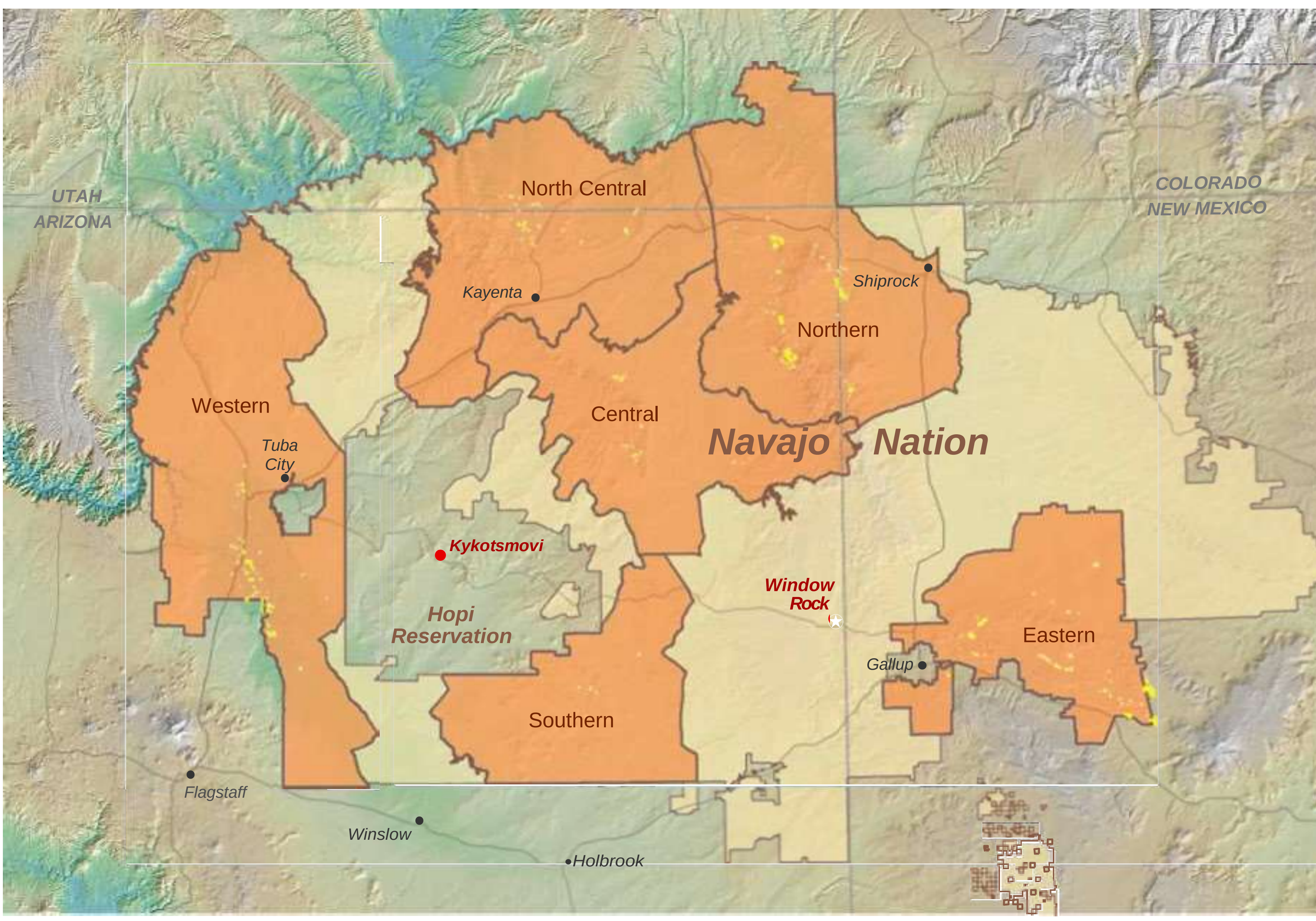
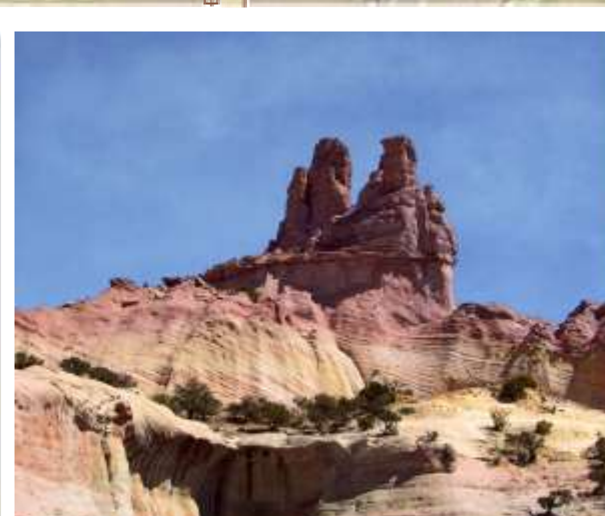
ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report And Atlas With Geospatial Data





USACE USEPA

Navajo Abandoned Mine Lands Reclamation Program

August 2007

NNEPA NAMLRP

REPORT COVER AND PHOTO CREDITS

The map on the cover shows the boundaries of the Navajo Nation and Hopi Reservation on a shaded-relief map. The Navajo Nation encompasses approximately 27,000 square miles in portions of three states: Arizona, New Mexico, and Utah. The map also shows the areas where uranium was mined across the Navajo Nation. Abandoned uranium mines (AUM) with mapped locations are shown in yellow on the map. Uranium mines were generally clustered in six regions of the Navajo Nation: North Central, Northern, Central, Eastern, Southern, and Western. The six regions are shown in orange on the map.

Photos from each of the six regions are depicted on the cover (clockwise from top left):

North Central Region: West Mitten Butte located in the Monument Valley Navajo Tribal Park, Oljato Chapter, Utah. Photo courtesy of TerraSpectra Geomatics (November 22, 2002).

Northern Region: Shiprock Peak (Tse' Bit' A'i' - Rock with Wings), a volcanic neck and dike located about 13 miles southwest of Shiprock, New Mexico in the Shiprock Chapter. Photo courtesy of TerraSpectra Geomatics (August 20, 2002).

Central Region: Spider Rock, an 800 foot red sandstone monolith located in Canyon de Chelly National Park, in the Chinle Chapter, Arizona. Photo courtesy of TerraSpectra Geomatics (May 7, 2001).

Eastern Region: Church Rock is a steeple shaped sandstone pillar located in the Red Rock State Park, about 10 miles east of Gallup, New Mexico, in Church Rock Chapter. Photo courtesy the McKinley Soil and Water Conservation District, USDA Service Center, (Accessed on April 6, 2007 at URL *http://mckinleyswcd.com/churchrock.jpg*).

Southern Region: Aerial view of the Hopi Buttes Volcanic Fields looking west. Photo courtesy Louis J. Maher, Dept. of Geology and Geophysics, Univ. of Wisconsin, Madison (Accessed on April 11, 2007 at URL *http://esp.cr.usgs.gov/hopibuttes*).

Western Region: Standing Rock Well in the central area of the Tuba City Chapter, Arizona. Photo courtesy the U.S. Army Corps of Engineers (August 12, 1998).

REPORT GRAPHIC ELEMENTS

Graphic elements used throughout this report are patterned after the Navajo Nation seal and flag. The seal (shown above) was designed by John Claw, Jr. of Many Farms, Arizona and was officially adopted by the Navajo Tribal Council in 1952, by resolution CJ-9-52. The original Navajo Nation seal bears a ring of 48 arrowheads that symbolize the Tribe's protection within the 48 states (as of 1952). Within this ring of arrowheads are three concentric circles that are open at the top. The circles represent a rainbow and symbolize the Navajo Nation. Within these rings are two corn plants, the sustainer of life for the Navajo, their tips yellow with pollen. Between the corn plants are a horse, cow, and sheep, representing livestock. The yellow sun shines from the east (at the top) on the four sacred mountains that are represented by their ceremonial colors: white, turquoise, yellow, and black. In May 1988, the Navajo Nation Council amended the original wording from "the Great Seal of the Navajo Tribe" to "the Great Seal of the Navajo Nation." They also increased the number of arrowheads to 50 to include representation of the states of Hawaii and Alaska (Navajo Nation Hospitality Enterprise, 2005).

In the Navajo Creation Story, it is told that their Creator placed them on a land between the following four mountains, which represent the four cardinal directions:

- Mount Blanca — Sacred Mountain of the East — Dawn or White Shell Mountain,
- Mount Taylor — Sacred Mountain of the South — Blue Bead or Turquoise Mountain
- San Francisco Peaks — Sacred Mountain of the West — Abalone Shell Mountain
- Mount Hesperus — Sacred Mountain of the North — Obsidian Mountain

The Navajo Nation flag (shown below), was designed by Jay R. Degroat, a Navajo student from Mariano Lake, New Mexico. It was officially adopted by the Navajo Nation Council in 1968 by Resolution CMY-55-68. On a tan background, the outline of the Navajo Nation is shown in copper, with the outline of the original 1868 Treaty Reservation in dark brown. At the cardinal points in the tan field are the four sacred mountains. A rainbow symbolizing Navajo sovereignty arches over the Navajo Nation and the sacred mountains. In the center of the Nation, a circular symbol depicts the sun above two green stalks of corn, which surrounds three animals representing the Navajo livestock economy, and a traditional hogan and modern home. Between the hogan and the home is an oil derrick symbolizing the resource potential of the Nation, and above this are representations of the wild fauna of the Nation. At the top, near the sun, the modern sawmill symbolizes the progress and industry characteristics of the Navajo Nation's economic development (Navajo Nation Hospitality Enterprise, 2005).

The Navajo consider east to be where everything begins — east signifies dawn and all things good and beautiful. On the Navajo Nation seal, the Navajo convention of east as "up" is used. For this document, the placement of the sacred mountains on the borders follows the cartographic convention of north at the top, as depicted on the Navajo Nation flag.

ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report and Atlas with Geospatial Data

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August 2007

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The authors would like to extend their appreciation to William Chenoweth, Consulting Geologist, whose personal knowledge of the his- tory of uranium mining on the Navajo Nation proved invaluable.

Special recognition is also extended to Glynn R. Alsup in honor of his tireless efforts on behalf of the United States Army Corps of Engi- neers and his devotion, commitment, and dedicated service to improving conditions on the Navajo Nation.

Report contributors from TerraSpectra Geomatics included Elaine Ezra, David Brickey, Larry Tinney, Teresa Bell, Ronald Ezra, Katahdin Withnall, Joseph Scepan, and Rick Van Remortel.

The following is a list of the organizations who generously shared knowledge, identified where to seek data, contributed data, and/or provided critical reviews and evaluations. Their contributions are gratefully acknowledged.

Ahéhee'

THANK YOU

Diné College Uranium Education Program
Navajo Abandoned Mine Lands Reclamation Program
Navajo Area Indian Health Service
Navajo Department of Data Resources
Navajo Department of Water Resources
Navajo Land Department - GIS Section
Navajo Nation Environmental Protection Agency - Navajo Superfund Program
Navajo Nation Environmental Protection Agency - Surface and Ground Water Protection Department
Navajo Tribal Utility Authority
Southwest Research Information Center (SRIC)
Sustainable Energy Solutions at Northern Arizona University
U.S. Army Corps of Engineers, Los Angeles District
U.S. Army Corps of Engineers, Albuquerque District
U.S. Bureau of Indian Affairs
U.S. Department of Energy
U.S. Environmental Protection Agency, Region 9
U.S. Fish and Wildlife Service
U.S. Geological Survey, USGS Navajo Nation Studies Program
U.S. Geological Survey, Flagstaff
U.S. Geological Survey, Albuquerque

This report is dedicated to Navajo Miners and their families.

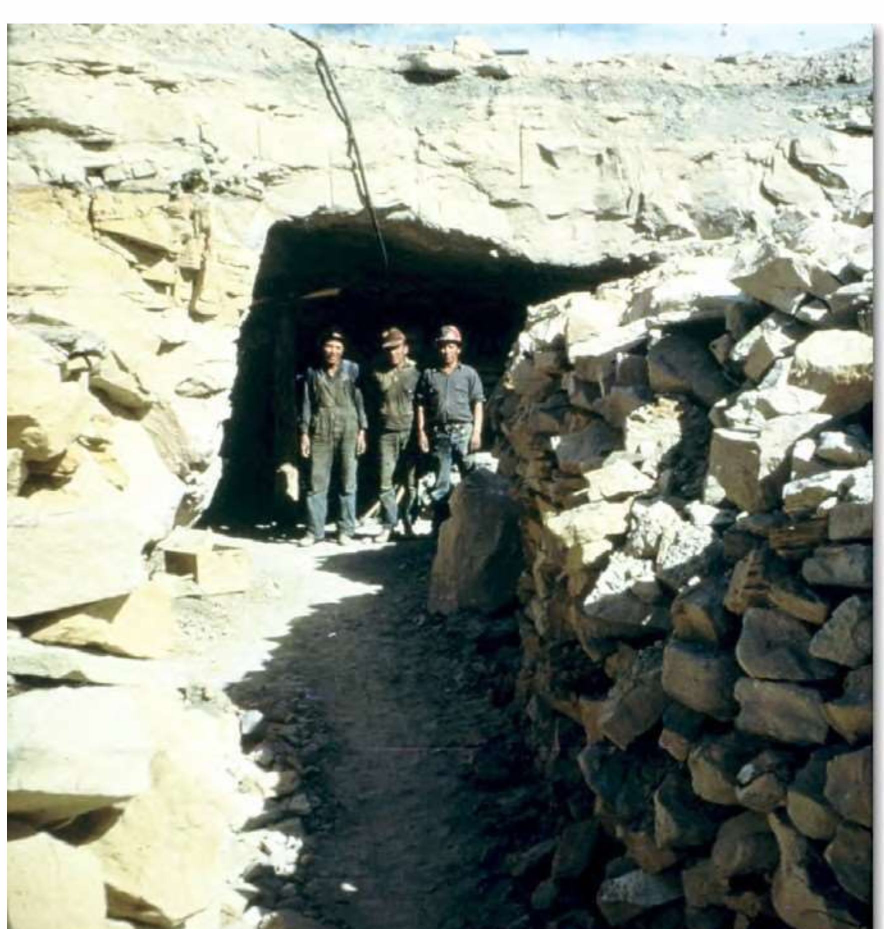

Photo of Navajo Miners Working at the King Tutt Point Mine Plot 2, East Reservation Lease taken by Kenneth Hatfield, 1953. Photo courtesy William Chenoweth.

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PART 2 - ATLAS WITH GEOSPATIAL DATA

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EXECUTIVE SUMMARY

The Navajo Nation covers over 27,000 square miles in portions of three states: Arizona, New Mexico, and Utah. There has been widespread uranium mining on the Navajo Nation, beginning in the early 1900's. Peak uranium mining occurred between the 1940's and 1960's in support of the U.S. Government's defense programs. Substantial amounts of land throughout the Navajo Nation were disturbed by surface and underground mining. Over 1,200 mine features (e.g., portals, prospects, rim strips, pits, vertical shafts or waste piles) associated with abandoned uranium mines (AUMs) have been identified. More than 600 AUM sites or related areas have been mapped throughout and within one mile of the Navajo Nation.

In November 1993, U.S. Congressional Subcommittee hearings were conducted in which the Navajo Nation presented testimony about AUMs on the Navajo Nation and requested assistance to determine if the AUMs posed a health risk to Navajo residents. Shortly thereafter, in 1994, the U.S. Environmental Protection Agency (EPA) Region 9 initiated the Navajo Abandoned Uranium Mines (NAUM) Project.

This *Abandoned Uranium Mines and the Navajo Nation* report documents NAUM Project data collection and screening results for all known AUMs on the Navajo Nation. The report has two parts: the *Navajo Nation AUM Screening Assessment Report* and the accompanying *Atlas with Geospatial Data.*

In 2002, the EPA Region 9 Superfund Site Assessment and Technical Support Team developed a custom set of Hazard Ranking System (HRS) screening criteria to assess AUMs on the Navajo Nation for possible remedial actions. The large geographic area covered by the Navajo Nation is beyond the normal scope for the HRS, so a custom model was developed to fit these unique circumstances. The method used to prioritize the AUM sites is based on a limited subset of the locational-distance criteria in the HRS. It does not include the complete set of criteria and factors built into the full HRS model. The scoring is not intended to identify actual risks, but rather to identify and prioritize areas for future investigation and response decisions.

The HRS-derived model used for this study was developed based on the presence of downstream surface water drainages and the numbers of structures and wells proximal to AUM sites. A Geographic Information System (GIS) database was developed for the study and included the following geospatial datasets for the analysis: 1) locations of all known abandoned uranium mines on and within 1 mile of the Navajo Nation, 2) structures within 1 mile of an AUM, 3) drinking water sources within 4 miles of an AUM, and 4) surface drainages 15 miles downstream from an AUM. The GIS was used to compare the individual AUM sites by distance from the human receptors. The *Navajo Nation AUM Screening Assessment Report* presents the analysis results from the model in data tables and maps. Based on the results of this broad-based screening process, EPA will consult with the Navajo Nation about the recommended follow-up investigations or cleanup responses that require attention.

The *Atlas with Geospatial Data* portion of this report describes the geospatial datasets used for the screening analysis. Due to the limited subset of criteria used in the HRS-derived model, the analysis resulted in some cases where AUM sites with little to no waste (e.g., a prospect with no uranium production) scored high due to close proximity to structures and wells. Conversely, some AUM sites with high volumes of waste scored low due to their remote locations with few structures or wells in close proximity. The prioritization process can be enhanced by the addition of more factors, criteria, and data into the model.

The EPA, Navajo Nation Environmental Protection Agency (NNEPA), Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and U.S. Army Corps of Engineers collectively developed a list of key data needed for the further assessment of AUMs. In order to minimize redundancy and costs, an important aspect of this effort was the systematic collection and review of existing data suitable for use in preliminary assessments and for model refinement. The list focused on data related to contaminant sources and their transport pathways, such as air, soil, ground water and surface water. The NAUM Project Team then carefully examined existing data sources, including those from other federal, state, Navajo agencies, and universities to identify data that could assist with providing answers to questions about the AUMs and the transport of potential contaminants on a Navajo Nationwide level.

The *Atlas and Geospatial Data* includes readily available regional scale data that were compiled for the Navajo Nation. The *Atlas and Geospatial Data* portion of the report is organized into three Sections: Section 1 - *Mining History and Mine Site Information;* Section 2 - *Mine Waste Characteristics; and* Section 3 - *Environmental Setting.* The Sections generally follow an Atlas format, with a text description of the dataset and a facing page with a map example. Referenced documents have been scanned and are provided in digital format on Digital Versatile Disks (DVDs), along with the report, all geospatial datasets used, and associated metadata.

This report can support improved decision-making and provides the following:

- Final documentation and distribution of GIS data, analyses, and maps generated for the screening phase of the NAUM study.
- Compilation of regional GIS data that will support the NNEPA and NAMLRP with further assessment of priority AUM sites.

The target audience of this report is broad, ranging from residents and Chapter Officials, students and teachers, community groups, and technical specialists in various Navajo Nation, State and Federal government agencies, and academic institutions. The content ranges from introductory tutorials to discipline-specific discussions related to environmental assessments.

From Testimony of the Navajo Nation Before the Subcommittee on Oversight and Investigations and the Subcommittee on Native American Affairs Regarding Abandoned Uranium Mines on the Navajo Nation - November 4, 1993:

"From the 1920s to the early 1970s, uranium ore was mined on the Navajo reservation for the U.S. atomic energy program. The primary purchaser and beneficiary of this mining activity was the U.S. government and the development of uranium resources was entrusted to the Atomic Energy Commission.

As a result of this mining, the Navajo Nation has been left with at least 1,104 known abandoned uranium mines and tons of hazardous radioactive uranium mine waste scattered across our lands.

Many Navajo people live and work in close proximity to highly contaminated soil, and breathe and drink contaminated air and water. Some residents live within a few hundred feet of highly radioactive wastes. Sheep and livestock - the basis for our subsistence - graze on contaminated vegetation and drink contaminated water. Often, Navajo homes are built with radioactive mine waste rocks and children play daily in the vicinity of mines and on mill tailing piles."

Based on a review of production records it is estimated that approximately 14% of the uranium used for the United States World War II and Cold War nuclear weapons and energy programs were mined from the Navajo Nation.

COMMUNITY INTRODUCTION

In April 2000, the Navajo Nation Environmental Protection Agency (NNEPA), the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP)[1] and the United States Environmental Protection Agency (EPA) Region 9 made a decision to map and screen all abandoned uranium mines on the Navajo Nation for possible remedial actions. In addition to their own data, the three agencies collected information from tribal, state, and federal agencies, including census, cultural, wildlife, and water resource agencies.

The Navajo Nation screening assessment that follows this introduction provides valuable information and maps of mine locations, the mine type, and how close the mines are to homes and water sources. If you have questions about the information or about our programs or the science involved, please feel free to contact any member of our team listed in the contact information provided (see MISSION STATEMENTS, page 3). Tribal and federal agencies will use the information to determine appropriate assessments, including possible cleanup actions.

For the purposes of this introduction, "abandoned uranium mines" are uranium mines that have been deserted and are no longer being maintained. Based upon several chapter meetings, the following are questions that the agencies have been frequently asked in their outreach work. These questions are important to people who live in areas with abandoned uranium mines. These questions focus on the environment and health.

ENVIRONMENT

1. *What are the impacts of abandoned uranium mines to the water we drink (ground water and surface water)?*

   Uranium is a common, naturally occurring radioactive material that is present in our environment and may be found in water, soil, rock formations, and air. If water is present in the ground next to rocks containing uranium, there will be a certain amount of uranium in the water. Uranium in water comes from different sources. Most of it comes from the water running over uranium bearing rocks and through the soil. Only a small amount comes from airborne dust that settles on water. In some cases, the uranium can be suspended in water, like mixing dirt to make muddy water. Human activities, such as mining, can move the uranium around and change the levels that you are exposed to.

2. *What are the impacts of abandoned uranium mines to soil?*

   Mining practices at abandoned uranium mines often disturbed the soils, thus making them less stable and more susceptible to erosion. Concentrated ore was brought to the surface and indirectly caused the spread of contaminated soils in staging areas. During the digging, the sandstone rock containing the ore was separated by hand, loaded into trucks and transported off-site for milling. Uranium was also spread by erosion and blowing dust and can be found concentrated at the waste piles and ore transfer stations. Soils disturbed by mining are also likely to support less vegetation or they may support a totally new species mix due to the changes in soil composition. Several of these locations on the Navajo Nation have been assessed to identify areas of concern.

3. *What are the impacts of abandoned uranium mines to air?*

   In the air, uranium exists as dust. Very small dust-like particles of uranium in the air fall out of the air onto surface water, plant surfaces, and soil either by themselves or when rain falls. The amount of uranium dust particles in air is usually very small, so it is not considered a significant concern for health impacts.

HEALTH

Uranium is naturally found everywhere in small amounts. We take uranium into our bodies through the food and water we ingest and from the air we breathe. Additionally, we are exposed to radiation from cosmic and natural sources on earth all the time. In a few places, there is more natural uranium in water than in food. People living in these areas take in more uranium from their drinking water than from their foods. When we breathe uranium dust, some of it is exhaled and some stays in our lungs. The size of the uranium dust particles and how easily they dissolve determines where in the body the uranium goes and how it leaves the body. Some of the uranium dust may gradually dissolve and go into the blood. The blood carries the uranium throughout the body and most of it leaves in your urine in a few days, but a little stays in your kidneys and bones.

1. *How far should I live from an abandoned uranium mine, whether it is reclaimed or not?*

   Reclaimed abandoned uranium mines should pose little risk for health hazards because work has been done to make the physical mine area safe and stable. The soils were carefully surveyed with radiation detecting equipment to identify problem areas. The uranium-contaminated soils were buried and many steep areas were stabilized to prevent further movement of the uranium containing soils. Drainage patterns have been diverted away from reclaimed areas to reduce the leaching capability of surface water. Any unreclaimed abandoned uranium mines may pose some risk. The agencies strongly advise people to reduce their exposure to places where there are abandoned uranium mines or mine wastes. People who already live near a mine, or a community considering an area for future development, will want to ask specific questions about a particular mine site or waste pile to better understand the risks. These questions are based on radiation safety principles known as ALARA (As Low as Reasonably Achievable), and follow three basic principles that can be applied to reduce potential exposures to radiation: time, distance, and shielding. Questions could include the following: How long is the person exposed, including residential, farming and recreational activities (time)? How close is the person to the source of exposure while doing these activities (distance)? Is there something between the person and the source of exposure that can absorb some of the radiation (shielding)?

   The agencies looked at how close structures (e.g., homes, churches, businesses) were located to the abandoned uranium mines to assess the potential for people to be exposed. This report serves as a tool for the agencies to discuss where cleanup decisions are needed, as well as how and who can address them.

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[1] NAMLRP provided technical and review assistance to the project.

2. *What will happen if I drink water that contains small particles (dissolved) of uranium and heavy metals?*

The Navajo Nation issued a health advisory in 2001 recommending people drink water from regulated safe drinking water sources such as Navajo Tribal Utility Authority (NTUA) and Indian Health Services (IHS) systems. These sources of water are sampled and tested routinely to ensure it is safe to drink. Water containing natural uranium is radioactive, but only to a weak extent. At high concentrations, uranium also has a toxic, chemical effect, and people have developed kidney disease drinking highly contaminated water for long periods. This is why EPA has established standards for uranium in drinking water throughout the United States which are safe for long-term water use. As long as the levels in the drinking water are below these concentrations, the water is safe to drink. The uranium drinking water standard is 30 parts per billion. Please refer to the EPA website for the list of drinking water standards for other elements of concern, including arsenic and lead: *http://www.epa.gov/safewater/mcl.html*. For more information on the health effects of uranium, arsenic and lead, please refer to the Agency for Toxic Substances and Disease Registry website: *http://www.atsdr.cdc.gov/toxfaq-u.html#bookmark05.*

Across the Navajo Nation we looked at how close water sources (for example wells, developed springs, and stock tanks) were located to the abandoned uranium mines to assess the potential for people to be exposed. Please see Figures 12 through 60 for maps showing the locations of water sources and mines on and within 1 mile of the Navajo Nation.

3. *What are the effects of ingesting uranium that has been taken up by livestock?*

There is not enough research in this area, but it is advisable that livestock not graze on areas where abandoned uranium mines are located.

4. *What can people do to reduce the risk of exposure to uranium?*

The most common and easiest things to do are the following:

- Avoid abandoned uranium mines, waste piles, or mill tailings piles.
- Do not collect any rocks from the vicinity of known uranium mines, waste ore piles, or transfer stations.
- Do not use suspect rocks for building homes, foundations, root cellars, corrals, bread ovens, fireplaces, or any other structures.
- If you have yellowish rocks or any rock you know has come from a uranium mine area in your home or yard, call the Navajo Superfund Project Manager at 928-871-6859 for additional information.
- Do not drink from unregulated water sources such as windmills, stock tanks, and springs.

5. *Is it safe to wash dishes or laundry with contaminated water?*

No, the agencies recommend using water from a regulated source such as NTUA and IHS systems.

If you have questions about your drinking water quality, please contact NNEPA Public Water Systems Supervision Program at 928-871-7600. You can reach NTUA at 928-729-5721.

Radiation Exposure Compensation Act (RECA)

Where can I apply for Radiation Exposure Compensation Act (RECA) benefits?

The Uranium Office in Shiprock, New Mexico can provide application packets and pertinent information for miners, transporters, millers, and "downwinders"

Larry Martinez
Uranium Office
Post Office Box 1890
Shiprock, New Mexico 87420
Telephone: 505-368-1261 Fax: 505-368-1266

Radiation Exposure Screening and Education Program (RESEP)

Where can I get screened for compensation requirements under the Radiation Exposure Screening and Education Program?

The following are screening facilities:

Shiprock Northern Indian Health Service
Post Office Box 160
Shiprock, New Mexico 87420
Telephone: 505-368-7032

RESEP Coordinator
Utah Navajo Health System
Montezuma Creek Clinic
Post Office Box 130
Montezuma Creek, Utah 84534
Telephone: 435-651-3291

RESEP Coordinator
Lake Powell Medical Center
647 Vista Avenue
Page, Arizona 86040
Telephone: 928-645-8123, ext. 206

RESEP Coordinator
North Country Community Health Center
2500 North Rose Street
Flagstaff, Arizona 86004
Telephone: 928-213-6100

BACKGROUND

Uranium mining on the Navajo Nation began in the early 1900's. Widespread mining of uranium ore for Cold War weapons and nuclear energy production occurred, with peak activities between the 1940's and 1960's on the Navajo Nation and throughout the Colorado Plateau. The Bureau of Indian Affairs (BIA) and the Navajo Nation negotiated mining leases and mining permits with a number of private mining companies, who in turn processed the ore at their own facilities (mill sites) or sold the raw uranium ore to such facilities. Ultimately, the former United States Atomic Energy Commission (AEC) acted as the sole market for all uranium concentrate (yellowcake) processed from the Navajo Nation during the period from 1947 - 1970. After 1970, milling companies sold their concentrate to electric utilities. All of the vanadium recovered from the ore was sold to the steel industry. Copper recovered from the Monument Valley ores was sold to copper smelters in Arizona (Chenoweth, 2007 - S07110701).

Most uranium mining activities ended in 1968 on the Navajo Nation, but the legacy of abandoned uranium mines (AUM), widely distributed wastes, and collateral environmental, cultural, and economic impacts continue (Sowder, 2001 - S12190201). It is probable that the mining activities led to dispersion of radioactive and heavy metal contaminated dusts, sediments, ground water, and surface water to varying degrees, depending on site conditions, mining practices, and the amount and grade of material extracted. Since uranium is a naturally occurring element, questions about how much dispersion or contamination occurred as a direct result of mining, who is at risk, and to what extent, are difficult to answer without a systematic review and analysis of the AUM sites.

