:	3-16-18

DETECTOR	
Manufacturer:	Reuter Stokes
Model:	RS-S131-200-ER000U
Serial No.:	1000992
Cal. Due Date:	3-16-18

Comments:
NMERS - HPIC

Source: Cs-137 Activity: 4 uCi Source Date: 4-12-96 Distance to Source: Contact housing

Serial No.: 544-96 Emission Rate: NA cpm/emissions

← µR/h →

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
6-26-17	0630	8.18	401.2	NA	~14.2	~8.5	~5.7	NW	Home2 Suites room: Farmington
6-26-17	2100	7.93	401.1	NA	~14.5	~8.6	~5.9	NW	Hilton Garden Inn room: Gallup
6-29-17	0850	8.25	401.3	NA	~18	~12.5	~5.5	NW	Section 26
6-30-17	0740	8.21	401.3	NA	~19	~13.4	~5.6	NW	ERG office

NW 6-30-17

Reviewed by: MM Review Date: 10/9/17

ERG Form ITC.201.A

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	196086
Cal. Due Date:	2-28-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR295014
Cal. Due Date:	2-28-18

Comments:
NNERT

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
6-26-17	0900	6.2	1109	101	38088	6806	31282	NW	Tsosie 1
6-26-17	1619	6.0	1095	99	38337	6166	32171	NW	Tsosie 1
6-27-17	1247	6.1	1108	100	36994	5161	31833	NW	Eunice Becenti
6-27-17	1358	6.0	1102	101	36293	5017	31276	NW	Eunice Becenti
6-28-17	0730	6.1	1111	101	36814	5111	31703	NW	Eunice Becenti
6-28-17	1952	5.9	1101	100	37391	5304	32087	NW	Gallup Garden Inn lot
6-29-17	0908	5.9	1106	100	35972	6002	29970	NW	Section 26
6-30-17	0855	5.9	1107	100	40749	9057	31692	NW	ERG office
					7-5-17				

Reviewed by: [signature] Review Date: 10/9/17

ERG Form ITC.201.A

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	138368
Cal. Due Date:	9-7-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR355763
Cal. Due Date:	9-7-18

Comments:
NNERT

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
9-12-17	0914	5.4	950	101	36935	6331	30604	NW	Barton 3
9-12-17	1432	5.3	944	99	38043	6468	31575	NW	Tsosie 1
9-13-17	0906	5.4	951	99	37146	6538	30608	NW	Alonzo
9-13-17	1600	5.3	944	99	35587	5991	29596	NW	Barton 3
9-14-17	0909	5.4	950	100	36080	6176	29904	NW	NA-0904
9-14-17	1255	5.3	948	100	36099	5764	30335	NW	NA-0904
9-15-17	0920	5.4	954	101	35208	5551	29657	NW	Eunice Becenti
9-15-17	1729	5.3	957	109	35937	5261	30676	NW	Eunice Becenti
9-19-17	0831	5.4	958	105	36467	6034	30433	NW	Section 26 @ trailer
9-19-17	1453	5.3	946	99	44454	14748	29706	NW	Section 26 @ corral
9-20-17	0736	5.3	953	102	37676	6987	30689	NW	Mexican Hat
9-20-17	1611	5.2	947	100	36842	6252	30590	NW	Mexican Hat

Reviewed by: [signature] Review Date: 10/19/17

ERG

Single-Channel Function Check Log

Environmental Restoration Group, Inc
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224

METER	
Manufacturer:	Ludlum
Model:	2221
Serial No.:	254757
Cal. Due Date:	~~8-21-18~~ NW 7-25-18

DETECTOR	
Manufacturer:	Ludlum
Model:	44-10
Serial No.:	PR292690
Cal. Due Date:	8-21-18

Comments:
UNEAT

Source: Cs-137 Activity: 4 uCi Source Date: 4-18-96 Distance to Source: 6 inches

Serial No.: 544-96 Emission Rate: NA cpm/emissions

Date	Time	Battery	High Voltage	Threshhold	Source Counts	BKG Counts	Net Counts	Initials	Note(s):
9-12-17	0930	5.8	1008	114	37751	6287	31464	NW	Barlin 3
9-12-17	1433	5.8	1003	111	37908	6408	31500	NW	Tsosie 1
9-13-17	0914	5.8	1007	110	37894	6629	31265	NW	Alonzo
9-13-17	1603	5.7	993	101	36184	5750	30434	NW	Barton 3
9-14-17	0903	5.8	1000	102	37308	6025	31283	NW	NA-0904
9-14-17	1250	5.8	996	102	36293	6018	30275	NW	NA-0904
9-15-17	0925	5.9	1002	104	35475	5289	30186	NW	Eunice Becenti
9-15-17	1725	5.8	959	105	36724	4764	31960	NW	Eunice Becenti
9-16-17	0908	5.8	1005	104	36645	5582	31063	NW	Eunice Becenti
9-16-17	1258	5.7	1001	106	37099	5588	31511	NW	Eunice Becenti @ asphalt road

Reviewed by: MM Review Date: 10/4/17

Appendix B Exposure Rate Measurements

Date and Time	Exposure Rate (mR/h)[a]	Location
06/26/2017 10:09	0.0126	Correlation Location 1
06/26/2017 10:10	0.0127	Correlation Location 1
06/26/2017 10:11	0.0132	Correlation Location 1
06/26/2017 10:12	0.0130	Correlation Location 1
06/26/2017 10:13	0.0128	Correlation Location 1
06/26/2017 10:14	0.0131	Correlation Location 1
06/26/2017 10:15	0.0134	Correlation Location 1
06/26/2017 10:16	0.0134	Correlation Location 1
06/26/2017 10:17	0.0132	Correlation Location 1
06/26/2017 10:18	0.0132	Correlation Location 1
06/26/2017 10:53	0.0229	Correlation Location 2
06/26/2017 10:54	0.0231	Correlation Location 2
06/26/2017 10:55	0.0230	Correlation Location 2
06/26/2017 10:56	0.0236	Correlation Location 2
06/26/2017 10:57	0.0236	Correlation Location 2
06/26/2017 10:58	0.0231	Correlation Location 2
06/26/2017 10:59	0.0233	Correlation Location 2
06/26/2017 11:00	0.0231	Correlation Location 2
06/26/2017 11:01	0.0232	Correlation Location 2
06/26/2017 11:43	0.0173	Correlation Location 3
06/26/2017 11:44	0.0179	Correlation Location 3
06/26/2017 11:45	0.0185	Correlation Location 3
06/26/2017 11:46	0.0177	Correlation Location 3
06/26/2017 11:47	0.0179	Correlation Location 3
06/26/2017 11:48	0.0182	Correlation Location 3
06/26/2017 11:49	0.0183	Correlation Location 3
06/26/2017 11:50	0.0181	Correlation Location 3
06/26/2017 11:51	0.0185	Correlation Location 3
06/26/2017 11:52	0.0185	Correlation Location 3
06/26/2017 12:20	0.0197	Correlation Location 4
06/26/2017 12:21	0.0210	Correlation Location 4
06/26/2017 12:22	0.0208	Correlation Location 4
06/26/2017 12:23	0.0211	Correlation Location 4
06/26/2017 12:24	0.0214	Correlation Location 4
06/26/2017 12:25	0.0211	Correlation Location 4
06/26/2017 12:26	0.0209	Correlation Location 4
06/26/2017 12:27	0.0211	Correlation Location 4
06/26/2017 12:28	0.0214	Correlation Location 4
06/26/2017 12:29	0.0215	Correlation Location 4
06/26/2017 13:13	0.0141	Correlation Location 5
06/26/2017 13:14	0.0151	Correlation Location 5
06/26/2017 13:15	0.0148	Correlation Location 5
06/26/2017 13:16	0.0151	Correlation Location 5
06/26/2017 13:17	0.0154	Correlation Location 5
06/26/2017 13:18	0.0146	Correlation Location 5
06/26/2017 13:19	0.0148	Correlation Location 5
06/26/2017 13:20	0.0147	Correlation Location 5
06/26/2017 13:21	0.0147	Correlation Location 5
06/26/2017 13:22	0.0152	Correlation Location 5

Tsosie 1 Exposure Rate Measurements for Correlation

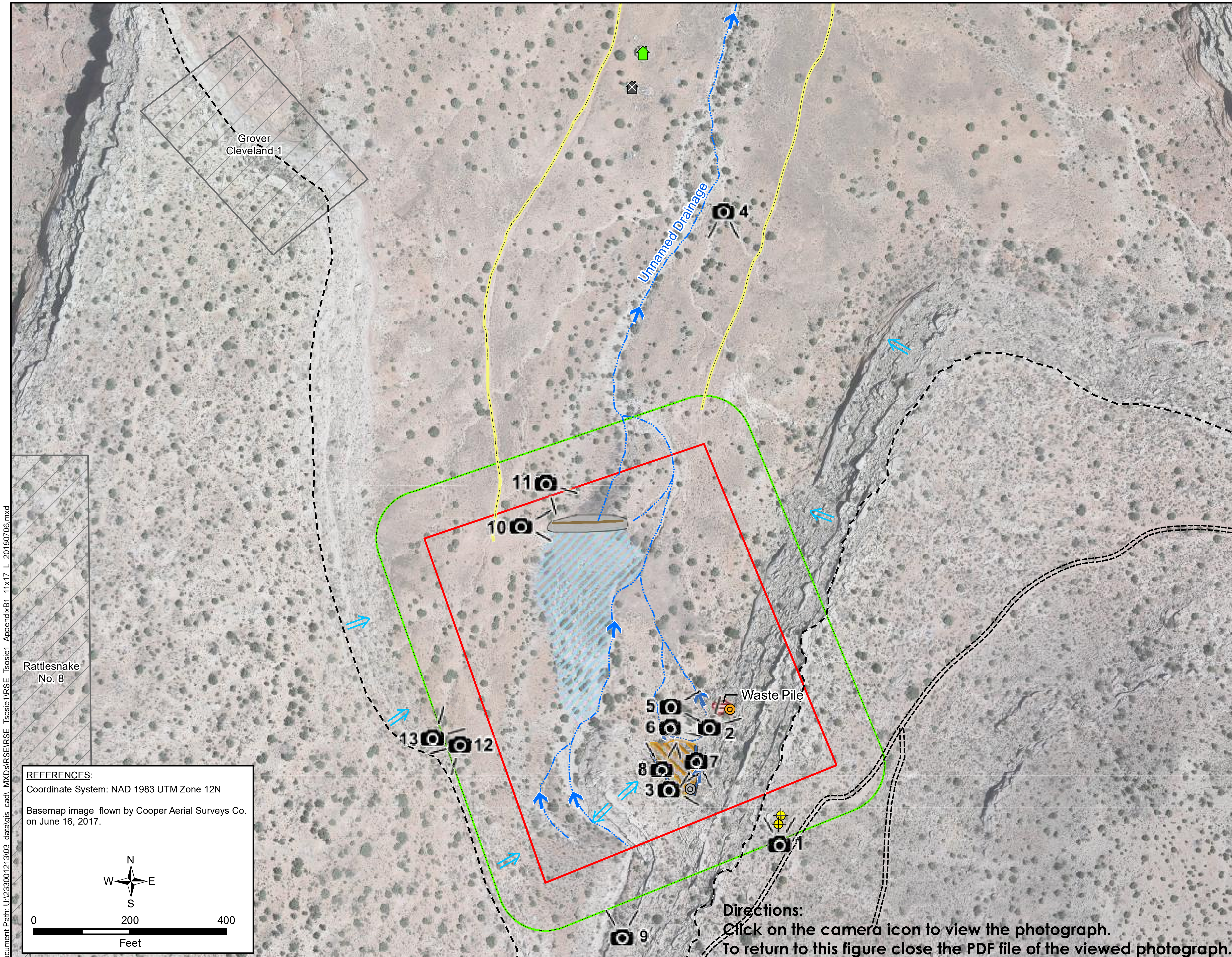
a. Results reported are averages of 60, 1-second measurements

Appendix B Photographs

B.1 Site Photographs

B.2 Regional Site Photographs

NAVAJO NATION
AUM Environmental Response Trust-First Phase



LEGEND

- Photograph Indicating Direction Taken
- Historical Borehole
- Approximate Buried Portal Location
- Habitable Building
- Sealed Portal
- Uninhabitable Building
- Flow Direction
- Approximate Overland Water Flow Direction
- Dam Crest
- Potential Haul Road
- Drainage
- Road
- Drainage Armored with
- Approximate Edge of Mesa
- Approximate Dam Footprint
- Temporary Ponding
- Reclaimed Area
- Waste Pile
- Claim Boundary
- Other Claim Boundary
- 100-Foot Claim Buffer

TITLE:

Site Photographs

PROJECT:

Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 7/18/2018

DOCUMENT NAME: Removal Site Evaluation Report

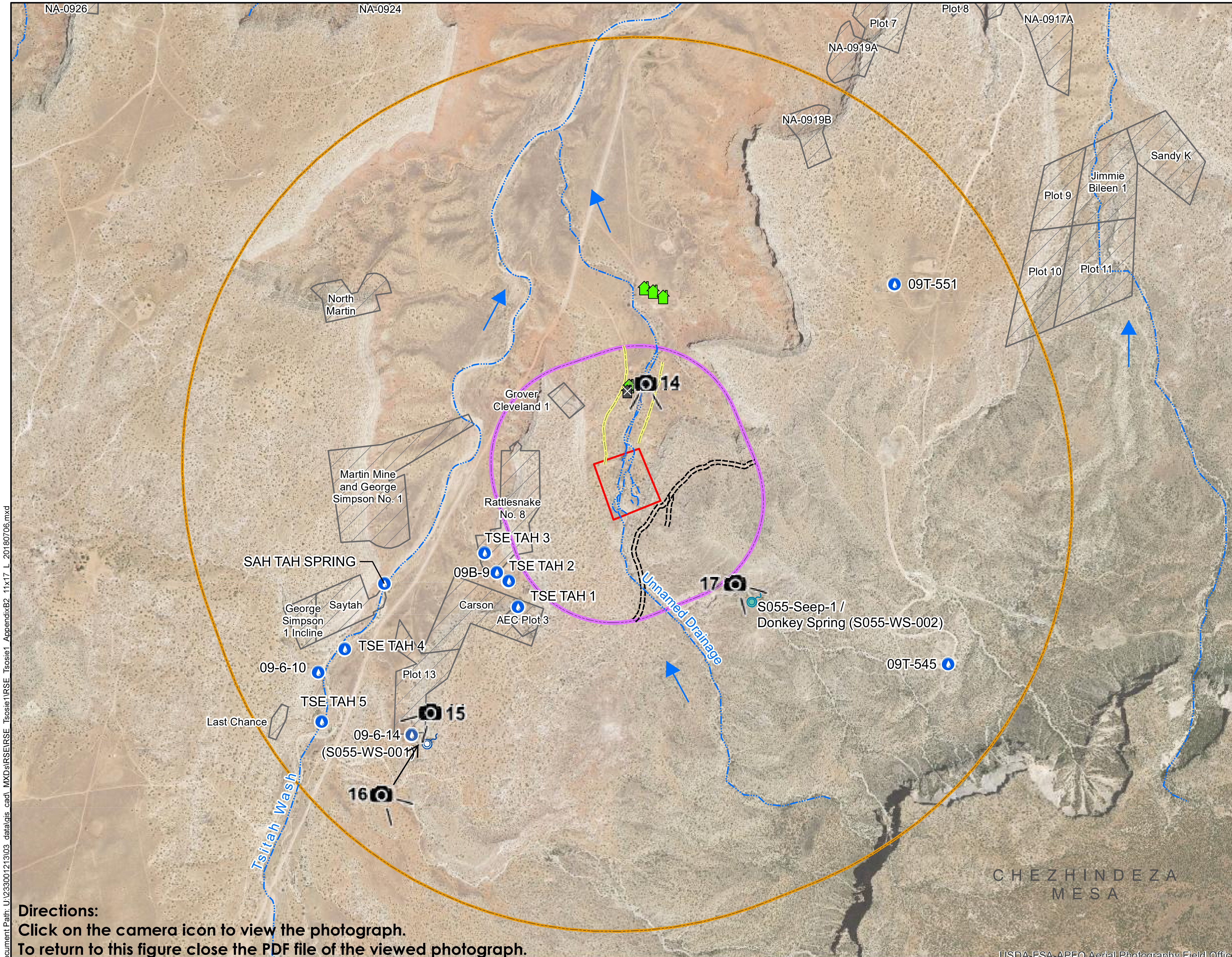
Stantec

AUTHOR: CBB

REVIEWER: EDZ

FIGURE: B-1

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_AppendixB1_11x17_L_20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Photograph Indicating Direction Taken
- Site Clearance Identified Potential Water Feature[1]
- Habitable Building
- Uninhabitable Building
- Seep
- Seep[2]
- Flow Direction
- Intermittent Stream/River
- Potential Haul Road
- Road
- Claim Boundary
- 1/4-Mile Claim Boundary Buffer
- 1-Mile Claim Boundary Buffer
- Other Claim Boundary

NOTES:

1. Potential water features and identification names identified in 2007 AUM Atlas and/or in database provided by the Navajo Nation Department of Water Resources.

2. S055-Seep-1 was identified with the help of residents that live near the Site.

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image accessed from the National Agriculture Imagery Program (NAIP) web mapping service (https://gis.apfo.usda.gov/arcgis/services/) on 7/18/2018

N W E S

0 1,250 2,500

Feet

TITLE:

Regional Site Photographs

PROJECT:

Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 7/18/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: CBB	REVIEWER: EDZ
	FIGURE: B-2	

Document Path: U:\233001213\03_data\gis_cad_MXDs\RSE\RSE_Tsosie1\RSE_Tsosie1_AppendixB2_11x17_L_20180706.mxd

Appendix C Field Activity Forms

C.1 Soil Sample Field Forms

C.2 Hand Auger Borehole Logs

C.3 Water Sample Field Forms

C.1 Soil Sample Field Forms

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055 - BG1 - 001, 201

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1520

SAMPLE COLLECTED BY MW/HR

WEATHER CONDITIONS 100° F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly grd sand w/ grvl

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (8055)

SAMPLE I.D. 8055-BG1-002

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1550

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sand w/ gravel

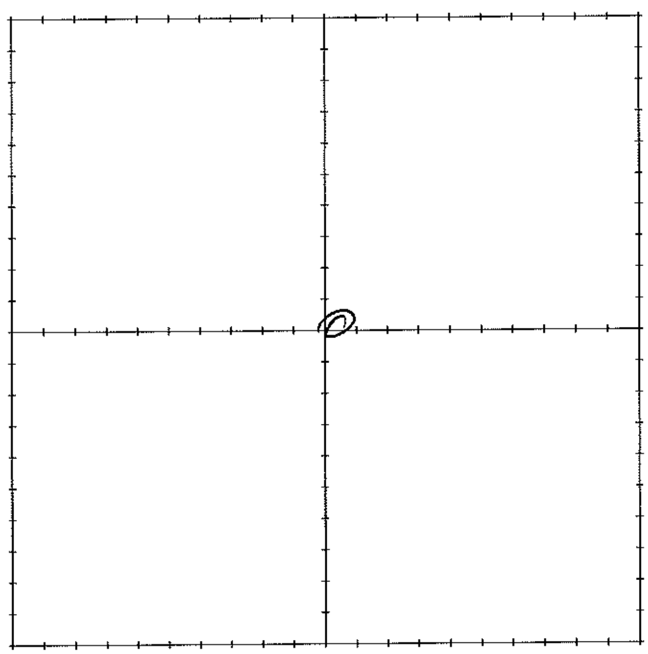
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 jars

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-BG1-003

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1556

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sand w/ gravels

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226 Metals

2

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Session 1 (5055)

SAMPLE I.D. 5055-BG1-004

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1605

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly grad sand w/ gravel

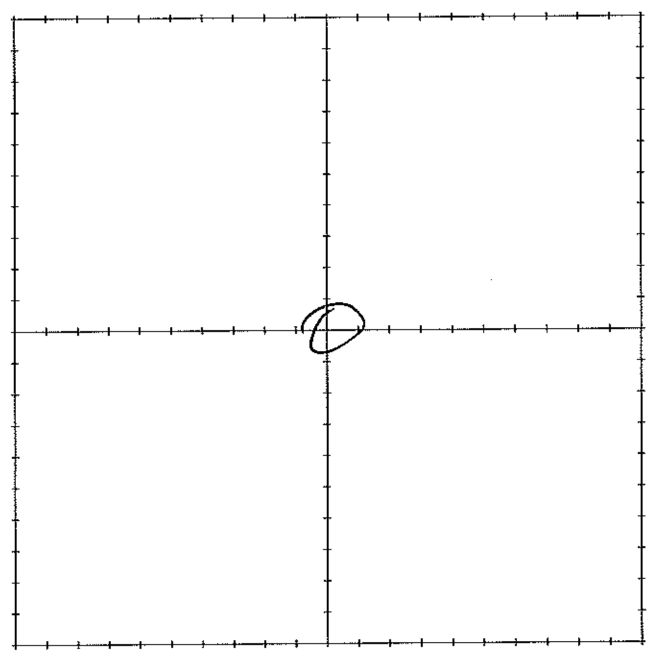
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 jars

ANALYSES: Ra-Th, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME: Tsoil-1 (S055)

SAMPLE I.D.: S055 - B01-005

SAMPLE COLLECTION DATE: 6/24/17

SAMPLE COLLECTION TIME: 1612

SAMPLE COLLECTED BY: MW / NR

WEATHER CONDITIONS: 100°F, sunny, calm

FIELD USCS DESCRIPTIONS: Poorly grad sand w/ gravels

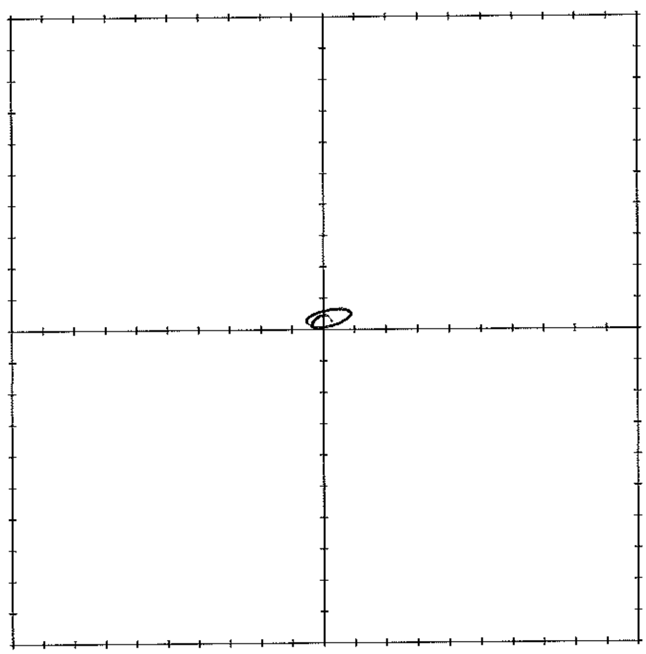
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☑ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☑ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE): 8-oz plas

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsoil (5055)

SAMPLE I.D. 5055-BG1-006

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1620

SAMPLE COLLECTED BY MW/HR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly grd sand w/ gravels, coarse sands

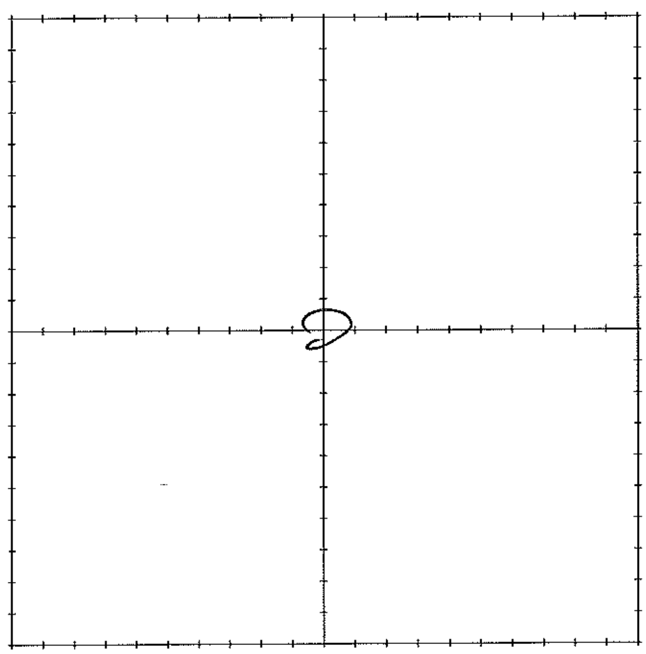
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☒ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie (8055)

SAMPLE I.D. 8055- BG1-007

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1625

SAMPLE COLLECTED BY MW / NR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly grad sand w/ gravel

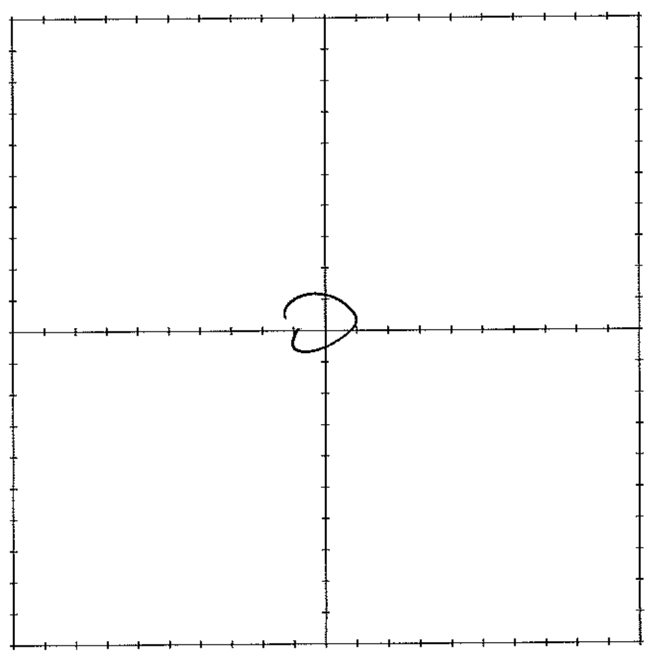
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziplocs

ANALYSES: Ra-226, Metals.



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-BG1-008

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1632

SAMPLE COLLECTED BY MO/HR

WEATHER CONDITIONS 100°F, Sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sand w/ gravels

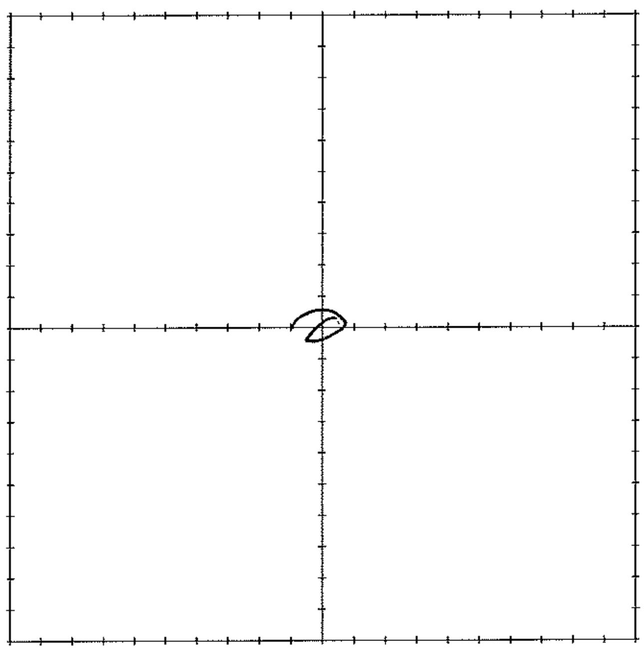
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☑ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☑ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zips

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME ~~SO~~ Tsosie 1 (S055)

SAMPLE I.D. S055 - BG1 - 009

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1640

SAMPLE COLLECTED BY MW/HR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly grdd sands w/ grvls

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-BG1-010

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1647

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sand, SP

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226 Metals

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Trosivol (5055)

SAMPLE I.D. 5055-B42-001

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1533

SAMPLE COLLECTED BY LR / HW

WEATHER CONDITIONS 100°, sunny, calm

FIELD USCS DESCRIPTIONS Fine tan sand, SP

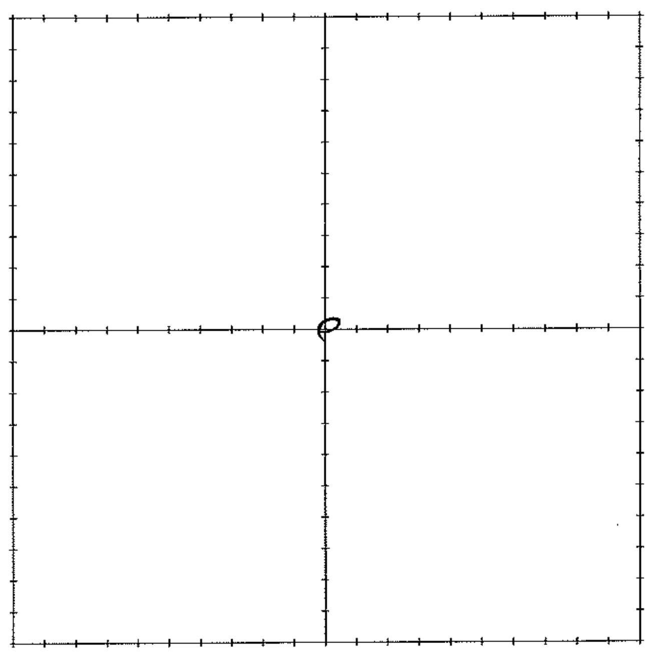
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zips

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Ts05tc1 (S055)

SAMPLE I.D. S055-BG2-002, 202

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1540

SAMPLE COLLECTED BY MW/LR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Fine tan sand, SP

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 jar

ANALYSES: Ra-226, Metals

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-BG2-003

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1550

SAMPLE COLLECTED BY MW/CR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Fine tan sand, SP

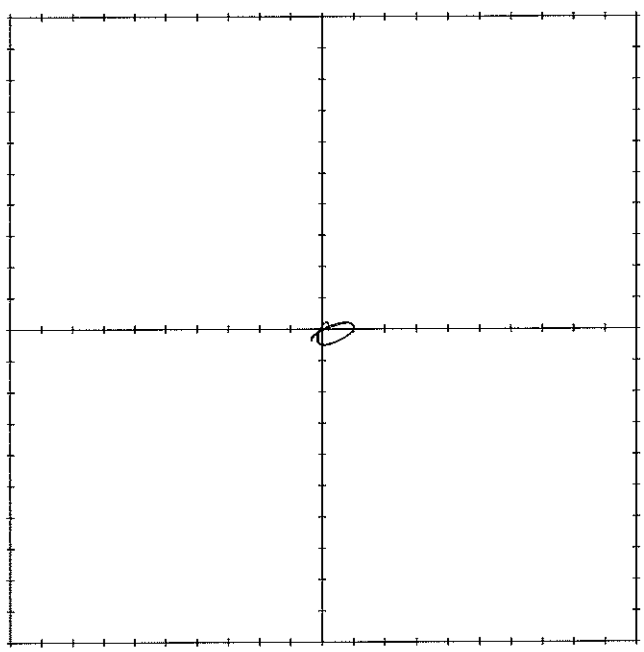
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (8055)

SAMPLE I.D. 8055-BG2-~~003~~-004

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1558

SAMPLE COLLECTED BY NW/LK

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Fine light brown sand, minor darker frags

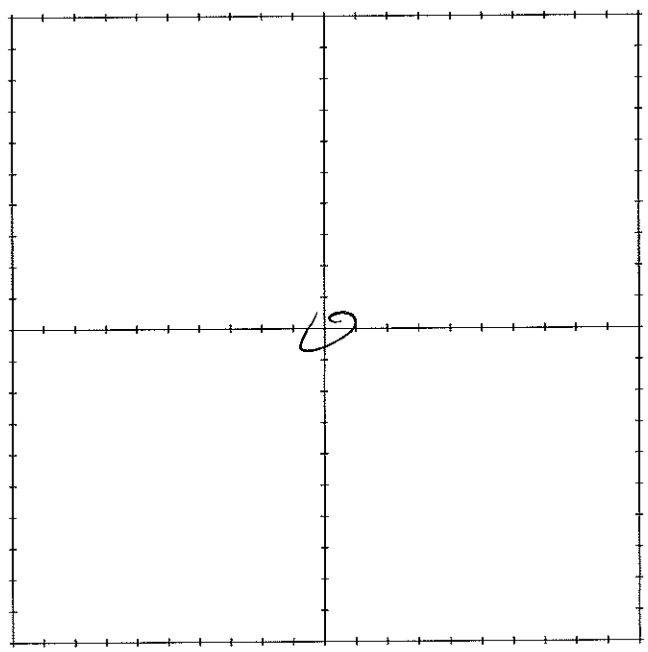
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☒ SOME; SAND SIZE ☐ FINE ☒ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie1 (S055)

SAMPLE I.D. S055-BG2-005

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1600

SAMPLE COLLECTED BY NWO/LK

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Fine tan sand, trace black med. frags, minor coarse sands