Congressional hearings were held on November 4, 1993, regarding AUMs on the Navajo Nation (U.S. House of Representatives, 1993 - S12120224). The Navajo Nation presented testimony before the Subcommittee on Oversight and Investigations and the Subcommittee on Native American Affairs regarding concerns about the mines and the Navajo Nation requested assistance to determine if the uranium mines posed a health risk to Navajo residents (Hoskie, 1993 - S12120225). The U.S. Environmental Protection Agency (EPA) presented testimony to describe its federal authority under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as Superfund, and how the EPA could assist the tribe.

The risk of human and ecological exposure to uranium on Navajo Lands occurs in the following three ways: 1) Naturally occurring radioactive material (NORM), 2) the AUM sites, and 3) uranium milling activities. CERCLA only addresses wastes resulting from man-made activities, such as mining, which includes waste piles. With respect to naturally occurring ore, EPA has no authority under CERCLA. EPA is also excluded from addressing mill sites; DOE and the Nuclear Regulatory Commission (NRC) have authority under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) to investigate and address the former mill sites located near the Navajo communities of Shiprock, New Mexico; Mexican Hat, Utah; Tuba City, Arizona; and Monument Valley, Arizona.

In response to the concerns raised by the Navajo Nation at the Congressional hearings, the EPA initiated the NAUM Project in 1994. Since the beginning of the NAUM Project, several studies have been conducted to determine the scope and impact of uranium mining on the Navajo Nation. The following describes the missions of the primary NAUM Project agencies.

MISSION STATEMENTS

NAVAJO NATION ENVIRONMENTAL PROTECTION AGENCY

On April 21, 1995, the Navajo Nation Council established the Navajo Nation Environmental Protection Agency (NNEPA). NNEPA is an independent regulatory agency within the Executive Branch of the Navajo Nation Government with regulatory, monitoring, and enforcement authority over matters relating to the quality of the environment and over any person or entity doing business within, or otherwise affecting the environment of the Navajo Nation. Funding for NNEPA is provided by Navajo Nation general funds, federal grants from the EPA, the U.S. Department of Justice, and from fees that are collected under existing Tribal environmental laws.

On May 22, 2001, the NNEPA received approval to amend the plans of operations for the Air & Toxics Department, the Surface and Ground Water Protection Department, the Waste Regulatory Compliance Department (WRCD), and the Criminal Enforcement Department. The first three departments are responsible for the civil and administrative enforcement of Tribal environmental laws and regulations. Criminal environmental crimes are investigated by the Criminal Enforcement Department. Each department consists of several programs that are responsible for program development, technical and enforcement development, conducting research, investigating and assessing environmental problems and concerns, monitoring cleanup and/or corrective actions, and providing technical assistance and training.

The Navajo Superfund Program (NSP) is one of several programs within the WRCD and is funded under an EPA CERCLA grant. Under CERCLA, NSP is responsible for conducting site assessments where hazardous substances may have been used by past development activities, such as uranium mining and milling activities that occurred on the Navajo Nation. NSP has conducted assessments at several AUM. Activities related to these assessments included collecting samples of soil sediments and both surface water and ground water. Other activities included conducting surveys using instruments to detect different types of radiation, conducting interviews of chapter officials and local residents, and reviewing U. S. Bureau of Indian Affairs (BIA) lease information to identify the companies that developed the mines. The information was submitted to EPA for use in the federal Hazard Ranking System (HRS) to score each site and to determine the threat associated with actual or potential releases of hazardous substances. EPA uses the HRS to set priorities for further site evaluation and determine possible remedial action if the site is eligible for placement on the National Priorities List (NPL). The NPL identifies sites at which EPA may conduct remedial response actions.

For further information about NNEPA, you may contact the following:

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NNEPA
Post Office Box 339
Window Rock, Arizona 86515
Telephone: 928-871-7692

Arlene C. Luther, Department Director
Waste Regulatory Compliance Department
NNEPA
Post Office Box 339
Window Rock, Arizona 86515
Telephone: 928-871-7993

Diana J. Malone, Program Manager
Navajo Superfund Program
NNEPA
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Window Rock, Arizona 86515
Telephone: 928-871-6859

NAVAJO ABANDONED MINE LANDS RECLAMATION PROGRAM (NAMLRP)

The NAMLRP was established in August 1988 as a program under the Navajo Nation's Division of Natural Resources. The purpose of the program is to fulfill the abandoned mine reclamation requirements of Public Law 95-87 "Surface Mining Control and Reclamation Act (SMCRA) of 1977." This legislation was amended and reauthorized in the Amendments Act of 2006.

Through SMCRA, reclamation funds for abandoned mine lands were established to address land and water resources impacted by abandoned mines for which there were no responsible parties. Reclamation could only be addressed to lands that have tribal trust status. Since SMCRA is directed towards the reclamation of coal related mining problems, NAMLRP was required to concentrate first on the reclamation of all known coal mining sites.

A trust fund was established in the U.S. Treasury as the Abandoned Mine Lands (AML) Reclamation Fund to be administered by the Secretary of the Interior. All active coal mining operations deposit 35 cents per ton of coal produced into the fund, while underground mining operations deposit 15 cents per ton of coal produced as of 2007. Fifty percent of the Abandoned Mine Lands Reclamation funds go to eligible tribes and states who can use it for administration, project development, and construction costs.

Since 1988 NAMLRP has been reclaiming abandoned coal and non-coal mine sites within the boundaries of the Navajo Nation. After the establishment of the NAMLRP, the following tasks were completed in order to understand the mining scenario throughout the Navajo Nation. NAMLRP completed an inventory, prioritized the abandoned mine sites according to Office of Surface Mining criteria, and made a determination as to which sites would be reclaimed. Several factors were taken into consideration, such as the need to protect public health, environmental problems, and overall safety for employees.

For further information about NAMLRP, you may contact the following:

Main Office

Madeline Roanhorse, Department Manager
AML Reclamation/UMTRA Department
Post Office Box 1875
Window Rock, Arizona 86515
Telephone: 928-871-6982

Shiprock AML Reclamation Program

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA)

The mission of the EPA is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people. EPA employs 18,000 people across the country, including the Washington, DC headquarters offices, ten regional offices, and more than a dozen laboratories. EPA conducts environmental science, research, education, and assessment efforts. EPA develops and enforces regulations, provides financial assistance, performs environmental research and cleanup of contaminated sites.

EPA's Region 9 covers the southwestern United States (Arizona, California, Nevada, and Hawaii) and it works with 147 federally recognized tribes. EPA Region 9 has a Memorandum of Understanding with the Navajo Nation to work with the NNEPA in a government to government relationship. In response to concerns raised by the Navajo Nation during a 1993 Congressional hearing, the EPA Region 9 Superfund Program initiated an investigation aimed at assessing human exposure to radiation and heavy metals from abandoned uranium mines. EPA conducted extensive field sampling of abandoned uranium mines, water sources, and homes during the 1990s. In 2002, EPA developed the Abandoned Uranium Mine Project Management Plan in partnership with the NNEPA to create a screening assessment mechanism, with close involvement by the NAMLRP.

The U.S. Army Corps of Engineers has produced a Geographic Information System (GIS) database and this report for EPA in support of AUM screening assessments on the Navajo Nation. The GIS database identifies the locations of all known abandoned uranium mines and uranium mining-related areas on the Navajo Nation and their proximity to structures, water sources, and surface water drainages. This report will allow the project team to recommend Superfund removal actions or assessments to determine a site's eligibility for Superfund removal actions and/or Superfund Site listing to the NNEPA. Based on the results of the mine screening study, EPA will consult with the Navajo Nation about the recommended follow-up investigations or cleanup responses requiring prompt attention.

With respect to future work, EPA and NNEPA will coordinate closely with the NAMLRP to directly address, or to seek additional resources to address sites such as waste piles, unreclaimed mines, and mine contaminated water sources.

For further information about EPA or the Navajo Nation AUM Screening Assessment Report, you may contact the following:

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GEOGRAPHIC INFORMATION SYSTEM (GIS)

The Navajo Nation AUM Screening Assessment Report and Atlas presents map products that were developed using a Geographic Information System (GIS). A GIS is a system of computer software, hardware, data, and personnel to manipulate, analyze, and present information that is tied to a spatial location.

A geographic or spatial location refers to the location on the earth where an object occurs. This may be in vector (point, line or polygon) or raster (grid or image) form. The location of these basic objects may be expressed in latitude and longitude, Universal Transverse Mercator (UTM) northing and easting coordinates, or some other standard coordinate system. Figure 1 presents an example of mapped features that are represented as points (structures as red squares and wells as blue dots), lines (drainages that are downstream from an AUM and shown as blue lines), polygons (AUM boundary shown as a yellow polygon), and a raster digital orthophotograph as the base image.

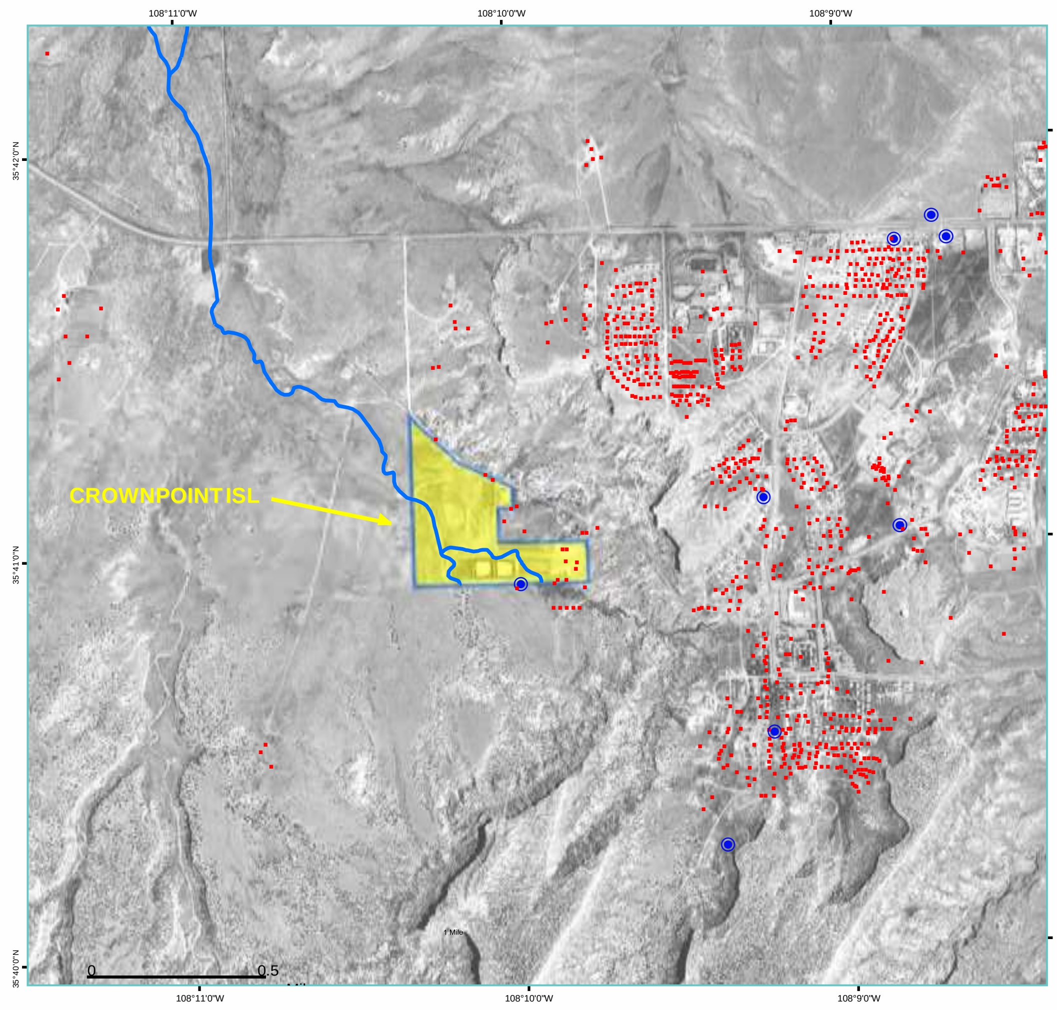


Figure 1. Points, Lines, and Polygons Displayed on Raster Imagery.

As with any database, once it is populated with data, it is possible to search and select on specific parameters. The GIS provides the functionality to select features by attributes or by location. Table 1 lists the results of selecting the wells that are shown in Figure 1. An example of some of the "attributes" that are stored in the wells data layer are shown in Table 1. The database includes information about each well or spring location, which is stored as a point (x,y coordinate) in the GIS. The selected attributes include the well identifier, alias names, the type of well, a code for use of the well, the depth of the well, the source aquifer, the static water level (SWL), and the U.S. Geological Survey identification number.

Table 1. Selected Attributes for the Water Source Dataset.

Well_ID	Alias	Type	Use	Well_Depth	Aquifer	SWL	USGS_ID
15-0579	CROWNPOINT #1	Water Well	MUN	2345.0	221WSRC	423.0	354105108091001
15-0580	15-UNK-0006/17N 12W 173333	Observation Well	OTH	2450.0	221WSRC	349.6	354148108083801
15-0581	CONOCO #2 (NTUA)	Water Well	MUN	2377.0	221WSRC	443.2	
15K-303	CROWNPOINT POWERHOUSE WELL	Water Well	DOM	2496.0	221MRSN	225.0	354033108091501
CRWNPT PM5	CROWNPOINT CANYON WELL PM5	Water Well	DOM	2544.0	221MRSN	335.0	354017108092201
CRWNPT PM6	CROWNPOINT BOARD. SCH. PM6	Water Well	DOM	2500.0	221MRSN	350.0	354103108083901
CRWNPT PM7		Water Well	UNK	2345.0	221WSRC	385.0	
SJ 01624		Well	IND				

Using a GIS, it is possible to symbolize the data based on attributes. In Figure 2 wells are symbolize by "Use" which includes the following categories:

- Domestic (DOM)
- Industrial (IND)
- Municipal (MUN)
- Other (OTH)
- Unknown (UNK)

Structures are symbolized by how the location was determined. Green structures were photo interpreted using orthophotography that was flown in 1997. Utility meter locations collected with a Global Positioning System (GPS) were provided by the Navajo Tribal Utility Authority. These meter data were used to add locations for "assumed structures", and are shown as red squares on Figure 2. These structures were not present on the orthophotography, indicating they were constructed after 1997. See DATA, page 13 for more discussion about the structures, wells, and AUM GIS datasets.

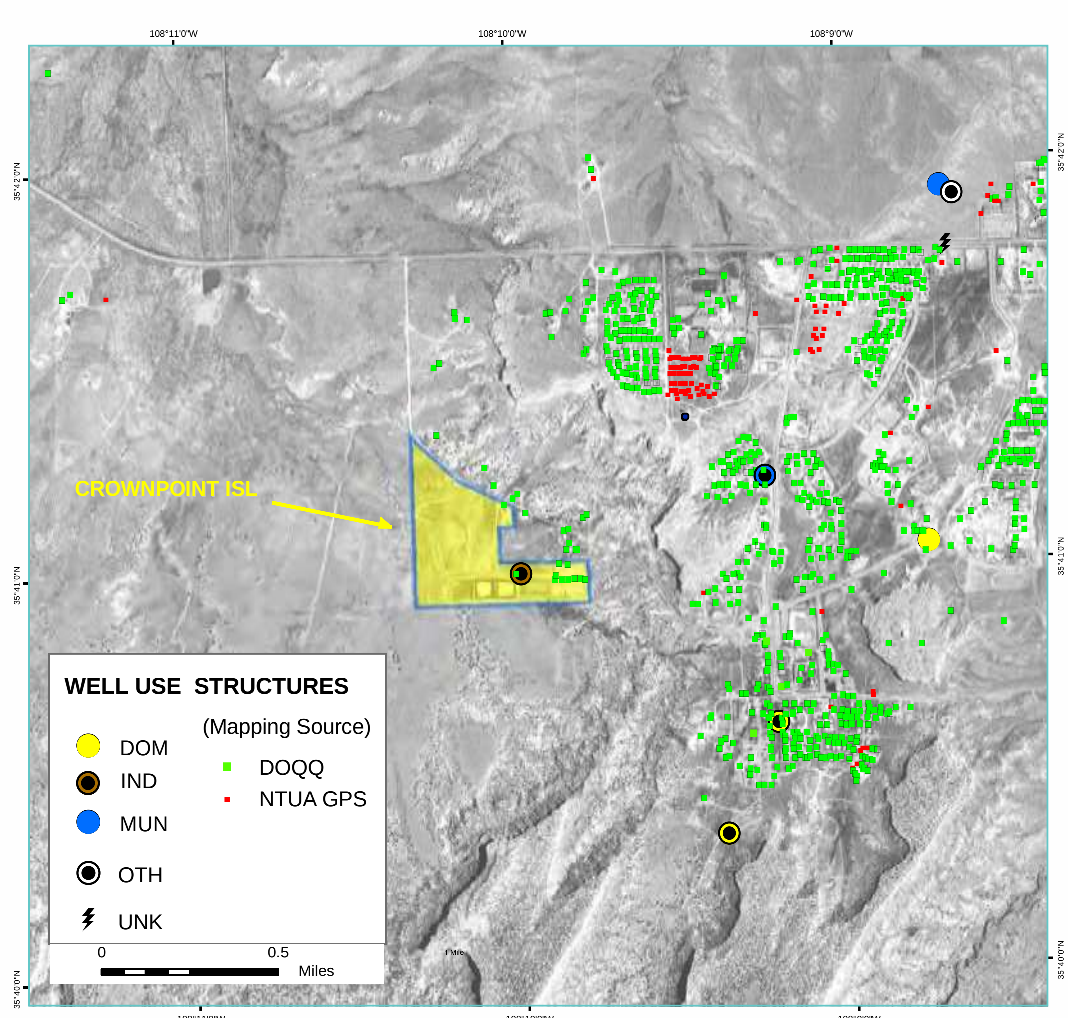


Figure 2. Using Attributes to Symbolize Information.

GEOGRAPHIC INFORMATION SYSTEM (GIS) (continued)

GIS provides analytical tools to allow the user to extract information from the data and the cartographic tools to present the results in a meaningful way. In the example shown in Figure 3, the GIS has been used to generate buffers around the Crownpoint ISL AUM at distances of 200 feet, 1/4 mile, and 1 mile. The GIS overlay functionality was used to tabulate the number of structures and wells that are located within each of these distances from the AUM. The 200 feet buffer is inclusive of the AUM.

The results of the buffer overlays are shown in the table below. Structure counts and well counts for each buffer distance are listed. Figure 3 provides a spatial view of the results, showing the locations of the wells and structure within each buffer.

BUFFER DISTANCE	STRUCTURE COUNT
200 Ft	18
1/4 Mile	10
1 Mile	642
Total	**670**

BUFFER DISTANCE	WELLS COUNT
200 Ft	1
1/4 Mile	0
1 Mile	4
Total	**5**

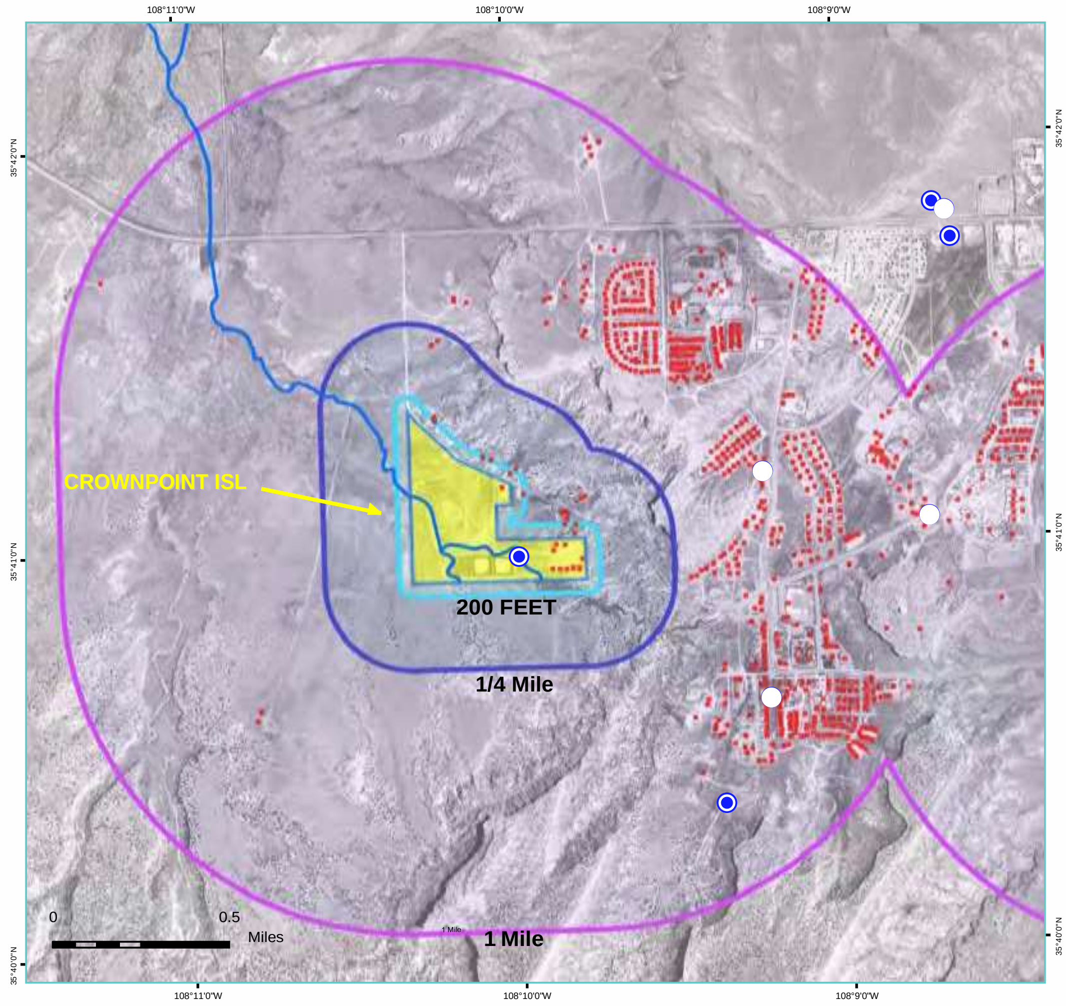


Figure 3. Using Buffer Analyses. Example of Crownpoint In Situ Leaching (ISL) Site.

By integrating spatial information with statistical and analytical processes in a GIS it is possible to develop models that can show spatial patterns that are not otherwise readily apparent. Figure 4 is an example of results of a model that uses broad physical characteristics to describe the potential for contamination of the aquifer from surface and near surface contaminants. These factors included: geology, precipitation, soil properties, slope, and stream courses (Blanchard, 2002 - S01200301).

Numeric scores were developed for each of the datasets listed above based on attributes in the database. For example, slope of the land affects the ability of precipitation to infiltrate soils and geology. Three slope ranges were assigned numerical values as follows: slopes less than 6 degrees increase infiltration of water into the land surface and were give a score of 3. Slopes of 6 to 12 degrees were assigned an intermediate score of 2. Slopes greater than 12 degrees were given a low score (1) because infiltration is minimized due to the runoff of water.

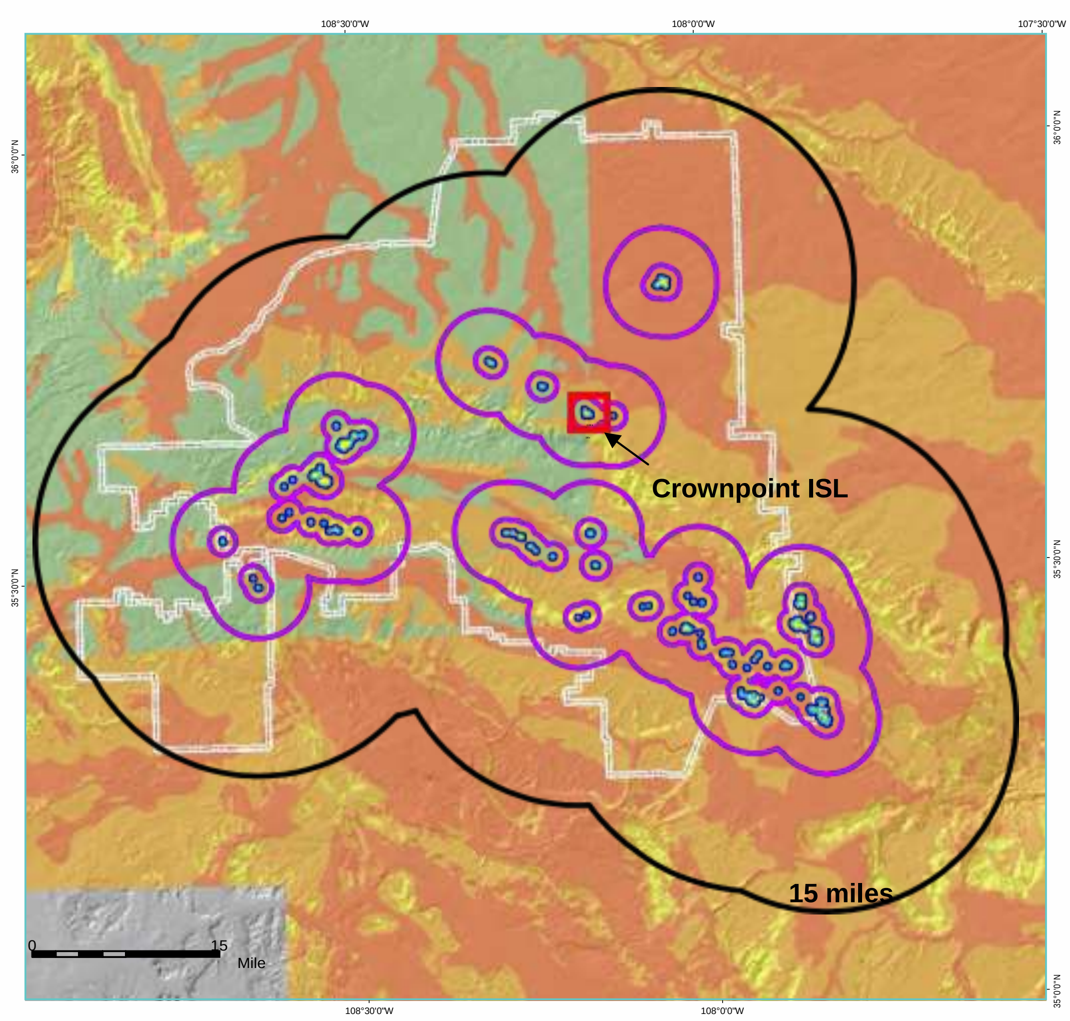


Figure 4. Developing Spatial Models.

- (green) = Insignificant potential for contamination of the aquifer
- (light yellow) = Least potential for contamination of the aquifer
- (gold) = Intermediate potential for contamination of the aquifer, and
- (orange) = Most potential for contamination of the aquifer.

Each of the other factors were scored in a similar manner as slope. The GIS datasets of geology, precipitation, soil properties, and slope were overlain using the GIS resulting in a combined GIS dataset. For each combined GIS polygon, the scores for precipitation, soil properties, and slope were summed and then multiplied by the geologic score to determine the final numeric score. These numeric scores were converted to four (4) categories of "potential for contamination" (shown above).

The area shown in Figure 4 covers the Eastern AUM Region (boundary shown in white), with the locations of the AUMs and buffers out to 15 miles. The modeled results for aquifer sensitivity may prove useful for further assessments of potential contamination from AUMs through ground water pathways.

REPORT ORGANIZATION

PART I - NAVAJO NATION AUM SCREENING ASSESSMENT REPORT

This first part of the report documents the approach and methodology used to develop scores for each of the AUMs on or within one (1) mile of the Navajo Nation. These scores will be used by the NAUM Project Team for screening and prioritization efforts. Results from the initial screening assessment are presented for each of six (6) AUM regions across the Navajo Nation in the form of tables and maps. Some observations about the results and recommendations for improving the scoring process are provided.

PART II - ATLAS AND GEOSPATIAL DATA

The second part of this report describes the geospatial data used to perform the screening assessments in the form of a map Atlas. Each of the GIS datasets are described with an example map on the facing page. This part of the report also presents other geospatial data that have been compiled across the Navajo Nation that could provide useful information for further screening assessment studies and refined prioritization efforts. The data are organized into three (3) Sections:

Section 1: Mining History and Mine Site Information
Section 2: Mine Waste Characteristics
Section 3: Environmental Setting

Mining History and Mine Site Information

Mining History and Mine Site Information presents an overview of the status of our knowledge of the location of abandoned uranium mines on and within 1 mile of the Navajo Nation (e.g., where they are found, what their uranium and vanadium production histories were, what their current reclamation status is, and why they are important as potential risks to human health and the environment). This section provides a description of the history of radium, vanadium, and uranium mining in the United States and the Navajo Nation. The process used to acquire a mining lease or tribal mining permit on the Navajo Nation is discussed. The methods used to evaluate and process different data sources, and the challenges each source presented, are discussed. Ownership and operator histories were researched and compiled for each of the leases and mining permits. The uranium and vanadium ore productions by mine (including tonnages and concentrations of vanadium and uranium ore) were compiled for the Navajo Nation AUMs. Summary tables and associated maps are presented. A key data layer in the NAUM Project GIS is the location and type of AUM site and mine features associated with uranium mining. Determining locations for the AUMs that were suitable for entry into the GIS database was challenging. The data sources and techniques used to develop the AUM sites and mine feature GIS datasets are described in this section.

Mine Waste Characteristics

A thorough site characterization should include an understanding of the different mining processes that occurred throughout mining operations. This type of information can be useful in determining the different types of waste that may be encountered at the site, and where additional sampling should occur, if required. This section provides available sampling data that have been collected on the Navajo Nation that may provide useful insights about the characteristics of the AUM sites (such as size and locations of sites, volumes of potential contaminants, and types of wastes). Information from data sampling and reclamation efforts are presented.

Environmental Setting

The last section of the Atlas provides information that describes the physical and cultural characteristics of the AUM Regions on the Navajo Nation. These types of data can be useful to better understand potential pathways and exposure risks. Data have been compiled from a variety of sources and include the following general categories:

- Administrative Boundaries, Population, and Infrastructure
- Landscape and Environment
- Climate
- Elevation and Topography
- Physiography and Geology
- Ground Water
- Surface Water
- Soils, Vegetation, Land Cover and Land Use
- Basemaps

Geospatial Data

The maps in this Screening Assessment Report and Atlas present the uranium mining history, mine locations and production, and environmental setting data that were compiled for the Navajo Nation. These data were processed into GIS datasets. The data covers the full extent of the Navajo Nation, whereas the earlier Assessment Reports were regionally-based. One of the purposes of the Atlas is to provide a description of these geospatial datasets. The data were developed and the Atlas maps were generated using Environmental Systems Research Institute's (ESRI) GIS software, ArcGIS 9.1.[1]

All of the datasets used in the Navajo Nation Atlas are provided on electronic media (DVD). The vector datasets are in geographic decimal degrees coordinates, using the North American Datum of 1983 (NAD83). The raster datasets have been projected to Universal Transverse Mercator (UTM), Zones 12 or 13 as appropriate, NAD83, meters.

Each thematic dataset has an associated metadata file. ESRI's ArcCatalog can be used to view the xml-based metadata for each dataset, or the .xml metadata file can be viewed in a text editor. Metadata describes the content, quality, condition, data sources, processing history, data usage constraints, and contact information.

A brief description of the data sources that were used to prepare the map are presented for most maps in the Atlas. With ESRI's ArcCatalog, a user can navigate to the file and view its metadata. The metadata includes a source key (Skey) for each data source used to develop a GIS dataset. An Skey number has the format, SMMDDYY###. The S stands for source, MM for the month number, DD for the date, YY for year, and ## for a unique sequential number beginning with 01.

The Skey is also assigned to source documents that were used as references to develop the accompanying text and tables for the report and each Atlas map. Reference documents used in the preparation of this Atlas have been scanned into Adobe Acrobat Portable Document Format or PDF format. These electronic versions of the reference documents are included on the GIS References DVD, with the exception of those that are copyrighted, or are in draft form, considered limited distribution, confidential, or proprietary by the document providers.

[1] Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

PURPOSE

The primary purpose of the NAUM Project is to identify AUMs, potential exposures, and to recommend methods to reduce exposure from AUMs on the Navajo Nation. There are more than 1,200 AUM features (e.g., adits, pits, rim strips) located throughout the Navajo Nation. Potential long-term exposure risks can persist even after the surface reclamation of AUM sites is completed. Therefore, an assessment of potential impacts to humans and the environment from the abandoned mines is needed.

A key goal for the NAUM Project is to provide a preliminary screening assessment mechanism to help prioritize Navajo Nation AUM sites using existing, readily available data through a GIS. The focus is to identify the areas with the highest apparent level of risk in order to recommend additional investigations by the appropriate Navajo or lead federal agency. In June 2005, the NAUM Project initiated a series of reports to document preliminary scoring results for AUMs in the six (6) AUM Regions on the Navajo Nation. These six (6) reports were completed and are provided on the GIS References DVD.

Northern AUM Region Screening Assessment Report	March, 2006
Western AUM Region Screening Assessment Report	May, 2006
North Central AUM Region Screening Assessment Report	July, 2006
Central AUM Region Screening Assessment Report	August 2006
Southern AUM Region Screening Assessment Report	October, 2006
Eastern AUM Region Screening Assessment Report	November, 2006

Scoring was accomplished using the methodology described in this report (See METHODOLOGY, page 12). Subsequent to publication of the individual AUM region screening assessment reports, additional information about the AUMs was researched as part of an effort to assign mine names and uranium/vanadium production values to each of the mapped AUMs. The purpose of this Navajo Nation AUM Screening Assessment Report is to provide an updated preliminary scoring for all AUMs mapped on and within one (1) mile of the Navajo Nation in a single document. A brief overview of the CERCLA process and a discussion of potential contaminants and exposure pathways related to AUMs is provided for background.

PROJECT APPROACH

This screening assessment was undertaken by using existing data, selecting indicators from the EPA's Hazard Ranking System (HRS), and applying the analytical capabilities of a GIS to score the AUMs. Key elements of this effort include identifying:

1. The location of the original sources (i.e., AUM)
2. The potential pathways for source exposures
3. The location of population indicators (structures) and water sources at risk for exposure

EPA's Superfund program uses the HRS to evaluate whether a site is serious enough to be listed on the National Priorities List (NPL). Because there are over 1,200 known AUM mine features on the Navajo Nation, EPA needed to screen and prioritize all sites before applying the CERCLA process shown in Figure 5.

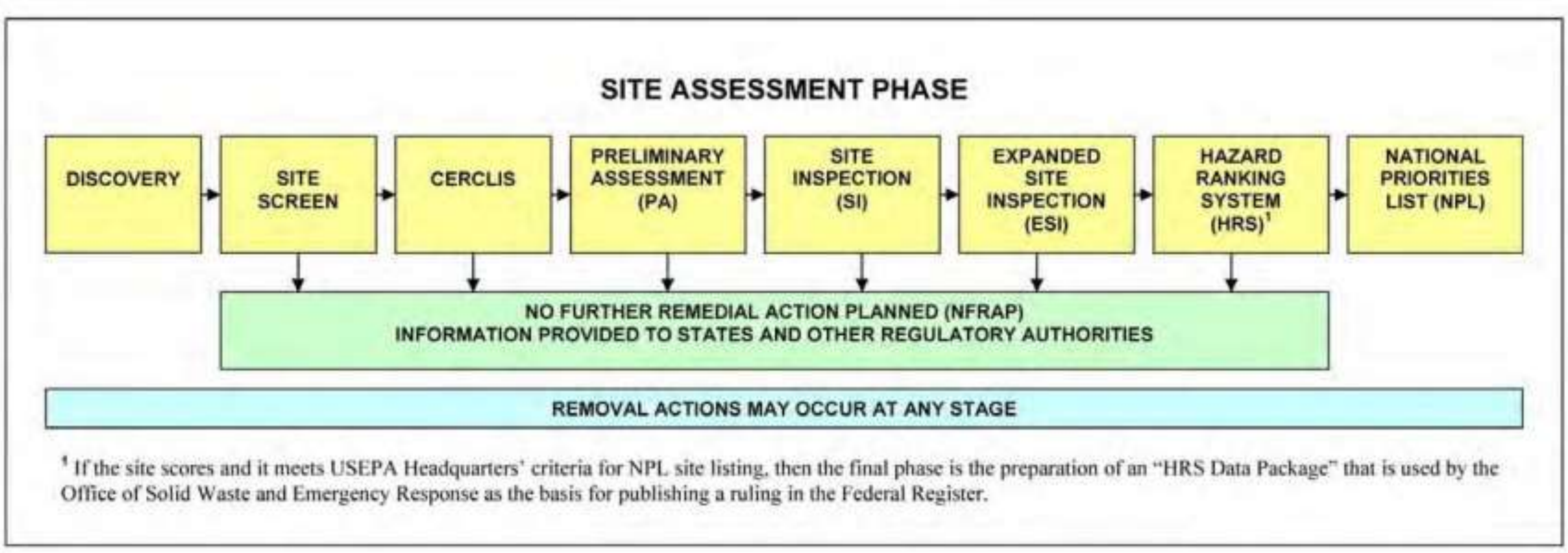


Figure 5. Superfund Process (modified after EPA, 1991– S01230301).

EPA decided to use the geographic measures from the HRS to develop a basic screening model for the AUMs. This screening model includes the location of all known AUM sites as potential sources of exposure. Table 2 provides the possible release mechanisms, pathways, exposure routes, and human and ecological receptors (targets) associated with AUMs.

PRIMARY SOURCES	RELEASE MECHANISM	PATHWAYS	EXPOSURE ROUTE	RECEPTOR		
				Area Resident	Livestock and Terrestrial Wildlife	Aquatic Wildlife
Uranium Mines and Natural Ore Bodies	Infiltration / Percolation	Ground water	Direct Contact			
	Storm Water Runoff	Surface Water and Sediments	Direct Contact			
	Particles/Dust	Soil Exposure	Inhalation			
			Direct Contact			
	Particles/Dust	Air	Inhalation			
			Direct Contact			

Table 2. Possible Pathways, Exposure Routes, and Human and Ecological Receptors (after EPA, 1991 - S01230301).

EPA's project team created an HRS-derived model to compare the individual AUM sites by distance from the human receptors. Radiation and toxic metals released from an AUM site can travel through the air, through the soils, and through surface- and ground water. The HRS-derived model includes those pathways of potential contamination, and then evaluates the presence of structures and drinking water sources as indicators of population at potential risk to exposure. This report presents the results from the model in maps and data tables that were designed to identify and prioritize the AUM sites that might pose the highest threat to their surrounding communities.

The results in this report were not generated using a complete HRS model, nor does the screening assessment specify NPL site candidates. Based on results from this broad-based screening process, the EPA, NNEPA and NAMLRP will discuss next steps. One of the possible results of the analysis in this report might be to conduct a Preliminary Assessment (PA) or Site Inspection (SI) at any specific sites identified as a priority via the scoring criteria and Navajo knowledge about the setting. Other decisions might entail referrals for EPA removal actions, referrals to other agencies, or a determination that no further action is necessary.

CONTAMINANTS AND EXPOSURE PATHWAYS

EPA identifies the most serious hazardous waste sites in the nation using the HRS. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Elevated uranium levels have been found in at least 54 of the 1,517 current or former NPL sites. However, the total number of NPL sites evaluated for uranium is not known. As more sites are evaluated, the sites at which uranium is found may increase (ATSDR, 1999[1] - S05160701. Uranium is a natural and commonly occurring radioactive element. It is found in very small amounts in nature in the form of minerals, but may be processed into a metal. Rocks, soil, surface and underground water, air, and plants and animals all contain varying amounts of uranium. Typical concentrations in most materials are a few parts per million (ppm). Some parts of the Navajo Nation exhibit higher than average uranium levels due to natural geological formations. Most uranium ores contain between 0.05 and 0.2% uranium, up to 1,000 times the levels normally found in soil. After the uranium is extracted, it is converted into uranium dioxide or other chemical forms by a series of chemical milling processes. The residue remaining after the uranium has been extracted is called mill tailings. Mill tailings contain a small amount of uranium, as well as other naturally radioactive waste products such as radium and thorium.

Natural uranium is a mixture of three isotopes of uranium, U-234, U-235, and U-238. Radioactive isotopes are constantly changing into different isotopes by giving off radiation. The half-life is the time it takes for half of that uranium isotope to give off its radiation and change into a different element. The half-lives of uranium isotopes are very long (244 thousand years for U-234, 710 million years for U-235, and 4½ billion years for U-238). The shorter half-life makes U-234 the most radioactive, and the longer half-life makes U-238 the least radioactive. U-234 will be about 20,000 times more radioactive and the U-235 will be 6 times more radioactive than the U-238. Radioactive decay of the parent U-238 material produces a series of new elements and radiation, including radium and radon, alpha and beta particles, and gamma radiation that individually interact and contaminate the air, water and soil media. Ultimately, uranium decays into a stable form of lead.

Because of the slow rate of decay, the total amount of natural uranium in the earth stays almost the same, but it can be moved from place to place through natural processes or by human activities. When rocks are eroded by water or wind, uranium minerals become a part of the soil. When it rains, the soil containing uranium minerals can be transported via leached material and deposited into rivers and lakes. Although exposure to uranium in natural settings may be limited, mining activities often result in increased exposure risks. Mining, milling, and other human activities, such as construction of structures using radioactive waste ore materials, can also move uranium around natural environments as an additional long-term exposure pathway. Mining activities disturb mineralization that can affect exposures. Traditionally, uranium has been extracted from open-pits and underground mines. In the past decade, alternative techniques such as in-situ leach mining, in which solutions are injected into underground deposits to dissolve uranium, have become more widely used. Activities such as removing overburden, tunneling, and transporting ore can expose previously protected mineral deposits to accelerated oxidation and increase their mobility through the environment. (EPA, 2000 - S02200302). These activities can also lead to the release of hazardous materials into the environment through air, water, and soil.

Air - Natural weathering processes of crustal rock and soil can change the crustal ratio of uranium isotopes. In some cases, human activities have also altered the normal crustal distribution of naturally occurring radioactive materials, resulting in what has been termed Technologically Enhanced Naturally-Occurring Radioactive Material (TNORM). No new radioactivity is produced, but uranium and its progeny are redistributed in such a way that real exposure or the potential for human exposure may increase. A major localized source of enhanced natural uranium can result from mining and milling operations. Uranium ore is removed from its natural location during open-pit, in-situ leach, or underground mining operations. The primary sources of airborne releases are from the actual mining, from ore crushing and grinding, from ore debris piles, and from ore stockpiles. Currently, mining and milling operations represent a minimal source of uranium release. Another method by which uranium may be introduced into the atmosphere is the natural process of erosion and wind activity. Wind erosion of tailings at uranium mining and milling activities can also result in the resuspension of uranium.

Water - The redistribution of uranium and uranium progeny to both surface water and ground water occurs primarily from the natural erosion of rock and soil; some redistribution also comes from the mining and milling. Uranium is discharged to surface water and/or ground water during mining operations. If an open-pit or underground mine extends below the water table, ground water must be removed to permit mining operations to continue. This is usually accomplished by pumping and discharging excess water into the ground or nearby bodies of water. Since mine water is generally concentrated with uranium, its introduction into surface water bodies may produce measurable increases in uranium levels. Waste waters from open-pit mines are typically one to two orders of magnitude greater in volume and radioactivity content than waters from shaft or underground mines. Contamination of ground water and surface water can also occur by water erosion of tailings piles.

Soil - Uranium is a naturally occurring radionuclide that is present in nearly all rocks and soils (soils being derived from erosion of the rocks). The average concentration in U.S. soils is about 2 pCi/g (3 ppm); however, much higher levels are found in areas such as the Colorado Plateau. The uranium present in the rocks and soil as a natural constituent represents natural background levels. Contamination of the soil can occur either from deposition of uranium originally discharged into the atmosphere, or from waste products discharged directly into or on the ground (e.g., water containing uranium from either underground or open-pit mines).

Uranium ore concentrations and associated radioactivity varies widely at mining areas and geological formations across the Navajo Nation. Other potential contaminants of concern include arsenic and lead. EPA is evaluating the likelihood for offsite migration of contaminants due to historic mining activities, but is not assessing natural occurrences (EPA, 2004 - S01130602).

[1] Unless otherwise cited, the information contained in this section is from "Toxicological Profile for Uranium," (ATSDR, 1999 - S051607001).

NAVAJO NATION AUM REGIONS

The Navajo Nation is located on the Colorado Plateau and covers over 27,000 square miles in northeast Arizona, northwest New Mexico, and southeast Utah and occupies portions of twelve (12) counties within those states. The tribal government structure consists of 110 Chapters. Section 3 “Environmental Setting” of the Atlas provides more detailed information about the administrative boundaries.

Significant amounts of uranium were produced from deposits in the Chinle and Morrison formations, and minor deposits occurred in the Bidahochi, Dakota Sandstone, Todilto Limestone, Navajo Sandstone, Kayenta, Moenkopi and Toreva formations. Uranium ores were mined from deposits located across the Navajo Nation. For the purposes of this report, six (6) AUM Regions are identified: North Central, Northern, Western, Central, Southern, and Eastern (Figure 6). The following provides brief descriptions of the six (6) AUM Regions and presents statistics about the number of AUMs that were mapped, how many AUMs had records of uranium/vanadium production, and how many AUMs were not productive or for which no records of uranium production were found.[1]

NORTH CENTRAL AUM REGION

The North Central AUM Region lies in northeastern Arizona and southeastern Utah. It spans four (4) counties: Apache, Coconino, and Navajo Counties in Arizona, and San Juan County, Utah. The region is comprised of five (5) Navajo Nation Chapters: Dennehotso, Kayenta, Mexican Water, Oljato, and Shonto. The region covers approximately 2,829 square miles in the Monument Valley and Navajo Uplands area of the Navajo Nation.

Uranium was mined in the North Central AUM Region in 1944 and between 1947 and 1969. A total of 68 AUM-related polygons were identified in the region. The Harvey Lee Sampson No.s 1 and 9 mine was the only AUM in the region that had reported production, but could not be located and, therefore, was not entered into the GIS dataset. Forty (40) productive AUMs were located in the region. Twenty-three (23) AUMs were mapped that had no records of uranium production, but did have evidence of surface disturbance (e.g., NAMLRP reclamation sites) and were located within a mining claim. The Mexican Hat Stockpile was also located in the North Central AUM Region. The Gothe Mine in Oljato Chapter was added to the GIS database after publication of the preliminary North Central AUM Region screening assessment report.

NORTHERN AUM REGION

The Northern AUM Region is located in the northeastern portion of the Navajo Nation, straddling three (3) counties and three (3) states: Apache County, Arizona; San Juan County, New Mexico; and San Juan County, Utah. The region is comprised of eleven (11) Chapters: Aneth, Beclabito, Cove, Lukachukai, Red Mesa, Red Valley, Round Rock, Sanostee, Shiprock, Sweetwater, and Teec Nos Pos. The region covers approximately 3,009 square miles in the hilly, high-altitude mountains and plains of the Navajo Nation.

Uranium was mined in the Northern AUM Region from 1948 to 1967 in the Carrizo Mountains and in the Sanostee area from 1952 to 1982. A small amount of radium was mined in 1920. A total of 271 AUM-related polygons were identified in the Northern AUM Region, which is 14 fewer than the preliminary Northern AUM Region screening assessment report. This is due to aggregation of several AUM polygons that were originally entered as separate NAMLRP reclamation projects. As part of the effort to assign mine names and production values to AUMs, it was determined that many of the reclamation projects covered a single AUM (e.g., reclamation projects NA-0303, NA-0304, NA-0305, NA-0307, NA-0309 and NA-0340 were all part of the Cove Mesa Mines AEC Lease Plot 7). A total of 174 productive uranium mines were located, and 55 AUMs were mapped with no production or records of production. Two (2) of the non-productive AUMs were transfer stations (Cove and Climax Transfer Stations).

WESTERN AUM REGION

The Western AUM Region is located on the western edge of the Navajo Nation, and is contained within Coconino County, Arizona. The region is comprised of seven (7) Chapters: Bodaway/Gap, Cameron, Coalmine Canyon, Coppermine, LeChee, Leupp, and Tuba City, covering approximately 4,028 square miles in the Painted Desert area of the Navajo Nation.

Uranium was mined in the Western AUM Region between 1951 and 1963. A total of 126 AUM-related polygons were identified in the region, which is two (2) more than reported in the preliminary Western AUM Region screening assessment report. The Julius Chee #4 was split into two (2) AUMs and the Hosteen Nez AUM was added. There were 98 productive uranium/vanadium AUMs located on or within one (1) mile of the Navajo Nation. Thirteen (13) AUMs were mapped with no production history, but which exhibited evidence of surface disturbance (e.g., trenches) and they were located within a mining claim.

CENTRAL AUM REGION

The Central AUM Region is located predominantly in northeastern Arizona, with a small portion of the Tsaile/Wheatfields Chapter extending into northwestern New Mexico. The region spans three (3) counties: Apache and Navajo Counties in Arizona, and San Juan County in New Mexico. The Central AUM Region is comprised of nine (9) Navajo Nation Chapters: Black Mesa, Chilchinbeto, Chinle, Many Farms, Rock Point, Rough Rock, Tachee/Blue Gap, Tsaile/Wheatfields, and Tselani/Conttonwood. The region covers approximately 2,196 square miles in the Black Mesa, Chinle Valley, and Defiance Plateau areas of the Navajo Nation.

Uranium was mined in the Central AUM Region between 1954 and 1968. There were a total of 34 AUM related polygons mapped in the Central AUM Region. Fifteen (15) AUMs with documented production were located in the region and thirteen (13) AUMs were mapped for which no records of uranium production were located.

[1] It should noted that in some cases there are multiple surface disturbances (AUM polygons) associated with a single AUM site. In these cases, each AUM polygon that was associated with a productive AUM site was assigned the same mine name. For example, uranium was mined from eleven (11) pits/rim strips on the Tom Wilson AUM in the Central AUM Region. Four (4) surface AUM polygons were mapped around these pits/rim strips, but uranium production was reported as a single value for the Tom Wilson mine. All four of these polygons were assigned the mine name “Tom Wilson.” For this reason, the number of AUM-related polygons that were mapped may be higher than the total number of AUM site reported in this section and throughout the report.

SOUTHERN AUM REGION

The Southern AUM Region is located on the south central border of the Navajo Nation. The region spans two (2) counties: Apache and Navajo Counties in Arizona. The region is comprised of six (6) Chapters: Dilkon, Greasewood Springs, Indian Wells, Steamboat, Teesto, and White Cone. The Southern AUM Region covers approximately 1,726 square miles in the Navajo Section of the Colorado Plateaus Province. A large part of the Southern AUM Region is located in the Hopi Buttes volcanic field.

Uranium was mined in the Southern AUM Region between 1954 and 1959. There was only one (1) productive AUM located in the region, the Morale mine. Five (5) AUMs were mapped that had no records of uranium production, but did had evidence of surface disturbance and they were located within a mining permit. A total of six (6) AUMs were mapped in the region.

EASTERN AUM REGION

The Eastern AUM Region is located in northwestern New Mexico and crosses into portions of three (3) counties: Cibola, McKinley, and San Juan. The region is comprised of seventeen (17) Navajo Nation Chapters: Haystack, Becenti, Bread Springs, Casamero Lake, Church Rock, Coyote Canyon, Crownpoint, Iyanbito, Littlewater, Mariano Lake, Nahodishgish, Pinedale, Red Rock, Rock Springs, Smith Lake, Standing Rock, and Thoreau. The Eastern AUM Region covers approximately 1,784 square miles in the "Checkerboard Area" of the Navajo Nation, which includes Tribal Trust Lands, fee lands, allotment lands, privately owned, and federal lands. See Section 3 - Land Status, page 3-4 in the Atlas. The Eastern AUM Region is located within the highly productive Grants Uranium District in northwestern New Mexico.

During a period spanning nearly three decades (1951 to at least 1989), the Grants Uranium District produced more uranium than any other district in the United States (McLemore and Chenoweth, 2003 - S08020606). There were 97 AUM-related areas mapped in the region. Sixty-five (65) AUMs with documented production were located in the region and 18 AUMs were mapped for which no records of uranium production were located. Changes from the preliminary Eastern AUM Region screening assessment report include: removal of six (6) AUM polygons associated with the Crownpoint Monument In-Situ Leach (ISL) and Crownpoint South Trend ISL plant sites, which were proposed but never constructed. The Section 25 Shaft AUM polygon was merged with the Section 25 mine AUM. The Section 32/33 AUM polygon was split into two (2) AUMs and individual production values were assigned. Finally, two (2) AUM polygons were added for the productive Haystack mine.

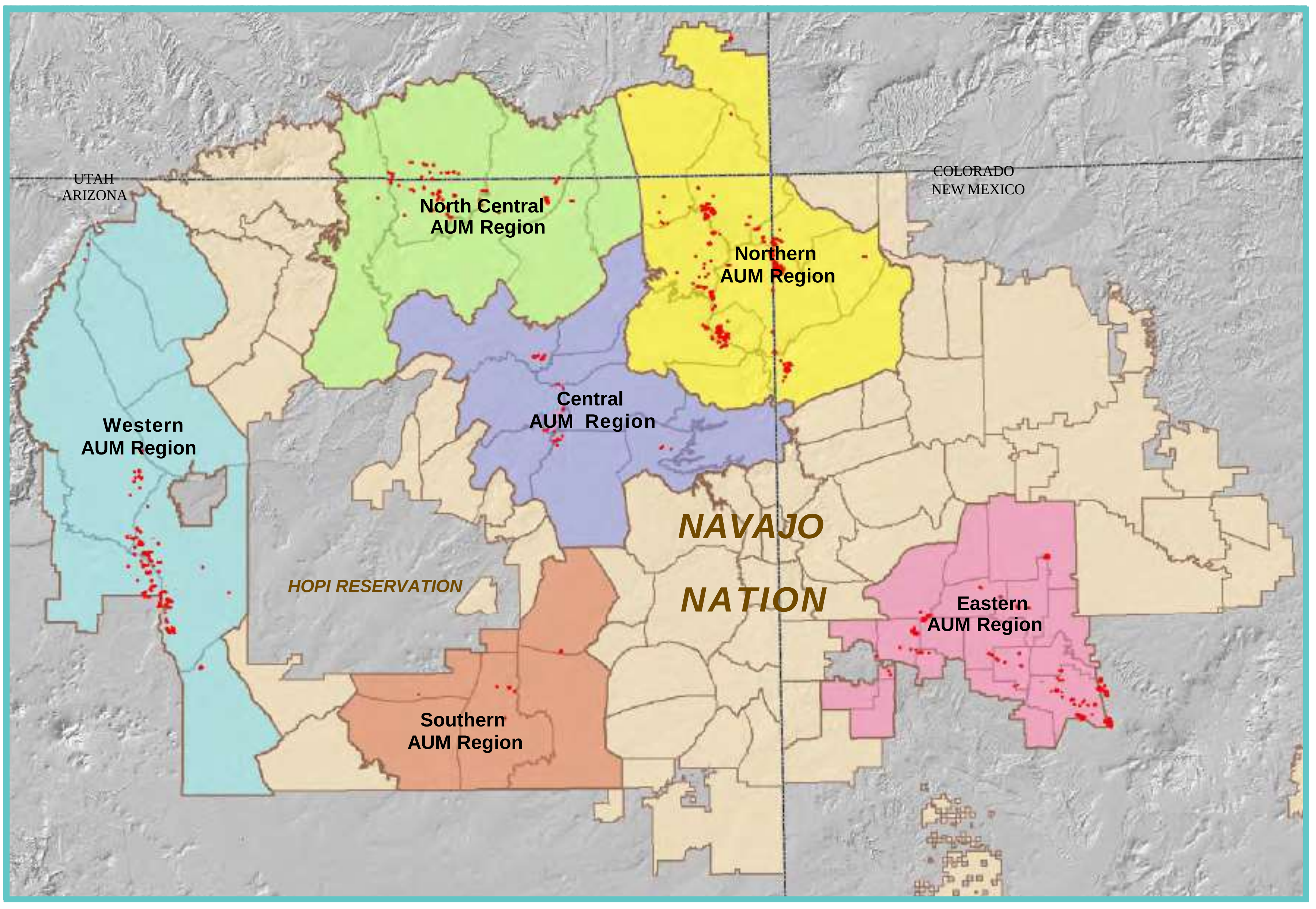


Figure 6. Locations of AUM Regions on the Navajo Nation.

METHODOLOGY

The methodology used to develop this Navajo Nation AUM Screening Assessment Report applied the following steps:

- Develop a Hazard Ranking System (HRS) derived model to assess and compare AUM priorities on the Navajo Nation
- Acquire data inputs for the HRS model and automate into a GIS database
- Apply the screening criteria using GIS analysis tools
- Generate a scoring list for each pathway and compile a composite scoring list for each AUM

HAZARD RANKING SYSTEM (HRS) DERIVED MODEL

EPA's Region 9 Superfund Site Assessment and Technical Support Team selected a subset of HRS criteria to develop preliminary screening scores for the AUMs. The purpose of this analytical model is to prioritize Navajo AUM sites using readily available data. The level of detail in this study is not as robust as required for remedy decision making, since the purpose of the screening model is not to determine actual risks, but rather to identify priority areas for future investigation. The EPA team considered probable Navajo exposure pathways as the basis for the model. The large area involved in the assessment falls beyond the normal scope for HRS, so a custom model was developed to best fit these unique circumstances.

Due to the unique nature of the task, the EPA team considered the probable Navajo exposure pathways and used 40 CFR 300, Federal Register Notice, HRS Final Rule, December 1990 (EPA, 1990 - S01130601) as the basis for the HRS-derived model. Given the EPA's experience collecting available and pertinent Navajo Nation environmental data and the large land area under consideration, the EPA decided to conservatively address all known release points (i.e., AUMs, mine related features, and waste piles), drainages downstream from AUMs, all known water wells (domestic, agricultural, and municipal), and all structures. However, sensitive environments, such as endangered species, and cultural data, were not readily available with enough locational specificity (compatible with GIS format) to input into the model. The inclusion of HRS criteria for sensitive environments would be recommended during future site-specific characterization activities, where the Navajo Nation would also be able to protect sensitive information with appropriate controls.

Consideration was given to the general fate and transport of radionuclides, as well as probable Navajo Nation exposure assessment scenarios. For example, the scenario of a rural homestead adjacent to an unfenced AUM site where the residents spend considerable hours outdoors with access to a nearby surface water source was considered. As a conservative assumption, it was presumed that all water sources may be used for human consumption and that uranium ore is mobile in dissolved media. For the two water pathways, a simple numeric progression was chosen. A high bias was used in weighting the soil and air pathway for close proximity (within 200 feet) due to the rural, agrarian lifestyle of the residents. A low bias was used in weighting the soil and air pathway for more distant proximity (>200 feet) due to the difficulty in attributing sources.

The AUM Project HRS-derived model for each of the pathways is listed below.