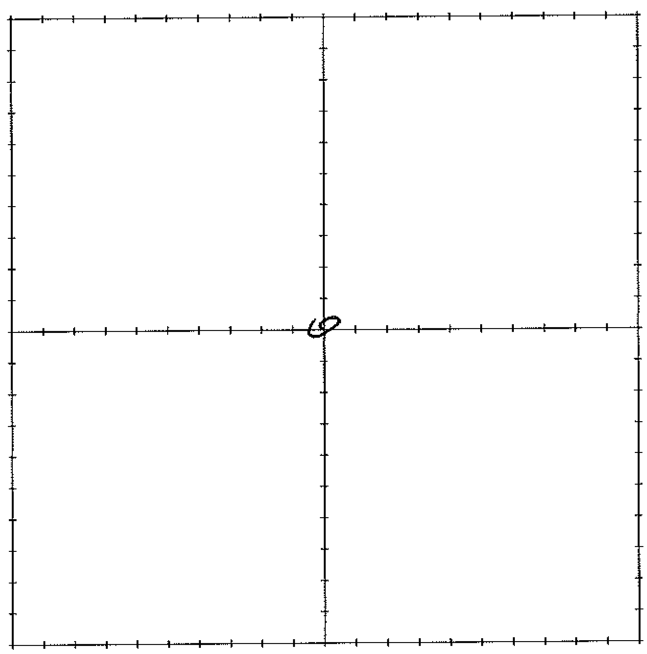
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☒ MINOR ☐ SOME; SAND SIZE ☐ FINE ☒ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zipper

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME: Tsosie 1 (S055)

SAMPLE I.D.: S055-BG2-006

SAMPLE COLLECTION DATE: 6/24/17

SAMPLE COLLECTION TIME: 1608

SAMPLE COLLECTED BY: MW/LR

WEATHER CONDITIONS: 100°F, sunny, calm

FIELD USCS DESCRIPTIONS: fine tan sand, minor granitic, trace coarse sand

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☒ MINOR ☐ SOME; SAND SIZE ☐ FINE ☒ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE): 2 ziploc

ANALYSES: Ra-226, Metals

6

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME: Tsosie 1 (S055)

SAMPLE I.D.: S055-BG2-007

SAMPLE COLLECTION DATE: 6/24/17

SAMPLE COLLECTION TIME: 1615

SAMPLE COLLECTED BY: HW/LM

WEATHER CONDITIONS: 100°F, sunny, calm

FIELD USCS DESCRIPTIONS: Fine light brown sand, 40% med. sand, trace coarse

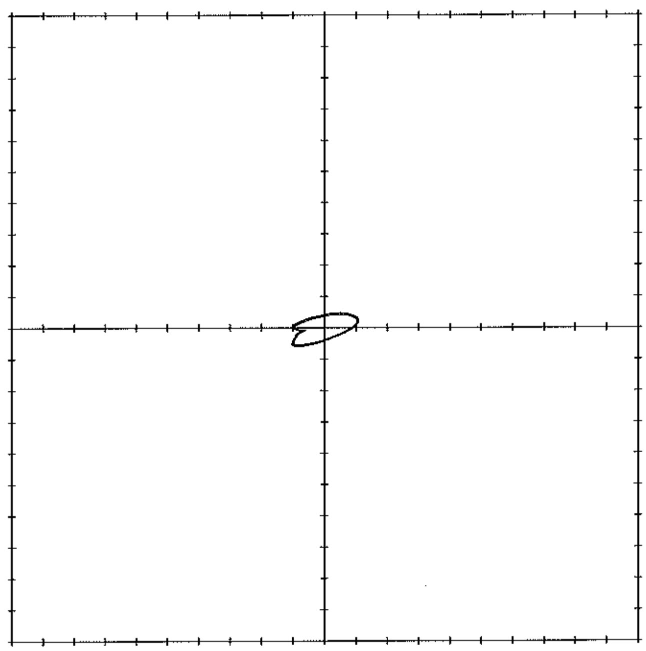
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☒ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE): 2 jars

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME: Coil (S055)

SAMPLE I.D.: S055-BG2-008

SAMPLE COLLECTION DATE: 6/24/17

SAMPLE COLLECTION TIME: 1621

SAMPLE COLLECTED BY: MW/UL

WEATHER CONDITIONS: 100°F, sunny, calm

FIELD USCS DESCRIPTIONS: very fine light brown sand, trace coarse gravel, minor fine gravel

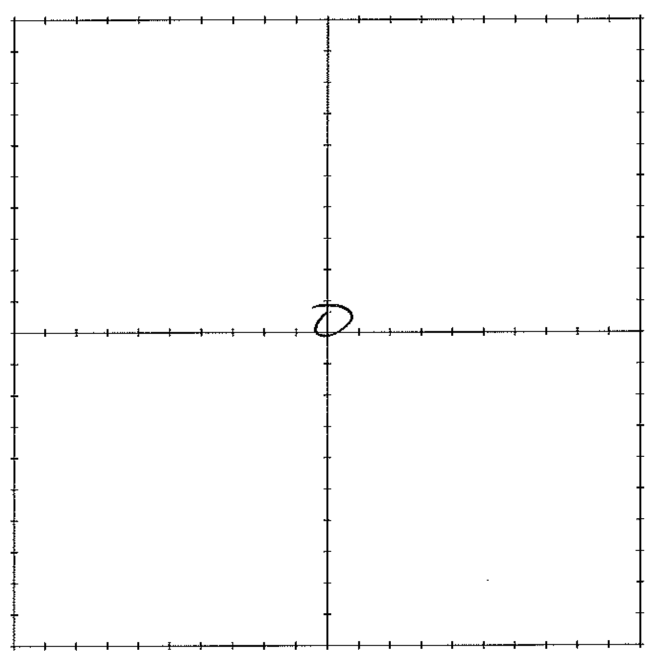
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE): 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Trosite 1 (S055)

SAMPLE I.D. S055-BG2-009 MS/MSD

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1628

SAMPLE COLLECTED BY NW/lu

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Fine tan/light brown sand, trace coarse gravel.

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC

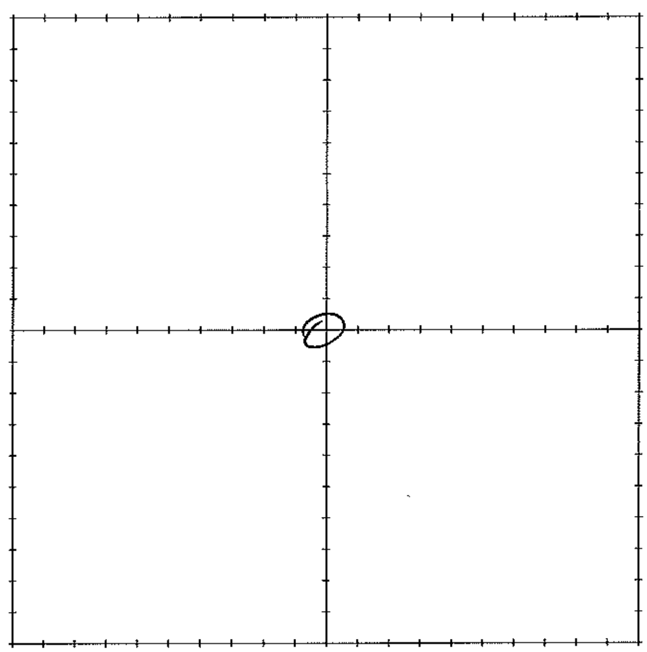
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☒ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zip

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Toxic 1 (8055)

SAMPLE I.D. 8055-BG2-010

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1640

SAMPLE COLLECTED BY NW/LR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Fine to med. brown/tan sand, minor coarse sand

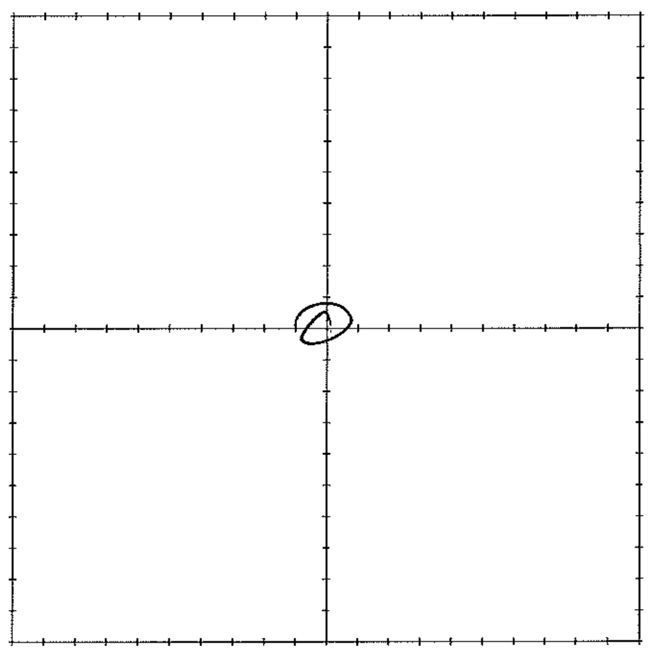
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☒ MINOR ☐ SOME; SAND SIZE ☐ FINE ☒ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zip

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (8055)

SAMPLE I.D. 8055-C01-001, 201

SAMPLE COLLECTION DATE 6/26/17

SAMPLE COLLECTION TIME 1020

SAMPLE COLLECTED BY ~~AE~~ LR

WEATHER CONDITIONS 90-100°, sunny, calm

FIELD USCS DESCRIPTIONS Fine light brown sand, some gravels

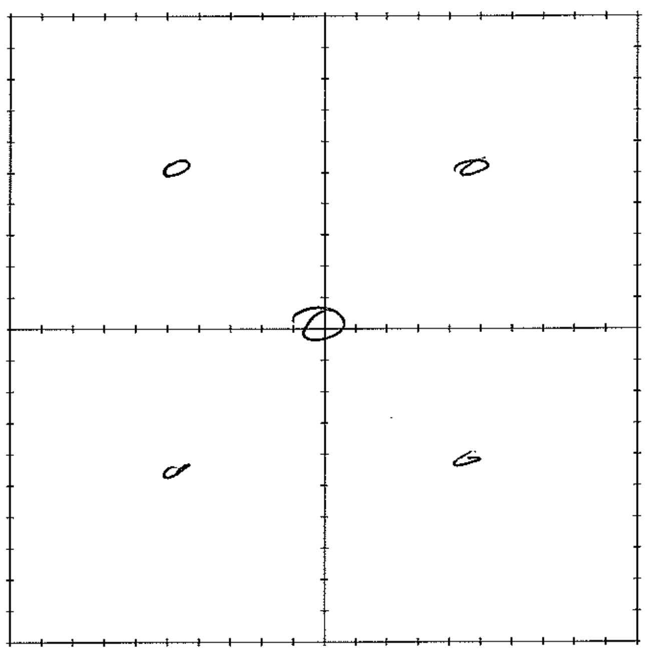
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☒ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zips

ANALYSES: Ra-226, Isotopic Thorium



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Isosiel (SOSS)

SAMPLE I.D. SOSS- 102-001

SAMPLE COLLECTION DATE 6/26/17

SAMPLE COLLECTION TIME 1035

SAMPLE COLLECTED BY LR

WEATHER CONDITIONS 90-100°F, sunny, calm

FIELD USCS DESCRIPTIONS 30% fine light brown sand, minor coarse/med sands

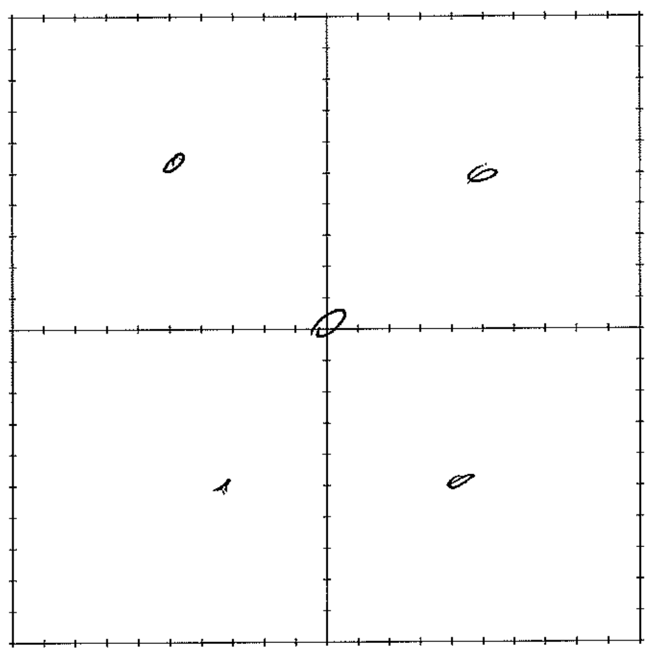
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zip

ANALYSES: Ra-226, Isotopic Thorium



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Erosion 1 (S055)

SAMPLE I.D. S055-C03-001

SAMPLE COLLECTION DATE 6/26/17

SAMPLE COLLECTION TIME 1123

SAMPLE COLLECTED BY LK

WEATHER CONDITIONS 90-100° F, sunny, calm

FIELD USCS DESCRIPTIONS Fine light brown soil, minor coarse/med. sands, platey cobbles on surface

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC

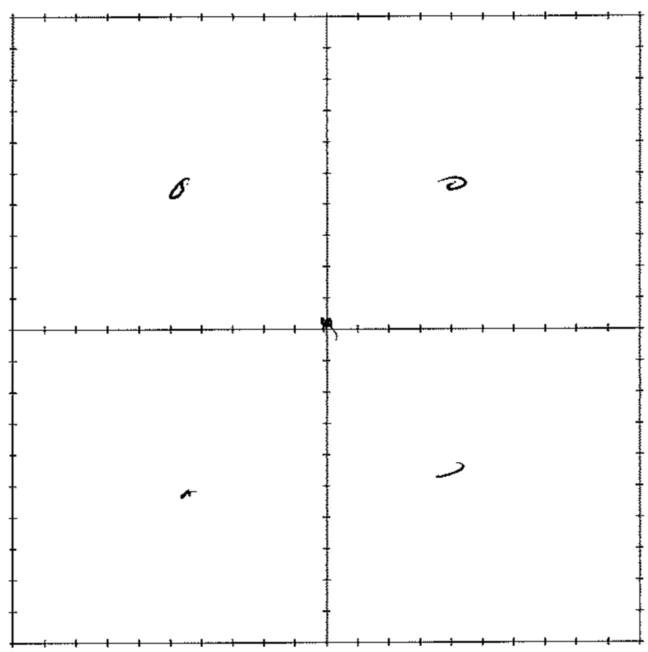
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☒ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☒ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zips

ANALYSES: Ra-226, Isotopic Thorium



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME: Isoin 1 (S055)

SAMPLE I.D.: S055-C04-001

SAMPLE COLLECTION DATE: 6/26/17

SAMPLE COLLECTION TIME: ~~[illegible]~~ 1207

SAMPLE COLLECTED BY: [illegible]

WEATHER CONDITIONS: 90-100°F, sunny, calm

FIELD USCS DESCRIPTIONS: ~~[illegible]~~ (Gravels, fine light brown sand)

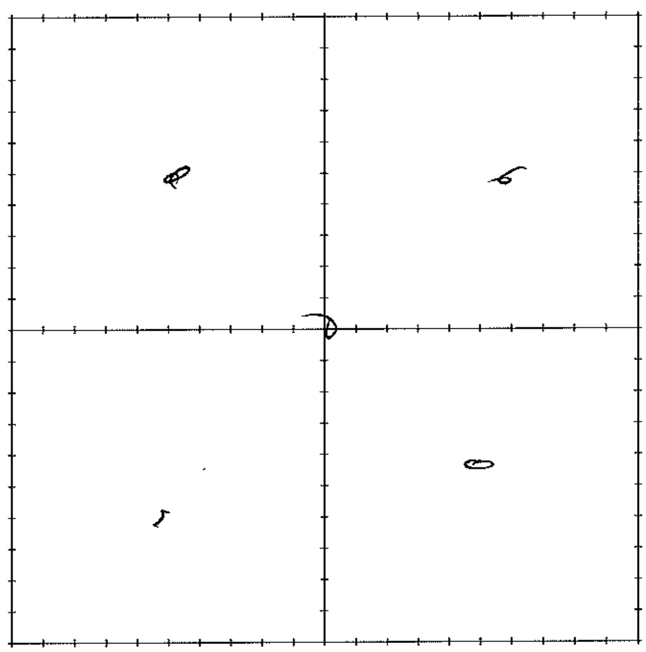
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☐ SW ☐ GC ☐ GM ☐ GP ☒ GW

QUALIFIERS: ☑ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☑ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE): 2 ziploc

ANALYSES: Ra-226, Isotopic Thorium



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Esoite 1 (8055)

SAMPLE I.D. 8055-C05-001 MS/MSD

SAMPLE COLLECTION DATE 6/26/17

SAMPLE COLLECTION TIME 1255

SAMPLE COLLECTED BY LR

WEATHER CONDITIONS 90-100°F, sunny, calm

FIELD USCS DESCRIPTIONS Fine light brown sand, trace coarse sand (black)

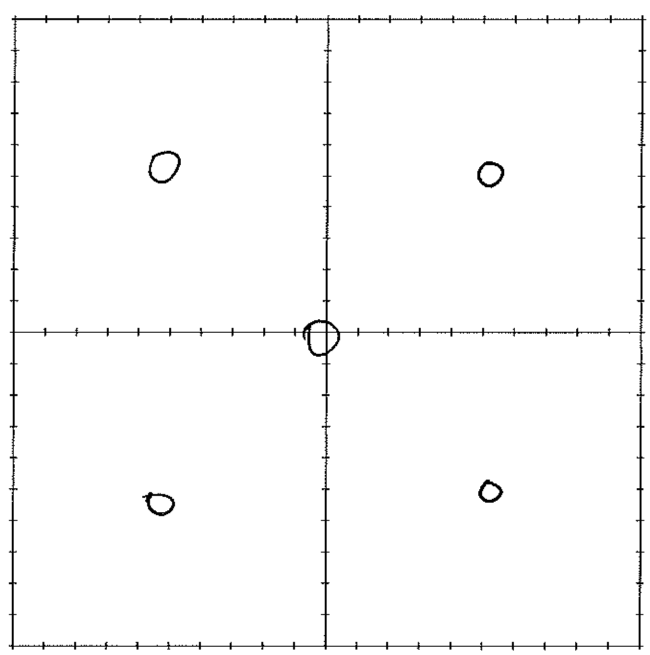
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 zips

ANALYSES: Ra-226, Isotopic Thorium



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Trosiel (S055)

SAMPLE I.D. S055-GX-001

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 0950

SAMPLE COLLECTED BY MW / NR

WEATHER CONDITIONS 100°+, Sunny

FIELD USCS DESCRIPTIONS Silty sand w/ gravel

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☒ SM ☐ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

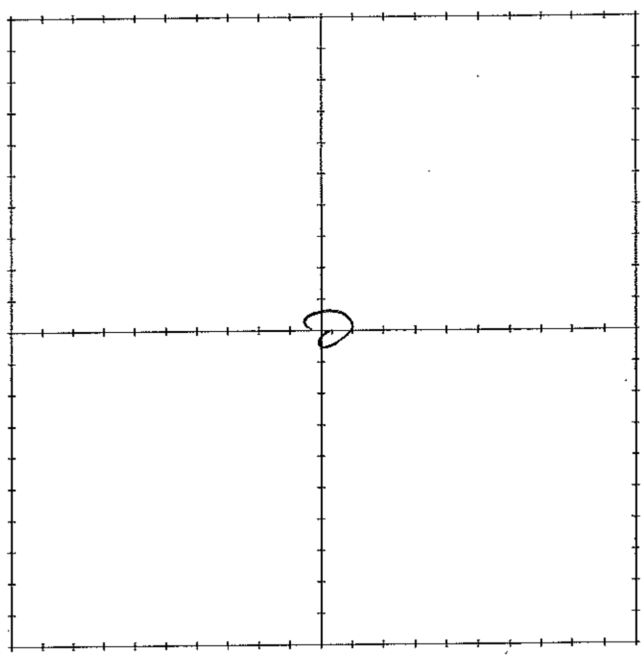
QUALIFIERS: ☐ TRACE ☐ MINOR ☒ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

MUNSELL COLOR —

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsoriel (5055)

SAMPLE I.D. 5055-CX-002

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 1007

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100° +, sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sand, SP-SM

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☒ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

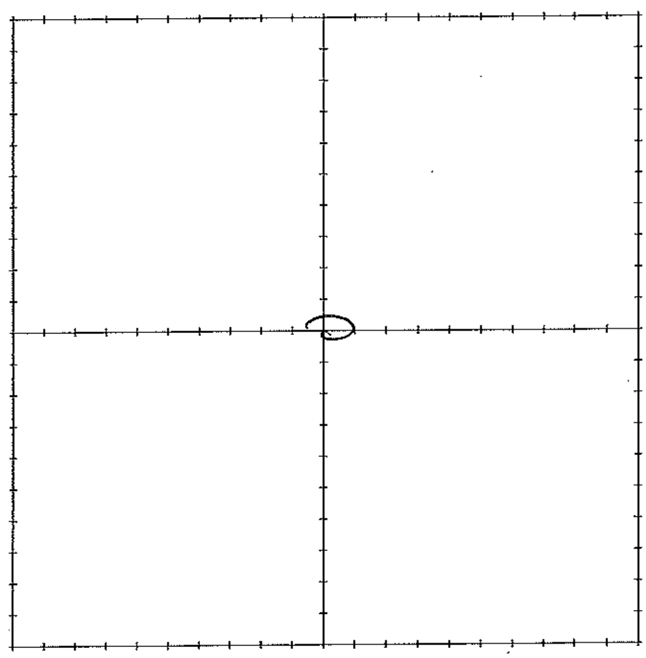
QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

MUNSELL COLOR —

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-CX-003/203

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 1030

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100°F+, sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sand w/ gravels, SP-

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☑ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

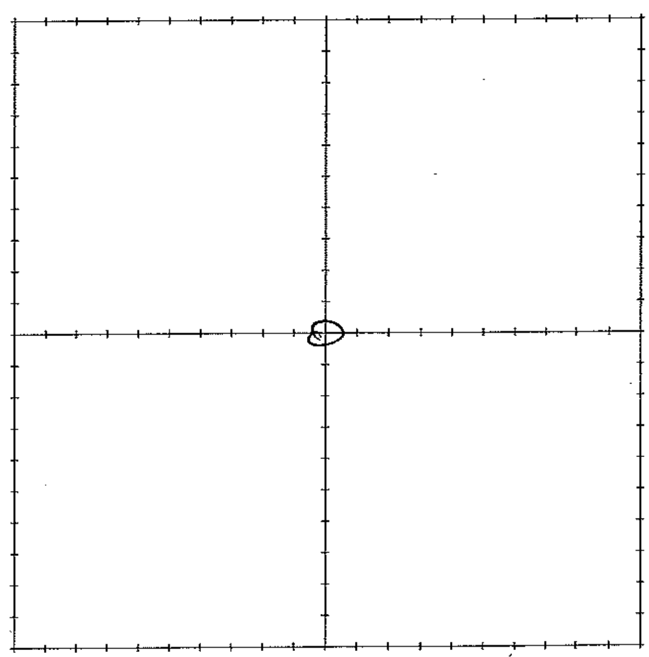
QUALIFIERS: ☑ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☑ COARSE

MOISTURE: ☑ DRY ☐ MOIST ☐ WET

MUNSELL COLOR —

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-CX-004

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 1050

SAMPLE COLLECTED BY MW/HR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sand with gravel, SP

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

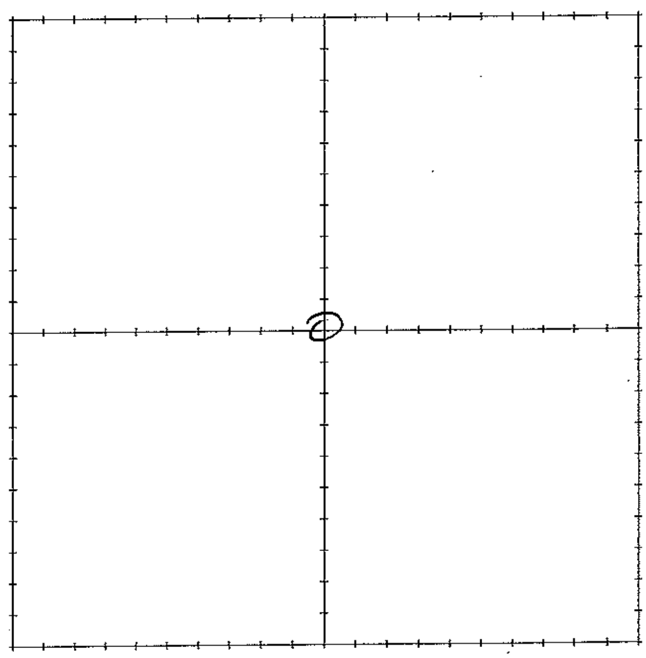
QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

MUNSELL COLOR —

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME: Tsosfd (S055)

SAMPLE I.D.: S055-CX-005 MS/MSD

SAMPLE COLLECTION DATE: 6/23/17

SAMPLE COLLECTION TIME: 1105

SAMPLE COLLECTED BY: MW/NR

WEATHER CONDITIONS: 100°F, sunny, calm

FIELD USCS DESCRIPTIONS: Poorly graded sand w/ gravels

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

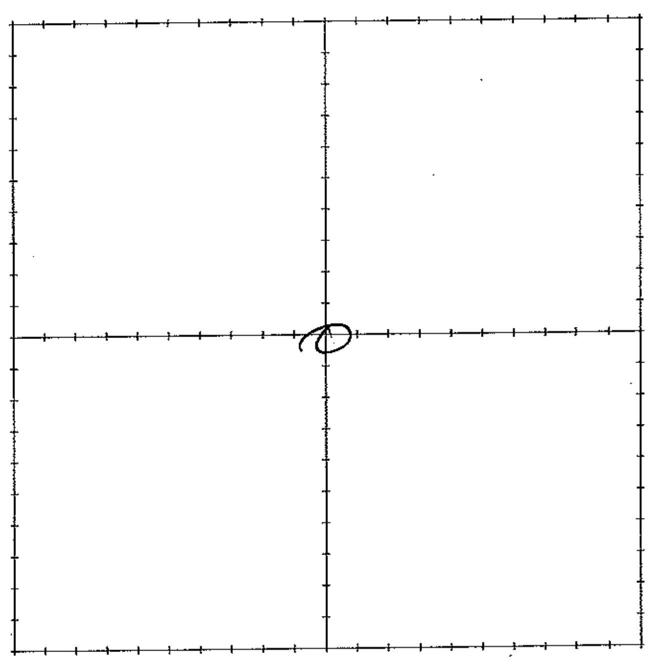
QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

MUNSELL COLOR: —

SAMPLE CONTAINERS (NUMBER AND TYPE): 2 zip

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie (S055)

SAMPLE I.D. S055-CX-006

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 1122

SAMPLE COLLECTED BY MW/KR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly grdd sand w/grvls and silt, SP-SM

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☒ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

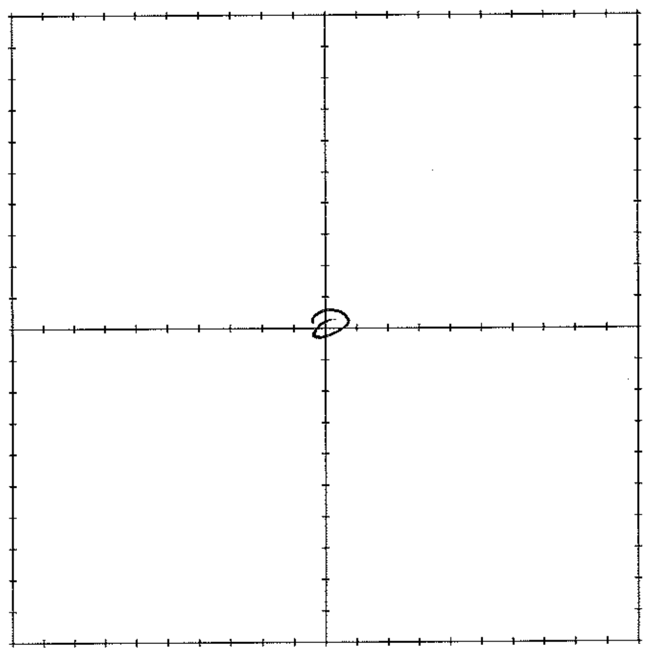
QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

MUNSELL COLOR —

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-CX-~~006~~ 007

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME ~~1122~~ 1138

SAMPLE COLLECTED BY MW / HR

WEATHER CONDITIONS 100° F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly grdd sand w/ grvls

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

MUNSELL COLOR —

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-CX-008

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 1157

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Poorly graded sands w/ gravels

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☒ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

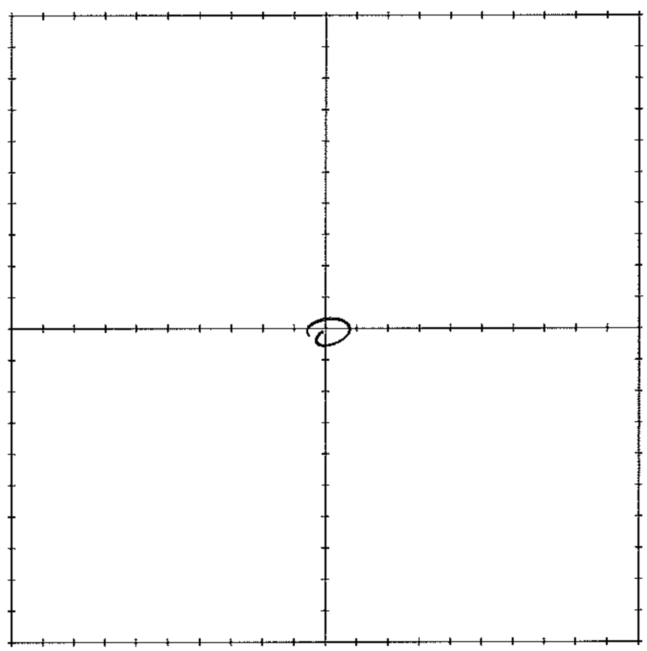
QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

MUNSELL COLOR —

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-CX-009

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 1209

SAMPLE COLLECTED BY MW/KR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS well grd sand w/ silts, SW-SM

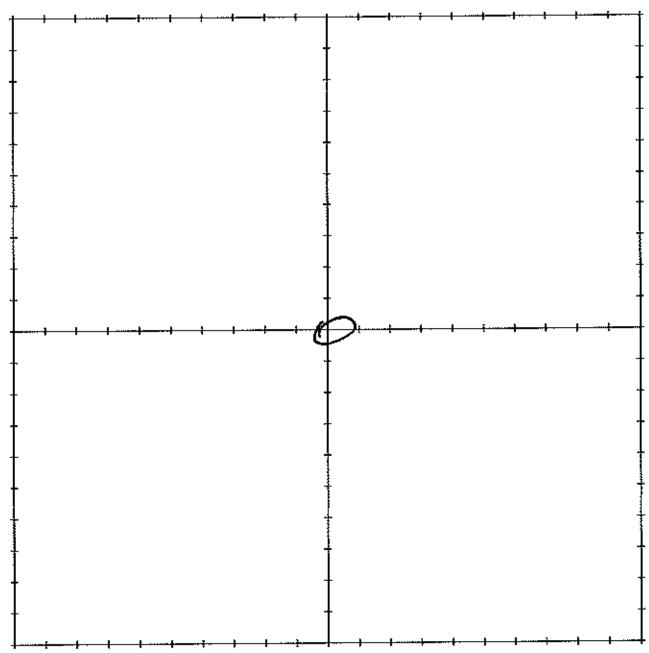
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☒ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals



MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (5055)

SAMPLE I.D. 5055-Cx-010

SAMPLE COLLECTION DATE 6/23/17

SAMPLE COLLECTION TIME 1225

SAMPLE COLLECTED BY MW/NR

WEATHER CONDITIONS 100°F, sunny, calm

FIELD USCS DESCRIPTIONS Well graded sand w/ gravels, sw

MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☐ SP ☒ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☒ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☒ COARSE

MOISTURE: ☒ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals

MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

MWH

SURFACE SOIL SAMPLE LOG FORM

AREA #/NAME Tsosie 1 (S055)

SAMPLE I.D. S055-CX-011

SAMPLE COLLECTION DATE 6/24/17

SAMPLE COLLECTION TIME 1002

SAMPLE COLLECTED BY MW

WEATHER CONDITIONS 100°, sunny, calm

FIELD USCS DESCRIPTIONS Fine poorly graded sand, SP, from sed. accum. along red. cap. incision

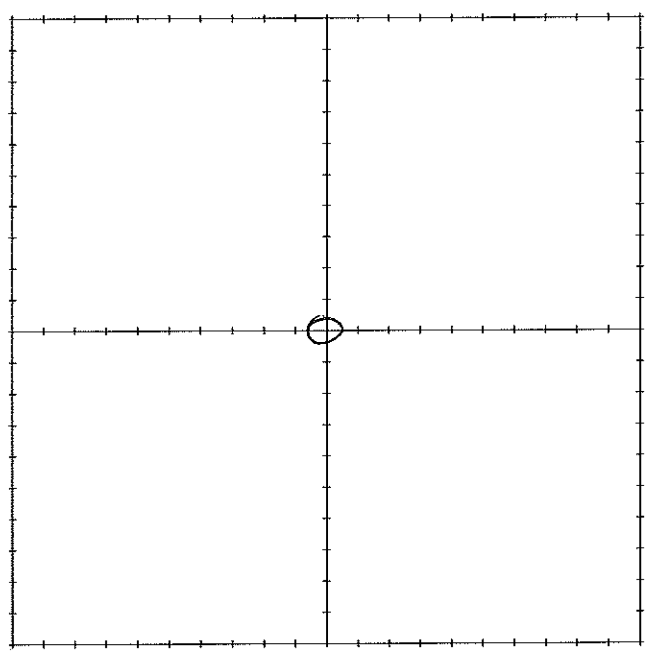
MAJOR DIVISIONS: ☐ OH ☐ CH ☐ MH ☐ OH ☐ CL ☐ ML ☐ SC
☐ SM ☑ SP ☐ SW ☐ GC ☐ GM ☐ GP ☐ GW

QUALIFIERS: ☐ TRACE ☐ MINOR ☐ SOME; SAND SIZE ☐ FINE ☐ MEDIUM ☐ COARSE

MOISTURE: ☑ DRY ☐ MOIST ☐ WET

SAMPLE CONTAINERS (NUMBER AND TYPE) 2 ziploc

ANALYSES: Ra-226, Metals

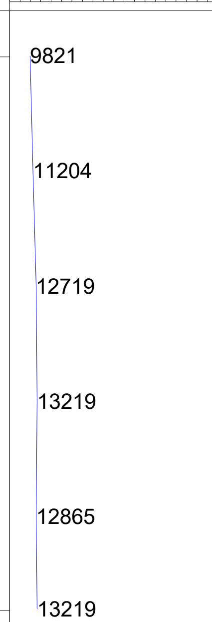


MARK INDIVIDUAL GRAB SAMPLE LOCATIONS IN GRID

C.2 Hand Auger Borehole Logs

BOREHOLE ID:	**S055-BG1-011**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec	COORDINATE SYSTEM:	NAD 1983 UTM Zone 12N		
DRILLING METHOD:	Hand auger	EASTING:	653306.99	NORTHING:	4082966.99
DRILLING EQUIPMENT:	Hand auger	DATE STARTED:	6/26/2017	DATE STARTED:	6/26/2017
SAMPLING METHOD:	Regular hand auger, 3 inch diameter	TOTAL DEPTH (ft.):	2.4	BOREHOLE ANGLE:	90 degrees
		LOGGED BY:	Luis Rodriguez		



DEPTH (feet)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION
0–2.4		POORLY GRADED SAND (SP): brown, medium grained sand, dry.
2.4		Terminated hand auger borehole at 2.4 ft. below ground surface. Refusal on rock.

SUBSURFACE SAMPLE INFORMATION

SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
S055-BG1-011-01	0-0.5	grab	1.45
S055-BG1-011-02	0.5-1	grab	0.97
S055-BG1-011-03	1-2	grab	1.06

Notes: cpm = counts per minute
pCi/g = picocuries per gram

grab = grab sample
comp = composite sample

- - - - = approximate contact

Stantec | NAVAJO NATION AUM Environmental Response Trust-First Phase

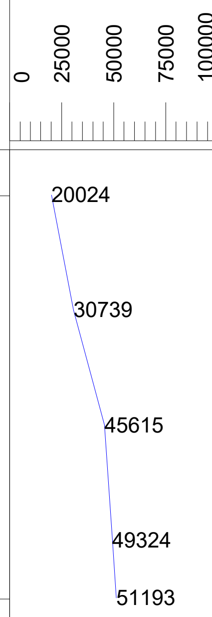
BOREHOLE ID:	**S055-BG2-011**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec
DRILLING METHOD:	Hand auger
DRILLING EQUIPMENT:	Hand auger
SAMPLING METHOD:	Regular hand auger, 3 inch diameter

COORDINATE SYSTEM:		NAD 1983 UTM Zone 12N	
EASTING:	653343.69	NORTHING:	4082926.27
DATE STARTED:	6/26/2017	DATE STARTED:	6/26/2017
TOTAL DEPTH (ft.):	1.75	BOREHOLE ANGLE:	90 degrees
LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL DESCRIPTION
0–1.75	POORLY GRADED SAND (SP): brown, fine to medium grained sand, dry.
1.75	Terminated hand auger borehole at 1.75 ft. below ground surface. Refusal on rock.

Gamma (cpm)



SUBSURFACE SAMPLE INFORMATION

SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
S055-BG2-011-1	0-0.8	grab	5.06
S055-BG2-011-2	0.8-1.75	grab	9.60

Notes: cpm = counts per minute
pCi/g = picocuries per gram
grab = grab sample
comp = composite sample
- - - - = approximate contact

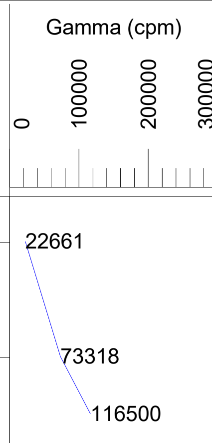
BOREHOLE ID:	**S055-SCX-001**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec
DRILLING METHOD:	Hand auger
DRILLING EQUIPMENT:	Hand auger
SAMPLING METHOD:	Regular hand auger, 3 inch diameter

COORDINATE SYSTEM:		NAD 1983 UTM Zone 12N	
EASTING:	653186.33	NORTHING:	4082628.66
DATE STARTED:	6/23/2017	DATE STARTED:	6/23/2017
TOTAL DEPTH (ft.):	0.9	BOREHOLE ANGLE:	90 degrees
LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0	POORLY GRADED SAND (SP): brown, fine grained sand, 100% sand, dry, loose. Soil potentialy part of waste rock cover material.	S055-SCX-001-01	0-0.5	grab	5.45
	POORLY GRADED SAND WITH GRAVEL (SP): gray, light brown, 60% sand, 40% gravel, dry, loose. Potential waste rock material.	S055-SCX-001-02	0.5-0.9	grab	56.20
1	Terminated hand auger borehole at 0.9 ft. below ground surface. Refusal on cobbles.				
2					
3					
4					
5					

Gamma (cpm)



Notes: cpm = counts per minute
pCi/g = picocuries per gram

grab = grab sample
comp = composite sample

- - - - = approximate contact

BOREHOLE ID:	**S055-SCX-002**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec	COORDINATE SYSTEM:	NAD 1983 UTM Zone 12N
DRILLING METHOD:	Hand auger	EASTING: 653174.77	NORTHING: 4082688.27
DRILLING EQUIPMENT:	Hand auger	DATE STARTED: 6/23/2017	DATE STARTED: 6/23/2017
SAMPLING METHOD:	Regular hand auger, 3 inch diameter	TOTAL DEPTH (ft.): 1	BOREHOLE ANGLE: 90 degrees
		LOGGED BY:	Luis Rodriguez

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	Gamma (cpm)
0	POORLY GRADED SAND (SP): tan, fine grained sand, some coarse sand, 100% sand, dry, loose. Borehole located in drainage below portal.	14693
0.5		18621
1	Terminated hand auger borehole at 1.0 ft. below ground surface. Refusal on rock.	19924

Gamma (cpm) scale: 0, 25000, 50000, 75000, 100000

SUBSURFACE SAMPLE INFORMATION

SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
S055-SCX-002-01	0-0.5	grab	6.06
S055-SCX-002-02	0.5-1	grab	4.73

Depth scale: 0, 1, 2, 3, 4, 5

Notes: cpm = counts per minute
pCi/g = picocuries per gram
grab = grab sample
comp = composite sample
- - - - = approximate contact

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BOREHOLE ID:	**S055-SCX-003**		
CLIENT:	NNAUMERT		
PROJECT:	Removal Site Evaluation		
SITE LOCATION:	Tsosie 1		

DRILLING CONTRACTOR:	Stantec	COORDINATE SYSTEM:		NAD 1983 UTM Zone 12N	
DRILLING METHOD:	Hand auger	EASTING:	653213.47	NORTHING:	4082671.02
DRILLING EQUIPMENT:	Hand auger	DATE STARTED:	6/23/2017	DATE STARTED:	6/23/2017
SAMPLING METHOD:	Regular hand auger, 3 inch diameter	TOTAL DEPTH (ft.):	1.75	BOREHOLE ANGLE:	90 degrees
		LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	Gamma (cpm) 0 / 25000 / 50000 / 75000 / 100000	SUBSURFACE SAMPLE INFORMATION: SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0		POORLY GRADED SAND (SP): gray, fine grained sand, coarse angular sand, trace gravel, gravels are shale.	19753				
			26595	S055-SCX-003-01	0-0.5	grab	8.20
1			33768	S055-SCX-003-02	0.5-1.5	grab	7.70
			38866				
			39355	S055-SCX-003-03	1.5-1.75	grab	8.60
2		Terminated hand auger borehole at 1.75 ft. below ground surface. Refusal on rock.					
3							
4							
5							

Notes: cpm = counts per minute
pCi/g = picocuries per gram
grab = grab sample
comp = composite sample
- - - - = approximate contact

BOREHOLE ID:	**S055-SCX-004**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec
DRILLING METHOD:	Hand auger
DRILLING EQUIPMENT:	Hand auger
SAMPLING METHOD:	Regular hand auger, 3 inch diameter

COORDINATE SYSTEM:		NAD 1983 UTM Zone 12N	
EASTING:	653165.67	NORTHING:	4082651.72
DATE STARTED:	6/24/2017	DATE STARTED:	6/24/2017
TOTAL DEPTH (ft.):	1	BOREHOLE ANGLE:	90 degrees
LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	Gamma (cpm) 0 – 25000 – 50000 – 75000 – 100000	SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0		SILTY SAND WITH GRAVEL (SP): brown, fine grained sand, sand 40%, gravel 30%, fines 30%, loose, dry.	12514				
				S055-SCX-004-01	0-0.5	grab	4.23
0.5			14029				
				S055-SCX-004-02	0.5-1	grab	3.11
1		Terminated hand auger borehole at 1.0 ft. below ground surface. Refusal on rock.	14440				
2							
3							
4							
5							

Notes: cpm = counts per minute
pCi/g = picocuries per gram

grab = grab sample
comp = composite sample

- - - - = approximate contact

BOREHOLE ID:	**S055-SCX-005**		
CLIENT:	NNAUMERT		
PROJECT:	Removal Site Evaluation		
SITE LOCATION:	Tsosie 1		
DRILLING CONTRACTOR:	Stantec	COORDINATE SYSTEM:	NAD 1983 UTM Zone 12N
DRILLING METHOD:	Hand auger	EASTING: 653122.59	NORTHING: 4082767.21
DRILLING EQUIPMENT:	Hand auger	DATE STARTED: 6/24/2017	DATE STARTED: 6/24/2017
SAMPLING METHOD:	Regular hand auger, 3 inch diameter	TOTAL DEPTH (ft.): 3	BOREHOLE ANGLE: 90 degrees
		LOGGED BY:	Luis Rodriguez

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	Gamma (cpm)
0	POORLY GRADED SAND (SP): light brown, fine grained sand, 100% sand, loose, dry.	9569
0.5		13116
0.75	SILTY SAND WITH GRAVEL (SM): brown, gray, coarse grained sand, 50% sand, 30% fines, 20% gravel, fine gravel.	
1		13198
1.5		12058
2		12230
2.5		11978
3	Terminated hand auger borehole at 3.0 ft. below ground surface. Hand auger terminated due to consistently low gamma measurements.	12667

Gamma (cpm) scale: 0, 25000, 50000, 75000, 100000

SUBSURFACE SAMPLE INFORMATION

SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
S055-SCX-005-01 S055-SCX-205-01	0-0.5	grab	0.81 0.45
S055-SCX-005-02	0.5-2	comp	0.60
S055-SCX-005-03	2-3	grab	0.60

Notes: cpm = counts per minute
pCi/g = picocuries per gram
grab = grab sample
comp = composite sample
- - - - = approximate contact

BOREHOLE ID:	**S055-SCX-006**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec
DRILLING METHOD:	Hand auger
DRILLING EQUIPMENT:	Hand auger
SAMPLING METHOD:	Regular hand auger, 3 inch diameter

COORDINATE SYSTEM:		NAD 1983 UTM Zone 12N	
EASTING:	653072.75	NORTHING:	4082710.2194
DATE STARTED:	6/24/2017	DATE STARTED:	6/24/2017
TOTAL DEPTH (ft.):	1.75	BOREHOLE ANGLE:	90 degrees
LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	Gamma (cpm)	SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0	POORLY GRADED SAND (SP): brown, fine grained sand, 100% sand, loose, dry.	9724	S055-SCX-006-01	0-0.5	grab	0.85
0.5		11771	S055-SCX-006-02	0.5-1.75	comp	1.11
1		12434				
1.5		13329				
1.75	Terminated hand auger borehole at 1.75 ft. below ground surface. Refusal on rock.					

Gamma (cpm) scale: 0, 25000, 50000, 75000, 100000

Depth scale: 0, 1, 2, 3, 4, 5

SUBSURFACE SAMPLE INFORMATION

Notes: cpm = counts per minute
pCi/g = picocuries per gram

grab = grab sample
comp = composite sample

- - - - = approximate contact

BOREHOLE ID:	**S055-SCX-007**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec	COORDINATE SYSTEM:	NAD 1983 UTM Zone 12N		
DRILLING METHOD:	Hand auger	EASTING:	653142.85	NORTHING:	4082718.3
DRILLING EQUIPMENT:	Hand auger	DATE STARTED:	6/24/2017	DATE STARTED:	6/24/2017
SAMPLING METHOD:	Regular hand auger, 3 inch diameter	TOTAL DEPTH (ft.):	1.75	BOREHOLE ANGLE:	90 degrees
		LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	Gamma (cpm) (0–100000)	SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0	SILTY SAND (SM): fine to coarse grained sand, 70% sands, 30% fines, dry, loose.	8496	S055-SCX-007-01	0-0.5	grab	0.61
0.5	increase in gravel, fine gravel, trace coarse gravel, 60% sands, 30% fines, 10% gravel.	9600	S055-SCX-007-02	0.5-1	grab	0.70
1	brown, fine grained sand, trace coarse sand, 80% sand, 20% fines.	12408	S055-SCX-007-03	1-1.8	grab	1.99
1.5		14937				
1.75	Terminated hand auger borehole at 1.75 ft. below ground surface. Refusal on rock.	16142				

Notes: cpm = counts per minute
pCi/g = picocuries per gram

grab = grab sample
comp = composite sample

- - - - = approximate contact

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BOREHOLE ID:	**S055-SCX-008**		
CLIENT:	NNAUMERT		
PROJECT:	Removal Site Evaluation		
SITE LOCATION:	Tsosie 1		

DRILLING CONTRACTOR:	Stantec	COORDINATE SYSTEM:	NAD 1983 UTM Zone 12N
DRILLING METHOD:	Hand auger	EASTING: 653183.38	NORTHING: 4082735.4
DRILLING EQUIPMENT:	Hand auger	DATE STARTED: 6/24/2017	DATE STARTED: 6/24/2017
SAMPLING METHOD:	Regular hand auger, 3 inch diameter	TOTAL DEPTH (ft.): 3.9	BOREHOLE ANGLE: 90 degrees
		LOGGED BY:	Luis Rodriguez

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	Gamma (cpm) (0–100000)	SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0	SILTY SAND (SM): tan, light brown, fine grained sand, 80% sands, 20% fines, dry, loose.	14866	S055-SCX-008-01	0-0.5	grab	4.28
1		17665				
1.5	trace clays.		S055-SCX-008-02	0.5-2.5	comp	1.28
2		16612				
2.5	tan, light brown, 70% sand, 25% fines, 5% gravel, trace sandstone gravel.					
3		16422	S055-SCX-008-03	2.5-3.9	comp	1.72
3.9	Terminated hand auger borehole at 3.9 ft. below ground surface. Refusal on rock.	18573				
4						
5						

Notes: cpm = counts per minute
pCi/g = picocuries per gram
grab = grab sample
comp = composite sample
- - - - = approximate contact

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NAVAJO NATION
AUM Environmental Response Trust-First Phase

BOREHOLE ID:	**S055-SCX-009**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec
DRILLING METHOD:	Hand auger
DRILLING EQUIPMENT:	Hand auger
SAMPLING METHOD:	Regular hand auger, 3 inch diameter

COORDINATE SYSTEM:		NAD 1983 UTM Zone 12N	
EASTING:	653221.48	NORTHING:	4082745.91
DATE STARTED:	6/24/2017	DATE STARTED:	6/24/2017
TOTAL DEPTH (ft.):	2.1	BOREHOLE ANGLE:	90 degrees
LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	Gamma (cpm)
0	SILTY SAND (SM): light brown, fine sand, 70% sands, 30% fines, dry, loose.	12904
0.5		17001
1		17019
1.5		16767
2		15143
2.1	Terminated hand auger borehole at 2.1 ft. below ground surface. Hand auger terminated due to consistently low gamma measurements.	

Gamma (cpm) scale: 0, 25000, 50000, 75000, 100000

SUBSURFACE SAMPLE INFORMATION

SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
S055-SCX-009-01	0-0.5	grab	2.40
S055-SCX-009-02	0.5-2.1	comp	2.76

Notes: cpm = counts per minute
pCi/g = picocuries per gram

grab = grab sample
comp = composite sample

- - - - = approximate contact

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NAVAJO NATION AUM Environmental Response Trust-First Phase

BOREHOLE ID:	**S055-SCX-010**		
CLIENT:	NNAUMERT		
PROJECT:	Removal Site Evaluation		
SITE LOCATION:	Tsosie 1		
DRILLING CONTRACTOR:	Stantec	COORDINATE SYSTEM:	NAD 1983 UTM Zone 12N
DRILLING METHOD:	Hand auger	EASTING:	653200.14 NORTHING: 4082807.2
DRILLING EQUIPMENT:	Hand auger	DATE STARTED:	6/24/2017 DATE STARTED: 6/24/2017
SAMPLING METHOD:	Regular hand auger, 3 inch diameter	TOTAL DEPTH (ft.):	0.9 BOREHOLE ANGLE: 90 degrees
		LOGGED BY:	Luis Rodriguez

DEPTH (feet)	LITHOLOGICAL DESCRIPTION	Gamma (cpm) (0 – 25000 – 50000 – 75000 – 100000)	SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0	POORLY GRADED SAND (SP): light brown, 100% sand, loose, dry.	11116	S055-SCX-010-01	0-0.5	grab	1.84
	SILTY SAND (SM): light brown, fine sand, 80% sands, 20% fines, dry, loose.	14984	S055-SCX-010-02	0.5-0.9	grab	2.01
	Terminated hand auger borehole at 0.9 ft. below ground surface. Refusal on rock.	15789				
1						
2						
3						
4						
5						

Notes: cpm = counts per minute
pCi/g = picocuries per gram
grab = grab sample
comp = composite sample
- - - - = approximate contact

BOREHOLE ID:	**S055-SCX-011**
CLIENT:	NNAUMERT
PROJECT:	Removal Site Evaluation
SITE LOCATION:	Tsosie 1

DRILLING CONTRACTOR:	Stantec
DRILLING METHOD:	Hand auger
DRILLING EQUIPMENT:	Hand auger
SAMPLING METHOD:	Regular hand auger, 3 inch diameter

COORDINATE SYSTEM:		NAD 1983 UTM Zone 12N	
EASTING:	653201.13	NORTHING:	4082876.04
DATE STARTED:	6/26/2017	DATE STARTED:	6/26/2017
TOTAL DEPTH (ft.):	0.7	BOREHOLE ANGLE:	90 degrees
LOGGED BY:	Luis Rodriguez		

DEPTH (feet)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	Gamma (cpm) 0 25000 50000 75000 100000	SAMPLE IDENTIFICATION	SAMPLE INTERVAL (ft bgl)	SAMPLE TYPE	LAB RESULTS RA-226 (pCi/g)
0		POORLY GRADED SAND (SP): brown, loose to medium dense, dry.	11914	S055-SCX-011-01 S055-SCX-211-01	0-0.7	grab	4.65 2.34
			14981				
		Terminated hand auger borehole at 0.7 ft. below ground surface. Refusal on rock.					
1							
2							
3							
4							
5							

Notes: cpm = counts per minute
pCi/g = picocuries per gram

grab = grab sample
comp = composite sample

- - - - = approximate contact

C.3 Water Sample Field Forms

WATER SAMPLE COLLECTION FORM

Project: Removal Site Evaluation Navajo Nation AUM Environmental Response Trust – First Phase

Date 5 / 24 / 17 **Arrival Time** 0834

Field Personnel
J. Kester K. Johnson

SITE DESCRIPTION

Surface Water ☒ **Well Water** ☐

Station Name Tsosie 1 seep **Station Number** 09-6-14

Site Description Seep locate ~0.5 mile SW of Tsosie 1 site. Sample from a 4ft high cement vault (hoses for access)

Water Characteristics (color, odor, appearance): Clear, small worms present (0.5 to 1 cm in length), no ~~odor~~ odor

SAMPLE COLLECTION

Collection Method: 1L bottle, Horizontal-bottle, Swing-sampler, Other(Peristaltic pump ✓). Up-stream / Across-stream

Sample ID: S055-WS-001 & S055-WS-201 ~~Dup~~ Duplicate **Sample Time:** 0915
LocID S486WS001

Field Measurements Entered 6/16/2017

Parameter	Sample 1 (normal sample)	Sample 2 (field dup or MS)	Sample 3 (MSD)
Time	0930		
pH	7.29		
Conductivity (µS/cm)	1286		
Turbidity (NTU)	0.31		
Water Temperature (°C)	17.8		
Salinity	—		
Oxidation Reduction Potential (mV)	147.3		

Seep is approximately 100 ft to east of vault. There is a ~~trench~~ drain built in seep area to collect water & direct it to a pipe that gravity feeds the ~~[illegible]~~ vault. The vault then gravity feeds the nearby trough (40 feet west). Pipe into trough was dripping.

SURFACE WATER FLOW MEASUREMENT FORM

Project: Removal Site Evaluation Navajo Nation AUM Environmental Response Trust – First Phase

Tsosie 1 seep

Date 5/24/17 **Time** 0834 **Station Number** 855-65-001 09-6-14

Field Personnel: K. Johnson T. Kester

Flow by Capture Method

Measurement Number	Time (sec)	Volume (L)

Seep spread along sandstone contact across a 30ft. area. dripping in places, but representative flow measurement could not be ~~opt~~ obtained

Entered 6/16/2017

WATER SAMPLE COLLECTION FORM

Project: Removal Site Evaluation Navajo Nation AUM Environmental Response Trust – First Phase

Date 04/23/2018 **Arrival Time** 1020

Field Personnel

K. Johnson, Residents – Hank & Perry Tso

SITE DESCRIPTION

Surface Water ☒ **Well Water** ☐

Station Name S055-Seep-1 "Donkey Spring" **Station Number** S055-Seep-1

Site Description Seep in a drainage 0.3 miles SE of Tsosie 1 site

Seep is along contact between sandstone bedrock & clay layer

Water Characteristics (color, odor, appearance): Clear, v. low flow. No odor

Flow was <10mL per minute (estimate)

SAMPLE COLLECTION

Collection Method: 1L bottle, Horizontal-bottle, Swing-sampler, Other(pump). Up-stream / Across-stream

Sample ID: S055-WS-002 **Sample Time:** 1024

Field Measurements			
Parameter	**Sample 1 (normal sample)**	**Sample 2 (field dup or MS)**	**Sample 3 (MSD)**
Time	1024		
pH	7.71		
Conductivity (µS/cm)	1254		
Turbidity (NTU)	NA *		
Water Temperature (°C)	14.6		
Salinity	NA		
Oxidation Reduction Potential (mV)	208.1		

Used pump to collect limited sample to measure field parameters. Could not collect analytical sample

* Stirred up a lot of sediment while sampling. Did not collect turbidity

SURFACE WATER FLOW MEASUREMENT FORM

Project: Removal Site Evaluation Navajo Nation AUM Environmental Response Trust – First Phase

Date 04/23/2018 **Time** 1020 **Station Number** SO55-Seep-1

Field Personnel: K. Johnson ____________

Flow by Capture Method

Measurement Number	Time (sec)	Volume (L)
1	100	< 10mL (est)

Appendix D Evaluation of RSE Data

D.1 Background Reference Area Selection

D.2 Statistical Evaluation

BACKGROUND REFERENCE AREA SELECTION

1.0 INTRODUCTION

This appendix presents the rationale for selection of the background reference areas for the Tsosie 1 Site (Site). To select the background reference areas for the Site, personnel considered geology, predominant wind direction, hydrologic influence, similarities of vegetation and ground cover, distance from the Site, and visual evidence of impacts due to mining (or other anthropogenic sources) in accordance with the *Multi-Agency Radiation Survey and Site Investigation Manual – Appendix A* ([MARSSIM] USEPA, 2000).

2.0 POTENTIAL BACKGROUND REFERENCE AREAS

The potential background reference area study was initiated during the Site Clearance desktop study and field investigations. In October 2016, two potential background reference areas (BG-1 and BG-2) were identified to represent the geologic formations at the Site where mining-impacted material was assumed to be present. These formations include: (1) the Salt Wash Member of the Morrison Formation (Morrison Formation) on the mesa top and mesa sidewalls (BG-1); and (2) the Summerville Formation in the plains area (BG-2) (refer to Figure D.1-1). The gamma survey and collection of soil samples at BG-1 and BG-2 were completed in June 2017.

Following review of data collected at BG-1, BG-2, and the Site, it was determined that additional potential background reference areas may be required to characterize soil and sediments at the Site. Two additional potential background reference areas were identified and gamma surveys were conducted in June 2017. BG-3 was identified to confirm the gamma measurements collected in BG-1 were representative of the Summerville Formation and the Quaternary deposits. While BG-1 and BG-3 are shown within separate geologic units on Figure D.1-1, it is important to consider that the Summerville Formation is overlain by unconsolidated soils and there was little to no difference between the soils at ground surface in the two potential background reference areas. During site characterization, field personnel identified two historical boreholes on the mesa top. Based on review of the Site Characterization data, it was determined that surface gamma survey measurements collected at BG-2 were potentially too elevated to represent the mesa top. Therefore, one additional potential background reference area (BG-4) was identified within the Morrison Formation on the mesa top; a gamma survey was conducted in June 2017. Following review of the data, it was determined that BG-3 and BG-4 would not be used to represent the Site, but BG-4 would be included in the RSE for comparison purposes, as described in Section 3.0 below.

The locations of the four potential background reference areas (BG-1, BG-2, BG-3, and BG-4) are shown along with the site geology, predominant wind direction, mining-related disturbances and reclamation-related disturbances in Figure D.1-1. The wind rose on Figure D.1-1 depicts regional wind data from the Cortez, CO airport, approximately 50 miles northeast of the Site, and it shows the predominant wind direction is from the northeast. However, field personnel generally observed wind from the west when in the area of the Site, and the topography at the Site likely causes the wind to swirl. The potential background reference areas are described below:

- BG-1 encompasses an area of 1,812 ft^2 (approximately 0.04 acres), is located 520 ft northeast of the claim boundary, and is cross-wind and hydrologically cross-gradient from the Site. The unconsolidated deposits in BG-1 represent the portions of the survey area that are within the Summerville Formation. The vegetation and ground cover at BG-1 are similar to the portions of the Site on the plains. While the area around BG-1 is mapped as the Summerville Formation, it should be noted that the ground surface consists of soils similar to soils observed at BG-3 (mapped as Quaternary deposits).

- BG-2 encompasses an area of 510 ft^2 (approximately 0.01 acres), is located 520 ft northeast of the claim boundary, and is cross-wind and hydrologically cross-gradient from the Site. The thin soils, colluvium-covered slopes, and bedrock outcrops represent the portions of the survey area that are within the Morrison Formation. The vegetation and ground cover at BG-2 are similar to the portions of the Site on the mesa sidewall.

- BG-3 encompasses an area of 1,709 ft^2 (approximately 0.04 acres), is located 760 ft northeast of the claim boundary, and is cross-wind and hydrologically cross-gradient from the Site. The thicker soils represent the portions of the survey areas within undifferentiated Quaternary deposits, including alluvium, colluvium, and eolian deposits. The vegetation and ground cover at BG-3 are similar to the portions of the Site on the plains.

- BG-4 encompasses an area of 318 ft^2 (approximately 0.01 acres), is located 350 ft south of the claim boundary, and is cross-wind and hydrologically up-gradient from the Site. The thin soils and bedrock outcrops represent the portions of the survey areas that are within the Morrison Formation. The vegetation and ground cover at BG-4 are similar to the portions of the Site on the mesa top.

The potential background reference area evaluation included surface gamma surveys, surface and subsurface static gamma measurements, and collection of surface soil samples and subsurface soil samples, as described below:

- BG-1 - 11 surface soil grab samples were collected from 11 locations; two subsurface soil grab samples, and surface and subsurface static gamma measurements were collected from borehole location S055-BG1-011

- BG-2 - 11 surface soil grab samples were collected from 11 locations; one subsurface soil grab sample, and surface and subsurface static gamma measurements were collected from borehole location S055-BG2-011

- BG-3 – surface gamma survey only

- BG-4 – surface gamma survey only

The sample locations for BG-1 and BG-2, and the surface gamma survey data for BG-1, BG-2, BG-3 and BG-4, are shown in Figure D.1-2. Samples were categorized as surface soil samples where sample depths were up to 0.5 ft bgs, and as subsurface samples where sample depths were greater than 0.5 ft bgs. Static gamma measurements were categorized as surface where static gamma was measured at the ground surface, and as subsurface where static gamma was measured at or greater than 0.1 ft bgs. Table 4-1 in the RSE Report provides the results of the sample analyses, and Tables D.1-1 and D.1-2 provide descriptive statistics for the metals/Ra-226 concentrations and the surface gamma measurements, respectively. Field forms, including borehole logs, are provided in Appendix C of the RSE Report.

The equipment used for the surface gamma survey were also used for static one-minute gamma measurements at the ground surface, and for subsurface gamma measurements at the borehole location. Soil samples and gamma measurements were collected according to the methods described in the *Removal Site Evaluation Work Plan* (MWH, 2016).

3.0 SELECTION OF BACKGROUND REFERENCE AREAS

Background reference areas were needed to represent the formations present at or near the Site where mining-related disturbances may have occurred: BG-1 is representative of the areas of the Site within the Summerville Formation, BG-2 and BG-4 are representative of the areas of the Site within the Morrison Formation, and BG-3 is representative of the areas of the Site within the Quaternary deposits. BG-1 was selected to represent the plains area of the site that includes both the Summerville Formation and the Quaternary deposits. As discussed in Section 2.0, there was little to no difference observed in the soils located at BG-1 and BG-3 (i.e., the Summerville Formation is covered by soils that are the same as those shown as Quaternary deposits on Figure D.1-1). Since it is assumed that mining-related impacts on the plains did not extend into the Quaternary deposits, BG-1 was selected to represent the areas of the Site within the Summerville Formation and the Quaternary deposits. Gamma survey measurements at BG-1 were also lower than gamma survey measurements at BG-3 (refer to Figure D.1-2 and Table D.1-2). BG-2 was selected over BG-4 to represent the mesa sidewall and the mesa top at the Site because the majority of the mining-related and reclamation-related disturbance occurred on the mesa sidewall. BG-4 does provide a valuable comparison to BG-2 regarding the lower gamma measurements on the mesa top and the heterogeneity present in the Morrison Formation. Therefore, BG-4 is included in the RSE Report for discussion purposes. Gamma survey measurements collected from BG-1 and BG-2 were used for the remainder of the Removal Site Evaluation for the Site.

4.0 REFERENCES

MWH, 2016. *Navajo Nation AUM Environmental Response Trust – First Phase Removal Site Evaluation Work Plan*. October.

USEPA, 2000. *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), EPA 402-R-97-016, Rev. 1.

Table D.1-1
Soil and Sediment Sampling Summary
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Statistic	Arsenic (mg/kg)	Molybdenum (mg/kg)	Selenium (mg/kg)	Uranium (mg/kg)	Vanadium (mg/kg)	Radium-226 (pCi/g)
Background Reference Area Study - Background Area 1 - Summerville Formation						
Total Number of Observations	11	11	11	11	11	11
Percent Non-Detects	--	91%	100%	--	--	--
Minimum[1]	0.82	--	--	0.5	3.4	0.57
Minimum Detect[2]	--	0.22	--	--	--	--
Mean[1]	1.46	--	--	0.867	5.38	0.979
Mean Detects[2]	--	0.22	--	--	--	--
Median[1]	1.4	--	--	0.84	5.7	1
Maximum[1]	2.4	--	--	1.3	6.7	1.45
Maximum Detect[2]	--	0.22	--	--	--	--
Distribution	Normal	Not Calculated	Not Calculated	Normal	Normal	Normal
Coefficient of Variation[1]	0.296	--	--	0.287	0.171	0.281
UCL Type	95% Student's-t UCL	Not Calculated	Not Calculated	95% Student's-t UCL	95% Student's-t UCL	95% Student's-t UCL
UCL Result	1.69	Not Calculated	Not Calculated	1.00	5.89	1.13
UTL Type	UTL Normal	Not Calculated	Not Calculated	UTL Normal	UTL Normal	UTL Normal
UTL Result	2.67	Not Calculated	Not Calculated	1.57	7.98	1.75
Background Reference Area Study - Background Area 2 - Morrison Formation						
Total Number of Observations	10	10	10	10	10	10
Percent Non-Detects	--	--	100%	--	--	--
Minimum[1]	3.7	0.24	--	4	4	4.56
Minimum Detect[2]	--	--	--	--	--	--
Mean[1]	6.62	0.469	--	5.42	7.98	5.56
Mean Detects[2]	--	--	--	--	--	--
Median[1]	5.60	0.475	--	5.55	7.00	5.55
Maximum[1]	12	0.66	--	6.6	14	6.83
Maximum Detect[2]	--	--	--	--	--	--
Distribution	Normal	Normal	Not Calculated	Normal	Normal	Normal
Coefficient of Variation[1]	0.397	0.370	--	0.136	0.353	0.148
UCL Type	95% Student's-t UCL	95% Student's-t UCL	Not Calculated	95% Student's-t UCL	95% Student's-t UCL	95% Student's-t UCL
UCL Result	8.14	0.57	Not Calculated	5.85	9.61	6.04
UTL Type	UTL Normal	UTL Normal	Not Calculated	UTL Normal	UTL Normal	UTL Normal
UTL Result	14.3	0.974	Not Calculated	7.57	16.2	7.96

Notes
[1] This statistic is reported by ProUCL when the dataset contains 100 percent detections.
[2] This statistic is reported by ProUCL when non-detect values exist in the dataset. The value reported is calculated using detections only.