Air Pathway – 200 feet, 1,320 feet (1/4 mile), and 1 mile

- For structures within 200 feet of an AUM site, assign 100 points per structure
- For structures that exist between 200 feet and 1,320 feet, assign 25 points per structure
- For structures that exist between 1,320 feet and 1 mile, assign 10 points per structure
- For structures beyond 1 mile, assign 0 points

Soil Exposure - 200 feet, 1,320 feet, and 1 mile

- For structures within 200 feet of an AUM site, assign 100 points per structure
- For structures that exist between 200 feet and 1,320 feet, assign 25 points per structure
- For structures that exist between 1,320 feet and 1 mile, assign 10 points per structure
- For structures beyond 1 mile, assign 0 points

Ground water Pathway - 1,320 feet, 1 mile, and 4 miles

- For wells within 1,320 feet of an AUM site, assign 100 points per well
- For wells that exist between 1,320 feet and 1 mile, assign 50 points per well
- For wells that exist between 1 mile and 4 miles, assign 10 points per well
- For wells beyond 4 miles, assign 0 points

Surface Water Pathway - 1 mile, 4 miles, and 15 miles

- For perennial or intermittent surface water within one mile of an AUM site, assign 100 points
- For perennial or intermittent surface water that exist between 1 mile and 4 miles, assign 50 points
- For perennial or intermittent surface water that exists between 4 miles and within 15 miles, assign 10 points
- For perennial or intermittent surface water beyond 15 miles, assign 0 points

DATA

The following data were required to apply the HRS-derived scoring algorithm. GIS datasets were generated and the primary sources used to develop these GIS datasets are listed below:

AUM Sites - Locations for AUMs on and within 1 mile of the Navajo Nation were derived from several sources. Primary sources included: NAMLRP Reclamation Project boundaries; unpublished NAMLRP field inventory locations; numerous uranium mine history reports and written communications from William L. Chenoweth; Navajo Tribal Mining Department Claim Maps, a database of uranium mines, prospects, occurrences, and mills in New Mexico (McLemore et al., 2005 - S09290601); a Monument Valley District property map (Malan, 1964 - S03010603), a report on radioactive occurrences and uranium production in Arizona (Scarborough, 1981 - S09240202), maps showing uranium-bearing diatremes of the Hopi Buttes, Arizona (Wenrich and Mascarenas, 1982 - S06280601 and 1989 - S07270601); U.S. Atomic Energy Commission Certification Reports; U.S. Department of Energy aerial radiation surveys funded by EPA, Region 9, U.S. Geological Survey (USGS) Digital Orthophoto Quarter Quadrangles (DOQQ); and USGS 7.5' topographic maps scanned as Digital Raster Graphic (DRG) files.

AUM boundary polygons were generated for each AUM. These polygons were used to represent the surface extents and locations of AUMs. Polygon boundaries for AUMs with underground workings were also generated when maps or drawings were available. In addition, the location of three (3) stockpiles used as a transfer station for uranium ore were identified and mapped: Cove, Climax, and Mexican Hat.

Structures - Structures include residences or other types of buildings where people may live, work, or gather. Locations of structures within 1 mile of AUMs were interpreted from DOQQs, DRGs, and utility meter locations. Structures are the target for the air and soil pathways.

Wells - A wells database was acquired from the Navajo Department of Water Resources and augmented using data from the Arizona Department of Water Resources, New Mexico Office of the State Engineer, Utah Department of Water Resources, U. S. Army Corps of Engineers water sample locations, USGS/EPA National Hydrography Dataset (NHD), Geographic Names Information System, USGS Ground Water Site Investigations Database, DRGs, DOQQs, and the Church Rock Uranium Monitoring Project (CRUMP, 2003 - S01140501). Wells were used as a target for the ground-water pathway.

Drainages - The high resolution NHD, DOQQs and DRGS were used to identify perennial and intermittent drainages downstream from AUMs.

Part II "*Atlas and Geospatial Data*" provides additional descriptions of the GIS datasets and their sources and provides examples of map products that were developed from the GIS datasets

Abandoned Uranium Mine
Spoil from the Haystack mine in the Haystack Chapter. Photo courtesy of TerraSpectra Geomatics (photo taken August 2006).

Structures
Structure within 200 feet of the Harvey Blackwater No. 3 Mine (NAMLRP reclamation project site NA-0226 in the Kayenta Chapter). Photo courtesy of TerraSpectra Geomatics (photo taken April 2005).

Wells
Windmill and water tank 8K-402 in the southeast portion of Oljato Chapter. Photo courtesy of U.S. Army Corps of Engineers (photo taken September 1998

Surface Water
Little Colorado River looking west from Cameron Trading Post Photo courtesy of TerraSpectra Geomatics (photo taken April 2005).

Figure 7. Example Photographs of Modified HRS Scoring Factors.

RESULTS

This section presents results from the HRS-derived screening model for AUM sites located on and within one (1) mile of the Navajo Nation. As previously stated, these scores are not intended to indicate actual risk, but will be used to assist with establishing priorities for future investigations. Previous screening assessment reports presented tables for each of the component pathway scores. The "Ground Water Pathway Score" tables presented the counts of wells that are located within the 1/4 mile, 1 mile, and 4 mile buffers and the total number of wells within 4 miles of each AUM. The scores for each buffer zone were tabulated and presented in a table for each AUM. The "Soil Pathway and Air Pathway Score" tables presented the counts of structures that are within the 200 foot, 1/4 mile, and 1 mile buffers as well as the total number of structures within 1 mile of each AUM. The scores for each buffer zone were tabulated and presented for each AUM. Since the air and soil pathway criteria are the same, the total score results for the soil pathway and air pathway were shown in the same table. These component pathway score tables have been generated for all AUMs mapped on the Navajo Nation, but due to the volume of information, they are not presented as individual tables in this report. They can be found on the GIS Data DVD as an MS Excel spreadsheet (DB/AUM/NN_Scoring.xls). Notable results for the ground water, soil, air, and surface water pathways are discussed in following sections.

Tables for the "Combined Pathway Score" for each AUM Region are presented in this report. The combined pathway score is the sum of the scores for each pathway for each AUM. There are six (6) Combined Pathway Score Tables and several associated maps showing the locations of the scored AUMs. The score tables are sorted by MAP-ID, which is an arbitrary number to facilitate map labeling. The MAP-ID is generally assigned so that MAP-ID increases from west to east and north to south within each AUM Region.

C = Central
E = Eastern
N = Northern
NC = North Central
S = Southern
W = Western

The MAP-ID numbers have a prefix that is associated with the AUM Region in which it occurs (shown at left). The region prefix has been added to the MAP-ID to allow correspondence with the previous six (6) screening assessment reports for comparison purposes. There are some changes to the AUMs from the previous reports, including:

- Added AUM - new MAP-ID
- Deleted AUM - gap in MAP-ID sequence
- Merged AUM - gap in MAP-ID sequence
- Split AUM - new information was obtained that allowed refinement to the boundary of an AUM. In these cases the MAP-ID are the same as the previous report, but the split polygons will share the same MAP-ID with the addition of a suffix (e.g., W112a and W112b).

SOIL PATHWAY AND AIR PATHWAY

The soil exposure pathway involves direct exposure to hazardous substances and areas of suspected contamination. This pathway differs from the three migration pathways in that it accounts for contact with in-place hazardous substances at the site rather than migration of substances from the site. Evaluation of the soil pathway using the modified HRS required knowing the location of the AUM sites and distance to structures. The HRS criteria used to evaluate the soil pathway were:

- For structures within 200 feet of an AUM site, assign 100 points per structure
- For structures between 200 feet and 1,320 feet, assign 25 points per structure
- For structures between 1,320 feet and 1 mile, assign 10 points per structure
- If no structures exist within 1 mile, assign 0 points

The air pathway involves wind that can entrain particulates from mine waste piles, roads, and other disturbed areas. Waste rock at AUM sites contains radionuclides and metals that may be released as fugitive dust, where they can be inhaled or ingested. This material can contaminate areas downwind as particles settle out of suspension in the air (EPA, 2000 - S02200302). Evaluation of the air pathway using the modified HRS also required knowing the location of AUM sites and distance to structures. Figure 8 (right) shows an example photograph depicting wind blown dust preceding a storm. These dust events can increase the potential for inhalation, ingestion, and transport of radionuclide particles associated with uranium mining.

Figure 8. Potential Air Pathway. Example of wind-blown dust during a storm in Monument Valley, Utah. Photo courtesy TerraSpectra Geomatics (taken 9/4/2004).

The buffer distances around the AUM sites and the factors associated with each distance are the same for both the soil and air pathways. A single table was generated for both pathways. Results for the soil and air pathway assessment can be found on the GIS Data DVD and are presented in the spreadsheet "DB/AUM/NN_scoring.xls" in the "Air_Soil_Scores" tab. The spreadsheet shows the number of structures that occur within 200 feet, 1/4 mile, and 1 mile of AUM sites. The number of structures within each buffer are multiplied by the scoring factor for each buffer. The scores for each buffer are summed to obtain the total score for each AUM site.

The highest scored AUM for the soil and the air pathways is the Crownpoint ISL AUM in the Crownpoint Chapter (MAP-ID #E35 - Figure 57). The soil pathway score for Crownpoint ISL is 8,470 and air pathway score is 8,470 for a total soil and air pathway score of 16,940. The soil and air pathway scores calculated for this site are based on eighteen (18) structures within 200 feet of the AUM, ten (10) structures in the 200 foot to 1/4 mile buffer, and 642 structures in the 1/4 mile to 1 mile buffer, for a total of 670 structures within one (1) mile of the AUM.

GROUND WATER PATHWAY

Mining operations can affect ground water quality in several ways. For example, underground workings can provide a direct conduit to aquifers. Ground water quality is also affected when waters infiltrate through surface materials (e.g., mine debris piles) into ground water. Contamination can also occur when there is a hydraulic connection between surface water and ground water. Any of these situations can cause elevated contaminant levels in ground water. In addition, contaminated ground water may discharge to surface water down gradient of the AUM site as contributions to base flow in a stream channel or spring (EPA, 2000 - S02200302).

Evaluation of the ground water pathway using the HRS-derived criteria required the location of the AUM sites and distance to wells (including developed springs). For the ground water pathway, when available, underground workings of the AUMs were mapped and the total area of the surface and underground extent of the AUM was used to generate the buffers. The HRS criteria used to evaluate the ground water pathway were:

- For wells within 1,320 feet of an AUM site, assign 100 points per well
- For wells between 1,320 feet and 1 mile, assign 50 points per well
- For wells between 1 mile and 4 miles, assign 10 points per well
- If no well exists within 4 miles, assign 0 points

Results for the ground water pathway assessment can be found on the GIS Data DVD and are presented in the spreadsheet "DB/AUM/NN_scoring.xls" in the "Groundwater_Scores" tab. The highest ground water pathway score is 1,290 and is located at the unproductive NAMLRP reclamation site NA-0238 in the Red Mesa Chapter (MAP-ID #N2 - Figure 23). The total ground water pathway score for this site is comprised of 0 wells within 1/4 mile of the AUM, 0 wells in the 1/4 mile to 1 mile buffer, and 129 wells in the 1 mile to 4 mile buffer.

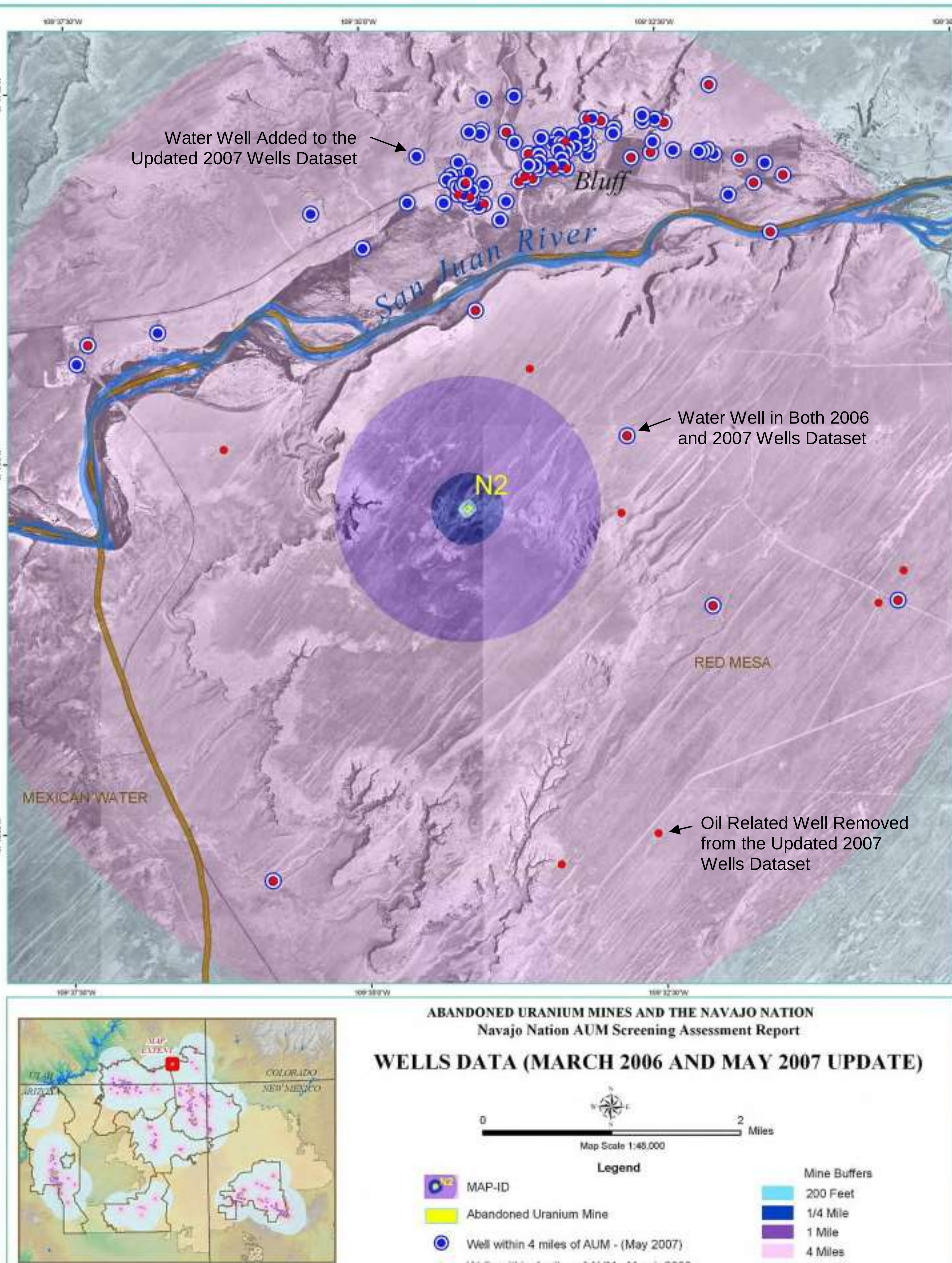


Figure 9. Example Comparison of Wells Data Used in March 2006 and Updated May 2007.

It should be noted that the wells dataset used for this report was updated from the version used for the previous AUM Region screening assessment reports. Figure 9 shows site NA-0238 (MAP-ID #N2) with the 1/4 mile, 1 mile, and 4 mile buffer around the AUM. Wells used in the Northern AUM Region screening assessment report (March, 2006) are shown as red dots. The updated wells dataset used for this report are shown as larger blue dots. This figure illustrates that several wells have been added, particularly near the community of Bluff, Utah. These new wells were made available from the Utah Division of Water Rights Database (dated 2/19/2007). A few wells were removed after determining they were oil or gas related wells and not likely used as drinking water sources. The updates to the wells data have resulted in some substantial changes in scores for some AUMs (e.g., the NA-0238 ground water score was 360 in the Northern AUM Region screening assessment report).

SURFACE WATER PATHWAY

Water erosion is the process by which soil particles are detached and transported from their original location. Sedimentation is the by-product of erosion, whereby eroded particles are deposited at a location different from their origin. Erosion is a concern for AUMs primarily because of the mine wastes. Major sources of erosion and sediment loadings at mining sites include waste rock and overburden piles, haul and access roads, exploration areas, and reclamation areas. Hazardous constituents (e.g., radionuclides and metals) associated with discharges from mining operations may be found at elevated levels in sediments (EPA, 2000 - S02200302).

Evaluation of the surface water pathway using the modified HRS required knowing the location of the AUM sites and distance to perennial and intermittent streams or drainages. The HRS criteria used to evaluate the surface water pathway were:

- For perennial or intermittent surface water within one mile of an AUM site, assign 100 points
- For perennial or intermittent surface water between 1 mile and 4 miles, assign 50 points
- For perennial or intermittent surface water between 4 miles and 15 miles, assign 10 points
- If no perennial or intermittent surface water exists within 15 miles, assign 0 points

All but two (2) of the AUM sites on or within one (1) mile of the Navajo Nation were located within one (1) mile of a downstream intermittent stream or drainage (see Figure 10) and scored 160 (score = 100+50+10). The two AUMs that do not have downstream drainages are both located in the Western AUM Region in the Coalmine Canyon Chapter. The Evans Huskon No. 35 mine (MAP-ID #W79 - Figure 37, page 54) was a rim strip/pit that produced about 170 pounds of uranium. There is no record that the AUM has been reclaimed. The Cam061 prospect (MAP-ID #W80 - Figure 37, page 54) is located within a quarter mile to the north-east of the Evan Huskon No. 35 mine. No records of production were located for this AUM. This AUM is a mine feature that was mapped by NAMLRP, but did not require reclamation.

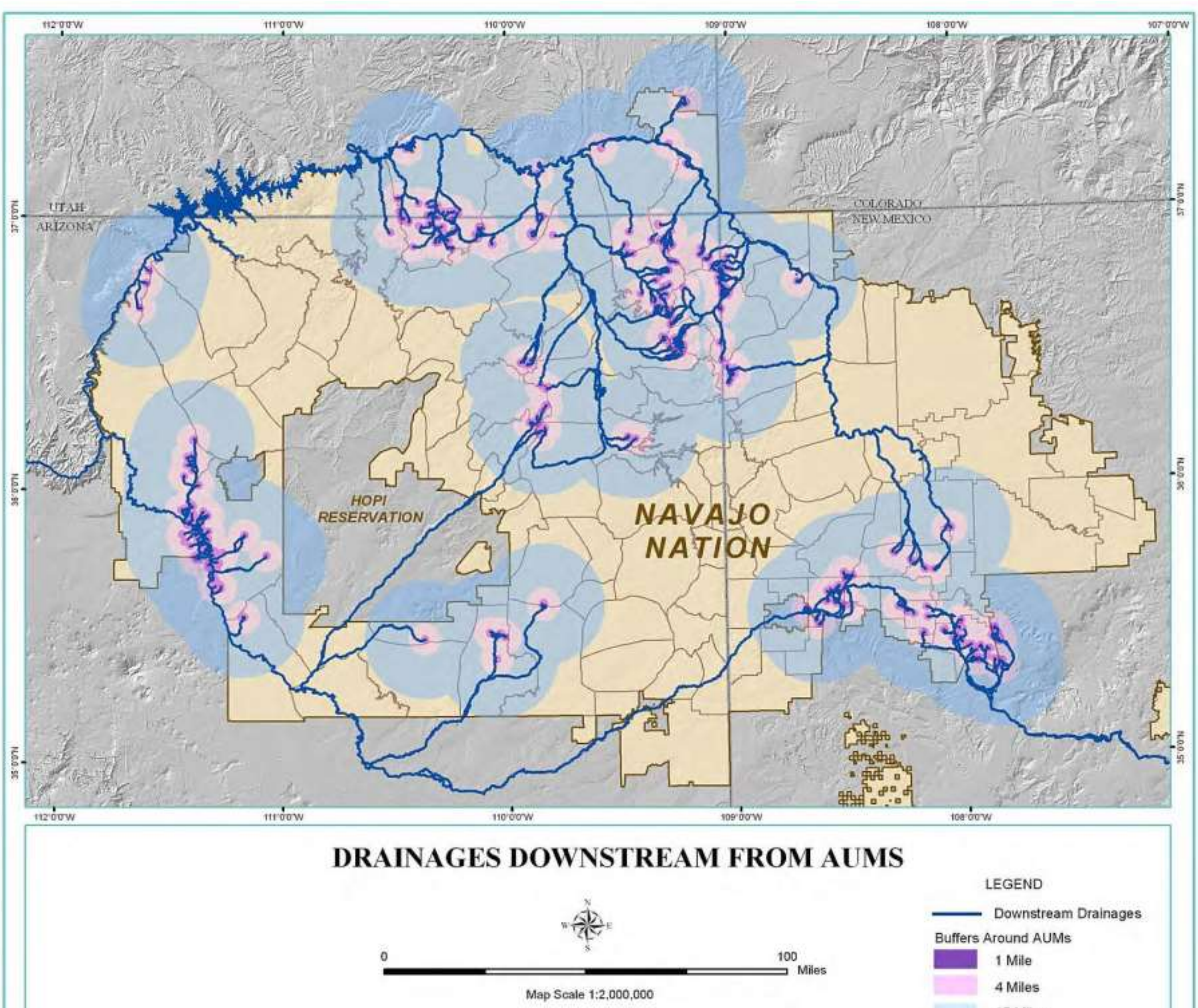


Figure 10. Surface Water Drainages Downstream from AUM Sites.

COMBINED PATHWAYS

After total scores were developed for each of the four pathways it was possible to tabulate a combined pathways score for each of the AUM sites. Scores for air, soil, surface water, and ground water were summed to obtain combined scores, which are presented in the following tables by AUM Region. The tables are sorted by MAP-ID number.

- Table 4. North Central Combined Pathway Scores Table
- Table 5. Northern Combined Pathway Scores Table
- Table 6. Western Combined Pathway Scores Table
- Table 7. Central Combined Pathway Scores Table
- Table 8. Southern Combined Pathway Scores Table
- Table 9. Eastern Combined Pathway Scores Table

The GIS database was used to generate several maps depicting the combined pathways results. A map index was developed for each of the AUM Regions to show the locations of the AUM sites and the extents of the aggregated buffers that were generated around the AUM sites. Also shown on AUM Region Index figures are the extents of the map figures (enlargement) for the combined pathways. AUM sites are labeled with their corresponding MAP-ID on the map enlargements. Also shown are structures, wells, and drainages. Table 3 below lists the map figure number, title, and the range of MAP-IDs on each map. As previously discussed, there are some changes to the AUMs from the previous six (6) screening assessment reports, including: added AUMs have a new MAP-ID; deleted and merged AUM polygons do not appear in the score tables or maps; split AUMs polygons share the same MAP-ID with an alpha suffix (e.g., W112a).

Table 3. MAP-ID Correspondence to Figure Number.

FIGURE NUMBER	FIGURE TITLE	RANGE OF MAP-IDS
Figure 12	North Central AUM Region Combined Pathways - Map Figure Index	NC1 - NC68
Figure 13	Combined Pathways in the Monitor Mesa Area Map	NC1
Figure 14	Combined Pathways in the Mexican Hat Area Map	NC2
Figure 15	Combined Pathways in the North Nokai Mesa Area Map	NC3 - NC9 and N68*
Figure 16	Combined Pathways in the Oljato Area Map	NC10 - NC45
Figure 17	Combined Pathways in the South Nokai Mesa Area Map	NC46
Figure 18	Combined Pathways in the South El Capitan Flat Area Map	NC47 - NC53
Figure 19	Combined Pathways in the Monument Valley Area Map	NC54 - NC60
Figure 20	Combined Pathways in the Cane Valley Area Map	NC61 - NC67
Figure 21	Northern Region Combined Pathways - Map Index Map	N1 - N285
Figure 22	Combined Pathways in the North Central Aneth Area Map	N1
Figure 23	Combined Pathways in the Northwest Red Mesa Area Map	N2
Figure 24	Combined Pathways in the North Teec Nos Pos Area Map	N3 - N4
Figure 25	Combined Pathways in the South Red Mesa Area Map	N5 - N10
Figure 26	Combined Pathways in the Tse Tah Area Map	N11 - N58
Figure 27	Combined Pathways in the Northeast Carrizo Area Map	N59 - N85
Figure 28	Combined Pathways in the Southwest Sweet-water Area Map	N86
Figure 29	Combined Pathways in the West Carrizo Area Map	N87 - N124*
Figure 30	Combined Pathways in the East Carrizo Area Map	N129 - N190
Figure 31	Combined Pathways in the Shiprock Area Map	N191
Figure 32	Combined Pathways in the Lukachukai Area Map	N192 - 263
Figure 33	Combined Pathways in the Chuska Area Map	N264 - N285
Figure 34	Western Combined Pathways - Map Figure Index	W1 - W125
Figure 35	Combined Pathways in the Echo Cliffs Region	W1 - W4
Figure 36	Combined Pathways in the Southeastern Bodaway/Gap Region	W5 - W17
Figure 37	Combined Pathways in the Cameron Region	W18 - W70 * W72 - W91
Figure 38	Combined Pathways in the Adeii Eechii Cliffs Region	W71 and W125*
Figure 39	Combined Pathways in the Southern Little Colorado Region	W92 - W122*
Figure 40	Combined Pathways in the East Black Falls Region	W123 - W124
Figure 41	Central Region Combined Pathways - Map Figure Index	C1 - C34
Figure 42	Combined Pathways in the Rough Rock Area Map	C1 - C10
Figure 43	Combined Pathways in the Tachee Area Map	C11 - C30
Figure 44	Combined Pathways in the Chinle Area Map	C31 - C34
Figure 45	Southern Region Combined Pathways - Map Figure Index	S1 - S6
Figure 46	Combined Pathways in the Cedar Springs Area Map	S1
Figure 47	Combined Pathways in the Bidahochi Area Map	S2 - S5
Figure 48	Combined Pathways in the Greasewood Area Map	S6
Figure 49	Eastern Region Combined Pathways - Map Figure Index	E1 - E103
Figure 50	Combined Pathways in the Northwest Church Rock Area Map	E1 - E2
Figure 51	Combined Pathways in the Northeast Church Rock Area Map	E3 - E9
Figure 52	Combined Pathways in the Nahodishgish Area Map	E10 - E11*
Figure 53	Combined Pathways in the Becenti Area Map	E16
Figure 54	Combined Pathways in the Church Rock Area Map	E17 - E21
Figure 55	Combined Pathways in the Iyanbito Area Map	E22 - E28
Figure 56	Combined Pathways in the Mariano Lake Area Map	E29 - E34
Figure 57	Combined Pathways in the Crownpoint Area Map	E35 - E36*
Figure 58	Combined Pathways in the Western Hay-stack Area Map	E40 - E56
Figure 59	Combined Pathways in the Ambrosia Lake Area Map	E57 - E76
Figure 60	Combined Pathways in the Haystack Area Map	E77 - E103*

* Indicates MAP-ID ranges where AUM polygons were added, deleted, or merged, resulting in gaps in the MAP-ID numbers.

COMBINED PATHWAYS (continued)

Based on the modified HRS model used for this assessment, scores for AUM sites on and within one (1) mile of the Navajo Nation range from 10 to 17,640. The highest composite pathway score on the Navajo Nation is the Crownpoint ISL (In-Situ Leach) AUM. This AUM is located in the Eastern AUM Region in the Crownpoint Chapter (MAP-ID #E35 - Figure 57, page 74). The Composite Score of 17,640 is comprised of the following contributions from the individual pathways:

Air Pathway	
18 structures within the 200 foot buffer	18 x 100 = 1,800
10 structures between 200 feet and 1/4 mile, and	10 x 25 = 250
642 structures between 1/4 mile and 1 mile	642 x 10 = 6,420
	8,470
Soil Pathway	
18 structures within the 200 foot buffer	18 x 100 = 1,800
10 structures between 200 feet and 1/4 mile, and	10 x 25 = 250
642 structures between 1/4 mile and 1 mile	642 x 10 = 6,420
	8,470
Groundwater Pathway	
1 wells within 1/4 mile	1 x 100 = 100
4 wells between 1/4 mile and 1 mile, and	4 x 50 = 200
24 wells between 1 mile and 4 miles of the AUM site	24 x 10 = 240
	540
Surface Water Pathway	
Presence of downstream drainage from the AUM site through each of the buffers.	**160**
Composite Pathway Score for Crownpoint ISL	8,470 + 8,470 + 540 + 160 = **17,640**

Figure 11 below shows an enlargement of the one (1) mile buffer area around the Crownpoint ISL and the Section 29-Conoco (the fourth highest scoring AUM on the Navajo Nation) to illustrate the significance that proximity to the community of Crownpoint has on the scoring. The Crownpoint ISL AUM was shutdown when the price of uranium collapsed and there was no production from this AUM. However, a shaft was sunk to the ore horizon and surface facilities were constructed. Section 29 Conoco was also unproductive, although a shaft was sunk to the ore horizon just before the uranium market collapsed.

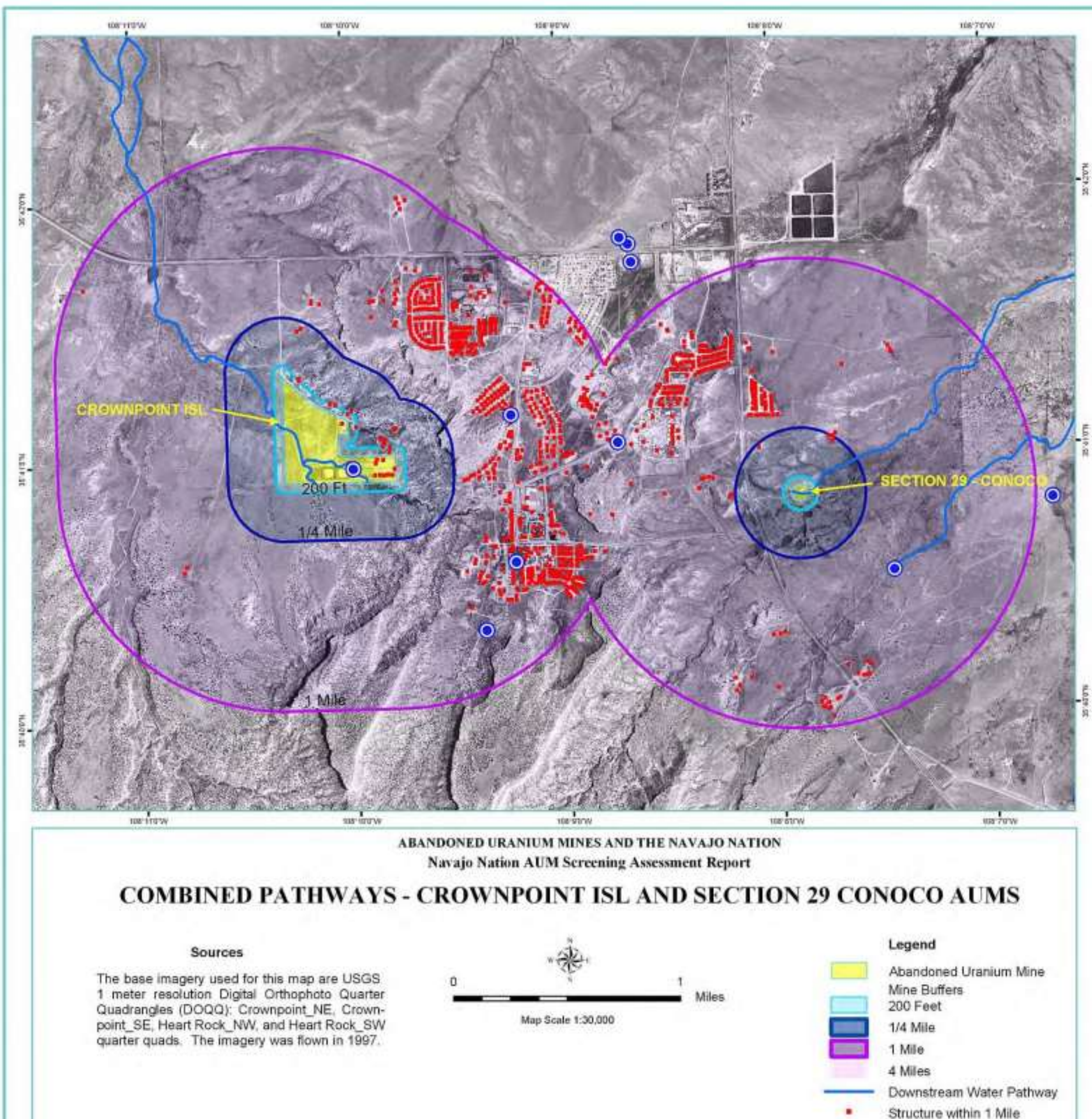


Figure 11. Crownpoint ISL and Section 29-Conoco AUMs Combined Pathways Factors.