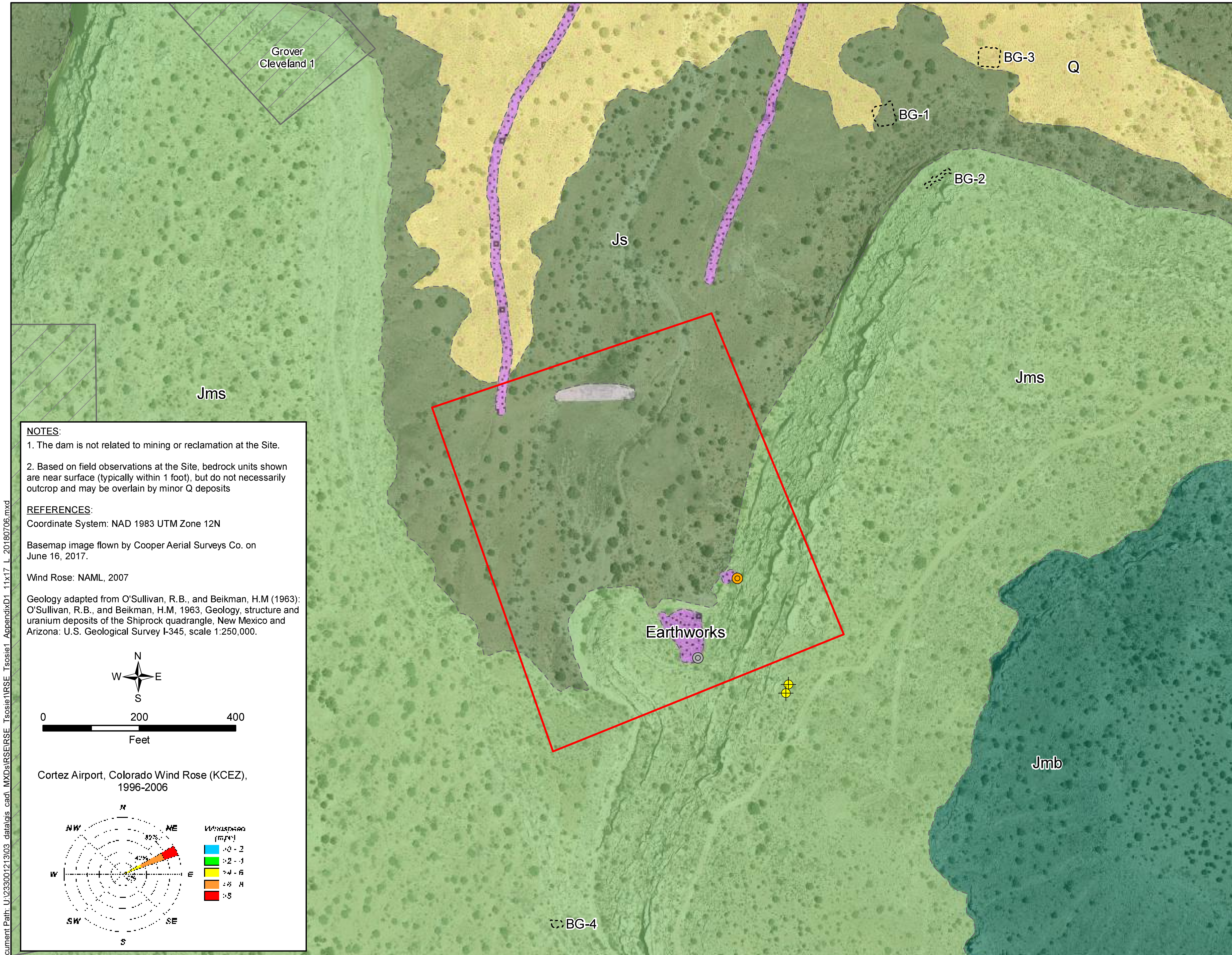
CV	Coefficient of variation
KM	Kaplan Meier
mg/kg	Milligrams per kilogram
--	Not applicable
pCi/g	Picocuries per gram
WH	Wilson Hilferty

Table D.1-2
Surface Gamma Survey Summary
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Geologic Formation Statistic	Background Reference Area 1 (BG-1) Summerville Formation	Background Reference Area 2 (BG-2) Morrison Formation	Background Reference Area 3 (BG-3) Quaternary Deposits	Background Reference Area 4 (BG-4) Morrison Formation
Total Number of Observations	232	325	230	172
Minimum	6,744	12,454	8,681	7,343
Mean	8,822	20,105	10,591	10,228
Median	8,837	18,526	10,522	10,052
Maximum	11,218	36,929	13,153	14,247
Distribution	Normal	Normal	Normal	Gamma
Coefficient of Variation	0.090	0.271	0.0738	0.111
UCL Type	95% Student's-t UCL	95% Student's-t UCL	95% Student's-t UCL	95% Approximate Gamma UCL
UCL Result	8,908	20,603	10,677	10,370
UTL Type	UTL Normal	UTL Normal	UTL Normal	UTL Gamma WH
UTL Result	10,273	29,861	12,016	12,391

Notes

cpm	Counts per minute
UCL	Upper confidence limit
UTL	Upper tolerance limit



NOTES:

1. The dam is not related to mining or reclamation at the Site.

2. Based on field observations at the Site, bedrock units shown are near surface (typically within 1 foot), but do not necessarily outcrop and may be overlain by minor Q deposits

REFERENCES:

Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

Wind Rose: NAML, 2007

Geology adapted from O'Sullivan, R.B., and Beikman, H.M (1963): O'Sullivan, R.B., and Beikman, H.M., 1963, Geology, structure and uranium deposits of the Shiprock quadrangle, New Mexico and Arizona: U.S. Geological Survey I-345, scale 1:250,000.

N
W E
S

0 200 400
Feet

Cortez Airport, Colorado Wind Rose (KCEZ), 1996-2006

NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- Historical Borehole
- Approximate Buried Portal Location
- Sealed Portal
- Potential Background Reference Area
- Claim Boundary
- Other Claim Boundary
- Geologic Contact (Inferred)

Site Geology

HOLOCENE

- Approximate Dam Footprint[1]
- Earthworks: Human-caused disturbance of the land surface potentially related to mining or reclamation.
- Q: Quaternary Deposits – Undifferentiated (Pleistocene and Holocene) – includes sandy to gravelly colluvial and alluvial deposits, and eolian sand deposits.

JURASSIC

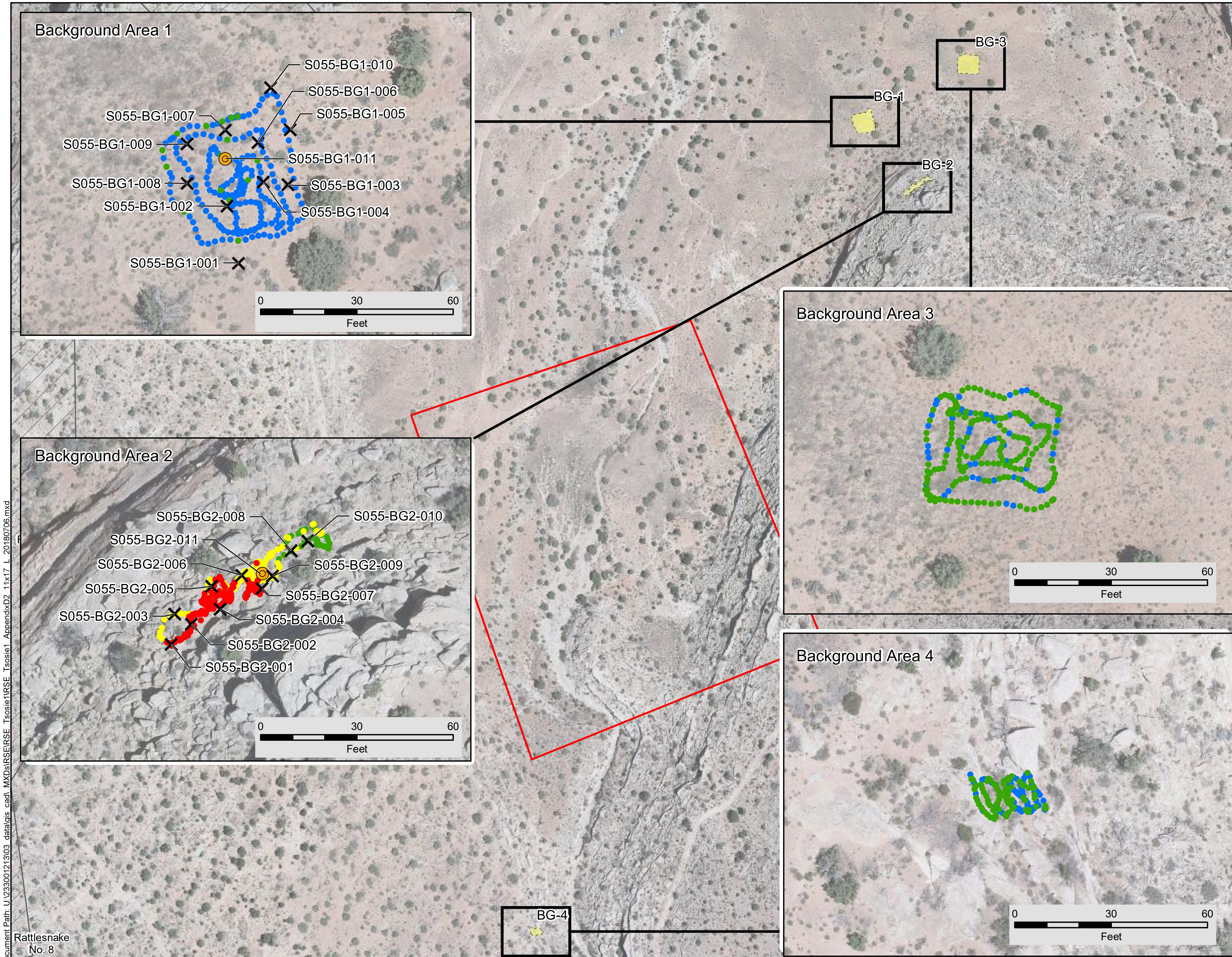
- Jmb: Brushy Basin Member of the Morrison Formation (Upper Jurassic) - green, purple, and gray shale and siltstone, gray and tan sandstone, and conglomeritic sandstone, may locally include the Burrow Canyon formation.
- Jms: Salt Wash Member of the Morrison Formation (Upper Jurassic) – Yellowish gray to greenish-gray cross-bedded very fine to medium-grained calcareous sandstone inter-bedded with greenish-gray and reddish-brown claystone.
- Js: Summerville Formation (Upper Jurassic) – Reddish-brown to light-orange very fine- to fine-grained flat bedded silty sandstone and thin-bedded silty sandstone, claystone, and siltstone; forms banded steep slopes and cliffs.

TITLE:
Geologic Map and Potential Background Reference Areas

PROJECT:
Removal Site Evaluation
Tsosie 1 Mine Site

DATE: 9/24/2018	DOCUMENT NAME: Removal Site Evaluation Report	
Stantec	AUTHOR: CBB	REVIEWER: EDZ
	FIGURE: D.1-1	

Document Path: U:\123300121\03 data\gis cad\ MXDs\RSE\RSE\RSE Tsosie1\RSE Tsosie1 AppendixD1 11x17 L 20180706.mxd



NAVAJO NATION
AUM Environmental Response Trust-First Phase

LEGEND

- ✕ Surface Sample Location
- Subsurface Borehole Location at Background Reference
- Claim Boundary
- Other Claim Boundary
- Potential Background Reference Area

Gamma Survey

Counts per Minute (CPM)

- 6,744 - 10,000
- 10,001 - 15,000
- 15,001 - 20,000
- 20,001 - 36,929

REFERENCES:
Coordinate System: NAD 1983 UTM Zone 12N

Basemap image flown by Cooper Aerial Surveys Co. on June 16, 2017.

N W E S

0 200 400
Feet

TITLE:	Potential Background Reference Area Gamma Radiation Survey Results and Soil Sample Locations
PROJECT:	Removal Site Evaluation Tsosie 1 Mine Site
DATE: 9/24/2018	DOCUMENT NAME: Removal Site Evaluation Report
Stantec	AUTHOR: CBB; REVIEWER: EDZ
	FIGURE: D.1-2

STATISTICAL EVALUATION

1.0 INTRODUCTION

This statistical evaluation presents the methods used in, and results of, statistical analyses performed on gamma radiation survey results and soil sample analytical results collected from the Tsosie 1 Site (Site). The evaluation includes comparing background reference area and Survey Area data distributions, and documents the decision process followed to select site-specific investigation levels (ILs). The ILs are used to confirm contaminants of potential concern (COPCs) listed in the *RSE Work Plan*, and to support identification of technologically enhanced naturally occurring radioactive materials (TENORM) at the Site.

2.0 EVALUATIONS

The evaluation process included compiling the results for gamma radiation surveys and soil sample analytical results from two background reference areas and two Survey Areas. These areas are designated Background Reference Area 1 (BG-1), Background Reference Area 2 (BG-2), Survey Area A and Survey Area B. The Background Reference Areas (BG-2 and BG-2) were selected to represent the Site's natural conditions as described in Appendix D.1. The gamma radiation survey data and soil sample analytical results for the background reference areas and Survey Areas were evaluated to determine the appropriate ILs for the Site as follows:

1. Identify and examine potential outlier values. Potential outlier values were identified statistically and, if justified upon further examination, removed from a dataset prior to further evaluation and calculations. No data were removed from the dataset for the calculations presented in this appendix.

2. Compare data populations between BG-1 and Survey Area A, and BG-2 and Survey Area B (box plots, probability plots, hypothesis testing with Wilcoxon Mann-Whitney test). Soil sample and gamma radiation survey results were compared between BG-1 and Survey Area A, and BG-2 and Survey Area B qualitatively and quantitatively to evaluate similarity or difference in data distributions between the areas, and as a component of evaluating background reference area adequacy and representativeness.

3. Develop descriptive statistics. Descriptive statistics for gamma survey results and soil sample analytical results (e.g., number of observations, mean, maximum, median, etc.) were generated to facilitate qualitative comparisons of soil sample and gamma radiation survey results from one area to another.

4. Select ILs for the Site based on the results of the statistical evaluations.

3.0 RESULTS

The following sections present the evaluation of potential outlier values in the dataset, calculated descriptive statistics, and comparison of data populations between groups in support of determining ILs for use at the Site.

3.1 POTENTIAL OUTLIER VALUES

A potential outlier is a data point within a random sample of a population that is different enough from the majority of other values in the sample as to be considered potentially unrepresentative of the population, and therefore requires further inspection and evaluation. Unrepresentative values in a dataset have potential to yield distorted estimates of population parameters of interest (e.g., means, upper confidence limits, upper percentiles). Therefore, potential outliers in the Site data were evaluated further prior to performing data comparisons (Section 3.2) and developing the descriptive statistics (Section 3.3). In the context of this statistical evaluation, extreme values and statistical outliers are referred to as potential outliers.

A potential outlier value in a sample may be a true representative value in the test population (not a “discrepant” value), simply representing a degree of inherent variation present in the population. Furthermore, a statistical determination of one or more potential outliers does not indicate that the measurements are actually discrepant from the rest of the data set. Therefore, general statistical guidance does not recommend that extreme values (potential outliers) be removed from an analysis solely on a statistical basis. Statistical outlier tests can provide supportive information, but a reasonable scientific rationale needs to be identified for the removal of any potential outlier values (e.g., sampling error, records error, or the potential outlier is determined to violate underlying assumptions of the sampling design, such as the targeted geology).

In the background reference areas, soil samples were collected randomly. Potential outliers in the BG-1 and BG-2 datasets were examined using box plots, probability plots and statistical testing. Descriptive statistics were then calculated with and without the potential outlier values, as applicable. Finally, the potential outlier values were evaluated to determine if a reason could be found to remove the data points before calculating the final statistics. The results of these evaluations are described in the following sections.

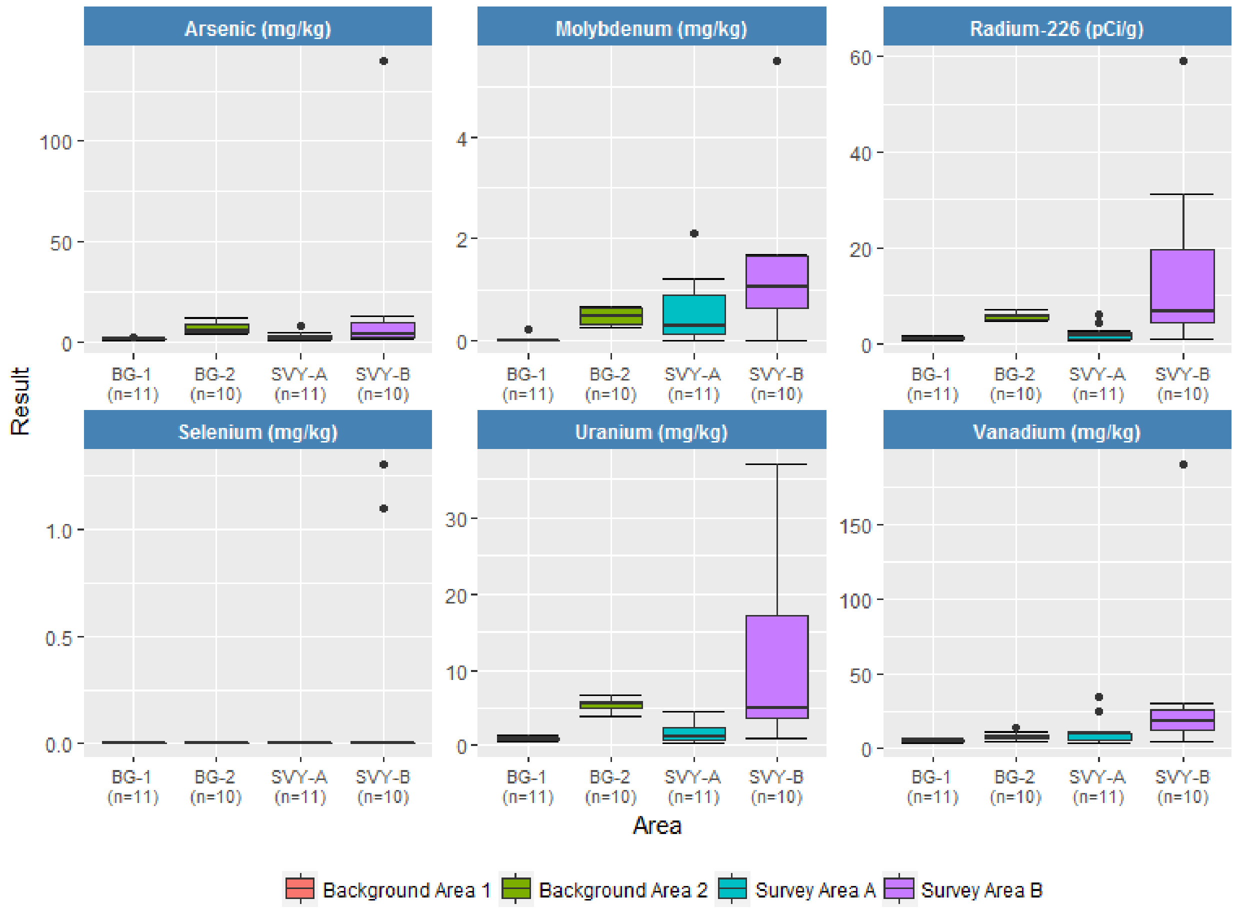
In the Survey Areas at the Site, soil samples were collected using a judgmental sampling approach. Specifically, some sample locations were selected to characterize areas of higher gamma radiation and, as a result, potential outlier values are not unexpected in the Survey Area sample statistics. Potential outliers in this context mean values that are well-separated from the majority of the data set coming from the far/extreme tails of the data distribution (USEPA, 2016a). Descriptive statistics for the Survey Areas and some comparisons to background reference areas are still presented for qualitative assessment. However, extreme outlier values in the Survey Areas are not evaluated further nor removed from the dataset.

3.1.1 Box Plots

Box plots depict descriptive statistics from a group of data (Figure 1A). The interquartile range is represented by the bounds of the box, the minimum and maximum values, not including potential outlier values (extreme values), are depicted by the whiskers (vertical lines), and any potential outliers are identified as singular dots. Statistical outliers are defined as values outside 1.5 times the interquartile range above or below the box.

3.1.1.1 Soil Sample Results Box Plots

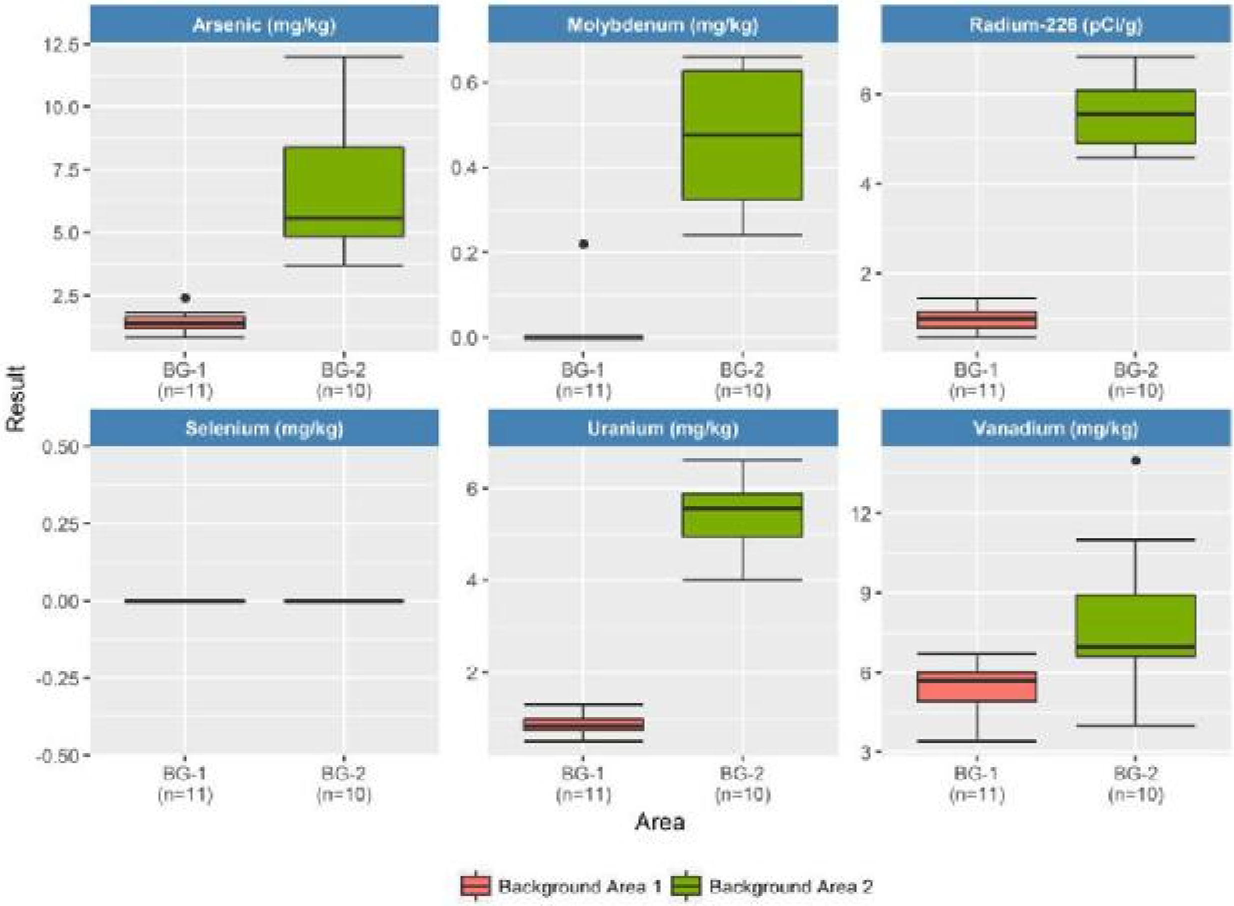
Figure 1A. Survey Areas A, B and Background Reference Areas 1(BG-1) and Background Reference Area 2 (BG-2) Soil Sample Box Plots



The soil sample box plots shown on Figure 1A depict differences in the data distributions for analytical constituent concentrations between BG-1, BG-2 and Survey Areas A and B. One or more analytical constituent datasets contain potential outlier values in both background reference areas and in both Survey Areas.

Potential outlier values are of greatest concern in the BG-1 and BG-2 datasets as these data are used to determine the ILs. Background reference area data are presented alone in Figure 1B.

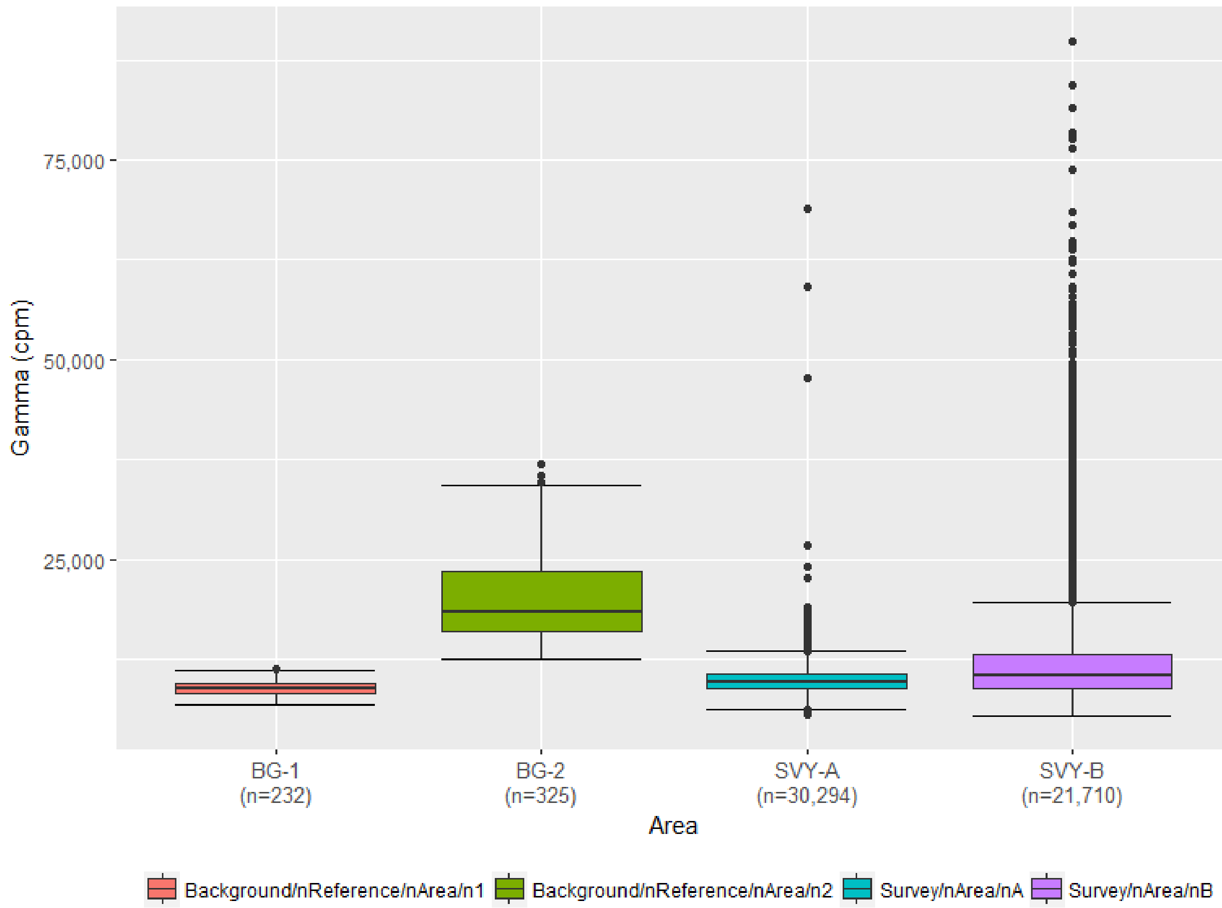
Figure 1B. Background Reference Areas 1(BG-1) and Background Reference Area 2 (BG-2) Soil Sample Box Plots



One value each for arsenic (As) and molybdenum (Mo) in BG-1 soil, and one value for vanadium (V) in BG-2 soil, are identified as potential outliers (i.e., outside 1.5 times the interquartile range) in the box plots in Figure 1B.

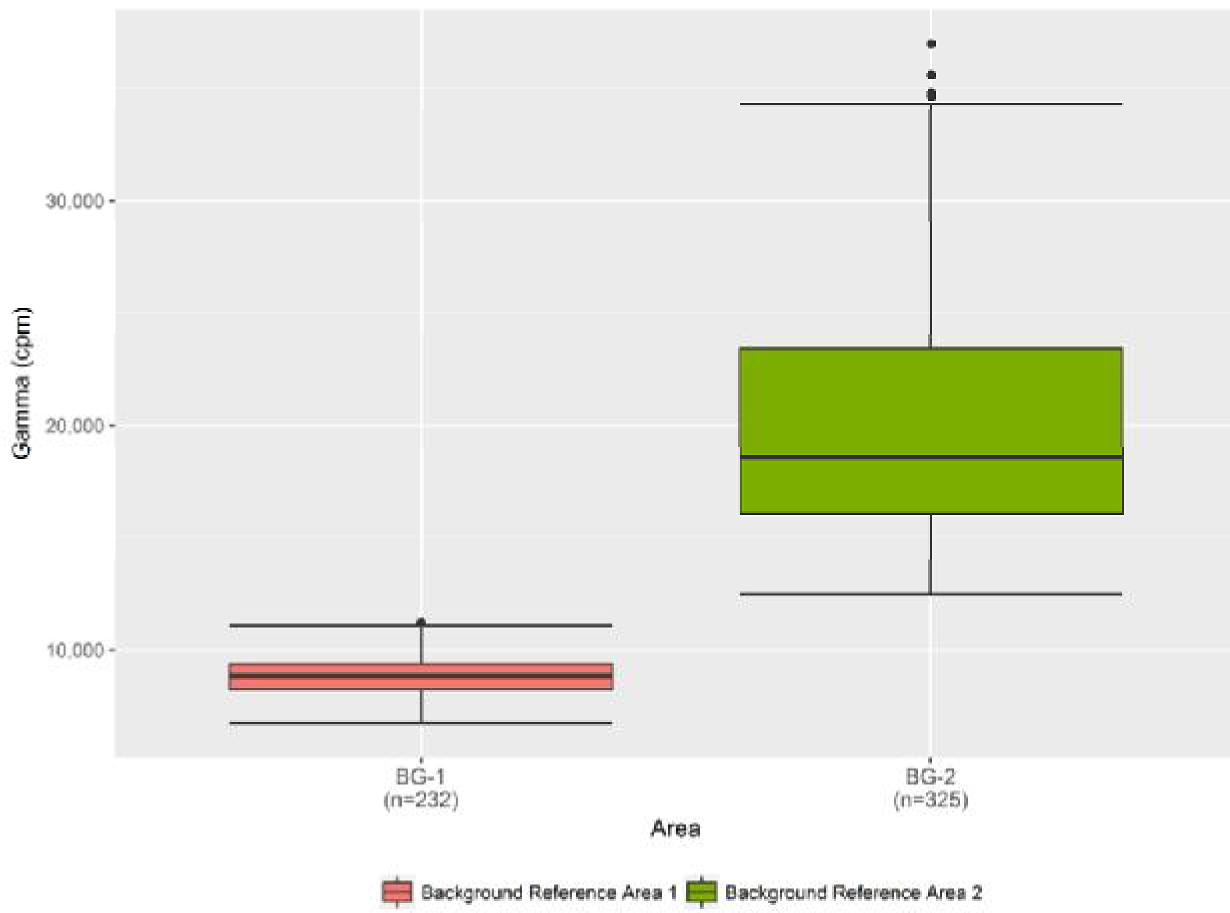
3.1.1.2 Gamma Radiation Results Box Plots

Figure 2A. Survey Areas and Background Reference Area Gamma Radiation Box Plots



The gamma radiation survey results box plots shown on Figure 2A depict differences in the data distribution for gamma measurements between BG-1, BG-2 and Survey Areas A and B. The large number of potential outlier values in the Survey Area A and Survey Area B box plots indicate high skewness or possibly non-normally distributed data, instead of outlier values. Based on Site geology, the gamma radiation potential outlier values observed for the Survey Area data on Figure 2A represent localized areas of higher gamma radiation with respect to other parts of each of the Survey Areas, as would be expected in areas with varying levels of mineralization, naturally occurring radioactive material (NORM) and potential TENORM.

Figure 2B. Background Reference Area Gamma Radiation Box Plots



As shown in Figure 2B, there is one potential outlier in the BG-1 dataset, and four potential outliers in the BG-2 dataset. These potential outlier values do not represent skewed data as do the Survey Area results, and the gamma data are shown to be more normally distributed in BG-1 and BG-2 than in the Survey Areas. The potential outlier values are most likely representative of natural variation of gamma in these areas. These observations are further evaluated with the use of probability plots in Section 3.1.2 and statistical testing in Section 3.1.4.

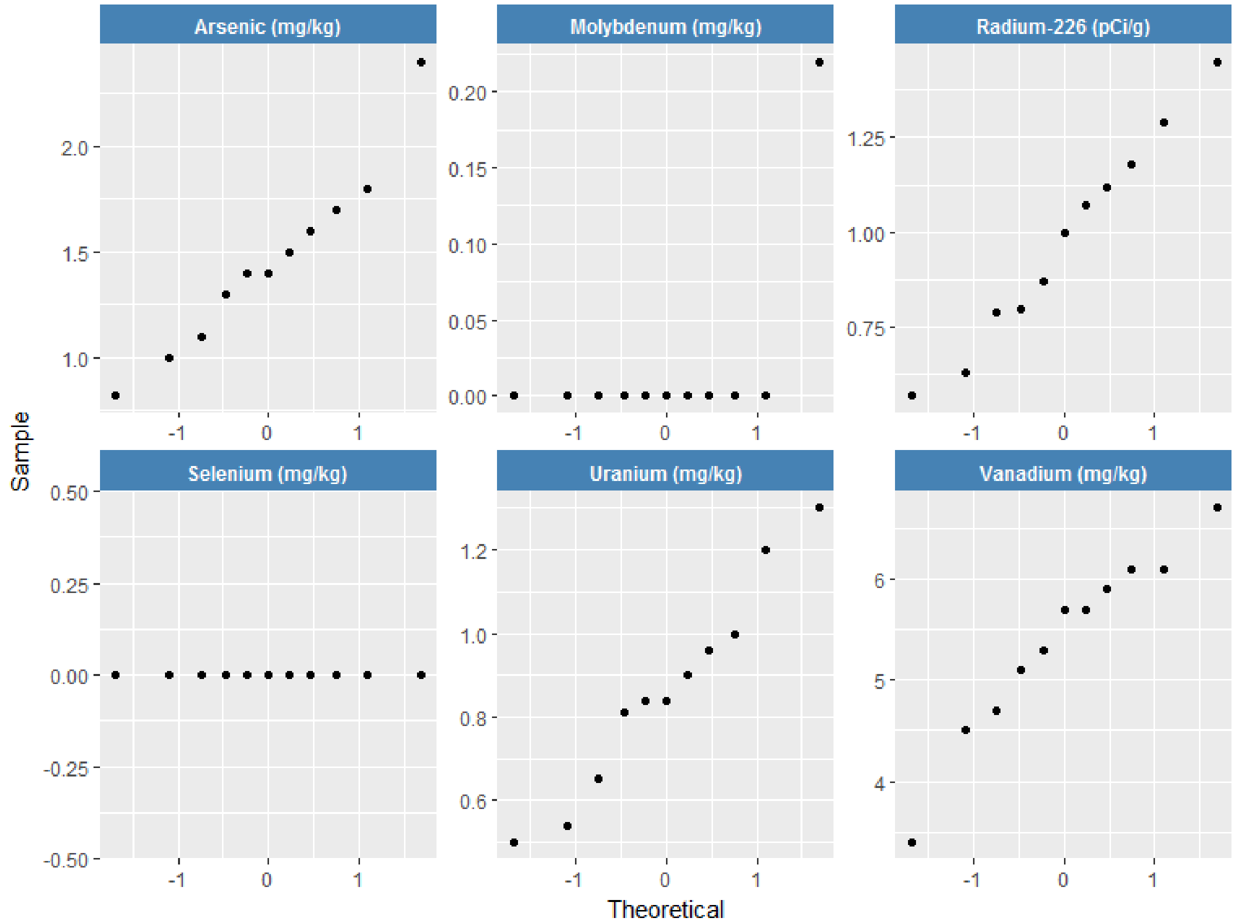
3.1.2 Probability Plots

The normal probability plot is a graphical technique for assessing whether or not a data set is approximately normally distributed and where there may be potential outlier values. The data are plotted against a theoretical normal distribution in such a way that the points, if normally distributed, should form an approximate straight line. Curved lines may indicate non-normally or lognormally distributed data, and "S"-shaped lines may indicate two distinct groups within the dataset.

3.1.2.1 Soil Sample Results Probability Plots

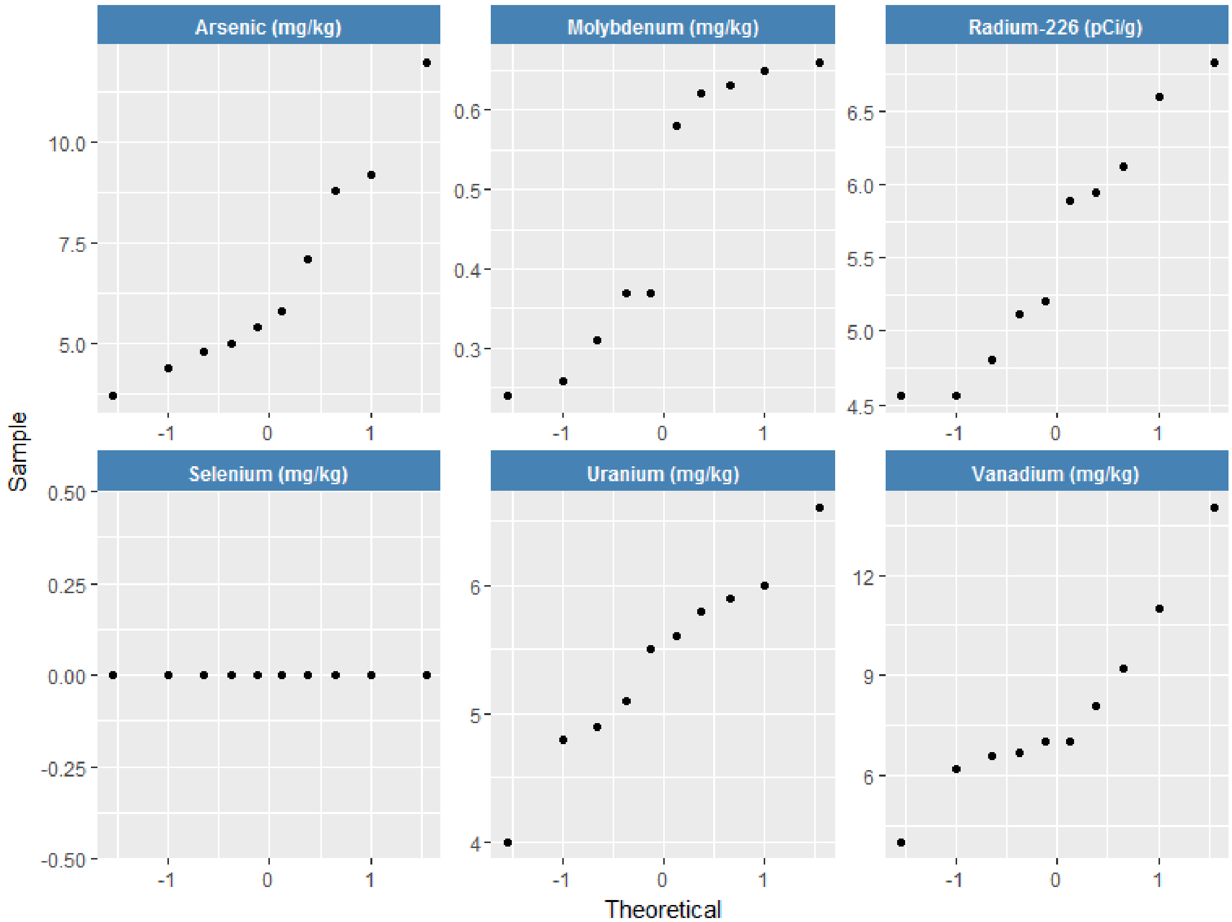
Figures 3 and 4 depict the probability plots for metals and Ra-226 results at BG-1 and BG-2.

Figure 3. Background Reference Area 1 (BG-1) Soil Sample Probability Plots



One high value each for arsenic and molybdenum were identified as potential outliers (i.e., outside 1.5 times the interquartile range) in the BG-1 box plots in Figure 1B. When viewed in the probability plots in Figure 3, the one arsenic value appears to be substantially higher than the rest of the arsenic dataset, while the high value for molybdenum is the only detected value for that metal in the BG-1 dataset. The single detect in the molybdenum dataset is anomalous, but as the remaining non-detect values cannot be evaluated statistically it is not considered further as a potential outlier. The potential outlier value in the arsenic dataset is tested further for statistical significance as a potential outlier in Section 3.1.3.

Figure 4. Background Reference Area 2 (BG-2) Soil Sample Probability Plots

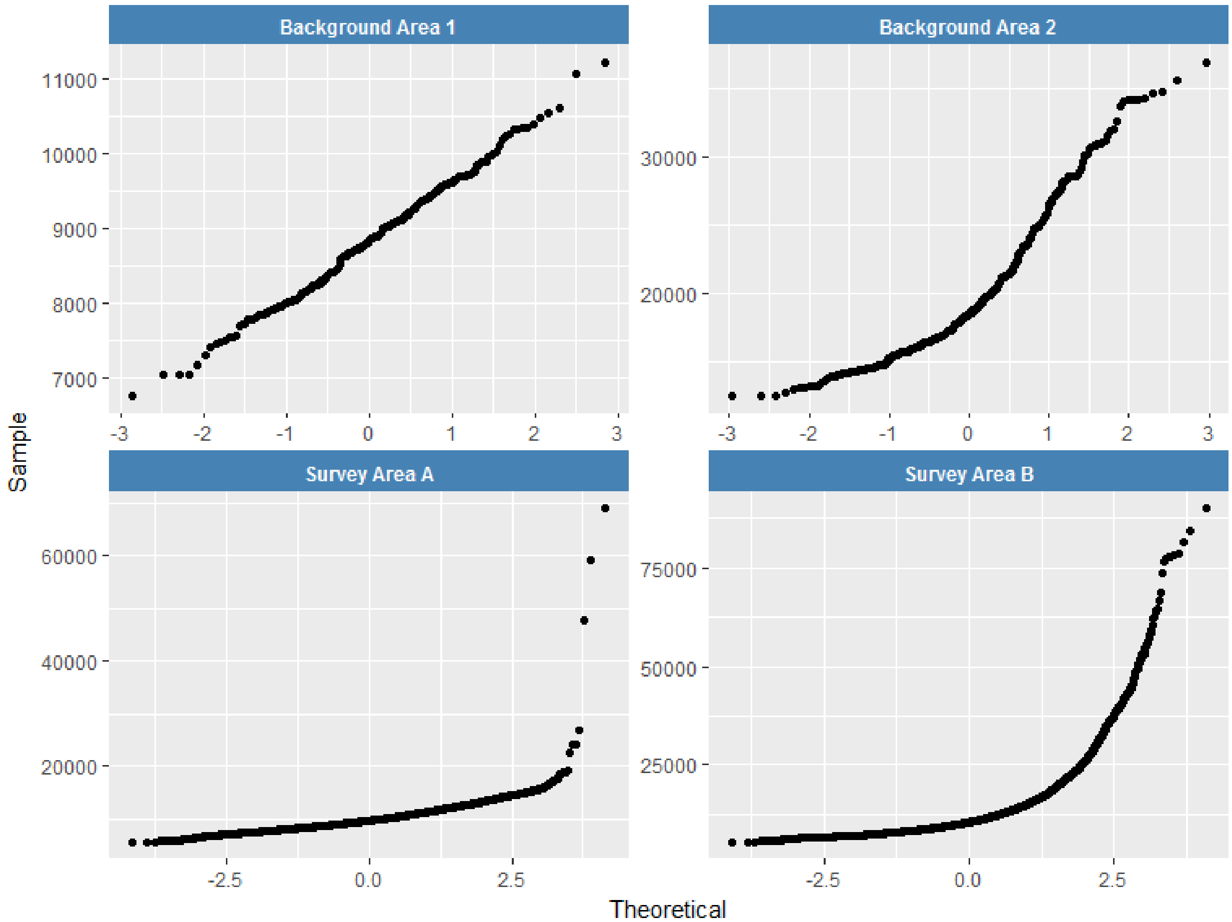


One high value for vanadium was identified as a potential outlier (i.e., outside 1.5 times the interquartile range) in the BG-1 box plots in Figure 1B. When viewed in the probability plots in Figure 4, the highest vanadium value does appear elevated with respect to the remaining values in the vanadium dataset. The probability plots for vanadium, arsenic, and molybdenum are non-linear and the probability plots for Ra-226 and uranium deviate slightly from linearity, indicating that concentrations of these analytical constituents are not normally distributed in BG-2 soil. The probability plot for selenium in Figure 4 shows that all results are non-detect in soil samples analyzed from BG-2. The potential outlier value in the vanadium dataset is tested further for statistical significance as a potential outlier in Section 3.1.3.

3.1.2.2 Gamma Survey Results Probability Plots

Figure 5 depicts the probability plots for gamma radiation results at background reference areas and the Survey Areas.

Figure 5. Survey Area and Background Reference Area Gamma Probability Plots



The BG-1 gamma probability plot in Figure 5 is approximately linear, indicating a normal distribution. The two highest values in BG-1 appear to be higher than, and slightly out of line with, the distribution of the rest of the dataset; however, only the highest value was identified as a potential outlier in Figure 2B (i.e., outside 1.5 times the interquartile range). The BG-2 gamma probability plot in Figure 5 is not linear, indicating a non-normal distribution. The four highest values, identified as potential outliers in Figure 2B, are distinct from the rest of the dataset, although only the highest value is significantly elevated. The single potential outlier in BG-1 and the four potential outliers in BG-2 are further evaluated for statistical significance in Section 3.1.4.

The gamma probability plots in Figure 5 for Survey Areas A and B are non-linear and indicate that elevated gamma values in these Survey Areas represent distinct sub-groups of gamma radiation. Higher values in the datasets for Survey Area A and B are not likely potential outliers, but rather are representative of the spatial variability of gamma radiation in these areas.

3.1.3 Potential Soil Sample Data Outliers

Two results are identified as potential outlier values in the box plots in Figure 1B and probability plots in Figures 3 and 4. These values are:

Background Reference Area 1 (BG-1)

- Arsenic: 2.40 mg/kg

Background Reference Area 2 (BG-2)

- Vanadium: 14.0 mg/kg

Dixon's Test (Dixon, 1953) is designed to be used for data sets containing only one or two potential outlier values. Therefore, Dixon's Test was performed to the 95% confidence level on each of the potential outlier values. The results of Dixon's Test are summarized in Table 1.

Table 1. Summary of Dixon's Test on Maximum Values

Area	Constituent	Location ID	Method	Hypothesis	p_Value	Conclusion
Background Reference Area 1 (BG-1)	As	S055-BG1-002	Dixon test for potential outliers	High value 2.40 is a potential outlier	> 0.05	Hypothesis rejected
Background Reference Area 2 (BG-2)	V	S055-BG2-010	Dixon test for potential outliers	High value 14.0 is a potential outlier	> 0.05	Hypothesis rejected

As = Arsenic V = Vanadium

The test concludes that neither of the potential outliers tested are statistically significant (p value < 0.05).

3.1.4 Potential Gamma Data Outliers

Potential outlier values are observed for both the BG-1 and BG-2 gamma dataset shown in the boxplots in Figure 2B and the probability plots in Figure 5. Because the number of values in the background reference area gamma datasets is >30, Dixon’s Test was not appropriate for testing potential outlier values. Instead, because the values appear to be generally normally distributed, it was appropriate to identify potential outliers using Z, t and chi squared scoring methods at the 95% confidence level. These tests were performed in the 'Outliers' package in R (Lukasz Komsta, 2011), and the results are summarized in Table 2. The R programming language complements ProUCL in its ability to provide more meaningful and useful graphics and summarizes the results equivalent to ProUCL. Because ProUCL and R packages follow similar statistical procedures, the results are comparable. The interquartile range evaluation (values outside 1.5 times the interquartile range) results are also provided in Table 2.

Table 2. Potential Gamma Outlier Interquartile Range, Z Score, t Score and Chi Squared Score Results

Area	Value (cpm)	Interquartile Range Result	Z Score Result	t Score Result	Chi Sq Score Result
Background Reference Area 1 (BG-1)	11,218	High	Potential Outlier	Potential Outlier	Potential Outlier
Background Reference Area 2 (BG-2)	36,929	High	Potential Outlier	Potential Outlier	Potential Outlier
	35,563	High	Potential Outlier	Potential Outlier	Potential Outlier
	34,762	High	Potential Outlier	Potential Outlier	Potential Outlier
	34,613	High	Potential Outlier	Potential Outlier	Potential Outlier

Cpm Counts per minute

One possible reason for the potential outliers in a gamma radiation data set may be the presence of a localized source of radiation. The gamma results were reviewed spatially, and no scientific reason was found to remove the higher background reference area values from the dataset. However, descriptive statistics are calculated with and without these values for comparison in Section 3.3.2.

3.2 COMPARE DATA POPULATIONS

Group comparison analyses provide insight into the relative concentrations of constituents between background reference areas and Survey Areas. Observations made during these analyses may indicate the need for further evaluation or discussion regarding the influence of potential outlier values, and the use of background data. For instance, if two or more background reference areas were determined to be statistically similar to each other, these data could be combined to calculate more robust statistics (not a factor in this evaluation, as one background reference area was selected to represent each Survey Area). Alternatively, testing of this kind may reveal background concentrations statistically higher than corresponding Survey Area concentrations, requiring additional interpretation or modifications in the use of background reference area datasets. Finally, results of these evaluations are a component of determining background reference area representativeness, though statistical comparisons are not the only factors to be considered in judging representativeness. Factors such as geologic materials, predominant wind direction, distance from the Site, visual evidence of impacts due to mining (or other anthropogenic sources) and soil depth are all important to the selection of background reference areas.

Group comparisons, therefore, are considered instructive as a component of the overall evaluation of soil sample and gamma radiation survey results collected from background reference areas and Survey Areas. Relative data distributions were investigated by evaluating the boxplots and probability plots in Figures 1A through 5, and by hypothesis testing with the non-parametric Mann-Whitney test, as applicable.

3.2.1 Evaluation of Box Plots

3.2.1.1 Soil Sample Box Plots

The box plot comparison in Figures 1A and 1B suggests that mean metals and Ra-226 values may differ between the background reference areas and the Survey Areas. As shown in Figures 1A and 1B, concentrations of all analytical constituents except for arsenic and selenium were elevated at Survey Area A compared with BG-1 and at Survey Area B compared with BG-2. Arsenic concentrations are similar at BG-1 compared with Survey Area A and at BG-2 compared with Survey Are B, and selenium was detected at Survey Area B only. Additionally, concentrations of all analytical constituents except for selenium are higher at BG-2 relative to BG-1, and at Survey Area B relative to Survey Area A. When interpreting the soil sample boxplots in Figures 1A and 1B, it is important to note that samples at background reference areas were collected randomly, while samples in the Survey Areas were collected judgmentally from areas of suspected contamination. Analytical constituent-specific observations from the boxplots in Figures 1A and 1B indicate:

- Arsenic. Arsenic concentrations are similar between BG-1 and Survey Area A and between BG-2 and Survey Area B, with the exception of one very high potential outlier at Survey Area B. Arsenic concentrations are higher at both BG-2 and Survey Area B than at BG-1 and Survey Area A.

- Molybdenum. Molybdenum concentrations are higher at Survey Area A than at BG-1, and higher at Survey Area B than at BG-2. Additionally, molybdenum concentrations are higher at BG-2 than at BG-1, and higher at Survey Area B than at Survey Area A.

- Ra-226. Mean Ra-226 concentrations are similar between BG-1 and Survey Area A, and BG-2 and Survey Area B, although the range of concentrations, and maximum concentration, are much greater at the Survey Areas than at the background reference areas. The Ra-226 concentrations at BG-2 and Survey Area B are higher than the Ra-226 concentrations at BG-1 and Survey Area A.

- Selenium. Selenium was detected twice, at Survey Area B. Selenium was not detected at Survey Area A or the two background reference areas.

- Uranium. Mean uranium concentrations are similar between BG-1 and Survey Area A, and BG-2 and Survey Area B, although the range of concentrations, and maximum concentration, are greater at the Survey Areas than at the background reference areas. The uranium concentrations at BG-2 and Survey Area B are higher than the Ra-226 concentrations at BG-1 and Survey Area A.

- Vanadium. The mean vanadium concentration is similar between BG-1, BG-2, and Survey Area A, although the maximum concentration is higher at BG-2 than at BG-1, and considerably higher at Survey Area A compared with BG-1 and BG-2. The mean and maximum concentrations of vanadium at Survey Area B are higher than at Survey Area A and the background reference areas.

3.2.1.2 Gamma Radiation Box Plots and Probability Plots

The boxplot comparison in Figures 2A and 2B suggests that the mean gamma counts are similar between BG-1 and Survey Areas A and B, and less than the mean gamma count for BG-2. The range in gamma count data as well as the maximum gamma count values are much greater at the Survey Areas than in background reference areas. The gamma radiation data distribution at BG-1 is approximately normal, while the gamma radiation distributions at BG-2 and the Survey Areas are non-normal, and indicate possible sub-groups of higher values (Figure 5). The highest values at the Survey Areas include many potential outliers. Observed differences between datasets are further evaluated in Section 3.2.2 using the non-parametric Mann-Whitney test.

3.2.2 Mann-Whitney Testing

The Mann-Whitney test (Bain and Engelhardt, 1992) is a nonparametric test used for determining whether a difference exists between two or more population distributions. This test is also known as the Wilcoxon Rank Sum (WRS) test. This test evaluates whether measurements from one population consistently tend to be larger (or smaller) than those from another population. This test was selected over other comparative tests such as the Student's t test and analysis of variance (ANOVA) because it remains robust in the absence of required assumptions that these two tests require such as normally distributed data and equality of variances.

Soil samples at background reference areas were collected randomly, while soil samples in the Survey Areas were collected judgmentally (see Section 3.1). Mann-Whitney testing is not appropriate for comparative analysis if one or both groups contain data collected using a judgmental approach. Therefore, the Mann-Whitney test was not performed for soil sample data between background reference areas and Survey Areas. Gamma radiation data, however, do represent non-judgmental sampling, and so the Mann-Whitney test was appropriate for comparison between background reference areas and Survey Areas (Table 3). Therefore, the test was performed 2-sided on the background reference area and Survey Area gamma radiation data. The two-sided test accounts for results from one group being lower or higher than any other group (i.e., the hypothesis tested whether the two groups differ, independent of which group is higher). A test result p-value of 0.05 or smaller indicates that a significant difference exists between any two groups that are compared. Results of the Mann-Whitney testing are presented in Table 3.

Table 3. Summary of Gamma Survey Mann-Whitney Test Results

Comparison	p_Value	Description
Background Reference Area 1 (BG-1) vs Survey Area A	<0.05	Significant Difference
Background Reference Area 1 (BG-1) Potential Outliers Excluded vs Background Reference Area 1 (BG-1)	0.936	No Significant Difference
Background Reference Area 1 (BG-1) Potential Outliers Excluded vs Survey Area A	<0.05	Significant Difference
Background Reference Area 2 (BG-2) vs Survey Area B	<0.05	Significant Difference
Background Reference Area 2 (BG-2) Potential Outliers Excluded vs Background Reference Area 2 (BG-2)	0.787	No Significant Difference
Background Reference Area 2 (BG-2) Potential Outliers Excluded vs Survey Area B	<0.05	Significant Difference
Background Reference Area 1 (BG-1) vs Background Reference Area 2 (BG-2)	<0.05	Significant Difference
Survey Area A vs Survey Area B	<0.05	Significant Difference

The results of the Mann-Whitney testing on gamma radiation survey results in Table 3 indicate the following:

- Gamma results are statistically elevated in Survey Area A with respect to BG-1, and statistically elevated at BG-2 with respect to Survey Area B. The observation is valid both with and without the inclusion of the potential outliers in the BG-1 and BG-2 datasets.

- Additionally, gamma results are statistically elevated at BG-2 relative to BG-1, and at Survey Area B relative to Survey Area A.

- The observation that gamma results at Survey Area A are statistically elevated relative to gamma results at BG-1 is likely attributable to the fact that background reference areas may not fully represent the degree of natural mineralization present at the Survey Areas (see RSE Report Section 3.2.2.2). This latter point does not prohibit use of the gamma ILs calculated from these background reference areas, but this observation should be considered, as Site conditions are further evaluated for remediation.

- The fact that the mean gamma result at BG-2 is statistically elevated relative to the mean gamma result at Survey Area B, while the maximum gamma result at Survey Area B is more than double the maximum result at BG-2, is a result of the non-normal distribution of the gamma data at Survey Area B, including a sub-group of higher values.

- The inclusion or removal of potential outlier values has no effect on the results of the Mann-Whitney test between background reference areas and Survey Areas.

3.3 DESCRIPTIVE STATISTICS

Descriptive statistics, including the upper confidence limit (UCL) of the mean and the 95-95 upper tolerance limit (UTL), were calculated from gamma survey data and soil sample results. Descriptive statistics are important for any data evaluation to present the basic statistics of a data set with regards to its limits (maximum and minimum), central tendencies (mean and median) as well as data dispersion (coefficient of variance). The ILs for the Site also are taken from the descriptive statistics, namely the 95-95 UTL. The UTL value is selected by ProUCL as the maximum value in the dataset when the data are determined to be non-parametric. The parameters and constituents evaluated include gamma radiation, arsenic, molybdenum, selenium, uranium, vanadium, and Ra-226. Selenium results were 100 percent non-detect at BG-1, BG-2, and Survey Area A, and therefore summary statistics for selenium were not calculated at these areas.

Statistics were calculated using Environmental Protection Agency (EPA) ProUCL version 5.1 software. Statistical methodology employed by the software is documented in the *ProUCL Version 5.1 Technical Guide Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations* (EPA, 2015). In the case of non-detect results, ProUCL does not recommend detection limit substitution methods (e.g., 1/2 the detection limit), considering these methods to be imprecise and out of date (EPA, 2015). The software instead calculates descriptive statistics for the detected results only, and follows various methods accordingly to calculate UCL and UTL values based on the percentage of non-detect results present in the dataset and on the distribution of the data (i.e., normal, lognormal, gamma, or unknown distribution).

Descriptive statistics for soil samples and gamma radiation survey results have been calculated with and without the potential outlier values previously identified, as applicable. Select descriptive statistics for these constituents are presented in Tables 4 and 5.

3.3.1 Soil Sample Analytical Results Summary

As described in Section 3.2.1.1, arsenic results appear similar between background reference areas and Survey Areas except for one extreme value at Survey Area B, while other analytical constituents are detected at higher concentrations in Survey Areas than in their respective background reference areas. Selenium was only detected twice, in Survey Area B. An important consideration when comparing concentrations of metals and Ra-226 between background reference areas and Survey Areas is that the background reference areas were selected to be representative of the geology present in the region around the Site, whereas the Site was selected as a mine claim because it is in an area of mineralized[1] bedrock likely to have localized, naturally elevated uranium concentrations (see RSE Report Section 3.2.2.2).

1. “Mineralized areas” are qualitatively identified as areas with gamma radiation that is elevated compared to surrounding areas due to the presence of higher concentrations of naturally occurring uranium.

It should be noted that concentrations of several of the metals measured in the Survey Areas are within the range of metals concentrations typically observed in Western U.S. soils (United States Geological Survey [USGS], 1984):

- Arsenic (mean = 5.5 mg/kg; range <0.10 – 97 mg/kg)
- Molybdenum (mean = 0.85 mg/kg; range <3 – 7 mg/kg)
- Selenium (mean = 0.23 mg/kg; range <0.1 – 4.3 mg/kg)
- Uranium (mean = 2.5 mg/kg; range 0.68 – 7.9 mg/kg)
- Vanadium (mean = 70 mg/kg; range 7 – 500 mg/kg)

As shown in Table 4, maximum detected concentrations of all metals at Survey Area A, and molybdenum, selenium, and vanadium at Survey Area B, are within typical ranges reported for Western U.S soils, and may not be related to the uranium mineralization. Exceptions to the above are arsenic and uranium at Survey Area B; elevated concentrations of these constituents in the Survey Area are likely related to Site activities (see RSE Report Section 4.6).

Table 4. Summary of Soil Sampling Results

Area	Statistic	Arsenic (mg/kg)	Molybdenum (mg/kg)	Selenium (mg/kg)	Uranium (mg/kg)	Vanadium (mg/kg)	Radium-226 (pCi/g)
Background Reference Area 1 (BG-1) All Data	Total Number of Observations	11	11	11	11	11	11
	Percent Non-Detects	--	91%	100%	--	--	--
	Minimum¹	0.820	--	--	0.500	3.40	0.570
	Minimum Detect²	--	0.220	--	--	--	--
	Mean¹	1.46	--	--	0.867	5.38	0.979
	Mean Detects²	--	0.220	--	--	--	--
	Median¹	1.40	--	--	0.840	5.70	1.00
	Maximum¹	2.40	--	--	1.30	6.70	1.45
	Maximum Detect²	--	0.220	--	--	--	--
	Distribution	Normal	Not Calculated	Not Calculated	Normal	Normal	Normal
	Coefficient of Variation¹	0.296	--	--	0.287	0.171	0.281
	UCL Type	95% Student's-t UCL	Not Calculated	Not Calculated	95% Student's-t UCL	95% Student's-t UCL	95% Student's-t UCL
	UCL Result	1.69	Not Calculated	Not Calculated	1.00	5.89	1.13
	UTL Type	UTL Normal	Not Calculated	Not Calculated	UTL Normal	UTL Normal	UTL Normal
	UTL Result	2.67	Not Calculated	Not Calculated	1.57	7.98	1.75
Background Reference Area 2 (BG-2) All Data	Total Number of Observations	10	10	10	10	10	10
	Percent Non-Detects	--	--	100%	--	--	--
	Minimum¹	3.70	0.240	--	4.00	4.00	4.56
	Minimum Detect²	--	--	--	--	--	--
	Mean¹	6.62	0.469	--	5.42	7.98	5.56
	Mean Detects²	--	--	--	--	--	--
	Median¹	5.60	0.475	--	5.55	7.00	5.55
	Maximum¹	12.0	0.660	--	6.60	14.0	6.83
	Maximum Detect²	--	--	--	--	--	--
	Distribution	Normal	Normal	Not Calculated	Normal	Normal	Normal
	Coefficient of Variation¹	0.397	0.370	--	0.136	0.353	0.148
	UCL Type	95% Student's-t UCL	95% Student's-t UCL	Not Calculated	95% Student's-t UCL	95% Student's-t UCL	95% Student's-t UCL
	UCL Result	8.14	0.570	Not Calculated	5.85	9.61	6.04
	UTL Type	UTL Normal	UTL Normal	Not Calculated	UTL Normal	UTL Normal	UTL Normal
	UTL Result	14.3	0.974	Not Calculated	7.57	16.2	7.96
Survey Area A	Total Number of Observations	11	11	11	11	11	11
	Percent Non-Detects	--	27%	100%	--	--	--
	Minimum¹	0.620	--	--	0.310	3.80	0.590
	Minimum Detect²	--	0.230	--	--	--	--
	Mean¹	2.69	--	--	1.70	11.8	1.96
	Mean Detects²	--	0.768	--	--	--	--
	Median¹	2.10	--	--	1.10	9.60	1.38
	Median Detects²	--	0.590	--	--	--	--
	Maximum¹	7.50	--	--	4.50	35.0	6.06
	Maximum Detect²	--	2.10	--	--	--	--
	Distribution	Gamma	Normal	Not Calculated	Gamma	Lognormal	Gamma
	Coefficient of Variation¹	0.729	--	--	0.911	0.804	0.881
	CV Detects²	--	0.852	--	--	--	--
	UCL Type	95% Adjusted Gamma UCL	95% KM (t) UCL	Not Calculated	95% Adjusted Gamma UCL	95% H-UCL	95% Adjusted Gamma UCL
	UCL Result	4.30	0.950	Not Calculated	3.19	19.2	3.41
	UTL Type	UTL Gamma WH	UTL KM Normal	Not Calculated	UTL Gamma WH	UTL Lognormal	UTL Gamma WH
	UTL Result	10.5	2.25	Not Calculated	8.79	59.2	8.89

Area	Statistic	Arsenic (mg/kg)	Molybdenum (mg/kg)	Selenium (mg/kg)	Uranium (mg/kg)	Vanadium (mg/kg)	Radium-226 (pCi/g)
Survey Area B	Total Number of Observations	10	10	10	10	10	10
	Percent Non-Detects	--	10%	80%	--	--	--
	Minimum¹	1.60	--	--	0.840	4.30	0.800
	Minimum Detect²	--	0.360	1.10	--	--	--
	Mean¹	18.8	--	--	11.2	34.1	14.6
	Mean Detects²	--	1.60	1.20	--	--	--
	Median¹	4.00	--	--	5.00	18.0	6.58
	Median Detects²	--	1.10	1.20	--	--	--
	Maximum¹	140	--	--	37.0	190	59.1
	Maximum Detect²	--	5.50	1.30	--	--	--
	Distribution	Unknown	Gamma	Normal	Gamma	Unknown	Gamma
	Coefficient of Variation¹	2.28	--	--	1.15	1.63	1.27
	CV Detects²	--	0.960	0.118	--	--	--
	UCL Type	95% Chebyshev (Mean, Sd) UCL	95% KM Adjusted Gamma UCL	95% KM (t) UCL	95% Adjusted Gamma UCL	95% Chebyshev (Mean, Sd) UCL	95% Adjusted Gamma UCL
	UCL Result	77.7	3.37	1.08	27.6	111	38.6
	UTL Type	UTL Non-Parametric	UTL KM Gamma WH	UTL KM Normal	UTL Gamma WH	UTL Non-Parametric	UTL Gamma WH
	UTL Result	140	7.44	1.33	81.7	190	114

¹	This statistic is reported by ProUCL when the dataset contains 100 percent detections.
²	This statistic is reported by ProUCL when non-detect values exist in the dataset. The value reported is calculated using detections only.
CV	Coefficient of variation
KM	Kaplan Meier
mg/kg	Milligrams per kilogram
--	Not applicable
pCi/g	Picocuries per gram
WH	Wilson Hilferty
Note	The UTL result that is shown on the table is based on the output from ProUCL. ProUCL evaluates the data and provides all possible UCLs from its UCL module for three possible data distributions, then identifies a recommended UCL value. ProUCL does not identify a recommended UTL value. The UTLs are therefore based on the distribution of the recommended UCL. Please refer to *ProUCL Version 5.1 Technical Guide Statistical Software for Environmental Applications for Data Sets with and without Non-detect Observations* (EPA, 2015) for further information

3.3.2 Gamma Radiation Results Summary

Table 5 presents the descriptive statistics output from the ProUCL software for the gamma radiation survey results.