Table 4. North Central AUM Region Combined Pathway Scores.

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
NC1	Oljato	Whirlwind	0	0	0	160	160
NC2	Off Navajo Nation	Mexican Hat Stockpile	910	775	775	160	2620
NC3	Oljato	Horsetrail	10	10	10	160	190
NC4	Oljato	Tract 15	10	0	0	160	170
NC5	Oljato	Alfred Mills	10	0	0	160	170
NC6	Oljato	Tract 12	10	0	0	160	170
NC7	Oljato	Tract 14	0	0	0	160	160
NC8	Oljato	Mon060	0	0	0	160	160
NC9	Shonto	Tract 17	0	0	0	160	160
NC10	Oljato	Tract 7	50	0	0	160	210
NC11	Oljato	Taylor Reid No. 1	390	0	0	160	550
NC12	Oljato	Taylor Reid No. 1	330	10	10	160	510
NC13	Oljato	C-3	340	20	20	160	540
NC14	Oljato	Mitten No. 3	390	70	70	160	690
NC15	Oljato	Charles Keith	710	1105	1105	160	3080
NC16	Oljato	Copper Point	570	230	230	160	1190
NC17	Oljato	Norcross	460	450	450	160	1520
NC18	Oljato	Skyline Road	460	30	30	160	680
NC19	Oljato	Tom Holliday	440	30	30	160	660
NC20	Oljato	Mitten No. 1	410	40	40	160	650
NC21	Oljato	Mitten No. 1	400	70	70	160	700
NC22	Oljato	Utah No. 1 Lease	370	200	200	160	930
NC23	Oljato	Skyline	380	240	240	160	1020
NC24	Oljato	Rock Door No. 1	490	1145	1145	160	2940
NC25	Oljato	Monument No. 3	240	70	70	160	540
NC26	Oljato	Utah No. 1	460	20	20	160	660
NC27	Oljato	Radium Hill No. 1	520	20	20	160	720
NC28	Oljato	Fern No. 1	470	0	0	160	630
NC29	Oljato	Harve Black No. 2	730	240	240	160	1370
NC30	Oljato	Tract 11	30	10	10	160	210
NC31	Oljato	Tract 11E	60	10	10	160	240
NC32	Oljato	Tract 24 Mine - B	270	90	90	160	610
NC33	Oljato	Tract 24 Mine - A	280	80	80	160	600
NC34	Oljato	Starlight	480	10	10	160	660
NC35	Oljato	Starlight East	540	10	10	160	720
NC36	Oljato	Moonlight	530	150	150	160	990
NC37	Oljato	Daylight	420	30	30	160	640
NC38	Oljato	Mitten No. 2	410	200	200	160	970
NC39	Oljato	Monument No. 1 North	390	220	220	160	990
NC40	Oljato	Golden Crown	450	305	305	160	1220
NC41	Oljato	Monument No. 1	360	190	190	160	900
NC42	Oljato	Sunlight	500	35	35	160	730
NC43	Oljato	South Sunlight	520	35	35	160	750
NC44	Oljato	Big Four No. 2	470	40	40	160	710
NC45	Oljato	Big Chief	330	0	0	160	490
NC46	Oljato	Tract 2B	40	20	20	160	240
NC47	Oljato	Joe Rock #7-9	110	20	20	160	310
NC48	Oljato	Bootjack	130	20	20	160	330
NC49	Oljato	Firelight No. 6	120	115	115	160	510
NC50	Oljato	Alma-Seegan	80	210	210	160	660
NC51	Oljato	Black Rock Trench	40	185	185	160	570
NC52	Oljato	Black Rock	40	150	150	160	500
NC53	Oljato	Sally	40	180	180	160	560
NC54	Oljato	Binale 2	70	0	0	160	230
NC55	Oljato	Mitchell Mesa	30	0	0	160	190
NC56	Oljato	Binale 1	30	0	0	160	190
NC57	Oljato	Lone Mesa 2 Claim	120	0	0	160	280
NC58	Kayenta	Round Mesa Claim	50	0	0	160	210
NC59	Kayenta	AEC Sample 13756 & USGS Sample MV-8	20	0	0	160	180
NC60	Kayenta	Sam Charlie No. 1	20	0	0	160	180
NC61	Kayenta	Harvey Blackwater No. 3	40	305	305	160	810
NC62	Kayenta	Harvey Blackwater No. 1	90	50	50	160	350
NC63	Kayenta	Harvey Blackwater Claim (South)	150	80	80	160	470
NC64	Kayenta	Harvey Blackwater No. 4	160	70	70	160	460
NC65	Kayenta	Monument No. 2	130	0	0	160	290
NC66	Kayenta	Monument No. 2	500	160	160	160	980
NC67	Dennehotso	Bluestone No. 1	120	60	60	160	400
NC68	Oljato	Gothe Mine	0	0	0	160	160

Table 5. Northern AUM Region Combined Pathway Scores.

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
N1	Off Navajo Nation	Pete	420	10	10	160	600
N2	Red Mesa	NA-0238	1290	0	0	160	1450
N3	Aneth	Montezuma Creek Mine	620	60	60	160	900
N4	Teec Nos Pos	Aneth 1	210	70	70	160	510
N5	Red Mesa	Tom Morgan 1	40	80	80	160	360
N6	Red Mesa	Barton 3	50	140	140	160	490
N7	Red Mesa	John Lee Benally	120	80	80	160	440
N8	Red Mesa	Phillip Dee 1	180	150	150	160	640
N9	Red Mesa	NA-0509A	230	240	240	160	870
N10	Sweetwater	Johnny McCoy 1	470	440	440	160	1510
N11	Teec Nos Pos	John Kee 4	190	305	305	160	960
N12	Teec Nos Pos	Capitan Benally No. 4A	70	80	80	160	390
N13	Red Mesa	Brodie 1	130	260	260	160	810
N14	Teec Nos Pos	Block K	200	215	215	160	790
N15	Teec Nos Pos	NA-0928	230	100	100	160	590
N16	Teec Nos Pos	Silentman 1	190	125	125	160	600
N17	Teec Nos Pos	McKenzie 3	270	145	145	160	720
N18	Teec Nos Pos	Plot 2	270	185	185	160	800
N19	Teec Nos Pos	NA-0904	290	160	160	160	770
N20	Teec Nos Pos	Plot 1	310	150	150	160	770
N21	Teec Nos Pos	Plot 4	220	170	170	160	720
N22	Teec Nos Pos	Plot 3	220	185	185	160	750
N23	Teec Nos Pos	Plot 5	220	295	295	160	970
N24	Sweetwater	NA-0926	230	130	130	160	650
N25	Sweetwater	NA-0924	220	160	160	160	700
N26	Teec Nos Pos	Hoskie Henry	160	560	560	160	1440
N27	Teec Nos Pos	Pope 1	160	420	420	160	1160
N28	Teec Nos Pos	Plot 6	170	575	575	160	1480
N29	Teec Nos Pos	Hoskie Henry	170	525	525	160	1380
N30	Teec Nos Pos	NA-0919B	160	270	270	160	860
N31	Teec Nos Pos	NA-0919A	160	300	300	160	920
N32	Teec Nos Pos	Plot 7	170	390	390	160	1110
N33	Teec Nos Pos	Tse079	170	410	410	160	1150
N34	Teec Nos Pos	Plot 8	170	400	400	160	1130
N35	Teec Nos Pos	Black Rock Point Mines	170	430	430	160	1190
N36	Teec Nos Pos	NA-0917A	170	460	460	160	1250
N37	Teec Nos Pos	Plot 9	170	200	200	160	730
N38	Teec Nos Pos	Jimmie Bileen 1	170	170	170	160	670
N39	Teec Nos Pos	Sandy K	170	200	200	160	730
N40	Teec Nos Pos	Plot 10	170	200	200	160	730
N41	Teec Nos Pos	Plot 11	170	170	170	160	670
N42	Sweetwater	North Martin	450	255	255	160	1120
N43	Sweetwater	Grover Cleveland 1	490	110	110	160	870
N44	Sweetwater	Martin Mine & George Simpson No. 1	590	250	250	160	1250
N45	Sweetwater	Rattlesnake No. 8	690	150	150	160	1150
N46	Sweetwater	Tsosie 1	490	110	110	160	870
N47	Sweetwater	George Simpson 1 Incline	680	280	280	160	1400
N48	Sweetwater	Saytah	640	300	300	160	1400
N49	Sweetwater	Carson	840	170	170	160	1340
N50	Sweetwater	AEC Plot 3	690	90	90	160	1030
N51	Sweetwater	Plot 13	890	270	270	160	1590
N52	Sweetwater	Last Chance	670	270	270	160	1370
N53	Sweetwater	Melvin Benally No. 1	120	130	130	160	540
N54	Sweetwater	Saytah Canyon	120	130	130	160	540
N55	Sweetwater	CBW-MC Mine	140	140	140	160	580
N56	Sweetwater	Saytah Canyon	140	120	120	160	540
N57	Sweetwater	Melvin Benally No. 3	110	185	185	160	640
N58	Sweetwater	School Boy	90	0	0	160	250
N59	Teec Nos Pos	Rattlesnake No. 1	190	10	10	160	370
N60	Teec Nos Pos	Bettie No. 1	50	0	0	160	210
N61	Beclabito	Zona No. 1	80	0	0	160	240
N62	Beclabito	Ruben No. 1	80	0	0	160	240
N63	Beclabito	Jim Lee No. 1, Richard King No. 1	140	0	0	160	300
N64	Beclabito	Todakonzie No. 1	90	0	0	160	250
N65	Beclabito	NA-0424	310	1985	1985	160	4440
N66	Beclabito	NA-0420	210	2815	2815	160	6000
N67	Beclabito	Harvey Begay 3	140	0	0	160	300
N68	Red Valley	Tony Tuc	100	0	0	160	260

Table 5. Northern AUM Region Combined Pathway Scores (continued)

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
N69	Beclabito	Upper Red Canyon	100	0	0	160	260
N70	Beclabito	Kings 6	110	100	100	160	470
N71	Beclabito	Barton & Begay	100	100	100	160	460
N72	Beclabito	Barton & Begay	180	20	20	160	380
N73	Beclabito	Rocky Flats No. 2	140	20	20	160	340
N74	Beclabito	Bec064	110	0	0	160	270
N75	Beclabito	Canyon No. 1	110	0	0	160	270
N76	Beclabito	Bec068	110	0	0	160	270
N77	Beclabito	John John 1	140	20	20	160	340
N78	Beclabito	John John 1	130	20	20	160	330
N79	Beclabito	John John 1	130	20	20	160	330
N80	Beclabito	King No. 2	130	20	20	160	330
N81	Beclabito	Rocky Flats No. 1	130	0	0	160	290
N82	Beclabito	Rocky Flats No. 1	130	0	0	160	290
N83	Beclabito	Rocky Flats No. 1	180	0	0	160	340
N84	Beclabito	Rocky Flats No. 1	180	30	30	160	400
N85	Beclabito	Rocky Flats No. 1	170	30	30	160	390
N86	Sweetwater	Chester Mud No. 1	10	90	90	160	350
N87	Sweetwater	Eurida Mine	20	50	50	160	280
N88	Sweetwater	Plot 14	20	20	20	160	220
N89	Sweetwater	East Workings	10	50	50	160	270
N90	Sweetwater	NA-0505B	10	50	50	160	270
N91	Sweetwater	Plot 16	10	50	50	160	270
N92	Sweetwater	Plot 15	10	0	0	160	170
N93	Sweetwater	NA-0504	20	80	80	160	340
N94	Sweetwater	Chimney No. 1	10	0	0	160	170
N95	Sweetwater	Sunnyside	0	10	10	160	180
N96	Sweetwater	Sunnyside	0	10	10	160	180
N97	Sweetwater	Swt018	0	120	120	160	400
N98	Red Valley	Tohe Thlany Begay Mine	0	0	0	160	160
N99	Red Valley	Cov192	0	0	0	160	160
N100	Sweetwater	AEC Plot B	0	40	40	160	240
N101	Sweetwater	Mildred 1	0	0	0	160	160
N102	Sweetwater	NA-0512	0	10	10	160	180
N103	Sweetwater	AEC Plot D	0	20	20	160	200
N104	Sweetwater	Sheepskin Mesa	0	10	10	160	180
N105	Sweetwater	Tree Mesa	0	10	10	160	180
N106	Sweetwater	Swt003	0	10	10	160	180
N107	Sweetwater	NA-0510	0	0	0	160	160
N108	Sweetwater	Kinusta Mesa	0	20	20	160	200
N109	Sweetwater	NA-0511	0	20	20	160	200
N110	Sweetwater	Cove Mesa Mines (Cato Sells)	0	0	0	160	160
N111	Red Valley	Cove Mesa Mines (Cato Sells)	0	10	10	160	180
N112	Red Valley	Cove Mesa Mines (Cato Sells)	0	10	10	160	180
N113	Sweetwater	Cove Mesa Mines (AEC Lease Plot 7)	0	0	0	160	160
N114	Sweetwater	Cove Mesa Mines (AEC Lease Plot 7)	0	0	0	160	160
N116	Red Valley	Cove Mesa Mines (AEC Lease Plot 7)	0	0	0	160	160
N118	Sweetwater	Cove Mesa Mines (AEC Lease Plot 7)	0	0	0	160	160
N119	Red Valley	Cove Mesa Mines (AEC Lease Plot 7)	0	0	0	160	160
N120	Sweetwater	Cove Mesa Mines (AEC Lease Plot 7)	10	0	0	160	170
N122	Red Valley	Cove Mesa Mines (AEC Lease Plot 7)	10	0	0	160	170
N123	Sweetwater	Cove Mesa Mines (AEC Lease Plot 7)	10	0	0	160	170
N124	Sweetwater	Cove Mesa Mines (AEC Lease Plot 7)	10	0	0	160	170
N129	Red Valley	Cottonwood Butte	190	30	30	160	410
N130	Red Valley	Syracuse Mine	160	0	0	160	320
N131	Red Valley	Hazel	170	30	30	160	390
N132	Red Valley	NA-0410	200	30	30	160	420
N133	Red Valley	North Star	210	30	30	160	430
N134	Red Valley	Lone Star	200	30	30	160	420
N135	Red Valley	Valley View	150	50	50	160	410
N136	Red Valley	White Cap	160	0	0	160	320
N137	Red Valley	Upper Canyon	250	160	160	160	730
N138	Red Valley	Leroy	250	130	130	160	670
N139	Red Valley	Lower Canyon	240	130	130	160	660
N140	Red Valley	NA-0405	240	200	200	160	800
N141	Red Valley	Oak Springs Mine (Gravel Cap)	400	540	540	160	1640
N142	Red Valley	Oak Springs Mine	400	475	475	160	1510
N143	Red Valley	Oak238	260	235	235	160	890

Table 5. Northern AUM Region Combined Pathway Scores (continued)

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
N144	Red Valley	VCA Plot 7 Mines	260	195	195	160	810
N145	Red Valley	VCA Plot 7 Mines	260	135	135	160	690
N146	Red Valley	Franks Point	230	90	90	160	570
N147	Red Valley	Upper Salt Rock	190	30	30	160	410
N148	Red Valley	VCA Plot 7 Mines	180	30	30	160	400
N149	Red Valley	Lower Salt Rock	180	30	30	160	400
N150	Red Valley	Williams Point	270	40	40	160	510
N151	Red Valley	Salt Canyon	220	0	0	160	380
N152	Red Valley	Salt Canyon	220	10	10	160	400
N153	Red Valley	VCA Plot 3	310	170	170	160	810
N154	Red Valley	Lookout Point	270	90	90	160	610
N155	Red Valley	Lookout Point Incline	310	190	190	160	850
N157	Red Valley	VCA Plot 3	170	20	20	160	370
N158	Red Valley	Shadyside No. 2	170	30	30	160	390
N159	Red Valley	Shadyside No. 1	180	50	50	160	440
N160	Red Valley	VCA Plot 3	180	40	40	160	420
N161	Red Valley	Begay No. 2	180	40	40	160	420
N162	Red Valley	Begay Incline	180	90	90	160	520
N164	Red Valley	Shadyside Incline	260	90	90	160	600
N166	Red Valley	VCA Plot 3	400	460	460	160	1480
N167	Red Valley	Nelson Point	360	360	360	160	1240
N168	Red Valley	Tent No. 1	360	200	200	160	920
N169	Red Valley	Oak143, Oak146	310	350	350	160	1170
N174	Red Valley	NA-0824	270	60	60	160	550
N175	Red Valley	Junction	220	80	80	160	540
N176	Red Valley	King Tutt Point	250	210	210	160	830
N177	Red Valley	Carrizo No. 1	170	90	90	160	510
N178	Red Valley	Begay No. 1	170	120	120	160	570
N179	Red Valley	King Tutt 1	210	120	120	160	610
N180	Red Valley	Red Wash Point	210	135	135	160	640
N181	Red Valley	Oak124, Oak125	170	120	120	160	570
N182	Red Valley	Begay No. 1	210	120	120	160	610
N183	Red Valley	Alongo Mines	220	145	145	160	670
N184	Red Valley	Red Rock	290	395	395	160	1240
N185	Red Valley	NA-0828	250	305	305	160	1020
N186	Red Valley	Oak230	250	290	290	160	990
N187	Red Valley	Red Wash (Leroy Pettigrew)	250	290	290	160	990
N188	Red Valley	Red Wash (Hosteen S. Begay)	160	80	80	160	480
N189	Red Valley	Upper Red Wash	140	120	120	160	540
N190	Red Valley	Upper Red Wash	140	35	35	160	370
N191	Shiprock	Climax Transfer Station	70	1705	1705	160	3640
N192	Red Valley	East Mesa Mines	70	0	0	160	230
N193	Red Valley	West Mesa Mine	80	0	0	160	240
N194	Cove	Cove Transfer Station	330	2030	2030	160	4550
N195	Round Rock	Mexican Cry Mine	30	0	0	160	190
N196	Round Rock	Mexican Cry Mine	30	0	0	160	190
N197	Round Rock	Hall Mine	30	0	0	160	190
N198	Round Rock	Tom Joe No. 6	30	0	0	160	190
N199	Round Rock	Nakai Chee Begay Mine	30	0	0	160	190
N200	Cove	Cato No. 2	120	10	10	160	300
N201	Cove	Cato No. 1 Pit	120	340	340	160	960
N202	Cove	Frank Jr. Mine	120	60	60	160	400
N203	Cove	NA-0319	120	20	20	160	320
N204	Cove	Mesa VI Mine	160	20	20	160	360
N205	Cove	NA-0319	160	20	20	160	360
N206	Cove	Mesa V Adit	120	0	0	160	280
N207	Cove	Mesa V Incline	120	0	0	160	280
N208	Cove	Mesa V Mine	160	0	0	160	320
N209	Cove	Mesa V Mine	160	20	20	160	360
N210	Cove	NA-0318	120	0	0	160	280
N211	Cove	Cov087	160	20	20	160	360
N212	Cove	Mesa IV 1/2 Mine and Simpson 181	160	20	20	160	360
N213	Cove	North Portal, Frank No. 1 Mine	160	20	20	160	360
N214	Cove	East Portal, Frank No. 1 Mine	160	20	20	160	360
N215	Cove	Frank No. 2	150	20	20	160	350
N216	Cove	South Portal, Frank No. 1 Mine	130	20	20	160	330
N217	Cove	NA-0316	130	20	20	160	330
N218	Cove	Cov068	120	0	0	160	280

Table 5. Northern AUM Region Combined Pathway Scores (continued)

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
N219	Cove	Mesa IV, Mine No. 2	120	0	0	160	280
N220	Cove	Mesa IV, Mine No. 3	120	0	0	160	280
N221	Cove	Mesa IV, Mine No. 1	120	10	10	160	300
N222	Cove	Mesa II Pit	120	0	0	160	280
N223	Cove	Mesa IV 1/4 Mine	130	20	20	160	330
N224	Cove	Mesa IV, West Mine	120	30	30	160	340
N225	Cove	Mesa I Mine 11	100	0	0	160	260
N226	Cove	Mesa I Mine 15	110	0	0	160	270
N227	Cove	Mesa I Mine 10	140	0	0	160	300
N228	Cove	Mesa I Mine 13	140	0	0	160	300
N229	Cove	Mesa I Mine 12	100	0	0	160	260
N230	Cove	Mesa I Mine 14	70	0	0	160	230
N231	Round Rock	Jimmie King No. 9 Mine	30	0	0	160	190
N232	Cove	Mesa IV, East Side	70	10	10	160	250
N233	Cove	Mesa III, Northwest Mine	70	25	25	160	280
N234	Cove	Cov000	70	10	10	160	250
N235	Cove	Mesa III, West Mine	80	25	25	160	290
N236	Cove	Mesa III Mine	70	25	25	160	280
N237	Cove	Mesa II 1/2, Mine 4	70	25	25	160	280
N238	Cove	Mesa II 1/2 Mine	70	10	10	160	250
N239	Cove	NA-0313	70	10	10	160	250
N240	Cove	Mesa II 1/4 Mine	70	10	10	160	250
N241	Cove	Mesa II, Mine 4	70	0	0	160	230
N242	Cove	Henry Phillips Mine	70	0	0	160	230
N243	Cove	Mesa I 1/2 Mine	60	0	0	160	220
N244	Cove	Mesa II, Mine No. 1, P-150	70	10	10	160	250
N245	Cove	Mesa II, Mine No. 1 & 2, P-21	70	10	10	160	250
N246	Cove	Mesa I 3/4, Mine No. 2, P150	70	10	10	160	250
N247	Cove	Mesa I 1/2, West Mine	60	0	0	160	220
N248	Cove	Mesa I 1/4 Mine	100	30	30	160	320
N249	Round Rock	NA-0333	40	0	0	160	200
N250	Round Rock	NA-0332	40	0	0	160	200
N251	Round Rock	Tommy James Mine	50	0	0	160	210
N252	Round Rock	Step Mesa Mine	60	0	0	160	220
N253	Cove	Mesa I 3/4 Incline	80	0	0	160	240
N254	Round Rock	Flag No. 1 Mine	70	0	0	160	230
N255	Round Rock	Black No. 1 Mine	60	0	0	160	220
N256	Round Rock	Black No. 2 Mine (West)	50	0	0	160	210
N257	Round Rock	Black No. 2 Mine	50	0	0	160	210
N258	Cove	Billy Topaha Mine	50	0	0	160	210
N259	Round Rock	Joleo Mine	50	0	0	160	210
N260	Round Rock	Cisco Mine	50	0	0	160	210
N261	Round Rock	Camp Mine	40	0	0	160	200
N262	Round Rock	Knife Edge Mesa Mine	60	0	0	160	220
N263	Round Rock	NA-0343	60	0	0	160	220
N264	Red Valley	Rocky Spring	150	380	380	160	1070
N265	Red Valley	H. B. Roy No. 1	30	0	0	160	190
N266	Sanostee	Key and Tohe	20	20	20	160	220
N267	Sanostee	Castle Tsosie	10	0	0	160	170
N268	Sanostee	Joe Ben 1	10	0	0	160	170
N269	Sanostee	Joe Ben 2	10	0	0	160	170
N270	Sanostee	Deneh Nezz 3	10	0	0	160	170
N271	Sanostee	Deneh Nezz 1, 2	10	0	0	160	170
N272	Sanostee	Enos Johnson Claim?	10	0	0	160	170
N273	Sanostee	John Joe 1	10	0	0	160	170
N274	Sanostee	Enos Johnson	10	0	0	160	170
N275	Sanostee	Enos Johnson	10	0	0	160	170
N276	Sanostee	Joe Ben 3	10	0	0	160	170
N277	Sanostee	NA-0603	10	0	0	160	170
N278	Sanostee	Enos Johnson 3	10	0	0	160	170
N279	Sanostee	Enos Johnson 1, Enos Johnson 2	10	0	0	160	170
N280	Sanostee	Enos Johnson	10	0	0	160	170
N281	Sanostee	Enos Johnson	10	0	0	160	170
N282	Sanostee	Horace Ben	10	0	0	160	170
N283	Sanostee	Carl Yazzie 1	10	0	0	160	170
N284	Sanostee	H. B. Roy No. 2	10	10	10	160	190
N285	Sanostee	Reed Henderson	0	0	0	160	160

Table 6. Western AUM Region Combined Pathway Scores

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
W1	Bodaway/Gap	Jimmie Boone	40	0	0	160	200
W2	Bodaway/Gap	Tommy	50	120	120	160	450
W3	Bodaway/Gap	June	50	40	40	160	290
W4	Bodaway/Gap	Thomas No. 1	190	10	10	160	370
W5	Bodaway/Gap	Martin Johnson No. 4	110	490	490	160	1250
W6	Bodaway/Gap	Earl Huskon No. 1	20	10	10	160	200
W7	Bodaway/Gap	Max Huskon No. 5	30	0	0	160	190
W8	Bodaway/Gap	Paul Huskie No. 21	30	0	0	160	190
W9	Bodaway/Gap	Earl Huskon No. 3	30	0	0	160	190
W10	Bodaway/Gap	A & B No. 5	20	0	0	160	180
W11	Bodaway/Gap	Max Huskon No. 1	20	40	40	160	260
W12	Bodaway/Gap	Henry Sloan No. 1	30	110	110	160	410
W13	Bodaway/Gap	Henry Sloan No. 1	20	95	95	160	370
W14	Bodaway/Gap	Charles Huskon No. 7 (MP-357)	20	25	25	160	230
W15	Bodaway/Gap	A & B No. 13	70	80	80	160	390
W16	Bodaway/Gap	A & B No. 7	40	50	50	160	300
W17	Coalmine Canyon	Charles Huskon No. 5	40	20	20	160	240
W18	Coalmine Canyon	Charles Huskon No. 6	40	45	45	160	290
W19	Coalmine Canyon	Lemuel Littleman No. 7	80	40	40	160	320
W20	Coalmine Canyon	Jeepster No. 1	80	60	60	160	360
W21	Bodaway/Gap	Montezuma No. 7C	40	0	0	160	200
W22	Bodaway/Gap	Montezuma No. 7B	40	0	0	160	200
W23	Bodaway/Gap	Montezuma No. 7B	100	0	0	160	260
W24	Bodaway/Gap	Montezuma No. 7A	130	0	0	160	290
W25	Bodaway/Gap	Montezuma No. 2	130	0	0	160	290
W26	Bodaway/Gap	Montezuma No. 2	130	0	0	160	290
W27	Bodaway/Gap	Montezuma No. 2	130	150	150	160	590
W28	Coalmine Canyon	Casey No. 3	130	190	190	160	670
W29	Coalmine Canyon	Jack Daniels No. 3	50	0	0	160	210
W30	Coalmine Canyon	Kachina No. 6	190	205	205	160	760
W31	Coalmine Canyon	Charles Huskon No. 19	190	160	160	160	670
W32	Coalmine Canyon	Charles Huskon No. 19	240	265	265	160	930
W33	Coalmine Canyon	Jack Daniels No. 5	300	555	555	160	1570
W34	Coalmine Canyon	Jack Daniels No. 1	250	555	555	160	1520
W35	Coalmine Canyon	Jack Daniels No. 4	320	520	520	160	1520
W36	Coalmine Canyon	Evans Huskon No. 34	60	20	20	160	260
W37	Coalmine Canyon	Charles Huskon No. 20	60	20	20	160	260
W38	Coalmine Canyon	Charles Huskon No. 12	230	560	560	160	1510
W39	Cameron	A & B No. 3	650	2535	2535	160	5880
W40	Coalmine Canyon	Max Johnson No. 1	340	430	430	160	1360
W41	Coalmine Canyon	Charles Huskon No. 1	380	590	590	160	1720
W42	Coalmine Canyon	Max Johnson No. 10	340	360	360	160	1220
W43	Coalmine Canyon	Lemuel Littleman No. 2	200	260	260	160	880
W44	Coalmine Canyon	Harvey Begay No. 1	180	0	0	160	340
W45	Coalmine Canyon	Max Johnson No. 9	280	0	0	160	440
W46	Coalmine Canyon	Elwood Canyon No. 1	230	0	0	160	390
W47	Coalmine Canyon	Alyce Tolino No. 1 & 3	280	110	110	160	660
W48	Coalmine Canyon	Evans Huskon No. 2	280	40	40	160	520
W49	Coalmine Canyon	Yazzie No. 101	270	40	40	160	510
W50	Coalmine Canyon	Yazzie No. 312	280	70	70	160	580
W51	Coalmine Canyon	Boyd Tisi No. 2	360	130	130	160	780
W52	Coalmine Canyon	Juan Horse No. 3	360	130	130	160	780
W53	Cameron	Lemuel Littleman No. 3	260	170	170	160	760
W54	Coalmine Canyon	Juan Horse No. 4	270	70	70	160	570
W55	Coalmine Canyon	Pat Lynch	60	0	0	160	220
W56	Cameron	A & B No. 2	440	915	915	160	2430
W57	Cameron	Charles Huskon No. 14	270	25	25	160	480
W58	Cameron	Harry Walker No. 19	210	20	20	160	410
W59	Cameron	Montezuma No. 1	250	10	10	160	430
W60	Coalmine Canyon	Manuel Denetsone No. 2	220	0	0	160	380
W61	Coalmine Canyon	Jefferson Canyon No. 1	140	0	0	160	300
W62	Cameron	Charles Huskon No. 3	120	0	0	160	280
W63	Cameron	Charles Huskon No. 3	80	0	0	160	240
W64	Cameron	Charles Huskon No. 3	90	0	0	160	250
W65	Cameron	Charles Huskon No. 3	110	10	10	160	290
W66	Coalmine Canyon	Jack Huskon No. 3	60	0	0	160	220
W67	Cameron	Black Hair No.4	180	190	190	160	720
W68	Cameron	Paul Huskie No. 20	80	110	110	160	460