Table 5. Summary of Walk-over Gamma Results

Area	Statistic	Gamma (cpm)
Background Reference Area 1 (BG-1) All Data	Total Number of Observations	232
	Minimum	6,744
	Mean	8,822
	Median	8,837
	Maximum	11,218
	Distribution	Normal
	Coefficient of Variation	0.090
	UCL Type	95% Student's-t UCL
	UCL Result	8,908
	UTL Type	UTL Normal
	UTL Result	10,273
Background Reference Area 1 (BG-1) Excluding Potential Outliers	Total Number of Observations	231
	Minimum	6,744
	Mean	8,811
	Median	8,834
	Maximum	11,065
	Distribution	Normal
	Coefficient of Variation	0.089
	UCL Type	95% Student's-t UCL
	UCL Result	8,896
	UTL Type	UTL Normal
	UTL Result	10,237
Background Reference Area 2 (BG-2) All Data	Total Number of Observations	325
	Minimum	12,454
	Mean	20,105
	Median	18,526
	Maximum	36,929
	Distribution	Normal
	Coefficient of Variation	0.271
	UCL Type	95% Student's-t UCL
	UCL Result	20,603
	UTL Type	UTL Normal
	UTL Result	29,861

Area	Statistic	Gamma (cpm)
Background Reference Area 2 (BG-2) Excluding Potential Outliers	Total Number of Observations	321
	Minimum	12,454
	Mean	19,914
	Median	18,478
	Maximum	34,247
	Distribution	Normal
	Coefficient of Variation	0.261
	UCL Type	95% Student's-t UCL
	UCL Result	20,392
	UTL Type	UTL Normal
	UTL Result	29,232
Survey Area A	Total Number of Observations	30,294
	Minimum	5,677
	Mean	9,950
	Median	9,735
	Maximum	68,902
	Distribution	Normal
	Coefficient of Variation	0.154
	UCL Type	95% Student's-t UCL
	UCL Result	9,964
	UTL Type	UTL Normal
	UTL Result	12,497
Survey Area B	Total Number of Observations	21,710
	Minimum	5,429
	Mean	11,935
	Median	10,506
	Maximum	89,945
	Distribution	Normal
	Coefficient of Variation	0.441
	UCL Type	95% Student's-t UCL
	UCL Result	11,994
	UTL Type	UTL Normal
	UTL Result	20,691

CPM Counts per minute

As noted for some metals and Ra-226 in Section 3.3.1, gamma results measured within BG-2 and Survey Areas A and B appeared to be elevated relative to gamma results measured in BG-1, however, Survey Area A contains a sub-group of higher gamma values that exceeds those at the background reference areas. This is likely because background reference areas were selected to represent the geology present in the region around the Site, whereas the Site was selected as a mine claim because it is in an area of mineralized bedrock likely to have localized naturally elevated uranium concentrations. Elevated gamma results in portions of the Survey Areas are likely attributable to historic waste piles, as well as a higher degree of natural mineralization within the Survey Areas relative to the background reference areas.

4.0 INVESTIGATION LEVELS

The calculated 95-95 UTL values described in Section 3.3 are used as the ILs for soil sampling results and gamma measurement results because they reflect the natural variability in the background data, and provide an upper limit from background data to be used for single-point comparisons to Survey Area data. The ILs for analytical results of soil samples and gamma radiation results in Survey Areas A and B are based on Background Reference Areas BG-1 and BG-2, respectively.

4.1 SURVEY AREA A INVESTIGATION LEVELS

- Arsenic (mg/kg): 2.67
- Molybdenum (mg/kg): None
- Selenium (mg/kg): None (All results non-detect)
- Uranium (mg/kg): 1.57
- Vanadium (mg/kg): 7.98
- Ra-226 (pCi/g): 1.75
- Gamma radiation measurements (cpm): 10,273

4.2 SURVEY AREA B INVESTIGATION LEVELS

- Arsenic (mg/kg): 14.3
- Molybdenum (mg/kg): 0.974
- Selenium (mg/kg): None (All results non-detect)
- Uranium (mg/kg): 7.57
- Vanadium (mg/kg): 16.2
- Ra-226 (pCi/g): 7.96
- Gamma radiation measurements (cpm): 29,861

5.0 REFERENCES

Bain, L.J. and Engelhardt, M. (1992). *Introduction to probability and Mathematical Statistics*. Second Edition. Duxbury Press, California.

Dixon, W.J. (1953). *Processing Data for Outliers*. Biometrics 9: 74-89.

EPA, (2015). *ProUCL Version 5.1 Technical Guide Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations*. https://www.epa.gov/sites/production/files/2016-05/documents/proucl_5.1_tech-guide.pdf

Lukasz Komsta (2011). *Outliers: Tests for outliers*. R package version 0.14. https://CRAN.R-project.org/package=outliers

R Core Team (2016). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Schiffler, R.E (1998). *Maximum Z scores and outliers*. Am. Stat. 42, 1, 79-80.

H. Wickham (2009). ggplot2: *Elegant Graphics for Data Analysis*. Springer-Verlag New York.

Appendix E Cultural and Biological Resource Clearance Documents

BIOLOGICAL EVALUATION

For the Proposed:

Tsosie 1
Abandon Uranium Mine - Environmental Response Trust Project

Sponsored by:

Stantec Consulting Services, Inc.

MWH. now part of Stantec

Prepared by:

Adkins Consulting, Inc.
180 East 12th Street, Unit 5
Durango, Colorado 81301

May 2017

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1. INTRODUCTION AND PROJECT BACKGROUND

The federal Endangered Species Act (ESA) of 1973, 16 U.S.C. §1531 et seq., requires all federal departments and agencies to conserve threatened, endangered, and critical and sensitive species and the habitats on which they depend, and to consult with the U.S. Fish and Wildlife Service (USFWS) on all actions authorized, funded, or carried out by each agency to ensure that the action will not likely jeopardize the continued existence of any threatened and endangered species or adversely modify critical habitat [USFWS 1998]. This report describes the potential for federal ESA-listed species and Navajo Nation Endangered Species List (NESL) endangered, threatened, candidate, or otherwise designated sensitive flora and fauna to occur in the proposed action area. The action area with regard to the ESA is defined as any area that may be directly or indirectly impacted by the proposed action [50 CFR §402.02]. This report is intended to provide the responsible official with information to make determinations of effect on species with special conservation status.

As the result of settlement by the United States, the Navajo Nation AUM Environmental Response Trust—First Phase was established to evaluate certain abandoned uranium mines located across the Navajo Nation. The project requires investigation of these sites prior to potential remediation activities in the future. MWH Global, now part of Stantec Consulting Services, Inc. (Stantec), will conduct exploratory activities at the Tsosie 1 abandoned uranium mine (AUM) such as pedestrian gamma surveys, mapping, well sampling, and surface soil sampling within the mine claim boundaries and surrounding buffer zone. Subsequent earthwork and long term monitoring may be involved after final approval by the Navajo Nation Environmental Protection Agency (NNEPA) in conjunction with the U. S. Environmental Protection Agency (USEPA).

In support of this project, Stantec contracted Adkins Consulting, Inc. (ACI) to conduct surveys for ESA-listed species and Navajo Nation Endangered Species List (NESL) endangered, threatened, candidate, or otherwise designated sensitive species.

The objectives of the biological surveys were as follows:

- To compile a list of ESA-listed or NESL species potentially occurring in the proposed action area.
- To provide a physical and biological description of the proposed action area.
- To determine the presence of ESA-listed or NESL species in the proposed action area.
- To assess potential impacts the proposed action may have on any ESA-listed or NESL species present in the area.
- To assess potential impacts to species protected under the Migratory Bird Treaty Act (MBTA).

2. PROJECT DESCRIPTION

2.1. Location

Tsosie 1 is located in Apache County Arizona, approximately 60 miles west of Farmington, New Mexico at an elevation ranging between approximately 5,770 to 5,930 feet. Global Positioning System coordinates are 36.877714°/ -109.281866° (NAD83 datum). The site is located on Navajo Tribal Trust Lands within the Bureau of Indian Affairs (BIA) Shiprock Agency. The legal description of the project surface location is as follows: Section 18, Township 40 North, Range 29 East, Gila and Salt River Principle Meridian. Project area maps are provided in Appendix A.

2.2. Estimated Disturbance

Stantec proposes a phased approach to scientific investigations at the Tsosie 1 AUM. The study area encompasses the claim boundary and a 100-foot perimeter buffer zone for a total of approximately 17.8 acres. Please refer to Appendix A for maps delineating the mine claim boundary and buffer zone.

- Phase I: Initial activity would entail pedestrian biological surveys and land surveying. Subsequent work would entail pedestrian gamma surveys, mapping, well sampling, and surface soil sampling. A maximum of 5 people would be onsite for no more than 5 to 7 days. Surface disturbance would be minimal and noise would be light.

- Phase II: Up to 8 people may be onsite all day for a period of one week. Equipment including an excavator or small mobile drilling unit may be used to collect one or more soil samples. Equipment travel would be confined to a temporary travel corridor approximately 20 feet in width. Within the travel corridor, vegetation and surface soil would sustain some disturbance but would not be bladed or bulldozed. During Phase II, noise may be moderate for a short duration, and surface disturbance will be light to moderate but confined to a minimal footprint within the study area. No permanent structures will be left on site.

3. AFFECTED ENVIRONMENT

3.1. Proposed Project Area (PPA)

The proposed project area (PPA) at Tsosie 1 includes the mine boundary with a 100-foot buffer zone surrounding the perimeter of the boundary. The affected environment or action area includes any area that may be directly or indirectly impacted by the proposed activities. Project area maps are provided in Appendix A.

3.1.1. Environmental Setting

Project activities would occur in northeastern Arizona located within the USEPA designated Arizona/New Mexico Plateau Level III Ecoregion. The Arizona/New Mexico Plateau occurs primarily in Arizona, Colorado, and New Mexico, with a small portion in Nevada. This ecoregion is approximately 45,870,500 acres, and the elevation ranges from 2,165 to 11,949 feet. The ecoregion's landscapes include low mountains, hills, mesas, foothills, irregular plains, alkaline basins, some sand dunes, and wetlands. This ecoregion is a large transitional region between the semiarid grasslands to the east, the drier shrublands and woodlands to the north, and the lower, hotter, less vegetated areas to the west and south.

Tsosie 1 is situated approximately one mile from the northwestern-most cliff face of Chezhindeza Mesa. The roughly rectangular PPA is nestled in the mouth of a small tributary canyon which joins the larger Tsitah wash to the northwest. The site includes ledged, sandstone cliffs with talus, roughly 50 to 100 feet in height, along the eastern side and lies adjacent to the cliffs on the south and west sides.

Soils

This area of Apache County is mainly escarpments separated by terraces and riverwashes, with slopes that range from 5 to 65 percent. According to the US Department of Agriculture's Natural Resources Conservation Service (NRCS) Web Soil Survey, the general soil mapping units underlying the PPA include the Arches-Kitsili-Mido complex, 1 to 25 percent slopes (mainly in the canyon bottom); and up the canyon walls, Rock outcrop-Rizno complex, 2 to 20 percent slopes and Kinusta-Eslendo-Rock outcrop complex, 15 to 70 percent slopes. The Arches-Kitsili-Mido complex is a loamy fine sand which is highly permeable and has a low available water storage (NRCS 2006).

Land Use

The land type on the Tsosie 1 site is rangeland and the principal land use is wildlife habitat. The area is near Indian Service Road 5049 and accessible by several maintained and unmaintained dirt roads.

Flora/Fauna

Vegetation communities found within the region include shrublands with big sagebrush, rabbitbrush, winterfat, shadscale saltbush, and greasewood; and grasslands of blue grama, Western wheatgrass, green needlegrass, and needle-and-thread grass. Higher elevations may support piñon pine and juniper woodlands. The Tsosie 1 site is sparsely vegetated sagebrush / shrubland vegetation with scattered piñon-juniper trees. Vegetative cover was estimated to be approximately 20 percent.

Wildlife or evidence of wildlife observed within the PPA included common raven (*Corvus corax*), cottontail rabbit (S*ylvilagus* sp.), coyote (*Canis latrans*), and turkey vulture (*Cathartes aura*). A Scott's Oriole (*Icterus parisorum*) pair was observed near the southwest corner of the project area.

The sandstone cliffs surrounding the site may provide potential nesting habitat for several raptor species. Additionally, cliff crevices and ledges may provide habitat for several bat species; however, there are no permanent water sources nearby which could be a limiting factor for bat species. Further analysis of sensitive species can be found in Section 4 of this document.

Hydrology/Wetlands

Under Executive Orders 11988 and 11990, Federal agencies are required to minimize the destruction, loss, or degradation of wetlands and floodplains, and preserve and enhance their natural and beneficial values. These habitats should be conserved through avoidance, or mitigated to ensure that there would be no net loss of wetlands function and value.

Run-off from precipitation in the project area generally drains northwest for 0.75 mile through an unnamed wash to Tsitah Wash. Tsitah Wash joins the San Juan River approximately 5 miles southeast of Aneth, Utah. The San Juan River, located approximately 20 miles northeast of the project area, is the nearest perennial water source. Several low areas within the open area of the canyon show signs of accumulating seasonal water, however, other wetland indicators were not present. There are no wetlands, seeps, springs, or riparian areas within the proposed project area. The proposed project activities would contribute to a negligible increase in sedimentation down gradient of the project area. This increase is not anticipated to be a factor due to the distance from perennial waters. There is no suitable habitat for ESA-listed fish, nor critical habitats thereof, within 20 miles of the PPA.

Cumulative impacts to surface waters would be negligible. Surface-disturbing activities other than the proposed action that may cause accelerated erosion include, but are not limited to, construction of roads, other facilities, and installation of trenches for utilities; road maintenance such as grading or ditch-cleaning; public recreational activities; vegetation manipulation and management activities; natural and prescribed fires; and livestock grazing. Because the proposed action would have a negligible impact to downstream surface water quality, the cumulative impact also would be negligible when added to other past, present, and reasonably foreseeable activities.

4. THREATENED, ENDANGERED, AND SENSITIVE SPECIES EVALUATION

The Endangered Species Act (ESA) of 1973 requires all federal departments and agencies to conserve threatened, endangered, and critical and sensitive species and the habitats on which they depend, and to consult with the U.S. Fish and Wildlife Service (USFWS) on all actions authorized, funded, or carried out by the agency to ensure that the action will not likely jeopardize the continued existence of any threatened and endangered species or adversely modify critical habitat.

4.1. Methods

4.1.1. *Off-site Methods*

Prior to conducting fieldwork, ACI compiled data on species listed under the ESA. Informal consultation was initiated by requesting an Official Species List from the USFWS Information, Planning, and Conservation System (IPaC) website (http://ecos.fws.gov/ipac/). ACI received the Official Species List (02EAAZ00-2016-SLI-0364) on April 8, 2016. See Table 1 for USFWS-listed threatened, endangered, or candidate species with potential to occur in the PPA.

The Navajo Nation Department of Fish and Wildlife (NNDFW), Navajo Natural Heritage Program (File # 15mwh101) sent MWH/Stantec a NESL information letter dated 29 December, 2015. The letter suggests biologists determine habitat suitability within the project area for the provided list of species of concern with potential to occur on the 7.5-minute quadrangles containing the project boundaries. The Navajo species of concern listed in the NESL information letter are included in Table 2.a below.

In addition to the above listed species, ACI reviewed species protected under the MBTA with potential to occur in the proposed project and action area (Table 3).

4.1.2. *On-site Survey Methods*

An on-site pedestrian survey was conducted in May 2017 by ACI personnel permitted by NNDFW. The purpose of the survey was to assess habitat potential for ESA-listed or NESL species. Field biologists with considerable experience identifying local plant and wildlife species lead survey crews. The survey consisted of walking transects ten feet apart throughout the PPA including a survey buffer of approximately 50 feet beyond the PPA edge of disturbance. Portions of the PPA not accessible by foot and surrounding areas (cliffs within 0.37 mile of the PPA) were visually inspected with binoculars and a high-powered scope for dens, nests, raptors, or past signs of raptor use. Weather conditions were mostly sunny with light winds and the temperature was approximately 60 to 64 degrees F.

Included in the site visit were surveys specifically targeting golden eagle (*Aquila chrysaetos*) following Navajo Natural Heritage Program (NNHP) guidelines. All plant and wildlife species observed in the action area were recorded, and digital photos were taken (Appendix B). Survey details can be found on the summary sheet attached as Appendix D.

4.2. ESA-Listed Species Analysis and Results

4.2.1. *Species from the USFWS IPaC Official Species List*

Table 1 includes ESA-listed species that have the potential to occur in the project area based on the USFWS IPaC Official Species List. Biologists evaluated habitat suitability within and surrounding the PPA for the species in Table 1.

Table 1: USFWS IPaC Official Species List for the Tsosie 1 Project

Species	Status	Occurrence Within Region	Habitat	Potential to Occur within Action Area
BIRDS				
Mexican spotted owl (*Strix occidentalis lucida*)	Threatened with Designated Critical Habitat	Year-round range.[1]	Mixed conifer forests. Typically where unlogged, uneven-aged, closed-canopy forests occur in steep canyons.1	No potential. Action area does not provide suitable habitat for species to occur.

Table 1: USFWS IPaC Official Species List for the Tsosie 1 Project

Species	Status	Occurrence Within Region	Habitat	Potential to Occur within Action Area
Western Yellow-Billed Cuckoo (*Coccyzus americanus*)	Threatened	Possible rare summer/breeding occurrences.[2]	In the southwestern U.S., associated with riparian woodlands dominated by cottonwood or willow trees. In New Mexico, native or exotic species may be used.[2]	No potential. Action area does not provide suitable habitat for species to occur.
FISHES				
Roundtail chub (*Gila robusta*)	Proposed Threatened	San Juan and Mancos Rivers. Rarely encountered in recent surveys; some found from Shiprock to near Lake Powell with most between Shiprock and Aneth. [2,3]	Rocky runs, rapids, and pools of creeks and small to large rivers; also large reservoirs in the upper Colorado River system.[2]	No potential. No perennial waters in or near the PPA. Action area is within the San Juan River watershed; however, negligible effects from the project to any drainage system are expected.
Zuni Bluehead Sucker (*Catostomus discobolus yarrowi*)	Endangered	Native to headwater streams of the Little Colorado River in east-central AZ and west-central NM; current range in NM is limited to the upper Río Nutria drainage.[2]	Low-velocity pools and pool-runs with seasonally dense perilithic and periphytic algae, particularly shady, cobble/boulder/bedrock substrates in streams with frequent runs and pools.[2]	No potential. Action area does not provide suitable habitat for species to occur.
MAMMALS				
Black-footed ferret (*Mustela nigripes*)	Endangered		Open habitat, including grasslands, steppe, and shrub steppe. Closely associated with prairie dog colonies. At least 40 hectares of prairie dog colony required to support one ferret.[2]	No potential. Action area does not provide suitable habitat for species to occur. Action area does not provide prairie dog colonies of sufficient size
Gray wolf (*Canus lupus*)	Proposed Experimental	In NE AZ, South of Hwy 60 in Apache, Coconino, and Navajo County; In NW NM, south of I-40 in Cibola, McKinley and Catron County.[2]	Not limited to any particular habitat type. Viable populations occur only where human population density and persecution level are low and prey densities are high. Birthing dens may be on bluffs or slopes among rocks or in enlarged badger holes. In Arizona and New Mexico, diet includes primarily elk and sometimes livestock, deer, rodents, or lagomorphs.[2]	No potential. Action area is outside of range for this species. No dens suitable for this species were found in the action area.

Table 1: USFWS IPaC Official Species List for the Tsosie 1 Project

Species	Status	Occurrence Within Region	Habitat	Potential to Occur within Action Area
REPTILES				
Northern Mexican gartersnake (*Thamnophis eques megalops*)	Threatened	Most of AZ; In SE NM including Catron, Grant and Hildago County [2]	Considered a riparian obligate except during dispersal. Occurs chiefly in the following general habitat types: (1) Source-area wetlands [e.g., cienegas (mid-elevation wetlands with highly organic, reducing (basic, or alkaline) soils), stock tanks (small earthen impoundment), etc.]; (2) large river riparian woodlands and forests; and (3) streamside gallery forests (as defined by well-developed broadleaf deciduous riparian forests with limited, if any, herbaceous ground cover or dense grass). Occurs at elev. from 130 to 8,497 (ft)	No potential. Action area does not provide suitable habitat for species to occur.

[1]USFWS; [2]NatureServe Explorer; [3]Navajo Endangered Species List, Species Accounts 2008

4.2.2. ESA-Listed Species Eliminated From Further Consideration

Table 1 includes seven (7) ESA-listed species that have the potential to occur in the project area based on the USFWS IPaC Official Species List. All of the species in Table 1 have been eliminated from further discussion in this report because there is no potential habitat in the PPA, and ACI believes the proposed project would have no direct, indirect or cumulative impacts to the species in Table 1.

4.3. NESL Species Analysis and Results

4.3.1. Navajo Endangered Species List (NESL) and Species of Concern

Table 2.a lists species of concern with potential to occur on the 7.5-minute quadrangle(s) containing the project boundaries. According to the NESL information letter received from the NFWD found in Appendix C, Golden eagle (*Aquila chrysaetos*) is known to occur within one mile of the project site vicinity. Biologists evaluated the potential for the species of concern listed in the table below to occur within the project area.

Additionally, the NESL information letter requested that the potential for black-footed ferret (*Mustela nigripes*) be evaluated if prairie dog towns of sufficient size (per NFWD guidelines) occur in the project area, and that potential for Parish's alkali grass (*Puccinellia parishii*) be evaluated if wetland conditions exist that contain white alkaline crusts. Species listed by the USFWS in Table 1 are not reiterated here.

Table 2.a: Navajo Endangered Species List (NESL) and Species of Concern

Species	Status	Habitat Associations	Potential to Occur in Project or Action Area
ANIMALS			
Northern Leopard Frog	NESL G2	Springs, slow streams, marshes, bogs, ponds, canals, flood plains, reservoirs,	No potential. Action area does not provide suitable

Species	Status	Habitat Associations	Potential to Occur in Project or Action Area
(*Lithobates pipiens*)		and lakes; usually permanent water with rooted aquatic vegetation. In summer, commonly inhabits wet meadows and fields. Takes cover underwater, in damp niches, or in caves when inactive. Over winters usually underwater. Eggs are laid and larvae develop in shallow, still, permanent water (typically), generally in areas well exposed to sunlight.[2,3,4]	habitat for species to occur.
Colorado pikeminnow (*Ptychocheilus lucius)*	NESL G2 USFWS-E	Warm-water rivers and tributaries of the Colorado River basin.[3,4] Known to occur in San Juan River from Shiprock to Lake Powel. [3,4]	No potential. No perennial waters in or near the PPA. Action area is within the San Juan River watershed; however, negligible effects from the project to any drainage system are expected.
Southwestern Willow Flycatcher (*Empidonax traillii extimus*)	NESL G2 USFWS-E	Breeds in dense riparian habitat. [3,4]	No potential. Action area does not provide suitable habitat for species to occur.
Mountain plover *(Charadrius montanus)*	NESL G4	Typically nests in flat (<2% slope) to slightly rolling expanses of grassland, semi-desert, or badland, in an area with short, sparse vegetation, large bare areas (often >1/3 of total area), and that is typically disturbed (e.g. grazed); may also nest in plowed or fallow cultivation fields. Nest is a scrape in dirt often next to a grass clump or old cow manure pile. Migration habitat is similar to breeding habitat.[2,3]	No potential. Action area does not provide suitable habitat for species to occur.
Golden eagle (*Aquila chrysaetos*)	NESL G3	In the west, mostly open habitats in mountainous, canyon terrain. Nests primarily on cliffs. [3]	Action area provides potential foraging habitat for species to occur. Cliffs approximately one mile southeast of the PPA provide potential nesting habitat.
American peregrine falcon (*Falco peregrinus*)	NESL G4 NM-T	Nests on steep cliffs >30 m tall (typically >45 m) in a scrape on sheltered ledges or potholes. Foraging habitat quality is an important factor; often, but not always, extensive wetland and/or forest habitat is within the falcon's hunting range of <=12 km. Nest in ledges or potholes on cliffs in wooded/forested habitats; Forage over riparian woodlands, coniferous & deciduous forests, shrublands, prairies. [3]	Action area provides marginal foraging habitat for species to occur. Cliffs approximately one mile southeast of the PPA may provide potential nesting habitat.
Western burrowing owl (*Athene cunicularia hypugaea*)	NESL G4	Open grasslands and sometimes other open areas (such as vacant lots). Nests in abandoned burrows, such as those dug by prairie dogs. [2,3]	No potential. Action area does not provide suitable habitat for species to occur.

Species	Status	Habitat Associations	Potential to Occur in Project or Action Area
PLANTS			
Parish's alkali grass (*Puccinellia parishii*)	NESL G4 NM-E	Alkaline springs, seeps, and seasonally wet areas that occur at the heads of drainages or on gentle slopes. Elevation: 2600-7200 feet.[2,3]	No potential. Action area does not provide suitable alkaline soils for species to occur.

Species are listed by the NESL as; Group 2: Endangered (survival or recruitment in jeopardy); Group 3: Endangered (survival or recruitment in jeopardy in foreseeable future); and Group 4: Species of Consideration. NESL Species with New Mexico State Endangered or Threatened status are labeled as NM-T or NM-E.

Sources: Sources: [1]New Mexico Natural Heritage Program 2010, [2]NatureServe Explorer; [3]Navajo Endangered Species List, Species Accounts 2008, [4] IUCN Red List

4.3.2. NESL Species Eliminated From Further Consideration

Table 2.a includes ten (8) NESL and Navajo Species of Concern that have the potential to occur in the project area based on general geographical association with actual records or habitat suitability. The following species have been eliminated from further discussion in this report because biologists determined the action area does not provide suitable habitat for them to occur: Northern Leopard Frog (*Lithobates pipiens*), Colorado pikeminnow (*Ptychocheilus lucius),* Southwestern Willow Flycatcher (*Empidonax traillii extimus*), Mountain plover *(Charadrius montanus)*, Western burrowing owl (*Athene cunicularia hypugaea*), and Parish's alkali grass *(Puccinellia parishii)*. None of these species were observed during surveys of the proposed project area or immediate surroundings. Critical habitats of these species do not exist within or adjacent to the proposed project area. There would be no direct, indirect or cumulative impacts to these species.

Habitat potential was assessed for the American peregrine falcon (*Falco peregrinus*) within the action area. ACI biologists determined the sandstone cliffs approximately one mile southeast could provide nesting habitat; however, based on the distance from the project boundary, this species would not be affected by the proposed project activities.

4.3.3. NESL Species Warranting Further Analysis

Table 2.b lists NESL and Navajo Species of Concern with potential to occur within the proposed project area based on habitat suitability or actual record of observation.

Table 2.b: NESL and Navajo Species of Concern Warranting Further Analysis

Species	Status	Habitat Associations	Potential to Occur in Project or Action Area
ANIMALS			
Golden eagle (*Aquila chrysaetos*)	NESL G3	In the west, mostly open habitats in mountainous, canyon terrain. Nests primarily on cliffs. [3]	Action area provides potential foraging habitat for species to occur. Sandstone cliffs in the vicinity may provide potential nesting habitat.

Species are listed by the NESL as; Group 2: Endangered (survival or recruitment in jeopardy); Group 3: Endangered (survival or recruitment in jeopardy in foreseeable future); and Group 4: Species of Consideration. NESL Species with New Mexico State Endangered or Threatened status are labeled as NM-T or NM-E.

Sources: Sources: [1]New Mexico Natural Heritage Program 2010, [2]NatureServe Explorer; [3]Navajo Endangered Species List, Species Accounts 2008, [4] IUCN Red List

4.4. Migratory Bird Species

The Migratory Bird Treaty Act (MBTA) implements various treaties and conventions between the U.S. and Canada, Japan, Mexico and the former Soviet Union for the protection of migratory birds. Under the Act, taking, killing or possessing migratory birds is unlawful.

The bald eagle (*Haliaeetus leucocephalus*) was delisted under the ESA on August 9, 2007. Both the bald eagle and golden eagle (*Aquila chrysaetos*) are still protected under the MBTA and Bald and Golden Eagle Protection Act (BGEPA). The BGEPA affords both eagles protection in addition to that provided by the MBTA, in particular, by making it unlawful to "disturb" eagles.

In preparation for conducting the migratory bird survey, information from the New Mexico Partners In Flight website (http://www.hawksaloft.org/pif.shtml), the New Mexico PIF highest priority list of species of concern by vegetation type, the USFWS's Division of Migratory Bird Management website (http://www.fws.gov/migratorybirds/), and the 2002 Birds of Conservation Concern Report for the Southern Rockies/Colorado Plateau Bird Conservation Region (BCR) No. 16, were used to develop a list of high priority migratory bird species with potential to occur in the area of the proposed action. Species addressed previously will not be reiterated here.

Table 3: Priority Birds of Conservation Concern with Potential to Occur in the Project Area

Species Name	Habitat Associations	Potential to Occur in the Project Area
Black-throated sparrow (*Amphispiza bilineata*)	Xeric habitats dominated by open shrubs with areas of bare ground.	Suitable habitat is present within the action area for species to occur.
Brewer's sparrow (*Spizella breweri*)	Closely associated with sagebrush, preferring dense stands broken up with grassy areas.	No suitable habitat is present within the action area for species to occur.
Gray vireo (*Vireo vicinior*)	Open stands of piñon pine and Utah juniper (5,800 – 7,200 ft) with a shrub component and mostly bare ground; antelope bitterbrush, mountain mahogany, Utah serviceberry and big sagebrush often present. Broad, flat or gently sloped canyons, in areas with rock outcroppings, or near ridge-tops.	Suitable habitat is present within the action area for species to occur.
Loggerhead shrike (*Lanius ludovicianus*)	Open country interspersed with improved pastures, grasslands, and hayfields. Nests in sagebrush areas, desert scrub, and woodland edges.	No suitable habitat is present within the action area for species to occur.
Mountain bluebird (*Sialia currucoides*)	Open piñon-juniper woodlands, mountain meadows, and sagebrush shrublands; requires larger trees and snags for cavity nesting.	No suitable habitat is present within the action area for species to occur.
Mourning dove (*Zenaida macroura*)	Open country, scattered trees, and woodland edges. Feeds on ground in grasslands and agricultural fields. Roost in woodlands in the winter. Nests in trees or on ground.	No suitable habitat is present within the action area for species to occur.
Sage sparrow (*Amphispiza belli*)	Large and contiguous areas of tall and dense sagebrush. Negatively associated with seral mosaics and patchy shrublands and abundance of greasewood.	No suitable habitat is present within the action area for species to occur.

Sage thrasher (*Oreoscoptes montanus*)	Shrub-steppe dominated by big sagebrush.	No suitable habitat is present within the action area for species to occur.
Scaled quail (*Callipepla squamata*)	Brushy arroyos, cactus flats, sagebrush or mesquite plains, desert grasslands, Plains grasslands, and agricultural areas. Good breeding habitat has a diverse grass composition, with varied forbs and scattered shrubs.	No suitable habitat present within the action area for species to occur. Lack of diverse grass composition with varied forbs likely a limiting factor.
Swainson's hawk (*Buteo swainsoni*)	A mixture of grassland, cropland, and shrub vegetation; nests on utility poles and in isolated trees in rangeland. Nest densities higher in agricultural areas.	No suitable habitat is present within the action area for species to occur.
Vesper sparrow (*Pooecetes gramineus*)	Dry montane meadows, grasslands, prairie, and sagebrush steppe with grass component; nests on ground at base of grass clumps.	No suitable habitat present within the action area for species to occur. Lack of significant grassland/prairie component a limiting factor.
Bald eagle (*Haliaeetus leucocephalus*)	Near lakes, rivers and cottonwood galleries. Nests near surface water in large trees. May forage terrestrially in winter	No suitable habitat present within the action area for species to occur.
Bendire's thrasher (*Toxostoma bendirei*)	Typically inhabits sparse desert shrubland & open woodland with scattered shrubs; breeding range in Arizona and in scattered locations in central & western portions of NM; most common in southwest NM.	Suitable habitat is present within the action area for species to occur.
Piñon jay (*Gymnorhinus cyanocephalus*)	Foothills throughout CO and NM wherever large blocks of piñon-juniper woodland habitat occurs.	No suitable habitat present within the action area for species to occur.
Prairie falcon (*Falco mexicanus*)	Arid, open country, grasslands or desert scrub, rangeland; nests on cliff ledges, trees, power structures.	Action area provides potential foraging and nesting habitat for species to occur.
Ferruginous hawk (*Buteo regalis*)	Breed in open country, usually prairies, plains and badlands; semi- desert grass-shrub, sagebrush-grass & piñon-juniper plant associations.	Action area provides potential foraging and nesting habitat for species to occur.

5. EFFECTS ANALYSIS

Effects or impacts can be either long term (permanent or residual) or short term (incidental or temporary). Short-term impacts affect the environment for only a limited period and then the environment reverts rapidly back to pre-action conditions. Long-term impacts are substantial and permanent alterations to the pre-existing environmental condition. Direct effects are those effects that are caused by the action and occur in the same time and place as the action. Indirect effects are those effects that are caused by or will result from the proposed action and are later in time but still reasonably certain to occur (USFWS 1998).

5.1. Direct and Indirect Effects

The PPA includes the claim boundary and a 100-foot perimeter buffer zone for a total of approximately 17.8 acres. The proposed action would result in a short term increase in human activity within the PPA at varying degrees depending on the project phase:

- Phase I: Initial activity would entail pedestrian biological surveys and land surveying. Subsequent work would entail pedestrian gamma surveys, mapping, well sampling, and surface soil sampling. A maximum of 5 people would be onsite for no more than 5 to 7 days. Surface disturbance would be minimal and noise would be light.
- Phase II: Up to 8 people may be onsite all day for a period of one week. Equipment including an excavator or small mobile drilling unit may be used to collect one or more soil samples. Equipment travel would be confined to a temporary travel corridor approximately 20 feet in width. Within the travel corridor, vegetation and surface soil would sustain some disturbance but would not be bladed or bulldozed. During Phase II, noise may be moderate for a short duration, and surface disturbance will be light to moderate but confined to a minimal footprint within the study area. No permanent structures will be left on site.

Best Management Practices (BMPs) incorporated into project design will reduce potential impacts including: confining equipment travel to PPA boundary, minimizing travel corridors as much as practicable, limiting truck and equipment travel within the PPA when surfaces are wet and soil may become deeply rutted, and using previously disturbed areas for travel when possible.

5.1.1. Golden eagle

Habitat potential was assessed for the golden eagle within the action area, and ACI biologists determined the sandstone cliffs surrounding the PPA provide potential nesting habitat for this species. ACI conducted surveys on May 8th, 2017 to closely examine the cliff faces within 0.37 mile of the PPA for any signs of raptor use. ACI biologists did not see any sign of active use by this species such as stick nests, fresh whitewash, or greenery within cavities, ledges or nests.

Phase I:
Noise and surface disturbance will be low and short term during pedestrian survey activity. Adult raptors would not be directly impacted by Phase I because of their mobility and ability to avoid areas of human activity. The PPA is not currently occupied as a nest territory; Phase I activities that may occur within the breeding season are unlikely to impact nesting behavior. Direct and indirect effects from Phase I are expected to be short term and negligible.

Phase II:
During Phase II, noise may be moderate for a short duration, and surface disturbance will be light to moderate within a minimal footprint at the study area. No permanent structures will be left on site. As of April 2017, the nesting habitat within 0.37 mile of the PPA boundary was not actively being used by golden eagle. Phase II activities that may occur within the breeding season are unlikely to impact potential nesting activity in the cliffs approximately 1 mile to the southeast due to the distance from the PPA, the short term nature of the disturbance, and the relatively moderate noise level that may occur.

5.1.2. Migratory Birds

The PPA encompasses approximately 17.8 acres of potential migratory bird habitat in the form of Great Basin Desert scrub and sandstone cliffs.

Phase I:
Noise and surface disturbance will be low during pedestrian survey activity. Adult migratory birds would not be directly impacted by Phase I because of their mobility and ability to avoid areas of human activity. Minor human presence during project activities within the breeding season may indirectly disturb or displace adults from nests and foraging habitats for a short period of time. Direct and indirect effects are expected to be short term and negligible.

Phase II:
Adult migratory birds would not be directly harmed by the activities because of their mobility and ability to avoid areas of human activity. During Phase II, noise may be moderate but for a short duration, and

surface disturbance will be light to moderate but confined to a minimal footprint within the study area. No permanent structures will be left on site. No active nests within the PPA are expected to be directly impacted during Phase II if activities occur outside of the typical migratory bird breeding season. The increased human presence during project activities within the breeding season may indirectly disturb or displace adults from nests and foraging habitats for a short period of time. Direct impacts are more likely if surface disturbing activities occur during the breeding season (April 1 through August 15).

5.2. Cumulative Effects

Cumulative impacts of an action include the total effects on a resource or ecosystem. Cumulative effects in the context of the Endangered Species Act pertain to non-Federal actions, and are reasonably certain to occur in the action area (USFWS 1998).

5.2.1. Golden eagle

Additional existing surface disturbances within the action area include unimproved access roads to the residences nearby, all-terrain vehicle use and active wildlife and livestock grazing. Local plant and animal pest control are also activities that occur in the vicinity. These foreseeable actions would cumulatively impact raptors through habitat loss or contamination. Human activity may also increase available prey base if the activity leads to an increase in rodent population numbers. The intensity of indirect effects would be dependent upon the species, its life history, time of year and/or day and the type and level of human and vehicular activity is occurring.

5.2.2. Migratory Birds

With the implementation of BMPs discussed in Section 5.1, the cumulative impact of the proposed action on migratory birds would be low based on the minimal surface disturbance involved and the availability of adjacent similar habitats.

6. CONCLUSIONS

U.S. Fish and Wildlife Service Listed Species (USFWS)

ACI conducted informal consultation with the USFWS and received an Official Species List for the proposed project area. Qualified ACI biologists evaluated habitat suitability within and surrounding the PPA for these species and concluded the potential does not exist for USFWS-listed species to occur within the proposed project area. No further consultation with the USFWS is required.

Migratory Birds

The proposed action phases would result in varying degrees of noise and surface disturbance within approximately 17.8 acres of potential migratory bird habitat in the form of Great Basin Desert scrub and sandstone cliffs. During Phase I, noise and surface disturbance will be low during pedestrian survey activity. Direct and indirect effects are expected to be short term and negligible. For Phase II, the total surface disturbance is unknown at this point; however equipment movement would be confined to only a few temporary travel corridors. Within the travel corridors, vegetation and surface soil would sustain some disturbance but would not be bladed or bulldozed. Possible direct impacts would be short term and are more likely if surface disturbing activities occur during the breeding season (April 1 through August 15). Effects to potential habitat for migratory birds is anticipated to be minor and short term due to the limited degree of vegetation and soil disruption and the abundance of adjacent habitat for these species.

Wetlands

Under Executive Orders 11988 and 11990, Federal agencies are required to minimize the destruction, loss, or degradation of wetlands and floodplains, and preserve and enhance their natural and beneficial values. These habitats should be conserved through avoidance, or mitigated to ensure that there would be no net loss of wetlands function and value. No impacts to wetlands are anticipated. The proposed project activities would contribute to a negligible increase in sedimentation down gradient of the project area. This increase is not anticipated to be a factor due to the distance from perennial waters. There is no suitable habitat for ESA-listed fish, nor critical habitats thereof, within 20 miles of the PPA.

Navajo Endangered Species List (NESL) and Species of Concern

One (1) NESL and Navajo species of concern has potential to occur within the PPA based on habitat suitability or actual record of observation. Based on site surveys, ACI determined the PPA contains potential foraging and nesting habitat for golden eagle.

Potential effects to this species are discussed in detail in Section 5 above. Phase II activities that may occur within the breeding season are unlikely to impact potential nesting activity in the nearby cliffs due to the distance from the PPA, the short term nature of the disturbance, and the relatively moderate noise level that may occur. With the implementation of recommendations discussed in Section 7 below, it is unlikely that the proposed action would result in detriment to the golden eagle.

7. RECOMMENDATIONS FOR AVOIDANCE

ACI recommends that the proponent implement standard Best Management Practices (BMPs) designed to protect sensitive wildlife species during project activity including: confining equipment travel to PPA boundary, minimizing travel corridors as much as practicable, limiting truck and equipment travel within the PPA when surfaces are wet and soil may become deeply rutted, and using previously disturbed areas for travel when possible.

8. SUPPORTING INFORMATION

8.1. Consultation and Coordination

John Nystedt, Fish and Wildlife Biologist/AESO Tribal Coordinator
USFWS AZ Ecological Services Office - Flagstaff Suboffice
Southwest Forest Science Complex, 2500 S Pine Knoll Dr, Rm 232
Flagstaff, AZ 86001

Pam Kyselka, Project Reviewer and
Chad Smith, Zoologist
Navajo Nation Department of Fish and Wildlife
Natural Heritage Program
PO Box 1480
Window Rock, AZ 86515

8.2. Report Preparers and Certification

Adkins Consulting, Inc.
180 E. 12th Street, Unit 5
Durango, Colorado 81301
Lori Gregory, Biologist; Sarah McCloskey, Field Biologist; Arnold Clifford, Lead Field Biologist

It is believed by Adkins Consulting that the proposed action would not violate any of the provisions of the Endangered Species Act of 1973, as amended. Conclusions are based on actual field examination and are correct to the best of my knowledge.

15 May 2017

______________________________ ________
Lori Gregory Date
Wildlife Biologist
Adkins Consulting
505.787.4088

8.3. References

Code of Federal Regulations (CFR). Interagency Cooperation - 50 CFR §402 (June 3, 1986). U.S. Government Publishing Office Electronic Code of Federal Regulations. 732 North Capitol Street, NW, Washington, DC. Retrieved from: https://www.gpo.gov/fdsys/search/home.action.

Hammerson, Geoffrey, Frank Solís, Roberto Ibáñez, César Jaramillo, Querube Fuenmayor. 2004. *Lithobates pipiens*. The IUCN Red List of Threatened Species 2004: e.T58695A11814172. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T58695A11814172.en. Downloaded on 10 June 2016.

Heil, Kenneth D. 2000. *Four Corners Invasive and Poisonous Plant Field Guide.* Bureau of Land Management (BLM), Farmington District, and San Juan College, Farmington, New Mexico.

NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: June 9, 2016).

Navajo Nation Division of Natural Resources, Department of Fish and Wildlife. 2008a. *Navajo Endangered Species List (NESL)*. Resources Committee Resolution No. RCS-41-08. Window Rock, AZ.

Navajo Nation Division of Natural Resources, Department of Fish and Wildlife. 2008b. *Navajo Endangered Species List (NESL) Species Accounts.* Retrieved from: http://www.nndfw.org/nnhp/species_acct.pdf

New Mexico Department of Game and Fish. *BISON-M (Biota Information System of New Mexico).* Available at: http://www.bison-m.org.

New Mexico Natural Heritage Program. 2006. The website of Natural Heritage New Mexico: An online resource. Version 2.0. Albuquerque, New Mexico, USA: University of New Mexico. http://nmnhp.unm.edu.

New Mexico Rare Plant Technical Council. 1999. *New Mexico Rare Plants*. Albuquerque, NM: New Mexico Rare Plants Home Page. http://nmrareplants.unm.edu.

Prall, Dexter . 2015. Navajo Endangered Species List (NESL) Information letter to Eileen Dornfest, MWH Global (File# 15mwh101). Navajo Nation Department of Fish and Wildlife, Natural Heritage Program, Window Rock, AZ.

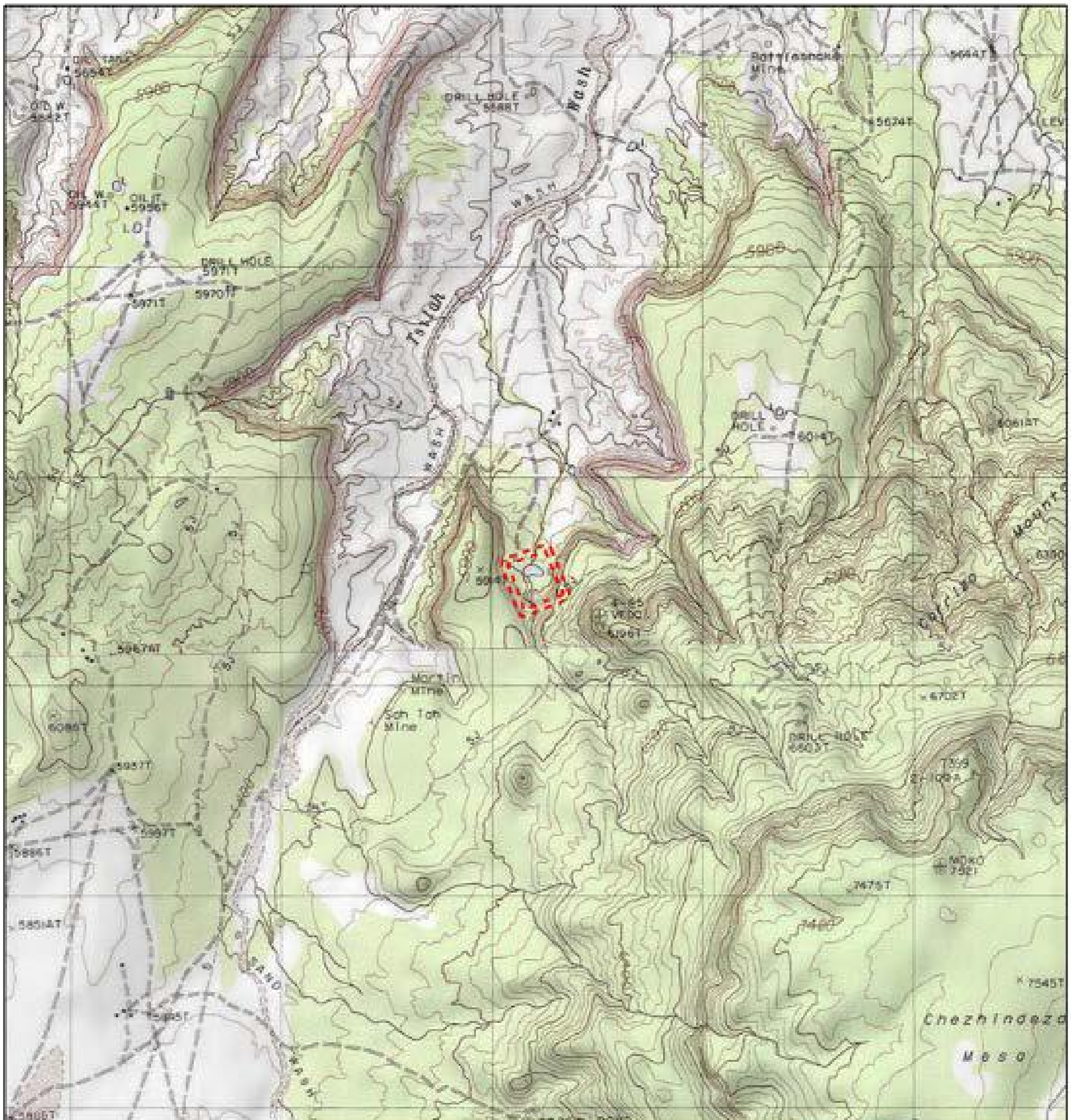
U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). 2006. Web Soil Survey. Version 1.1. NRCS. http://websoilsurvey.nrcs.usda.gov/app.

U.S. Fish and Wildlife Service (USFWS), Endangered Species Program. Information, Protection, and Conservation (iPaC). http://ecos.fws.gov/ipac/. Official Species List (02EAAZ00-2016-SLI-0364) dated April 8, 2016

U.S. Fish and Wildlife Service (USFWS) 1998. Final Endangered Species Act (ESA) Section 7 Consultation Handbook, March 1998. https://www.fws.gov/endangered/esa-library/pdf/esa_section7_handbook.pdf

U.S. Fish and Wildlife Service. 2008. *Wetlands Online Mapper.* National Wetlands Inventory (NWI). http://wetlandsfws.er.usgs.gov/wtlnds/launch.html.

APPENDIX A. MAPS



Adkins Consulting Inc.
Durango, Colorado

Abandon Uranium Mine - Environmental Response Trust Project Area

Tsosie 1

Section 18, Township 40N, Range 29E
Apache County, Arizona

Proposed Project Area

Survey Site

Survey Site Boundary

0 0.25 0.5 1 Miles

N

APPENDIX B. PHOTOGRAPHS

Looking southwest from western side of site

View to the southeast from the western side of site. Photo shows Chezhindeza Mesa which is approximately one mile from the site boundary.

APPENDIX C. NESL LETTER

NNHP
Navajo Natural Heritage Program

PO Box 1480
Window Rock, AZ
86515

P 928.871.6472
F 928.871.7603

http://nnhp.nndfw.org

15mwh101

19-November-2015

Eileen Dornfest - Project Manager
MWH Americas
3665 John F Kennedy Parkway
Bldg 1, Suite 206
Ft. Collins, CO 80525

SUBJECT: Navajo Nation AUM Environmental Response Trust (ERT) Project - 16 Abandoned Uranium Mine (AUM) Sites

Eileen Dornfest,

NNHP has performed an analysis of your project in comparison to known biological resources of the Navajo Nation and has included the findings in this letter. The letter is composed of seven parts. The sections as they appear in the letter are:

1. **Known Species** – a list of all species within relative proximity to the project
2. **Potential Species** – a list of potential species based on project proximity to respective suitable habitat
3. **Quadrangles** – an exhaustive list of quads containing the project
4. **Project Summary** – a categorized list of biological resources within relative proximity to the project grouped by individual project site(s) or quads
5. **Conditional Criteria Notes** – additional details concerning various species, habitat, etc.
6. **Personnel Contacts** – a list of employee contacts
7. **Resources** – identifies sources for further information

Known Species lists "species of concern" known to occur within proximity to the project area. Planning for avoidance of these species is expected. If no species are displayed then based upon the records of the Navajo Nation Department of Fish and Wildlife (NNDFW) there are no "species of concern" within proximity to the project. Refer to the Navajo Endangered Species List (NESL) Species Accounts for recommended avoidance measures, biology, and distribution of NESL species on the Navajo Nation (http://nnhp.nndfw.org/sp_account.htm).

Potential Species lists species that are potentially within proximity to the project area and need to be evaluated for presence/absence. If no species are found within the Known or Potential Species lists, the project is not expected to affect any federally listed species, nor significantly impact any tribally listed species or other species of concern. Potential for species has been determined primarily on habitat characteristics and species range information. A thorough habitat analysis, and if necessary, species specific surveys, are required to determine the potential for each species.

Species of concern include protected, candidate, and other rare or otherwise sensitive species, including certain native species and species of economic or cultural significance. For legally protected species, the following tribal and federal statuses are indicated: NESL, federal Endangered Species Act (ESA), Migratory

Bird Treaty Act (MBTA), and Eagle Protection Act (EPA). No legal protection is afforded species with only ESA candidate, NESL group 4 status, and species listed on the Sensitive Species List. Please be aware of these species during surveys and inform the NNDFW of observations. Reported observations of these species and documenting them in project planning and management is important for conservation and may contribute to ensuring they will not be up listed in the future.

In any and all correspondence with NNDFW or NNHP concerning this project please cite the Data Request Code associated with this document. It can be found in this report on the top right corner of the every page. Additionally please cite this code in any biological evaluation documents returned to our office.

1. Known Species *(NESL=Navajo Endangered Species List, FE=Federally Endangered, FT=Federally Threatened, FC=Federal Candidate)*

Species

AMPE = Amsonia peeblesii / Peebles' Blue-star NESL G4
AQCH = Aquila chrysaetos / Golden Eagle NESL G3
CASP = Carex specuicola / Navajo Sedge NESL G3 FT
LIPI = Lithobates pipiens / Northern Leopard Frog NESL G2
PEAMCI = Perognathus amplus cineris / Wupatki Pocket Mouse NESL G4
PUPA = Puccinellia parishii / Parish's Alkali Grass NESL G4

**All or parts of this project currently are within areas protected by the Golden and Bald Eagle Nest Protection Regulations; consult with NNDFW zoologist or EA Reviewer for more information and recommendations.

2. Potential Species

Species

ALGO = Allium gooddingii / Gooding's Onion NESL G3
AMPE = Amsonia peeblesii / Peebles' Blue-star NESL G4
AQCH = Aquila chrysaetos / Golden Eagle NESL G3
ASBE = Astragalus beathii / Beath Milk-vetch NESL G4
ASNA = Astragalus naturitensis / Naturita Milk-vetch NESL G3
ASWE = Asclepias welshii / Welsh's Milkweed NESL G3 FT
ATCU = Athene cunicularia / Burrowing Owl NESL G4
BURE = Buteo regalis / Ferruginous Hawk NESL G3
CASP = Carex specuicola / Navajo Sedge NESL G3 FT
CHMO = Charadrius montanus / Mountain Plover NESL G4
CIME = Cinclus mexicanus / American Dipper NESL G3
CIRY = Cirsium rydbergii / Rydberg's Thistle NESL G4
CYUT = Cystopteris utahensis / Utah Bladder-fern NESL G4
EMTREX = Empidonax traillii extimus / Southwestern Willow Flycatcher NESL G2 FE
ERAC = Erigeron acomanus / Acoma Fleabane NESL G3
ERRH = Erigeron rhizomatus / Rhizome Fleabane/zuni Fleabane NESL G2 FT
ERRO = Errazurizia rotundata / Round Dunebroom NESL G3
ERSI = Erigeron sivinskii / Sivinski's Fleabane NESL G4
FAPE = Falco peregrinus / Peregrine Falcon NESL G4
GIRO = Gila robusta / Roundtail Chub NESL G2
LENA = Lesquerella navajoensis / Navajo Bladderpod NESL G3
LIPI = Lithobates pipiens / Northern Leopard Frog NESL G2
MUNI = Mustela nigripes / Black-footed Ferret NESL G2 FE

PEAMCI = Perognathus amplus cineris / Wupatki Pocket Mouse NESL G4
PLZO = Platanthera zothecina / Alcove Bog-orchid NESL G3
PRSP = Primula specuicola / Cave Primrose NESL G4
PTLU = Ptchocheilus lucius / Colorado Pikeminnow NESL G2
PUPA = Puccinellia parishii / Parish's Alkali Grass NESL G4
SAPAER = Salvia pachyphylla ssp eremopictus / Arizona Rose Sage NESL G4
STOCLU = Strix occidentalis lucida / Mexican Spotted Owl NESL G3 FT
VUMA = Vulpes macrotis / Kit Fox NESL G4
ZIVA = Zigadenus vaginatus / Alcove Death Camass NESL G3

3. Quadrangles (7.5 Minute)

Quadrangles

Cameron SE (35111-G3) / AZ
Dalton Pass (35108-F3) / NM
Del Muerto (36109-B4) / AZ
Dos Lomas (35107-C7) / NM
Gallup East (35108-E6) / NM
Garnet Ridge (36109-H7) / AZ, UT
Horse Mesa (36109-F1) / AZ, NM
Indian Wells (35110-D1) / AZ
Mexican Hat SE (37109-A7) / UT, AZ
Oljeto (37110-A3) / UT, AZ
Toh Atin Mesa East (36109-H3) / AZ, UT
Toh Atin Mesa West (36109-H4) / AZ, UT

4. Project Summary *(EO1 Mile/EO 3 Miles=elements occuring within 1 & 3 miles., MSO=mexican spotted owl PACs, POTS=potential species, RCP=Biological Areas)*

SITE	EO1MI	EO3MI	QUAD	MSO	POTS	AREAS
Alongo Mines	None	AQCH	Horse Mesa (36109-F1) / AZ, NM	None	LIPI, FAPE, EMTREX, CHMO, BURE, ATCU, AQCH, ZIVA, PUPA, PLZO, CIRY, CASP	Area 3
Barton 3	None	None	Toh Atin Mesa West (36109-H4) / AZ, UT	None	PTLU, GIRO, EMTREX, CHMO, BURE, ATCU, AQCH, ZIVA, PLZO, CIRY, CASP	Area 3
Boyd Tisi No. 2 Western	None	AMPE, PEAMCI, LIPI	Cameron SE (35111-G3) / AZ	None	LIPI, PEAMCI, FAPE, EMTREX, BURE, AQCH, ERRO, ASBE, AMPE	Area 3
Charles Keith	None	None	Oljeto (37110-A3) / UT, AZ	None	LIPI, FAPE, EMTREX, CHMO, BURE, AQCH	Area 1, Area 3

SITE	EO1MI	EO3MI	QUAD	MSO	POTS	AREAS
Eunice Becenti	None	None	Gallup East (35108-E6) / NM	None	FAPE, EMTREX, ATCU, AQCH, LENA, ERGI, ERRH, ERAC	Area 3
Harvey Blackwater No. 3	AQCH	AQCH, PUPA	Garnet Ridge (36109-H7) / AZ, UT	None	VUMA, LIPI, FAPE, EMTREX, CIME, BURE, ATCU, AQCH, ZIVA, PUPA, PRSP, PLZO, CIRY, CASP, AGWE	Area 3
Harvey Blackwater No. 3	AQCH	AQCH, PUPA	Mexican Hat SE (37109-A7) / UT, AZ	None	VUMA, FAPE, EMTREX, ATCU, AQCH, ZIVA, PLZO, CIRY, CASP, AGWE	Area 1
Hoskie Tso No. 1	AQCH	AQCH	Indian Wells (35110-D1) / AZ	None	FAPE, CHMO, BURE, ATCU, AQCH, SAPAER	Area 3
Mitten No. 3	None	AQCH	Oljeto (37110-A3) / UT, AZ	None	LIPI, FAPE, EMTREX, CHMO, BURE, AQCH	Area 3
NA-0904	None	AQCH	Toh Atin Mesa East (36109-H3) / AZ, UT	None	STOCLU, LIPI, PTLU, GIRO, FAPE, EMTREX, CHMO, ATCU, AQCH, PUPA	Area 3
NA-0928	None	None	Toh Atin Mesa East (36109-H3) / AZ, UT	None	STOCLU, LIPI, PTLU, GIRO, FAPE, EMTREX, CHMO, ATCU, AQCH, PUPA	Area 3
Oak124, Oak125	AQCH	AQCH	Horse Mesa (36109-F1) / AZ, NM	None	LIPI, FAPE, EMTREX, CHMO, BURE, AQCH, ZIVA, PUPA, PLZO, CIRY, CASP	Area 3
Occurrence B	None	AQCH, CASP	Del Muerto (36109-B4) / AZ	None	LIPI, FAPE, EMTREX, CIME, AQCH, ZIVA, PLZO, CYUT, CIRY, CASP, ALGO	Area 3
Section 26 (Desiddero Group)	None	None	Dos Lomas (35107-C7) / NM	None	FAPE, CHMO, ATCU, AQCH	Area 3
Standing Rock	None	None	Dalton Pass (35108-F3) / NM	None	VUMA, MUNI, FAPE, CHMO, BURE, ATCU, AQCH, ERGI, ASNA	Area 3

SITE	EO1MI	EO3MI	QUAD	MSO	POTS	AREAS
Tsosie 1	AQCH	AQCH	Ton Atin Mesa East (36109-H3) / AZ, UT	None	STOCLU, LIPI, PTLU, GIRO, FAPE, EMTREX, CHMO, AQCH, PUPA	Area 1, Area 3

5. Conditional Criteria Notes *(Recent revisions made please read thoroughly. For certain species, and/or circumstances, please read and comply)*

A. **Biological Resource Land Use Clearance Policies and Procedures (RCP)** - The purpose of the RCP is to assist the Navajo Nation government and chapters ensure compliance with federal and Navajo laws which protect, wildlife resources, including plants, and their habitat resulting in an expedited land use clearance process. After years of research and study, the NNDFW has identified and mapped wildlife habitat and sensitive areas that cover the entire Navajo Nation.
The following is a brief summary of six (6) wildlife areas:
1.***Highly Sensitive Area*** – recommended no development with few exceptions.
2.***Moderately Sensitive Area*** – moderate restrictions on development to avoid sensitive species/habitats.
3.***Less Sensitive Area*** – fewest restrictions on development.
4.*Community Development Area* – areas in and around towns with few or no restrictions on development.
5.***Biological Preserve*** – no development unless compatible with the purpose of this area.
6.*Recreation Area* – no development unless compatible with the purpose of this area.
None - outside the boundaries of the Navajo Nation
This is not intended to be a full description of the RCP please refer to the our website for additional information at http://www.nndfw.org/clup.htm.

B. **Raptors** – If raptors are known to occur within 1 mile of project location: Contact Chad Smith at 871-7070 regarding your evaluation of potential impacts and mitigation.
o **Golden and Bald Eagles**- If Golden or Bald Eagle are known to occur within 1 mile of the project, decision makers need to ensure that they are not in violation of the Golden and Bald Eagle Nest Protection Regulations found at http://nnhp.nndfw.org/docs_reps/gben.pdf.
o **Ferruginous Hawks** – Refer to "Navajo Nation Department of Fish and Wildlife's Ferruginous Hawk Management Guidelines for Nest Protection" http://nnhp.nndfw.org/docs_reps.htm for relevant information on avoiding impacts to Ferruginous Hawks within 1 mile of project location.
o **Mexican Spotted Owl** - Please refer to the Navajo Nation Mexican Spotted Owl Management Plan http://nnhp.nndfw.org/docs_reps.htm for relevant information on proper project planning near/within spotted owl protected activity centers and habitat.

C. **Surveys** – Biological surveys need to be conducted during the appropriate season to ensure they are complete and accurate please refer to NN Species Accounts http://nnhp.nndfw.org/sp_account.htm. Surveyors on the Navajo Nation must be permitted by the Director, NNDFW. Contact Jeff Cole at (928) 871-7068 for permitting procedures. Questions pertaining to surveys should be directed to the NNDFW Zoologist (Chad Smith) for animals at 871-7070, and Botanist (Andrea Hazelton) for plants at (928)523-3221. Questions regarding biological evaluation should be directed to Jeff Cole at 871-7068.

D. **Oil/Gas Lease Sales** – Any settling or evaporation pits that could hold contaminants should be lined and covered. Covering pits, with a net or other material, will deter waterfowl and other migratory bird use. Lining pits will protect ground water quality.

E. **Power line Projects** – These projects need to ensure that they do not violate the regulations set forth in the Navajo Nation Raptor Electrocution Prevention Regulations found at http://nnhp.nndfw.org/docs_reps/repr.pdf.

F. **Guy Wires** – Does the project design include guy wires for structural support? If so, and if bird species may occur in relatively high concentrations in the project area, then guy wires should be equipped with highly visual markers to reduce the potential mortality due to bird-guy wire collisions. Examples of visual markers include aviation balls and bird flight diverters. Birds can be expected to occur in relatively high concentrations along migration routes (e.g., rivers, ridges or other distinctive linear topographic features) or where important habitat for breeding, feeding, roosting, etc. occurs. The U.S. Fish and Wildlife Service recommends marking guy wires with at least one marker per 100 meters of wire.

G. **San Juan River** – On 21 March 1994 (Federal Register, Vol. 59, No. 54), the U.S. Fish and Wildlife Service designated portions of the San Juan River (SJR) as critical habitat for Ptychocheilus lucius (Colorado pikeminnow) and Xyrauchen texanus (Razorback sucker). Colorado pikeminnow critical habitat includes the SJR and its 100-year floodplain from the State Route 371 Bridge in T29N, R13W, sec. 17 (New Mexico Meridian) to Neskahai Canyon in the San Juan arm of Lake Powell in T41S, R11E, sec. 26 (Salt Lake Meridian) up to the full pool elevation. Razorback sucker critical habitat includes the SJR and its 100-year floodplain from the Hogback Diversion in T29N, R16W, sec. 9 (New Mexico Meridian) to the full pool elevation at the mouth of Neskahai Canyon on the San Juan arm of Lake Powell in T41S, R11E, sec. 26 (Salt Lake Meridian). All actions carried out, funded or authorized by a federal agency which may alter the constituent elements of critical habitat must undergo section 7 consultation under the Endangered Species Act of 1973, as amended. Constituent elements are those physical and biological attributes essential to a species conservation and include, but are not limited to, water, physical habitat, and biological environment as required for each particular life stage of a species.