Table 6. Western AUM Region Combined Pathway Scores (continued)

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
W69	Cameron	Huskon No. 7	80	0	0	160	240
W70	Cameron	Yazzie No. 102	80	0	0	160	240
W71	Coalmine Canyon	Yellow Jeep No. 7A and 7B	10	0	0	160	170
W72	Cameron	Yazzie No. 105	50	0	0	160	210
W73	Cameron	Charles Huskon No. 10	70	0	0	160	230
W74	Cameron	Charles Huskon No. 10	70	10	10	160	250
W75	Coalmine Canyon	Lloyd House	20	0	0	160	180
W76	Cameron	Charles Huskon No. 8	60	0	0	160	220
W77	Cameron	Charles Huskon No. 8	100	0	0	160	260
W78	Cameron	Boyd Tisi No. 1	140	0	0	160	300
W79	Coalmine Canyon	Evans Huskon No. 35	10	0	0	0	10
W80	Coalmine Canyon	Cam061	10	0	0	0	10
W81	Coalmine Canyon	Mel Gardner	30	10	10	160	210
W82	Coalmine Canyon	Ryan No. 1	30	0	0	160	190
W83	Cameron	Taylor Reid No. 2	200	10	10	160	380
W84	Cameron	Taylor Reid No. 3	140	10	10	160	320
W85	Off Navajo Nation	Section 1 Lease	130	10	10	160	310
W86	Off Navajo Nation	Section 1 Lease	140	10	10	160	320
W87	Off Navajo Nation	Ada and Nordell	200	10	10	160	380
W88	Cameron	Charles Huskon No. 26	30	10	10	160	210
W89	Cameron	Charles Huskon No. 11	30	10	10	160	210
W90	Off Navajo Nation	New Liba Group	30	0	0	160	190
W91	Off Navajo Nation	New Liba Group	30	0	0	160	190
W92	Off Navajo Nation	Section 9 Lease	30	0	0	160	190
W93	Coalmine Canyon	Ramco No. 21	30	25	25	160	240
W94	Coalmine Canyon	Ramco No. 20	40	35	35	160	270
W95	Coalmine Canyon	Ramco No. 22	30	35	35	160	260
W96	Coalmine Canyon	Ryan No. 2	20	20	20	160	220
W97	Coalmine Canyon	Ryan No. 3	20	20	20	160	220
W98	Off Navajo Nation	Section 9 Lease	40	0	0	160	200
W99	Off Navajo Nation	Section 9 Lease	40	0	0	160	200
W100	Coalmine Canyon	Yazzie No. 1	40	10	10	160	220
W101	Coalmine Canyon	Yazzie No. 2	40	20	20	160	240
W102	Coalmine Canyon	Charles Huskon No. 17	30	20	20	160	230
W103	Coalmine Canyon	Jackpot No. 40	30	10	10	160	210
W104	Coalmine Canyon	Jackpot No. 1	30	20	20	160	230
W105	Coalmine Canyon	Jackpot No. 5	30	10	10	160	210
W106	Off Navajo Nation	Grub No. 14	50	0	0	160	210
W107	Off Navajo Nation	Black Point-Murphy Group	30	45	45	160	280
W108	Coalmine Canyon	Amos Chee No. 8	70	10	10	160	250
W109	Coalmine Canyon	Max Johnson No. 7	110	0	0	160	270
W110	Coalmine Canyon	Charles Huskon No. 9	110	30	30	160	330
W111	Coalmine Canyon	Emmett Lee No. 1	120	30	30	160	340
W112a	Coalmine Canyon	Julius Chee No. 4	120	30	30	160	340
W112b	Coalmine Canyon	Julius Chee No. 2	120	30	30	160	340
W113	Coalmine Canyon	Julius Chee No. 3	120	30	30	160	340
W114	Coalmine Canyon	Elwood Thompson No. 1	120	30	30	160	340
W115	Coalmine Canyon	Ramco No. 24	90	40	40	160	330
W116	Coalmine Canyon	Harry Walker No. 16	90	30	30	160	310
W117	Coalmine Canyon	Julius Chee No. 2	80	30	30	160	300
W118	Coalmine Canyon	Charles Huskon No. 4	80	40	40	160	320
W119	Coalmine Canyon	Paul Huskie No. 3	80	40	40	160	320
W120	Coalmine Canyon	Charles Huskon No. 18	80	30	30	160	300
W121	Coalmine Canyon	Julia Semallie	80	10	10	160	260
W122	Coalmine Canyon	Emmett Lee No. 3	80	10	10	160	260
W123	Leupp	Adolf Maloney No. 2	30	40	40	160	270
W124	Leupp	Amos Chee No. 2 and No. 3	30	0	0	160	190
W125	Coalmine Canyon	Hosteen Nez	110	0	0	160	270

Table 7. Central AUM Region Combined Pathway Scores

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
C1	Chilchinbeto	Tom Wilson	110	135	135	160	540
C2	Chilchinbeto	Tom Wilson	110	135	135	160	540
C3	Chilchinbeto	Tom Wilson	100	180	180	160	620
C4	Chilchinbeto	Tom Wilson	100	180	180	160	620
C5	Chilchinbeto	Jim Hatattly	120	140	140	160	560
C6	Chilchinbeto	Jim Hatattly	210	120	120	160	610
C7	Chilchinbeto	Tom Klee	270	290	290	160	1010
C8	Chilchinbeto	Tom Klee	130	110	110	160	510
C9	Rough Rock	Rough Rock Slope No. 9	190	40	40	160	430
C10	Many Farms	Dan Taylor No. 1	210	10	10	160	390
C11	Black Mesa	Frank Todecheenie No. 1	100	0	0	160	260
C12	Black Mesa	Sam Charley No. 1	100	0	0	160	260
C13	Black Mesa	Kasewood Bahe No. 1	100	0	0	160	260
C14	Black Mesa	Thomas Begay No. 1	100	0	0	160	260
C15	Black Mesa	Etsitty No. 1	30	90	90	160	370
C16	Black Mesa	Blk029	50	140	140	160	490
C17	Tachee/Blue Gap	Claim 35	40	535	535	160	1270
C18	Black Mesa	Claim 28	80	395	395	160	1030
C19	Black Mesa	Claim 28	80	395	395	160	1030
C20	Tselani/Cottonwood	Claim 16	20	0	0	160	180
C21	Tselani/Cottonwood	Edward Steve No. 1	20	40	40	160	260
C22	Tselani/Cottonwood	Blk022	20	40	40	160	260
C23	Tselani/Cottonwood	Claim 7	80	10	10	160	260
C24	Tselani/Cottonwood	Claim 10	80	10	10	160	260
C25	Tselani/Cottonwood	Claim 6	80	0	0	160	240
C26	Tselani/Cottonwood	Claim 3	40	0	0	160	200
C27	Tselani/Cottonwood	Claim 3 / Claim 4	40	0	0	160	200
C28	Tselani/Cottonwood	Arrowhead No. 2	40	0	0	160	200
C29	Tselani/Cottonwood	Arrowhead No. 1	40	0	0	160	200
C30	Tselani/Cottonwood	Black Mountain Vase	40	0	0	160	200
C31	Chinle	Zhealy Tso, North Prospect	80	80	80	160	400
C32	Chinle	Zhealy Tso, Pits	80	30	30	160	300
C33	Chinle	Zhealy Tso, South Prospect	80	60	60	160	360
C34	Chinle	Occurrence B	50	1980	1980	160	4170

Table 8. Southern AUM Region Combined Pathway Scores

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
S1	Teesto	NA-0750	320	150	150	160	780
S2	Indian Wells	Mail Box claim	210	380	380	160	1130
S3	Indian Wells	Morale Mine	190	50	50	160	450
S4	Indian Wells	Gwen claim	220	90	90	160	560
S5	Indian Wells	Hoskie Tso No. 1	230	165	165	160	720
S6	Steamboat	Sjodin claim	270	100	100	160	630

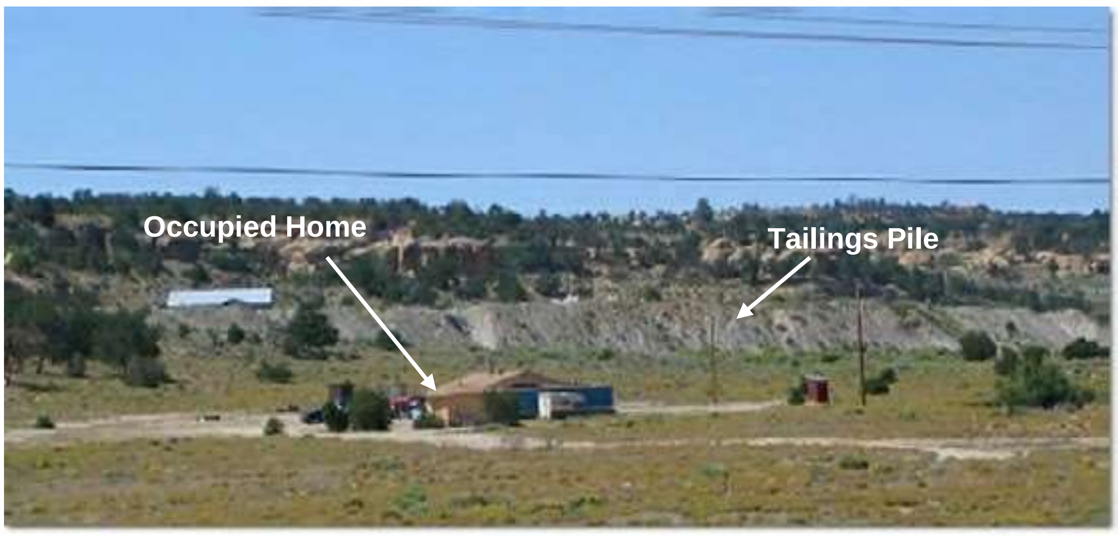
Photo showing the reclaimed Morale Mine with a water tank and livestock corral in close proximity. Photo courtesy TerraSpectra Geomatics (photo taken May 2006).

Table 9. Eastern AUM Region Combined Pathway Scores (continued)

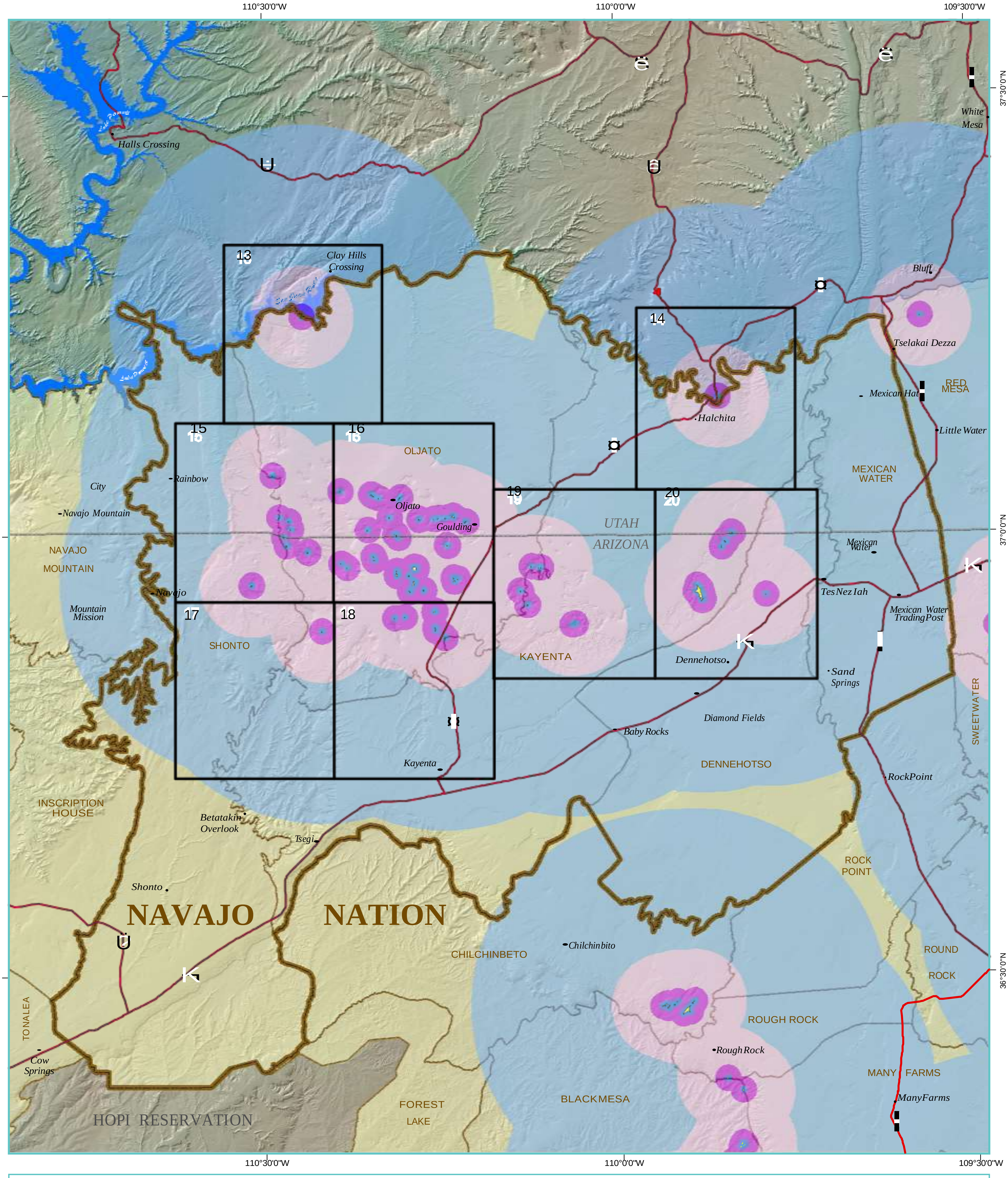
Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
E1	Church Rock	Grace Insitu Leach	110	255	255	160	780
E2	Church Rock	Section 13	120	270	270	160	820
E3	Coyote Canyon	NE Church Rock No. 2	510	140	140	160	950
E4	Coyote Canyon	NE Church Rock No. 1	320	770	770	160	2020
E5	Nahodishgish	NE Church Rock No. 1-East	350	520	520	160	1550
E6	Pinedale	NE Church Rock	540	1025	1025	160	2750
E7	Church Rock	Church Rock ISL	300	90	90	160	640
E8	Church Rock	Church Rock	470	640	640	160	1910
E9	Church Rock	Section 16 deposit	390	1430	1430	160	3410
E10	Nahodishgish	Standing Rock	200	635	635	160	1630
E11	Nahodishgish	Crownpoint, Section 9	650	380	380	160	1570
E16	Becenti	Nose Rock No. 1	100	300	300	160	860
E17	Church Rock	Hogback No. 4	500	140	140	160	940
E18	Church Rock	C D and S	300	620	620	160	1700
E19	Church Rock	Delter	240	520	520	160	1440
E20	Church Rock	Eunice Becenti	420	395	395	160	1370
E21	Church Rock	Diamond No. 2	400	115	115	160	790
E22	Church Rock	Foutz No. 3	210	615	615	160	1600
E23	Church Rock	Foutz No. 2	140	300	300	160	900
E24	Iyanbito	Foutz No. 1	140	300	300	160	900
E25	Iyanbito	Williams and Reynolds	100	10	10	160	280
E26	Iyanbito	Christensen Mine	130	0	0	160	290
E27	Iyanbito	Rats Nest Mine	140	0	0	160	300
E28	Iyanbito	Westwater #1	130	0	0	160	290
E29	Mariano Lake	Mariano Lake	130	465	465	160	1220
E30	Mariano Lake	Mariano Lake	200	785	785	160	1930
E31	Mariano Lake	Mac No. 1	230	790	790	160	1970
E32	Smith Lake	Black Jack No. 2	250	370	370	160	1150
E33	Smith Lake	Mac No. 2	170	80	80	160	490
E34	Smith Lake	Ruby No. 1	690	320	320	160	1490
E35	Crownpoint	Crownpoint ISL	540	8470	8470	160	17640
E36	Crownpoint	Section 29-Conoco	240	2725	2725	160	5850
E39	Smith Lake	Black Jack No. 1	530	540	540	160	1770
E40	Smith Lake	Ruby No. 3	700	295	295	160	1450
E41a	Casamero Lake	Section 32	230	115	115	160	620
E41b	Casamero Lake	Section 33	230	115	115	160	620
E42	Thoreau	Largo	780	60	60	160	1060
E43	Smith Lake	Reynolds	670	0	0	160	830
E44	Baca/Prewitt	Silver Bit No. 15	350	20	20	160	550
E45	Baca/Prewitt	Silver Bit No. 18	350	70	70	160	650
E46	Baca/Prewitt	Alta	360	0	0	160	520
E47	Baca/Prewitt	Francis	300	0	0	160	460
E48	Baca/Prewitt	Evelyn	320	0	0	160	480
E49	Baca/Prewitt	Elkins	780	190	190	160	1320
E50	Baca/Prewitt	Elkins	780	200	200	160	1340
E51	Baca/Prewitt	Billy the Kid	1210	1795	1795	160	4960
E52	Baca/Prewitt	Glover	1100	705	705	160	2670
E53	Baca/Prewitt	Red Top	950	465	465	160	2040
E54	Baca/Prewitt	Haven	690	240	240	160	1330
E55	Baca/Prewitt	Yucca	720	70	70	160	1020
E56	Baca/Prewitt	Red Cap	680	10	10	160	860
E57	Off Navajo Nation	Mary No. 1	210	130	130	160	630
E58	Off Navajo Nation	Kermac Mine No. 10	220	40	40	160	460
E59	Off Navajo Nation	Dysart No. 1	260	60	60	160	540
E60	Off Navajo Nation	Buckey	330	180	180	160	850
E61	Off Navajo Nation	Homestake Sapin Mine No. 15	370	50	50	160	630
E62	Baca/Prewitt	Kermac Mine No. 22	410	50	50	160	670
E63	Off Navajo Nation	Homestake Sapin Mine No. 23	430	60	60	160	710
E64	Off Navajo Nation	Kermac Mine No. 24	300	130	130	160	720
E65	Off Navajo Nation	Homestake Sapin Mine No. 25	300	315	315	160	1090
E66	Baca/Prewitt	Section 34	530	0	0	160	690
E67	Baca/Prewitt	Lost Mine	290	0	0	160	450
E68	Baca/Prewitt	Section 2	390	160	160	160	870
E69	Baca/Prewitt	Section 1	80	280	280	160	800
E70	Baca/Prewitt	Febco	70	230	230	160	690
E71	Baca/Prewitt	Silver Spur	90	150	150	160	550
E72	Baca/Prewitt	Section 5	140	250	250	160	800
E73	Baca/Prewitt	Junior	110	40	40	160	350

Table 9. Eastern AUM Region Combined Pathway Scores (continued)

Map-ID	Chapter	Mine Name / Identifier Name	Total Ground Water Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
E74	Baca/Prewitt	Section 4	150	60	60	160	430
E75	Baca/Prewitt	Dakota	110	50	50	160	370
E76	Baca/Prewitt	Pat	110	80	80	160	430
E77	Baca/Prewitt	Haystack	350	320	320	160	1150
E78	Baca/Prewitt	Haystack No. 2	410	420	420	160	1410
E79	Baca/Prewitt	Haystack	290	465	465	160	1380
E80	Baca/Prewitt	Bibo Trespass	270	610	610	160	1650
E81	Baca/Prewitt	Section 24	300	575	575	160	1610
E82	Baca/Prewitt	Haystack No. 1	280	815	815	160	2070
E83	Baca/Prewitt	Section 18	250	685	685	160	1780
E84	Baca/Prewitt	Section 18	240	820	820	160	2040
E85	Baca/Prewitt	Section 18 SEQ	260	590	590	160	1600
E86	Baca/Prewitt	Red Point Lode	100	0	0	160	260
E87	Baca/Prewitt	Section 22	220	110	110	160	600
E88	Off Navajo Nation	Bobcat	330	40	40	160	570
E89	Off Navajo Nation	Blue Peak	360	10	10	160	540
E90	Baca/Prewitt	Section 23	380	355	355	160	1250
E91	Baca/Prewitt	Section 26	260	655	655	160	1730
E92	Baca/Prewitt	Section 26	370	250	250	160	1030
E93	Off Navajo Nation	Section 25	580	140	140	160	1020
E95	Off Navajo Nation	Divide	440	10	10	160	620
E96	Off Navajo Nation	Section 25 Decline	610	10	10	160	790
E97	Baca/Prewitt	Section 26	290	250	250	160	950
E98	Off Navajo Nation	Section 25	590	90	90	160	930
E99	Off Navajo Nation	Section 25	690	10	10	160	870
E100	Off Navajo Nation	Section 30	550	10	10	160	730
E101	Off Navajo Nation	Section 36	570	10	10	160	750
E102	Baca/Prewitt	Haystack	290	510	510	160	1470
E103	Baca/Prewitt	Haystack	220	545	545	160	1470



Occupied home within 500 feet of the NE Churchrock AUM tailings pile. Photo courtesy of Southwest Research and Information Center.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

NORTH CENTRAL AUM REGION COMBINED PATHWAYS - MAP FIGURE INDEX

Sources

Abandoned uranium mine areas are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by several other sources. The Navajo Nation and Chapter boundaries are from the Navajo Land Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Selected Populated Places are from the USGS Geographic Names Information System (GNIS). Buffers were generated by TerraSpectra Geomatics. Map index figure outlines are approximate.

Map Area Designations

Figure
13 - Monitor Mesa
14 - Mexican Hat
15 - North Nokai Mesa
16 - Oljato
17 - South Nokai Mesa
18 - South El Capitan Flat
19 - Monument Valley
20 - Cane Valley

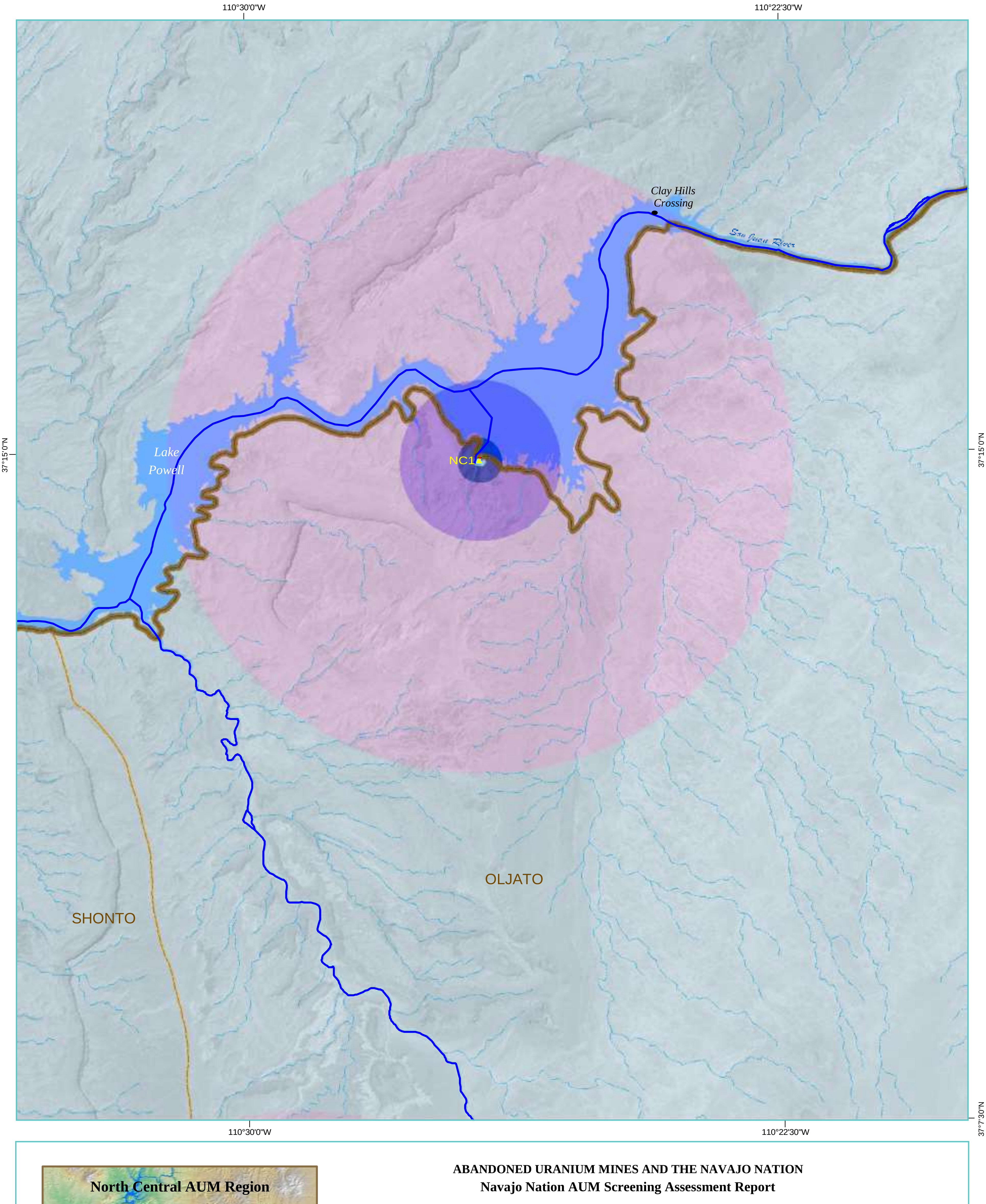
0 10 Miles

Map Scale 1:500,000

Legend

North Central AUM Region
Chapter
Abandoned Uranium Mine
Mine Buffers
1/4 Mile
1 Mile
4 Miles
15 Miles
Populated Places
Highways

Fig 12 No h Ce l AUM Regi n Co bined P h M p Fig Ind



ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - MONITOR MESA

0 — 4 Miles

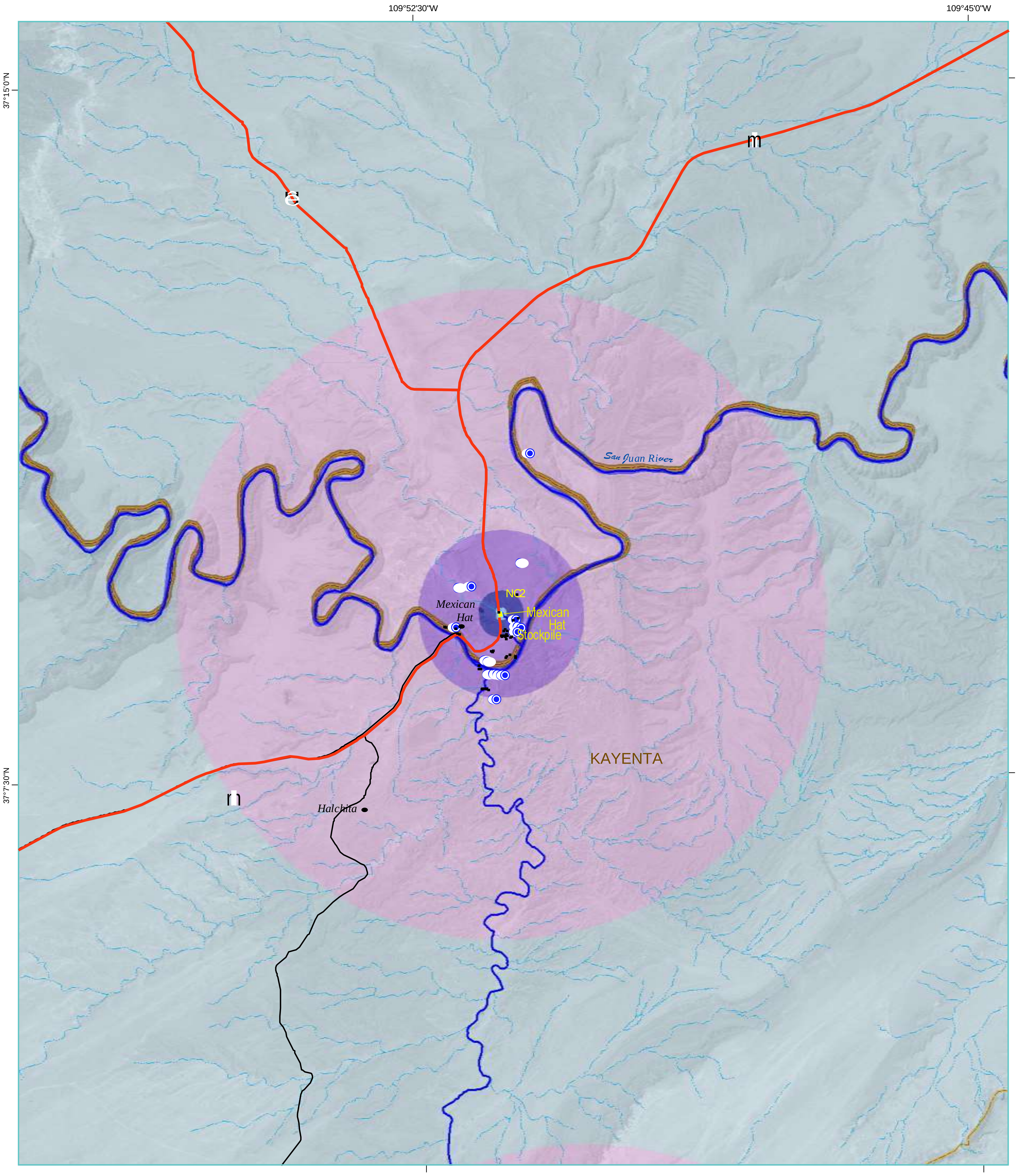
Map Scale 1:80,000

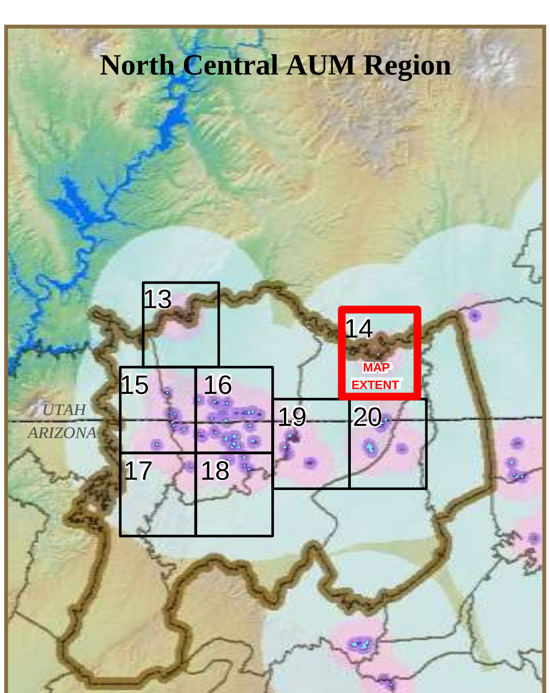
Legend

- NC1 Downstream Water Pathway MAP-ID
- Mine Feature
- Abandoned Uranium Mine
- Intermittent Stream
- North Central AUM Region
- Chapter

Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 13. Combined Pathways in the Monitor Mesa Area.





109°52'30"W

109°45'0"W

ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - MEXICAN HAT

N W E S

0 4 Miles

Map Scale 1:80,000

Legend

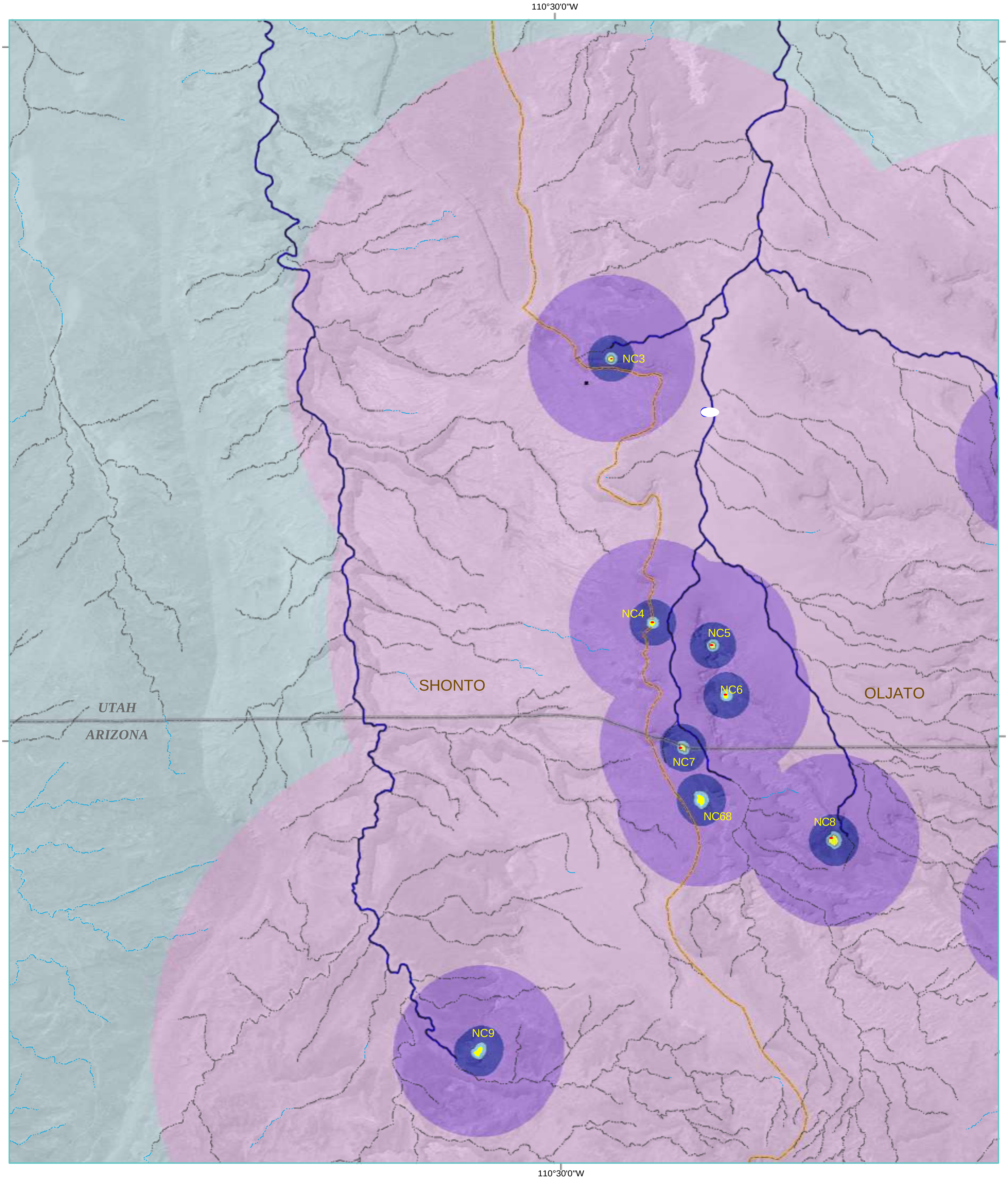
NC2 Downstream Water Pathway
Structure within 1 mile
Well within 4 milles

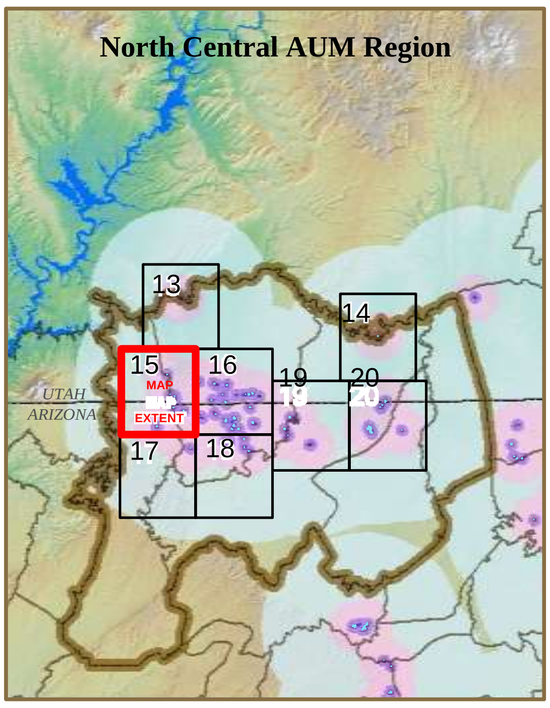
Abandoned Uranium Mine
Intermittent Stream
North Central AUM Region
Chapter
Highway
Paved Road

Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

MAP-ID

Figure 14. Combined Pathways in the Mexican Hat Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NORTH NOKAI MESA

0 4 Miles

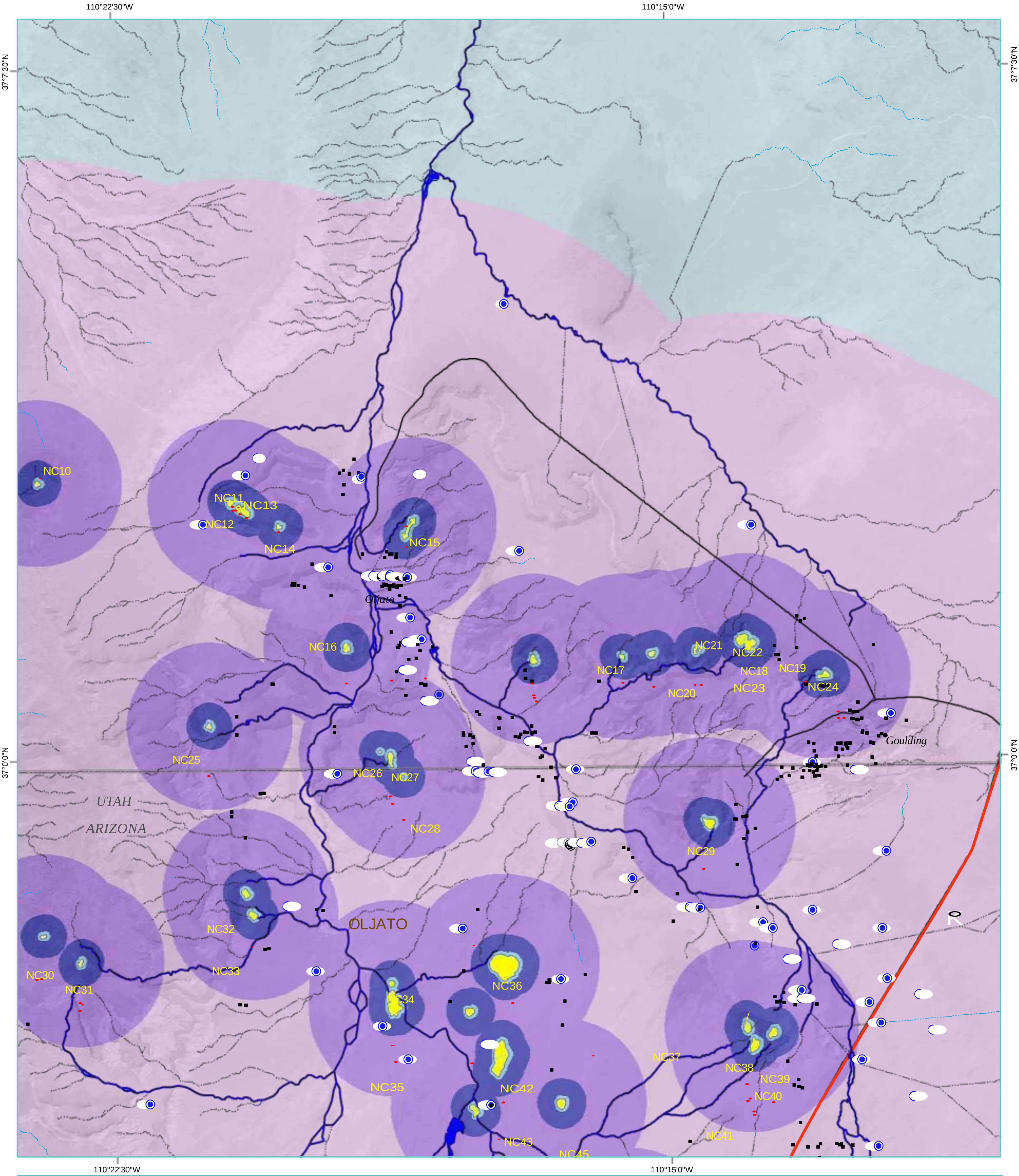
Map Scale 1:80,000

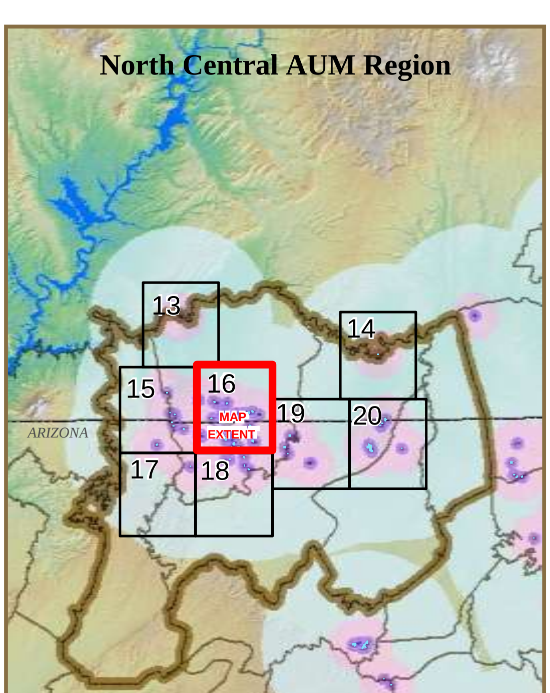
Legend

MAP-ID*
Mine Feature
Structure within 1 mile
Downstream Water Pathway
Intermittent Stream
Chapter
Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

* MAP-IDNC68 added

Figure 15. Combined Pathways in the North Nokai Mesa Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - OLJATO

N
W E
S

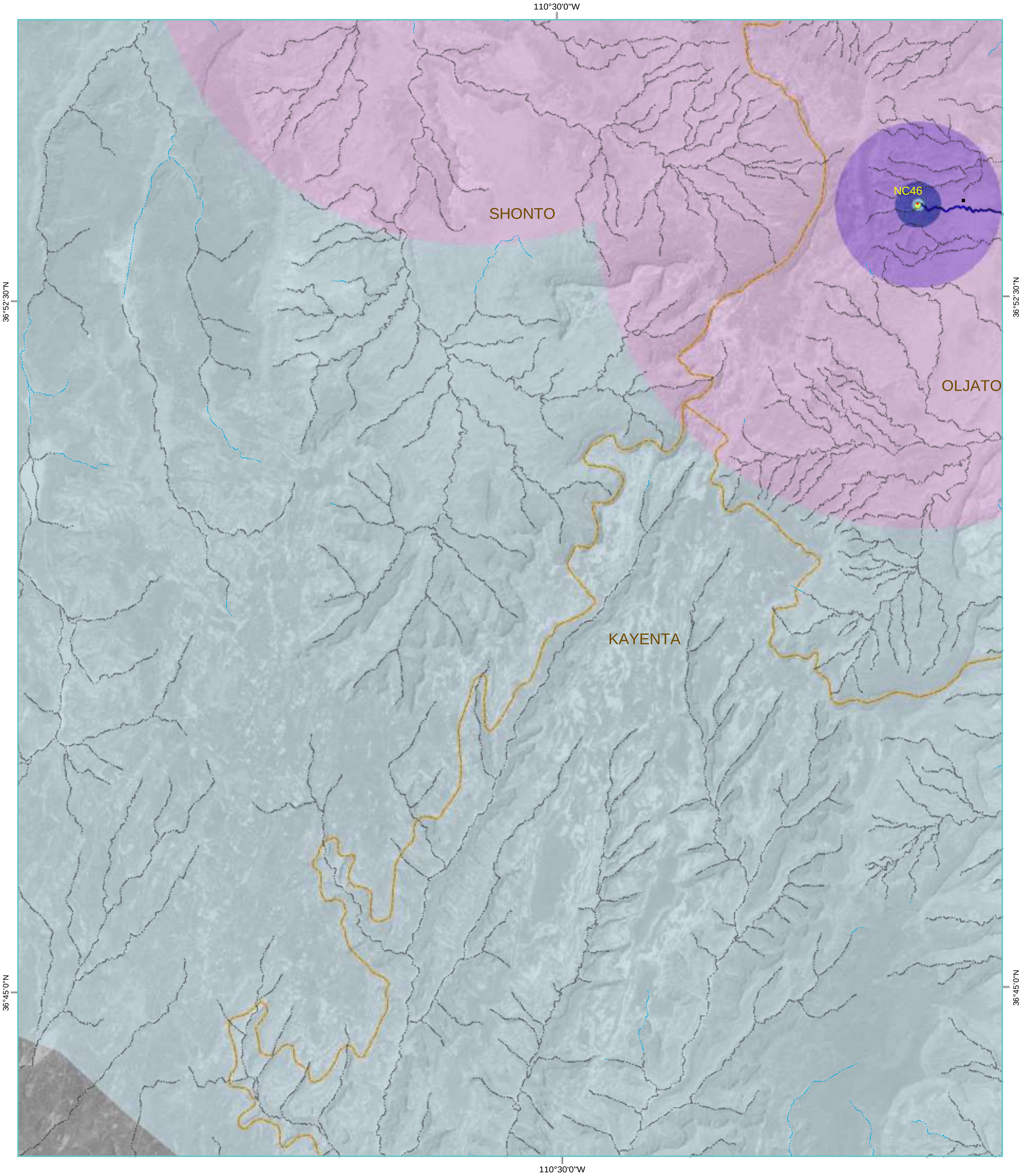
0 4 Miles

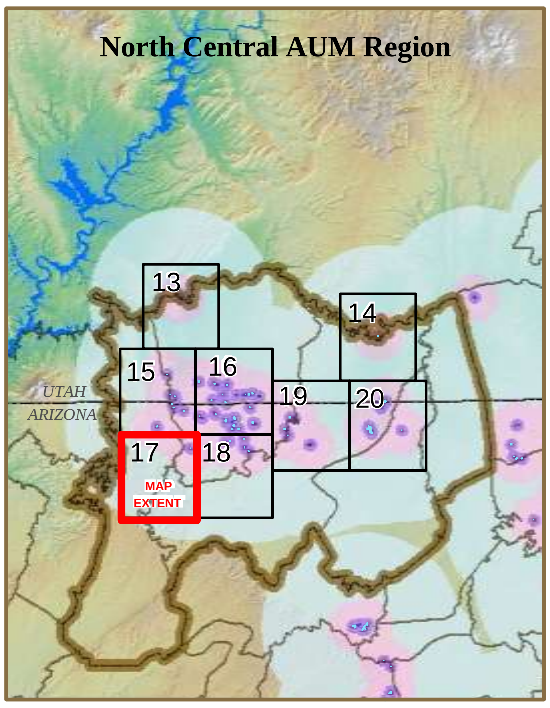
Map Scale 1:80,000

Legend

- NC10 MAP-ID
- Mine Feature
- Structure within 1 mile
- Well within 4 milles
- Downstream Water Pathway
- Intermittent Stream
- Highway
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 16. Combined Pathways in the Oljato Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Region Screening Assessment Report

COMBINED PATHWAYS - SOUTH NOKAI MESA

0 — 4 Miles

Map Scale 1:80,000

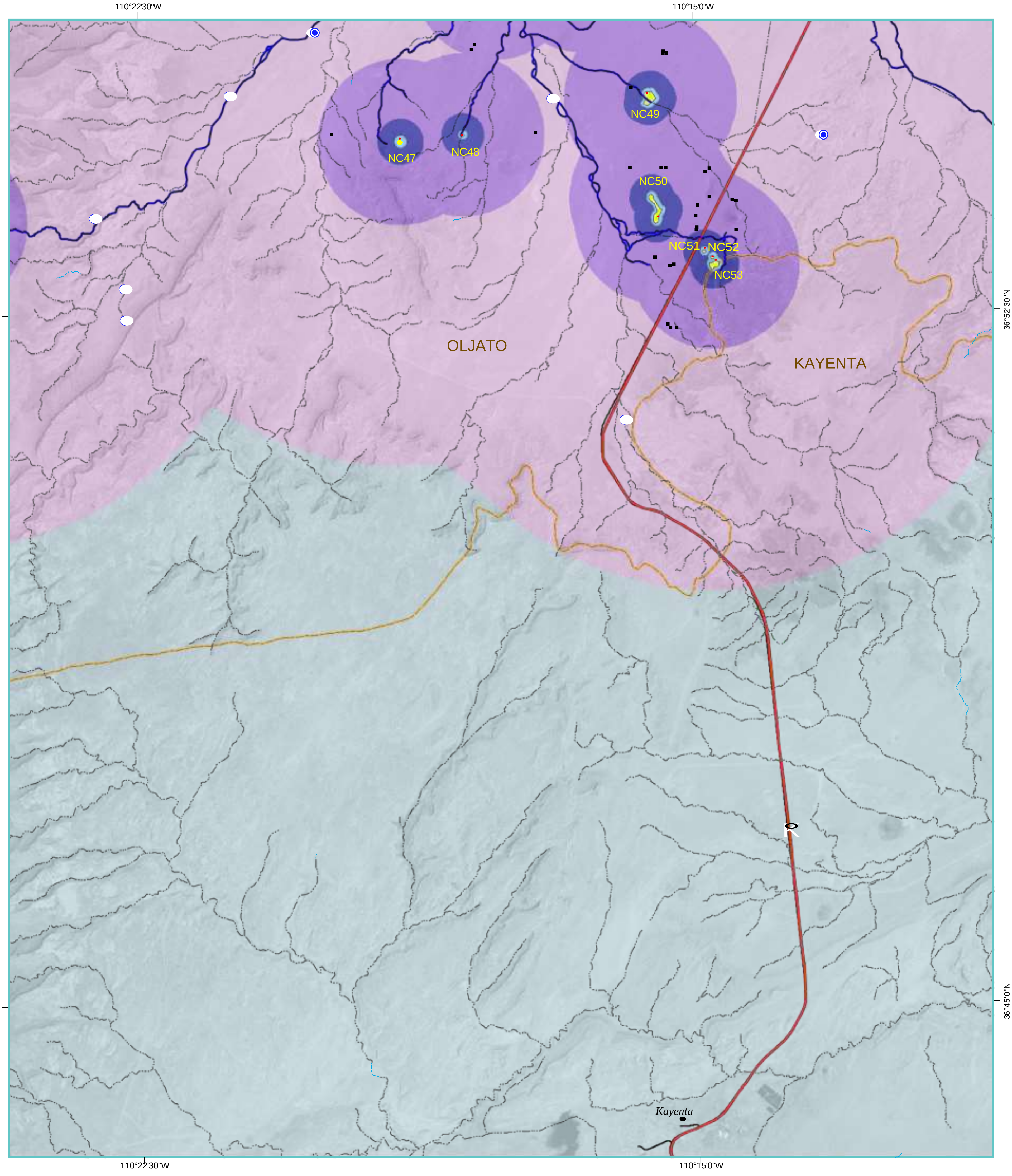
Legend

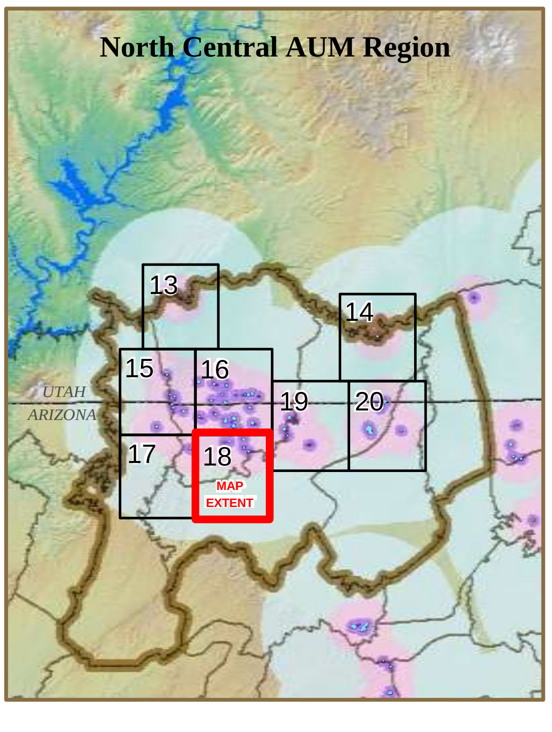
- NC46 MAP-ID
- Mine Feature
- Structure within 1 mile
- Downstream Water Pathway
- Intermittent Stream
- Chapter
- Abandoned Uranium Mine

Mine Buffers

- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 17. Combined Pathways in the South Nokai Mesa Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - SOUTH EL CAPITAN FLAT

N W E S

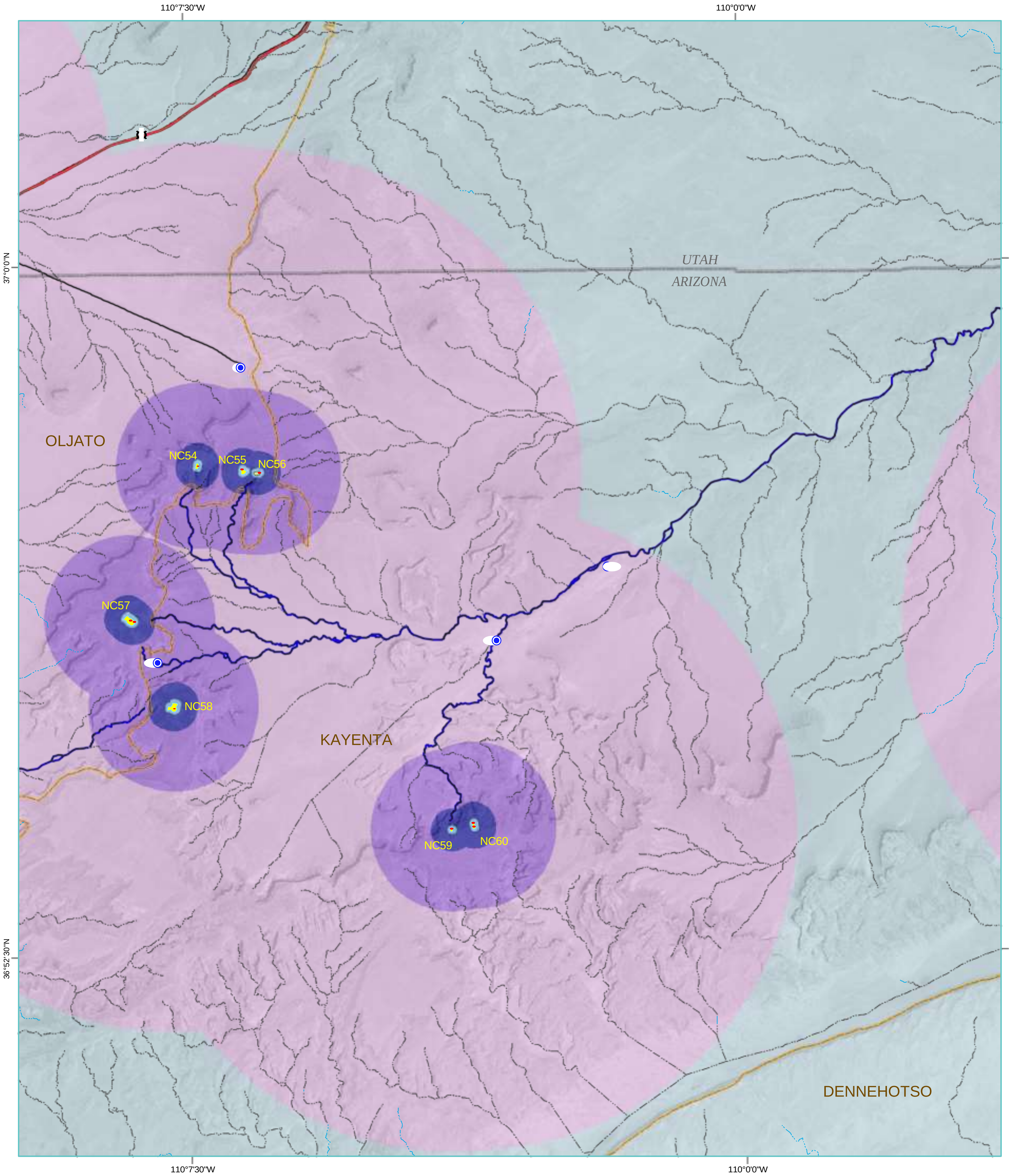
0 4 Miles

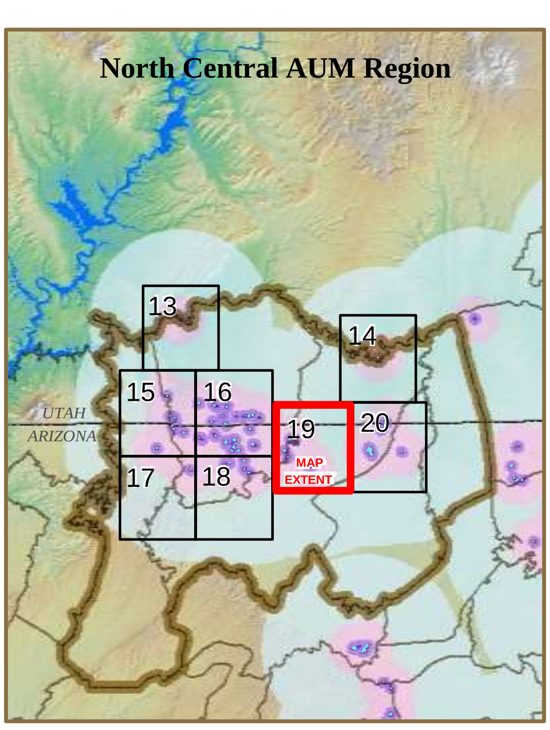
Map Scale 1:80,000

Legend

- NC47 MAP-ID
- Mine Feature
- Structure within 1 mile
- Well within 4 milles
- Downstream Water Pathway
- Intermittent Stream
- Chapter
- Highway
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 18. Combined Pathways in the South El Capitan Flat Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - MONUMENT VALLEY