H. **Little Colorado River** - On 21 March 1994 (Federal Register, Vol. 59, No. 54) the U.S. Fish and Wildlife Service designated Critical Habitat along portions of the Colorado and Little Colorado Rivers (LCR) for Gila cypha (humpback chub). Within or adjacent to the Navajo Nation this critical habitat includes the LCR and its 100-year floodplain from river mile 8 in T32N R6E, sec. 12 (Salt and Gila River Meridian) to its confluence with the Colorado River in T32N R5E sec. 1 (S&GRM) and the Colorado River and 100-year floodplain from Nautuloid Canyon (River Mile 34) T36N R5E sec. 35 (S&GRM) to its confluence with the LCR. All actions carried out, funded or authorized by a federal agency which may alter the constituent elements of Critical Habitat must undergo section 7 consultation under the Endangered Species Act of 1973, as amended. Constituent elements are those physical and biological attributes essential to a species conservation and include, but are not limited to, water, physical habitat, and biological environment as required for each particular life stage of a species.

I. **Wetlands** – In Arizona and New Mexico, potential impacts to wetlands should also be evaluated. The U.S. Fish & Wildlife Service's National Wetlands Inventory (NWI) maps should be examined to determine whether areas classified as wetlands are located close enough to the project site(s) to be impacted. In cases where the maps are inconclusive (e.g., due to their small scale), field surveys must be completed. For field surveys, wetlands identification and delineation methodology contained in the "Corps of Engineers Wetlands Delineation Manual" (Technical Report Y-87-1) should be used. When wetlands are present, potential impacts must be addressed in an environmental assessment and the Army Corps of Engineers, Phoenix office, must be contacted. NWI maps are available for examination at the Navajo Natural Heritage Program (NNHP) office, or may be purchased through the U.S. Geological Survey (order forms are available through the NNHP). The NNHP has complete coverage of the Navajo Nation, excluding Utah, at 1:100,000 scale; and coverage at 1:24,000 scale in the southwestern portion of the Navajo Nation. In Utah, the U.S. Fish & Wildlife Service's National Wetlands Inventory maps are not yet available for the Utah portion of the Navajo Nation, therefore, field surveys should be completed to determine whether wetlands are located close enough to the project site(s) to be impacted. For field surveys, wetlands identification and delineation methodology contained in the "Corps of Engineers Wetlands Delineation Manual" (Technical Report Y-87-1) should be used. When wetlands are present, potential impacts must be addressed in an environmental assessment and the Army Corps of Engineers, Phoenix office, must be contacted. For more information contact the Navajo Environmental Protection Agency's Water Quality Program.

J. **Life Length of Data Request** – The information in this report was identified by the NNHP and NNDFW's biologists and computerized database, and is based on data available at the time of this response. If project planning takes more than two (02) years from the date of this response, verification of the information provided herein is necessary. It should not be regarded as the final statement on the occurrence of any species, nor should it substitute for on-site surveys. Also, because the NNDFW information is continually updated, any given information response is only wholly appropriate for its respective request.

K. **Ground Water Pumping** - Projects involving the ground water pumping for mining operations, agricultural projects or commercial wells (including municipal wells) will have to provide an analysis on the effects to surface water and address potential impacts on all aquatic and/or wetlands species listed below. NESL Species potentially impacted by ground water pumping: Carex specuicola (Navajo Sedge), Cirsium rydbergii (Rydberg's Thistle), Primula specuicola (Cave Primrose), Platanthera zothecina (Alcove Bog Orchid), Puccinellia parishii (Parish Alkali Grass), Zigadenus vaginatus (Alcove Death Camas), Perityle specuicola (Alcove Rock Daisy), Symphyotrichum welshii (Welsh's American-aster), Coccyzus americanus (Yellow-billed Cuckoo), Empidonax traillii extimus (Southwestern Willow Flycatcher), Rana pipiens (Northern Leopard Frog), Gila cypha (Humpback Chub), Gila robusta (Roundtail Chub), Ptychocheilus lucius (Colorado Pikeminnow), Xyrauchen texanus (Razorback Sucker), Cinclus mexicanus (American Dipper), Speyeria nokomis (Western Seep Fritillary), Aechmophorus clarkia (Clark's Grebe), Ceryle alcyon (Belted Kingfisher), Dendroica petechia (Yellow Warbler), Porzana carolina (Sora), Catostomus discobolus (Bluehead Sucker), Cottus bairdi (Mottled Sculpin), Oxyloma kanabense (Kanab Ambersnail)

6. Personnel Contacts

Wildlife Manager
Sam Diswood
928.871.7062
sdiswood@nndfw.org

Zoologist
Chad Smith
928.871.7070
csmith@nndfw.org

Botanist
Vacant

Biological Reviewer
Pamela Kyselka
928.871.7065
pkyselka@nndfw.org

GIS Supervisor
Dexter D Prall
928.645.2898
prall@nndfw.org

Wildlife Tech
Sonja Detsoi
928.871.6472
sdetsoi@nndfw.org

7. Resources

National Environmental Policy Act

Navajo Endangered Species List:
http://nnhp.nndfw.org/endangered.htm

Species Accounts:
http://nnhp.nndfw.org/sp_account.htm

Biological Investigation Permit Application
http://nnhp.nndfw.org/study_permit.htm

Navajo Nation Sensitive Species List
http://nnhp.nndfw.org/study_permit.htm

Various Species Management and/or Document and Reports
http://nnhp.nndfw.org/docs_reps.htm

Consultant List
(Coming Soon)

Dexter D Prall

Digitally signed by Dexter D Prall
DN: cn=Dexter D Prall, o=Navajo Nation Department of Fish and Wildlife, ou=Navajo Natural Heritage Program, email=prall@nndfw.org, c=US
Date: 2015.11.19 15:56:30 -07'00'

Dexter D Prall, GIS Supervisor - Natural Heritage Program
Navajo Nation Department of Fish and Wildlife

MWH

BUILDING A BETTER WORLD

November 18, 2015

TO: Navajo Natural Heritage Program
Navajo Nation Dept. of Fish and Wildlife
ATTN: Sonja Detsoi and Dexter Prall
P.O. Box 1480
Window Rock, AZ 86515

FROM: MWH Americas
ATTN: Eileen Dornfest, Project Manager
3665 John F Kennedy Parkway
Bldg 1, Suite 206
Ft. Collins, CO 80525
Phone: (970) 377-9410
Fax: (970) 377-9406
E-mail: Eileen.Dornfest@mwhglobal.com

SUBJECT: Request for T and E Information for 16 Abandoned Uranium Mine (AUM) Sites

PROJECT NAME:
Navajo Nation AUM Environmental Response Trust (ERT) Project

LOCATION:
16 AUM Sites (attached in GIS shape files and USGS topographic maps)

SUMMARY DESCRIPTION OF PROJECT:
The work is to be conducted at 16 Abandoned Uranium Mines (AUMs) and includes Removal Site Evaluations (RSEs) according to CERCLA at each of the Sites. The RSEs are site investigations that include the following activities:

- conducting background soil studies
- conducting gamma radiation scans of surface soils
- sampling surface and subsurface soils and sediments related to historic mining operations
- assessing radiation exposure inside mine operations buildings, homes, or other nearby structures (if present at the Sites)
- sampling existing and accessible groundwater wells
- mitigating physical hazards and other interim response actions
- preparing a final written report documenting the work performed and information obtained for each of the Sites

MWH

BUILDING A BETTER WORLD

TOPOGRAPHIC MAPS ATTACHED:

- Blue Gap Quadrangle, Arizona-Apache Co.
- Cameron SE Quadrangle, Arizona-Coconino Co.
- Cameron South Quadrangle, Arizona-Coconino Co.
- Del Muerto Quadrangel, Arizona-Apache Co.
- Five Buttes Quadrangle, Arizona-Navajo Co.
- Garnet Ridge Quadrangle, Arizona-Utah
- Horse Mesa Quadrangle, Arizona-New Mexico
- Indian Wells Quadrangle, Arizona-Navajo Co.
- Tah Chee Wash Quadrangle, Arizona-Apache Co.
- Toh Atin Mesa East Quadrangle, Arizona-Utah
- Toh Atin Mesa West Quadrangle, Arizona-Utah
- Bluewater Quadrangle, New Mexico
- Bread Springs Quadrangle, New Mexico-McKinley Co.
- Dalton Pass Quadrangle, New Mexico-McKinley Co.
- Dos Lomas Quadrangle, New Mexico
- Gallup East Quadrangle, New Mexico-McKinley Co.
- Sand Spring Quadrangle, New Mexico-San Juan Co.
- Standing Rock Quadrangle, New Mexico-McKinley Co.
- Mexican Hat SE Quadrangle, Utah-San Juan Co.
- Oljato Quadrangle, Utah-San Juan Co.

3665 John F Kennedy Pkwy TEL 970 377 9410
Bldg 1, Suite 206 FAX 970 377 9406

APPENDIX D. NOTES FROM FIELD SURVEYS

Adkins Consulting Inc. Environmental Permitting Services 180 East 12 Street Suite #5 Durango, CO 81301 Phone: 505-793-1140	DAILY REPORT Field Surveys

PROJECT NAME: NN AUM ERT SITE: Tsosie 1

DATE: 5/8/17

WEATHER: ____________________

PERSONNEL ONSITE: Arnold Clifford (Principal Biologist), Jason St. Pierre (Field Assistant)

==

CONTRACTORS ONSITE NOTES:

Background/Purpose: MWH/Stantec contracted ACI to conduct surveys for sensitive plant and animal in the project area of effect (PAE).

Methods: ACI compiled data on species listed under the Endangered Species Act (ESA) and Navajo Endangered Species List (NESL) with potential to occur in the PAE. Surveyors arrived at the project site at 9:00 AM and conducted a thorough survey of the PAE for the species referenced below based on established protocol. Surveyors left the site at 10:30 AM.

Findings: Although there is a known Golden Eagle nest somewhere in the vicinity of the Tsosie 1 Site (exact location and distance from site not known), no Golden Eagles, Peregrine Falcons, or raptors of any kind, were observed during the site visit. Visible cliffs were scanned, and although some whitewash was observed on cliffs, none appeared to be associated with a current raptor nest. Additionally, Cutler milkweed (*Asclepias cutleri*) was not detected during the site visit.

COPY

THE NAVAJO NATION
HISTORIC PRESERVATION DEPARTMENT
PO Box 4950, Window Rock, Arizona 86515
TEL: (928) 871-7198 **FAX:** (928) 871-7886

CULTURAL RESOURCE COMPLIANCE FORM

ROUTE COPIES TO:	NNHPD NO.: HPD-16-1020
☑ DCRM	OTHER PROJECT NO.: DCRM 2016-20

PROJECT TITLE: A Cultural Resources Inventory of One Abandoned Uranium Mine for MWH Global, Inc. (Tsosie No.1) in Sweetwater Chapter, Navajo Nation

LEAD AGENCY: USEPA

SPONSOR: Sadie Hoskie, Navajo Nation AUM, Environmental Response Trust, P.O. Box 3330, Window Rock, AZ 86515

PROJECT DESCRIPTION: The proposed undertaking will involve the complete Removal Site Evaluations under the federal Comprehensive Environmental Response, Compensation and Liability Act of 1980 to define the horizontal extent of contamination in surface soils and sediments at former uranium mine area. The total area of effect is 10.7-acres. Ground disturbing activities will be intensive and extensive with the use of heavy equipment.

LAND STATUS:	Navajo Tribal Trust
CHAPTER:	Sweetwater
LOCATION:	*T.* 40 *N.,* *R.* 29 *E-* *Sec.* 18; Toh Atin Mesa East Quadrangle, Apache County Arizona G&SRPM
PROJECT ARCHAEOLOGIST:	Clifford Werito, Patricia Moone and Tristin Moone
NAVAJO ANTIQUITIES PERMIT NO.:	B16346
DATE INSPECTED:	10/4/16 – 10/05/2016
DATE OF REPORT:	11/04/2016
TOTAL ACREAGE INSPECTED:	17.7 – ac
METHOD OF INVESTIGATION:	Class III pedestrian inventory with transects spaced 10 m apart.
LIST OF CULTURAL RESOURCES FOUND:	**(1) Site (AZ-I-6-80)** **(8) Isolated Occurrences (IO)**
LIST OF ELIGIBLE PROPERTIES:	**(1) Site (AZ-I-6-80)**
LIST OF NON-ELIGIBLE PROPERTIES:	**(8) IO**
LIST OF ARCHAEOLOGICAL RESOURCES:	**None**

EFFECT/CONDITIONS OF COMPLIANCE: No historic properties affected with the following conditions:

Site AZ-I-6-80:
1. Site boundary will be flagged/temporary fenced by a qualified archaeologist prior to ground disturbing activities.
2. Site will be monitored by a qualified archaeologist within 50-ft of established site boundaries.
3. A report will be submitted to NNHPD within 30-days after monitoring.

In the event of a discovery [*"discovery"* means any previously unidentified or incorrectly identified cultural resources including but not limited to archaeological deposits, human remains, or locations reportedly associated with Native American religious/traditional beliefs or practices], all operations in the immediate vicinity of the discovery must cease, and the Navajo Nation Historic Preservation Department must be notified at (928) 871-7198.

FORM PREPARED BY: **Tamara Billie**
FINALIZED: December 27, 2016

Notification to Proceed Recommended ☑ Yes ☐ No
Conditions: ☑ Yes ☐ No

12/27/16

The Navajo Nation Historic Preservation Office — Date

Navajo Region Approval ☒ Yes ☐ No
12/30/2016

1/4/17

BIA – Navajo Regional Office — Date

BIOLOGICAL RESOURCES COMPLIANCE FORM
NAVAJO NATION DEPARTMENT OF FISH AND WILDLIFE
P.O. BOX 1480, WINDOW ROCK, ARIZONA 86515-1480

It is the Department's opinion the project described below, with applicable conditions, is in compliance with Tribal and Federal laws protecting biological resources including the Navajo Endangered Species and Environmental Policy Codes, U.S. Endangered Species, Migratory Bird Treaty, Eagle Protection and National Environmental Policy Acts. This form does not preclude or replace consultation with the U.S. Fish and Wildlife Service if a Federally-listed species is affected.

PROJECT NAME & NO.: Tsosie 1 - Abandoned Uranium Mine - Environmental Response Trust

DESCRIPTION: Proposed Phase I & II scientific investigations at an abandoned mine site. Phase I would entail biological and land surveying with a maximum of 5 people onsite for no more than 5-7 days. Disturbance would be light. Phase II would require the use of an excavator or a small mobile drilling unit to collect one or more soil samples with up to 8 people onsite for a period of one week. A temporary travel corridor 20 f. in width would be necessary to move equipment to the site. Disturbance would be light to moderate. No permanent structures would be left onsite. Total land use would be approximately 17.8 acres.

LOCATION: 36.877714°N 109.281866°, Teec Nos Pos Chapter, Apache County, Arizona

REPRESENTATIVE: Lori Gregory, Adkins Consulting, Inc. for MWH Global/Stantec

ACTION AGENCY: U.S. Environmental Protection Agency and Navajo Nation

B.R. REPORT TITLE / DATE / PREPARER: BE-Tsosie 1 Abandoned Uranium Mine - Environmental Response Trust/MAY 2017/Adkins Consulting, Inc.

SIGNIFICANT BIOLOGICAL RESOURCES FOUND: Area 1 & 3. Suitable nesting habitat is present in the project area for Migratory Birds not listed under the NESL or ESA. Migratory Birds and their habitats are protected under the Migratory Bird Treaty Act (16 USC §703-712) and Executive Order 13186. Under the EO, all federal agencies are required to consider management impacts to protect migratory non-game birds.

POTENTIAL IMPACTS

NESL SPECIES POTENTIALLY IMPACTED: NA

FEDERALLY-LISTED SPECIES AFFECTED: NA

OTHER SIGNIFICANT IMPACTS TO BIOLOGICAL RESOURCES: NA

AVOIDANCE / MITIGATION MEASURES: Mitigation measures will be implemented to ensure that there are no impacts to migratory birds that could potentially nest in the project area.

CONDITIONS OF COMPLIANCE*: NA

FORM PREPARED BY / DATE: Pamela A. Kyselka/02 JUN 2017

COPIES TO: (add categories as necessary)

☐ ____________________ ☐ ____________________

2 NTC § 164 Recommendation: Signature Date

☒Approval

☐Conditional Approval (with memo)

☐Disapproval (with memo)

☐Categorical Exclusion (with request letter)

☐None (with memo)

6/2/17

Gloria M. Tom, Director, Navajo Nation Department of Fish and Wildlife

*I understand and accept the conditions of compliance, and acknowledge that lack of signature may be grounds for the Department not recommending the above described project for approval to the Tribal Decision-maker.

Representative's signature Date

C:\old_pc2010\My Documents\NNHP\BRCF_2017\15mwh101_t1.doc

From:	Nystedt, John
To:	Justin Peterson
Cc:	Lori Gregory; Pam Kyselka; tbillie@navajo-nsn.gov; Harrilene Yazzie; Melissa Mata
Subject:	Navajo Nation AUM Environmental Response Trust - -First Phase
Date:	Monday, November 07, 2016 4:08:30 PM
Attachments:	image001.png

Justin,

Thank you for your November 6, 2016, email. This email documents our response regarding the subject project, in compliance with section 7 of the Endangered Species Act of 1973 (ESA) as amended (16 U.S.C. 1531 et seq.). Based on the information you provided, we believe no endangered or threatened species or critical habitat will be affected by this project; nor is this project likely to jeopardize the continued existence of any proposed species or adversely modify any proposed critical habitat. No further review is required for this project at this time. Should project plans change or if new information on the distribution of listed or proposed species becomes available, this determination may need to be reconsidered. In all future communication on this project, please refer to consultation numbers given below.

In keeping with our trust responsibilities to American Indian Tribes, by copy of this email, we will notify the Navajo Nation, which may be affected by the proposed action and encourage you to invite the Bureau of Indian Affairs to participate in the review of your proposed action.

Should you require further assistance or if you have any questions, please contact me as indicated below, or my supervisor, Brenda Smith, at 556-2157. Thank you for your continued efforts to conserve endangered species.

Claim 28	02EAAZ00-2016-SLI-0358
Section 26 (Desiddero Group)	02ENNM00-2016-SLI-0447
Mitten #3	06E23000-2016-SLI-0210
NA-0904	02EAAZ00-2016-SLI-0363
Occurrence B	02EAAZ00-2016-SLI-0361
Standing Rock	02ENNM00-2016-SLI-0448
Alongo Mines	02ENNM00-2016-SLI-0465
Tsosie 1*	02EAAZ00-2016-SLI-0364
Boyd Tisi No. 2 Western	02EAAZ00-2016-SLI-0355
Harvey Blackwater #3	02EAAZ00-2016-SLI-0356 / 06E23000-2016-SLI-0207
Oak 124/125	02ENNM00-2016-SLI-0466
NA-0928	02EAAZ00-2016-SLI-0360
Hoskie Tso #1	02EAAZ00-2016-SLI-0362
Charles Keith	06E23000-2016-SLI-0208
Barton 3	02EAAZ00-2016-SLI-0354
Eunice Becenti	02ENNM00-2016-SLI-0444

* It is our understanding that the Tsosie No. 1 site has been put on hold indefinitely due to access issues. However, provided the results of the survey were negative (i.e., no potential for

any ESA-listed species) then we would come to the same conclusion, above, as for the other 15 projects.

.·`·..·`·..·`·..·`·...·`·..·`·..·`·..·`·..·`·..·`·..·`·..·`·..·`·...·`·..·`·..·`·..·`·.

Fish and Wildlife Biologist/AESO Tribal Coordinator
USFWS AZ Ecological Services Office - Flagstaff Suboffice
Southwest Forest Science Complex, 2500 S Pine Knoll Dr, Rm 232
Flagstaff, AZ 86001-6381 (928) 556-2160 Fax-2121 Cell:(602) 478-3797
http://www.fws.gov/southwest/es/arizona/

Appendix F Data Usability Report, Laboratory Analytical Data, and Data Validation Reports

F.1 Data Usability Report

F.2 Laboratory Analytical Data and Data Validation Reports

(provided in a separate electronic file due to its file size and length)

F.1 Data Usability Report

DATA USABILITY REPORT

1.0 INTRODUCTION

This data usability report presents a summary of the validation results for the sample data collected from the Tsosie 1 Site (the Site) as part of the Removal Site Evaluation (RSE) performed for the Navajo Nation AUM Environmental Response Trust—First Phase. The purpose of the validation was to ascertain the data usability measured against the data quality objectives (DQOs) and confirm that results obtained are scientifically defensible.

Samples were collected between May 24, 2017 and June 26, 2017 and were analyzed by ALS Environmental of Ft. Collins, Colorado, for all methods except mercury in water. ACZ Laboratories, Inc. of Steamboat Springs, Colorado, analyzed water samples for mercury. Samples were analyzed for one or more of the following:

- Radium-226 in soil by United States Environmental Protection Agency (USEPA) Method 901.1
- Metals in soil by USEPA Method SW6020
- Isotopic thorium in soil by USDOEAS-06/EMSL/LV
- Radium-226 in water by USEPA Method 903.1
- Radium-228 in water by USEPA Method 904
- Gross alpha/beta in water by USEPA Method 900
- Total and dissolved metals in water by USEPA 200.8
- Total dissolved solids in water by USEPA 160.1
- Alkalinity in water by USEPA 310.1
- Chloride and sulfate in water by USEPA 300.0
- Total and dissolved mercury in water by USEPA Method 1631

Samples were collected and analyzed according to the procedures and specific criteria presented in the *Quality Assurance Project Plan, Navajo Nation AUM Environmental Response Trust (QAPP)* (MWH, 2016).

Project data were validated as follows:

- Laboratory Data Consultants, Inc. (LDC) of Carlsbad, California, performed validation of all radiological soil and water data, plus ten percent of the non-radiological data (Level IV only)

- All non-radiological soil and water data were validated by the Stantec Consulting Services Inc. (Stantec; formerly MWH) Project Chemist (Level III only)
- All samples received Level III data validation
- Ten percent of the sample results for all methods received a more detailed Level IV validation

The analytical data were validated based on the results of the following data evaluation parameters or quality control (QC) samples:

- Compliance with the QAPP
- Sample preservation
- Sample extraction and analytical holding times
- Initial calibration (ICAL), initial calibration verification (ICV), and continuing calibration verification (CCV) results
- Method and initial/continuing calibration blank (ICB/CCB) sample results
- Matrix spike/matrix spike duplicate (MS/MSD) sample results
- Laboratory duplicate results
- Serial dilution (metals analysis only)
- Interference check samples (ICS) (metals analysis only)
- Laboratory control sample (LCS) and laboratory control sample duplicate (LCSD) results
- Field duplicate sample results
- Minimum detectable concentration (radiological analyses only)
- Reporting limits
- Sample result verification
- Completeness evaluation
- Comparability evaluation

Sample results that were qualified due to quality control parameters outside of acceptance criteria are listed on Table F.1-1.

2.0 DATA VALIDATION RESULTS

Stantec reviewed the data validation reports and assessed the qualified data against the DQOs for the project. The following summarizes the data validation findings for each of the data evaluation parameters.

2.1 QUALITY ASSURANCE PROJECT PLAN COMPLIANCE EVALUATION

Based on the data validation, all samples were analyzed following the quality control criteria specified in the QAPP, with the following exception: ALS routinely dilutes all metals samples by a factor of 10 times in order to protect their ICP-MS instrument from the adverse effects of running samples with high total dissolved solids. This also includes running a long series of samples (as is common in a production laboratory) with intermediate dissolved solids. The vulnerable parts of the instrument are the nebulizer, which produces an aerosol, and the cones, which disperse the aerosol. These areas form scaly deposits from the samples in the sample solution, despite the nitric acid and other acids present in the digestate. These parts of the instrument periodically need to be taken apart and cleaned, but in a production setting the laboratory wants to avoid any downtime as much as possible. As an ameliorating factor, the laboratory also takes account of this dilution factor up front in the project planning stages. The laboratory will not quote a reporting limit for this instrument that cannot be achieved after the 10 times dilution required for the instrument. Not all of the requested reporting limits can be met using the laboratory's routine protocol. The dilution is narrated by the laboratory merely as a matter of transparency, as well as for the validator's information. The dilution should have no impact on the project's sensitivity goals.

Sample Preservation Evaluation. All samples were preserved as specified in the QAPP.

Holding Time Evaluation. All analytical holding times were met.

Initial Calibration, Initial Calibration Verification, and Continuing Calibration Verification Evaluation. All ICAL, ICV, and CCV results were within acceptance criteria.

Method Blank Evaluation. No sample data were qualified due to method blank results.

Initial and Continuing Calibration Blank Evaluation. No sample data were qualified due to ICB/CCB data.

Matrix Spike/Matrix Spike Duplicate Samples Evaluation. All MS/MSD recoveries were within acceptance criteria with the exception of a few metals. Table F.1-1 lists the analytes where an MS and/or MSD percent recovery was outside the acceptance criteria. Sample results were qualified with a "J+" flag for results that are estimated and potentially biased high; sample results were qualified with a "J-" flag for results that are estimated and potentially biased low. A few

MS/MSD RPDs were outside acceptance criteria. The results were qualified with a "J" flag if not otherwise qualified.

Laboratory Duplicate Sample Evaluation. For some analyses, the laboratory prepared and analyzed a duplicate sample. RPD results were evaluated between the parent and laboratory duplicate samples. One RPD was outside the acceptance criteria for the analysis of molybdenum. The sample result was already qualified with a "J-" flag.

Serial Dilution Evaluation. All serial dilution percent differences were within acceptance criteria.

Interference Check Sample Evaluation. All interference check samples were within acceptance criteria.

Laboratory Control Sample/Laboratory Control Sample Duplicate Evaluation. All LCS and LCSD recoveries were within acceptance criteria. All LCS/LCSD RPDs were within acceptance criteria.

Field Duplicate Evaluation. The RPDs were less than the guidance RPD of 30 percent established in the QAPP for all field duplicate pairs, with the exception of results for one metal and three radium-226. The primary cause for RPDs exceeding 30 percent for some duplicate pairs is assumed to be the heterogeneity/variability of soil samples. The sample IDs, sample results, and RPDs for those results that did not meet the guidance RPD are listed in Table F.1-2. Sample results were not qualified due to RPDs exceeding the guidance criteria, as described in the QAPP.

Minimum Detectable Concentration Evaluation. All minimum detectable concentrations met reporting limits with the exception of three samples for the analysis of radium-226 and two samples for the analysis of gross beta. However, the reported activity for each of these samples was greater than the achieved minimum detectable concentration and no qualification was needed.

Reporting Limit Evaluation. All sample data were reported to the reporting limit established in the QAPP, with the exception of the metals, as discussed at the beginning of this section related to dilution.

Sample Result Verification. All sample result verifications were acceptable with the exception of sixteen samples analyzed for radium-226. The sample density exceeded the limit of +/- 15% of the density of the calibration standard. Cases that exceed the limit of +/- 15% of the density of the calibration standard were qualified with a "J+" flag for those results that may be biased high and a "J-" flag for those results that may be biased low (see Table F.1-1).

Completeness Evaluation. All samples and QC samples were collected as scheduled, resulting in 100 percent sampling completeness for this project. Based on the results of the data validation described in the previous sections, all data are considered valid as qualified. No data were rejected; consequently, analytical completeness was 100 percent, which met the 95 percent analytical completeness goal established in the QAPP.

Comparability Evaluation. Comparability is a qualitative parameter that expresses the confidence that one data set may be compared to another. For this project, sample collection and analysis followed standard methods and the data were reported using standard units of measure as specified in the QAPP. In addition, QC data for this project indicate the data are comparable. As a result, the data from this project should be comparable to other data collected at this Site using similar sample collection and analytical methodology.

3.0 DATA VALIDATION SUMMARY

Precision. Based on the MS/MSD sample, LCS/LCSD sample, laboratory duplicate sample, and field duplicate results, the data are precise as qualified.

Accuracy. Based on the ICAL, ICV, CCV, MS/MSD, and LCS, the data are accurate as qualified.

Representativeness. Based on the results of the sample preservation and holding time evaluation; the method and ICB/CCB blank sample results; the field duplicate sample evaluation; and the RL evaluation the data are considered representative of the Site as reported.

Completeness. All media and QC sample results were valid and collected as scheduled; therefore, completeness for this RSE is 100 percent.

Comparability. Standard methods of sample collection and standard units of measure were used during this project. The analysis performed by the laboratory was in accordance with current USEPA methodology and the QAPP.

Based on the results of the data validation, all data are considered valid as qualified.

Table F.1-1
Summary of Qualified Data
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Field Sample Identification	Sample Date	Analysis Code	Analyte	Sample Result	Units	QC Type	QC Result	QC Limit	Added Flag	Comment
S055-C02-001	6/26/17	E901.1	Radium-226	30.5	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-008-01	6/24/17	E901.1	Radium-226	4.28	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-008-01	6/24/17	SW6020	Molybdenum	0.89	mg/kg	MS	74%	75% - 125%	J-	Result is estimated, potentially biased low. MS recovery below acceptance criteria.
S055-SCX-010-01	6/24/17	E901.1	Radium-226	1.84	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-010-02	6/24/17	E901.1	Radium-226	2.01	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-011-01	6/26/17	E901.1	Radium-226	4.65	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-211-01	6/26/17	E901.1	Radium-226	2.34	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-001-01	6/23/17	SW6020	Uranium	3.7	mg/kg	MS MSD	241% 345%	75% - 125% 75% - 125%	J+	Result is estimated, potentially biased high. MS and MSD recoveries above acceptance criteria.
S055-SCX-001-01	6/23/17	SW6020	Vanadium	30	mg/kg	MSD MS/MSD RPD	291% 45%	75% - 125% 20%	J+	Result is estimated, potentially biased high. MSD recovery above acceptance criteria. MS/MSD RPD outside acceptance criteria.
S055-SCX-001-01	6/23/17	E901.1	Radium-226	5.45	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-001-02	6/23/17	E901.1	Radium-226	56.2	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.

Notes
mg/kg milligrams per kilogram
pCi/g picocuries per gram
LCS laboratory control sample
LR laboratory replicate (duplicate)
MS matrix spike
MSD matrix spike duplicate
RPD relative percent difference

Field Sample Identification	Sample Date	Analysis Code	Analyte	Sample Result	Units	QC Type	QC Result	QC Limit	Added Flag	Comment
S055-SCX-002-01	6/23/17	E901.1	Radium-226	6.06	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-002-02	6/23/17	E901.1	Radium-226	4.73	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-003-01	6/23/17	E901.1	Radium-226	8.2	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-SCX-003-02	6/23/17	E901.1	Radium-226	7.7	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-CX-001	6/23/17	E901.1	Radium-226	0.8	pCi/g	Result Verification		±15%	J+	Result is estimated, potentially biased high. Sample density differs by more than 15% of LCS density.
S055-CX-003	6/23/17	E901.1	Radium-226	0.91	pCi/g	Result Verification		±15%	J-	Result is estimated, potentially biased low. Sample density differs by more than 15% of LCS density.
S055-CX-203	6/23/17	E901.1	Radium-226	0.91	pCi/g	Result Verification		±15%	J-	Result is estimated, potentially biased low. Sample density differs by more than 15% of LCS density.
S055-CX-005	6/23/17	SW6020	Arsenic	8.3	mg/kg	MS MS/MSD RPD	194% 38%	75% - 125% 20%	J+	Result is estimated, potentially biased high. MS recovery above acceptance criteria. MS/MSD RPD outside acceptance criteria.
S055-CX-005	6/23/17	SW6020	Vanadium	22	mg/kg	MSD	143%	75% - 125%	J+	Result is estimated, potentially biased high. MSD recovery above acceptance criteria.
S055-CX-005	6/23/17	SW6020	Molybdenum	1.7	mg/kg	MSD MS/MSD RPD LR	72% 21% 44%	75% - 125% 20% 20%	J-	Result is estimated, potentially biased low. MSD recovery below acceptance criteria. MS/MSD RPD outside acceptance criteria.
S055-CX-011	6/24/17	E901.1	Radium-226	23.5	pCi/g	Result Verification		±15%	J-	Result is estimated, potentially biased low. Sample density differs by more than 15% of LCS density.

Notes
mg/kg milligrams per kilogram
pCi/g picocuries per gram
LCS laboratory control sample
LR laboratory replicate (duplicate)
MS matrix spike
MSD matrix spike duplicate
RPD relative percent difference

Table F.1-2
Results that did not Meet the Relative Percent Difference Guidance
Tsosie 1
Removal Site Evaluation Report - Final
Navajo Nation AUM Environmental Response Trust - First Phase

Primary Sample / Duplicate Indentification	Sample Date	Parameter	Primary Result	Duplicate Result	Units	RPD (%)
S055-BG1-001/S055-BG1-201	6/24/2017	Radium-226	1.29	0.60	pCi/g	73%
S055-SCX-011-01/S055-SCX-211-01	6/26/2017	Radium-226	4.65	2.34	pCi/g	66%
S055-SCX-005-01/S055-SCX-205-01	6/24/2017	Radium-226	0.81	0.45	pCi/g	57%
S055-CX-003/S055-CX-203	6/23/2017	Uranium	1	0.67	mg/kg	40%

Notes
mg/kg milligrams per kilogram
pCi/g picocuries per gram
RPD relative percent difference