N W E S

0 4 Miles

Map Scale 1:80,000

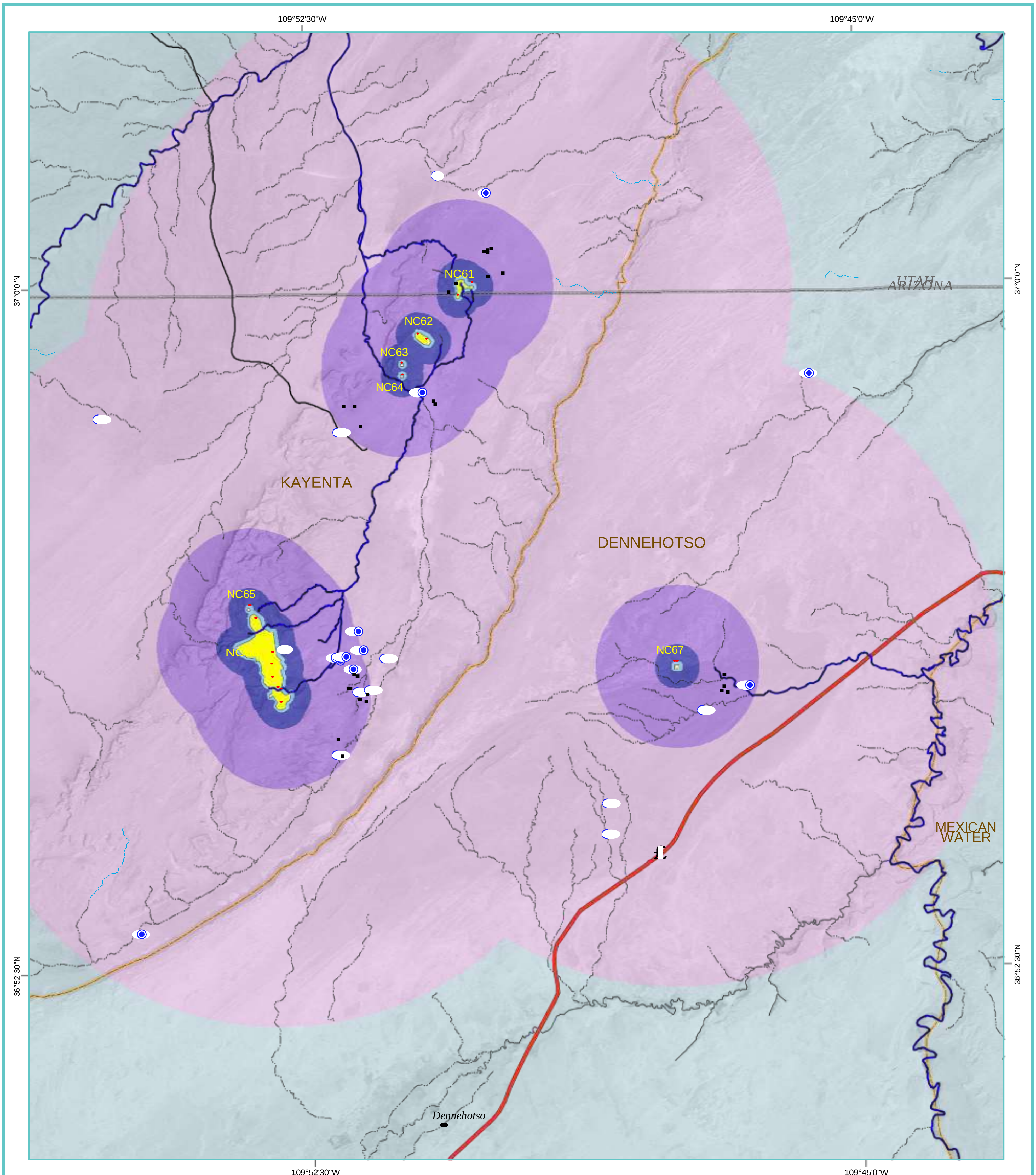
Legend

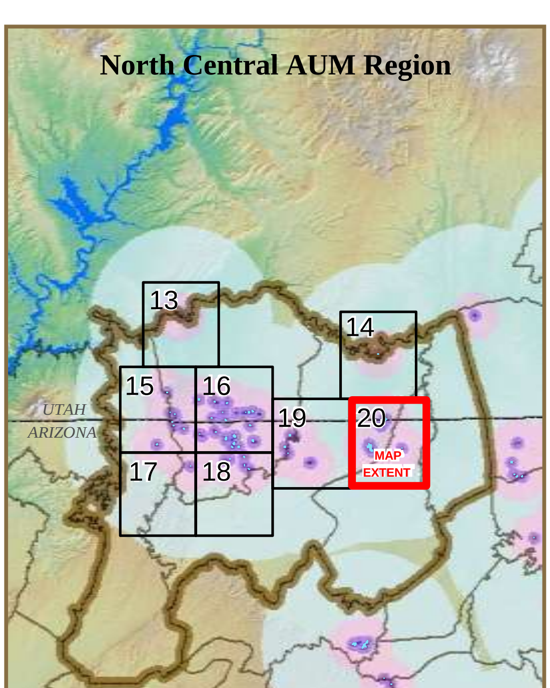
NC54 MAP-ID
Mine Feature
Well within 4 milles

Downstream Water Pathway
Intermittent Stream
Chapters
Highway
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 19. Combined Pathways in the Monument Valley Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - CANE VALLEY

N W E S

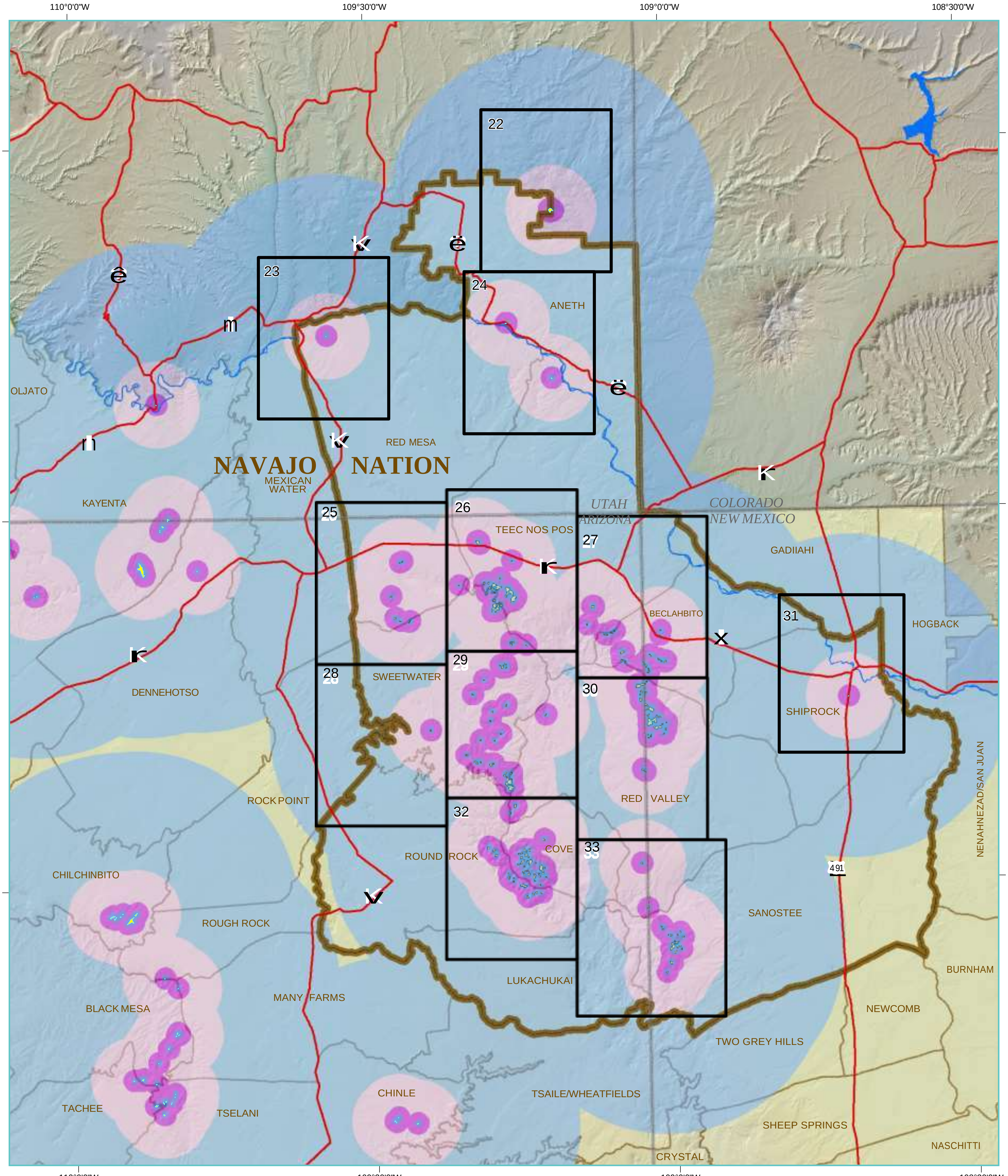
0 4 Miles

Map Scale 1:80,000

Legend

NC61	MAP-ID		Downstream Water Pathway		Abandoned Uranium Mine
	Mine Feature		Perennial Stream		Mine Buffers
	Structure within 1 mile		Intermittent Stream		200 Feet
	Well within 4 miles		Chapter		1/4 Mile
			Highway		1 Mile
			Paved Road		4 Miles
					15 Miles

Figure 20. Combined Pathways in the Cane Valley Area.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

NORTHERN AUM REGION COMBINED PATHWAYS - MAP INDEX

Sources

Abandoned uranium mine areas are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by several other sources. The Navajo Nation and Chapter boundaries are from the Navajo Land Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Buffers were generated by TerraSpectra Geomatics. Map index figure outlines are approximate.

Map Index Area Designations

Figure

22 - North Central Aneth
23 - Northwest Red Mesa
24 - North Teec Nos Pos
25 - South Red Mesa
26 - Tse Tah
27 - Northeast Carrizo
28 - Southwest Sweetwater
29 - West Carrizo
30 - East Carrizo
31 - Shiprock
32 - Lukachukai
33 - Chuska

0 20 Miles

Map Scale 1:600,000

Legend

Northern AUM Region

Abandoned Uranium Mine

Mine Buffers

1/4 Mile

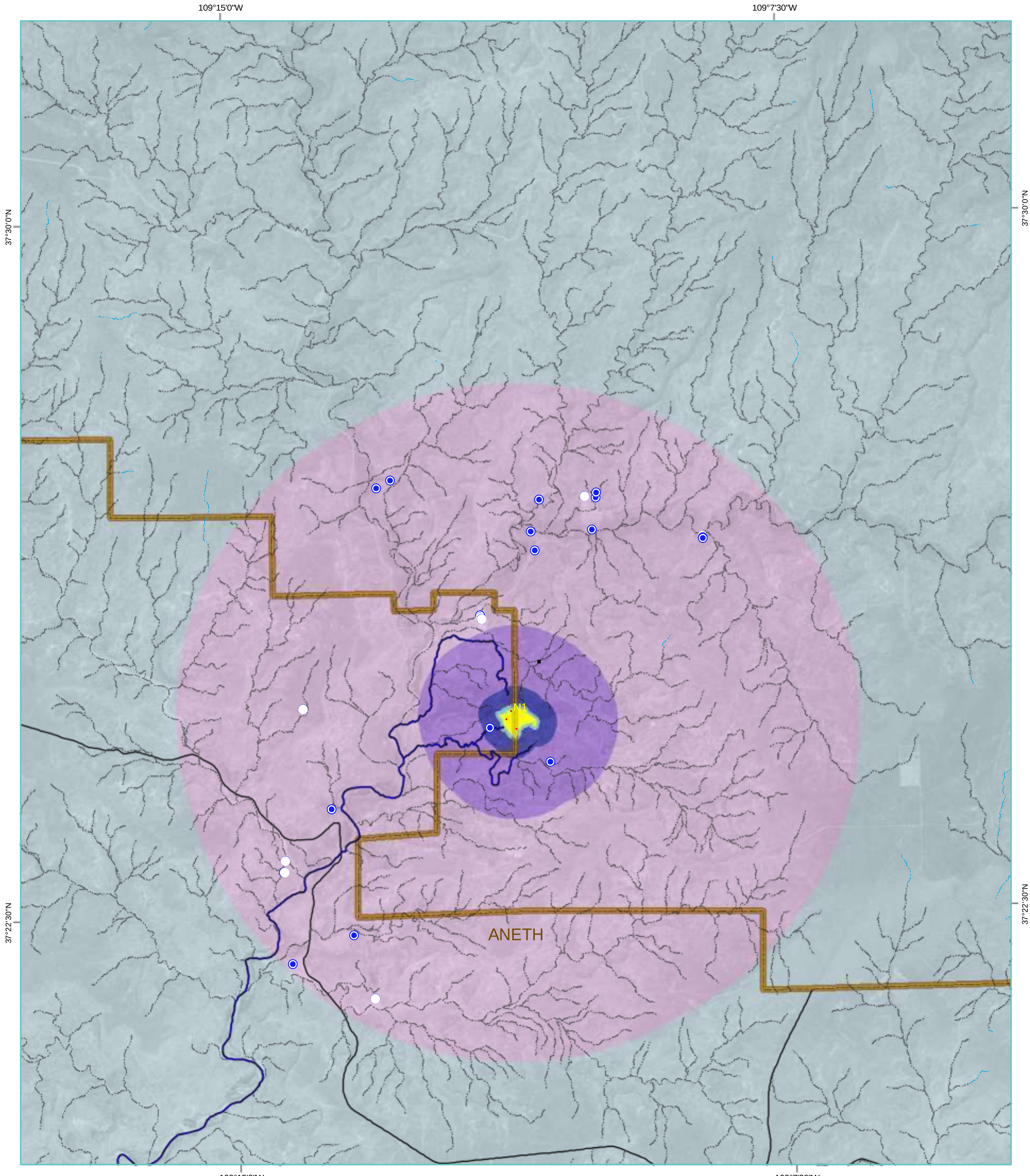
1.5 Miles

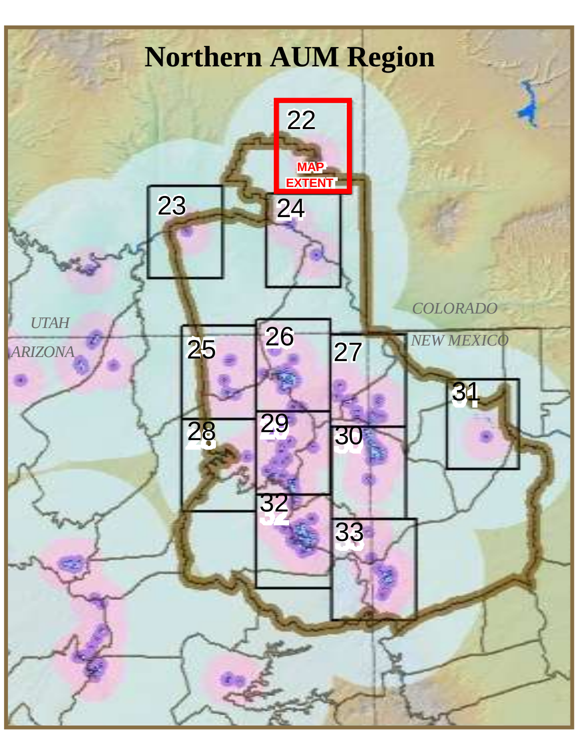
1 Mile

4 Miles

Highways

Figure 21. Northern AUM Region Combined Pathways Map Figure Index.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NORTH CENTRAL ANETH

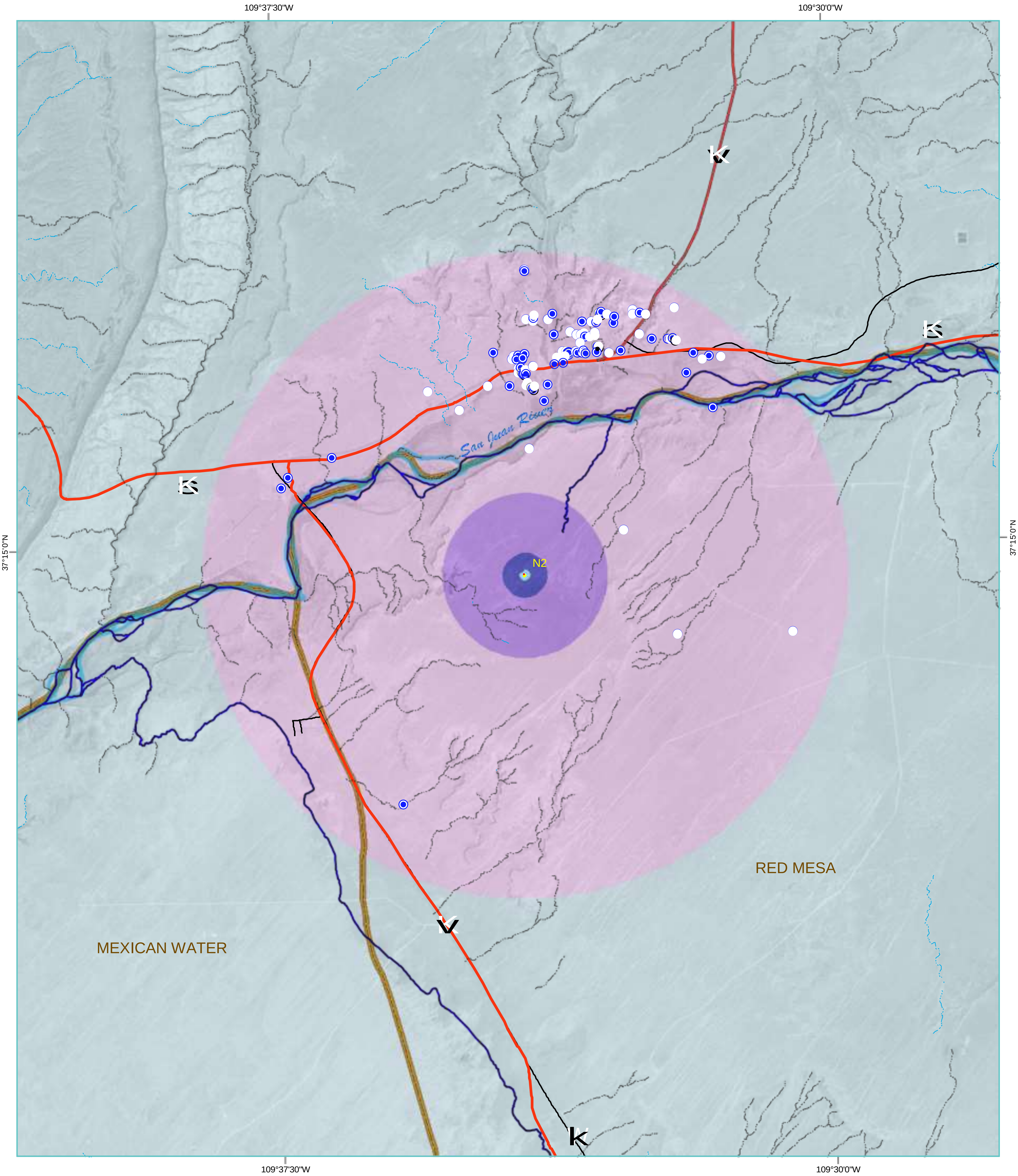
0 — 4 Miles

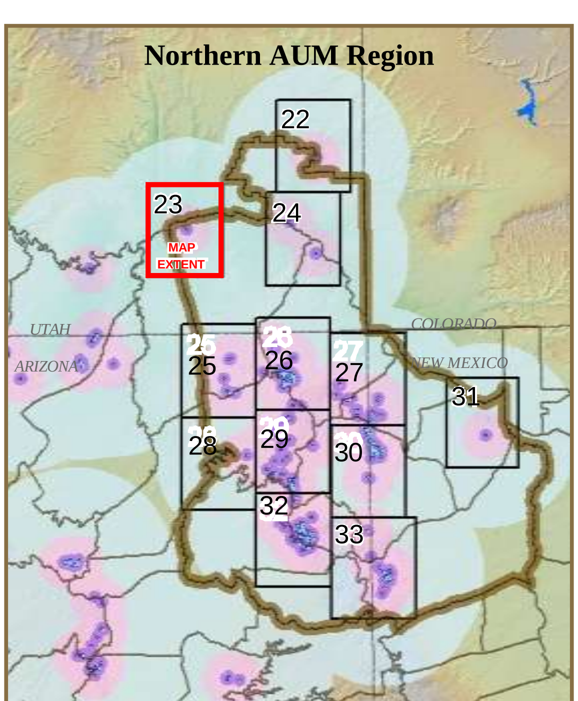
Map Scale 1:80,000

Legend

- MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Intermittent Stream
- Northern AUM Region
- Chapter
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 22. Combined Pathways in the North Central Aneth Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NORTHWEST RED MESA

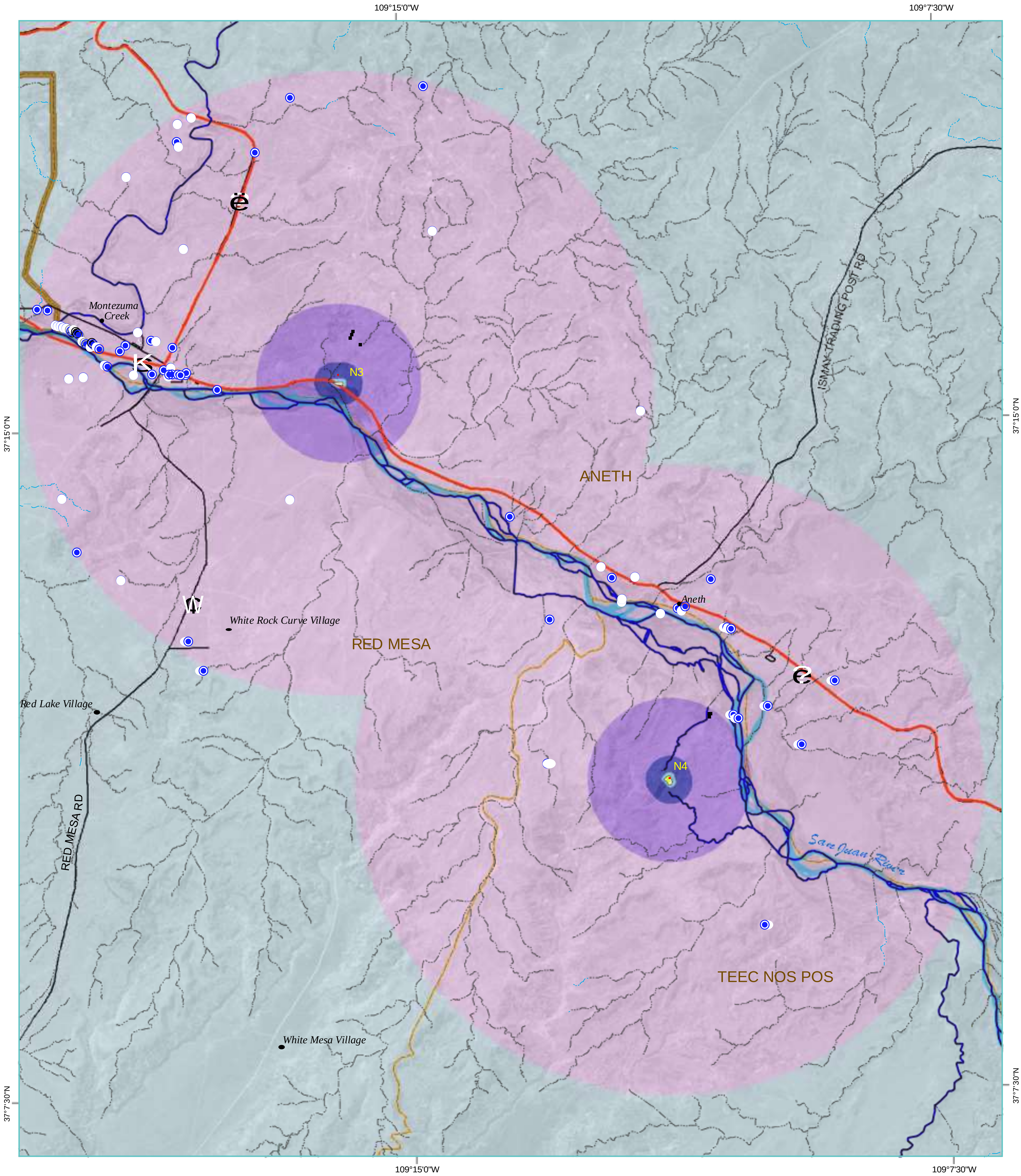
0 4 Miles

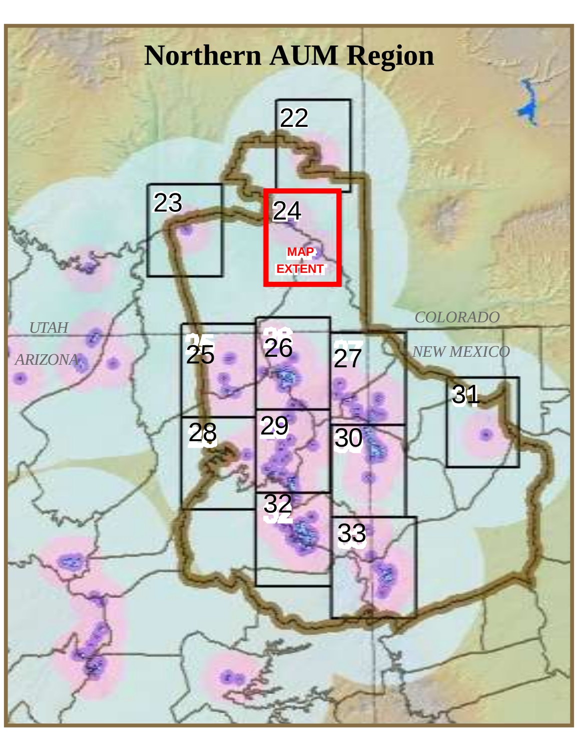
Map Scale 1:80,000

Legend

- MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Perennial Stream
- Intermittent Stream
- Northern AUM Region
- Chapter
- Highway
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 23. Combined Pathways in the Northwest Red Mesa Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NORTH TEEC NOS POS

N W E S

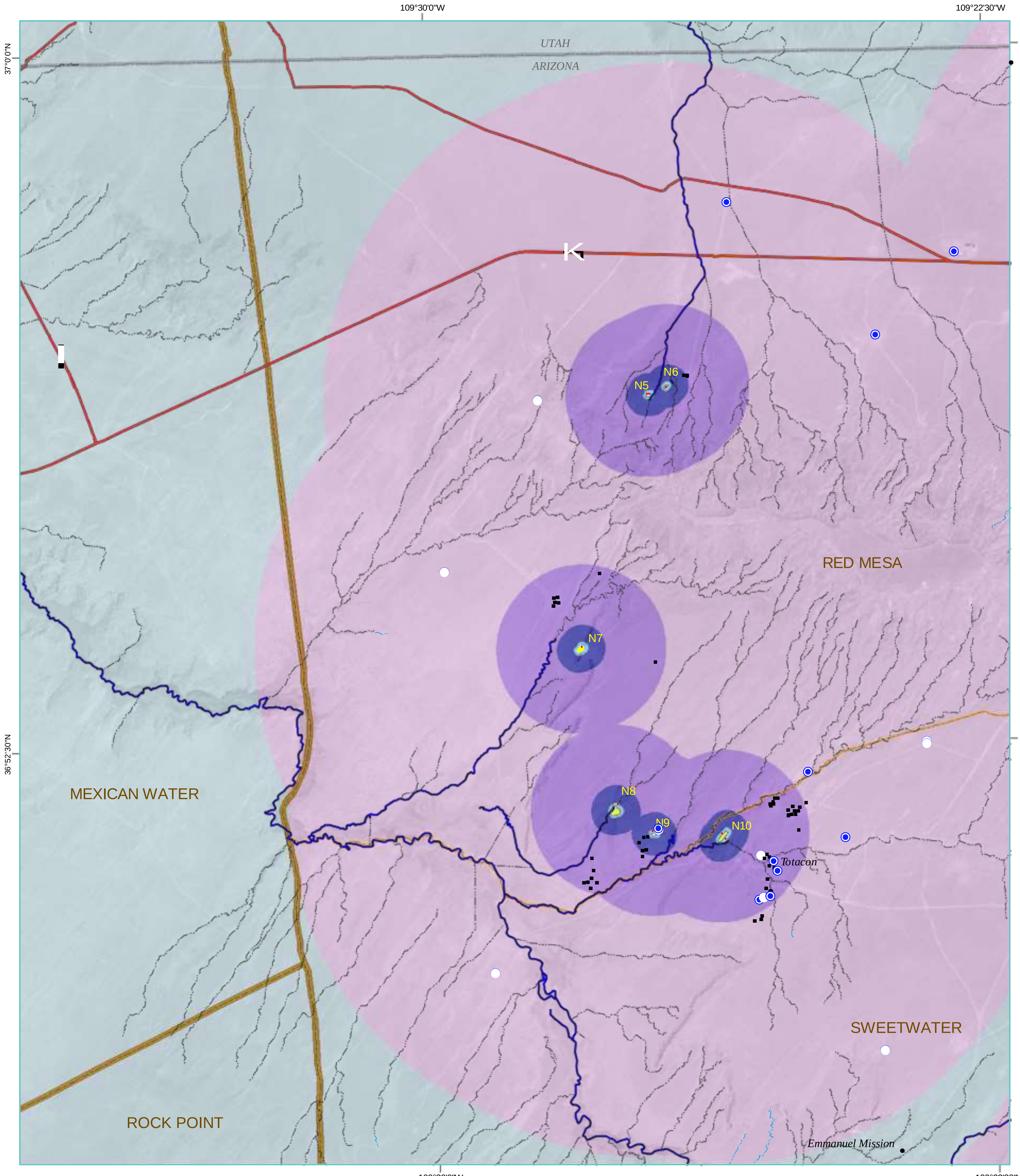
0 4 Miles

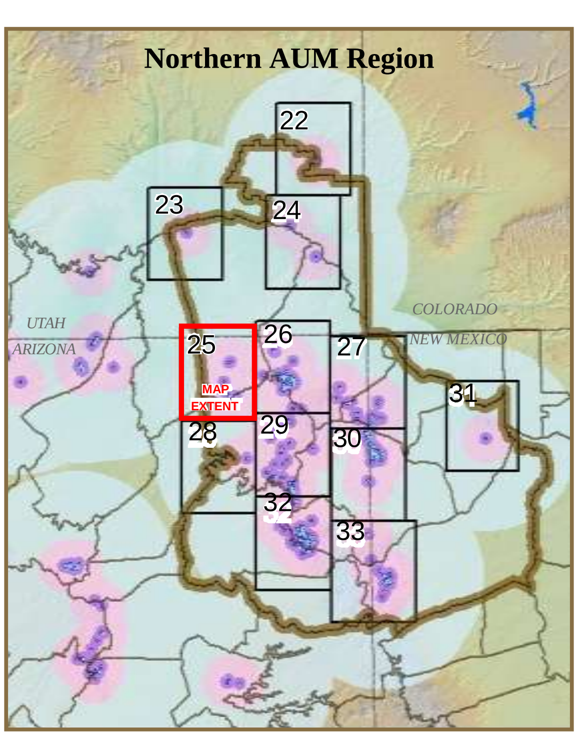
Map Scale 1:82,500

Legend

- N3 MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Perennial Stream
- Intermittent Stream
- Northern AUM Region Chapter
- Highway
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 24. Combined Pathways in the North Teec Nos Pos Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - SOUTH RED MESA

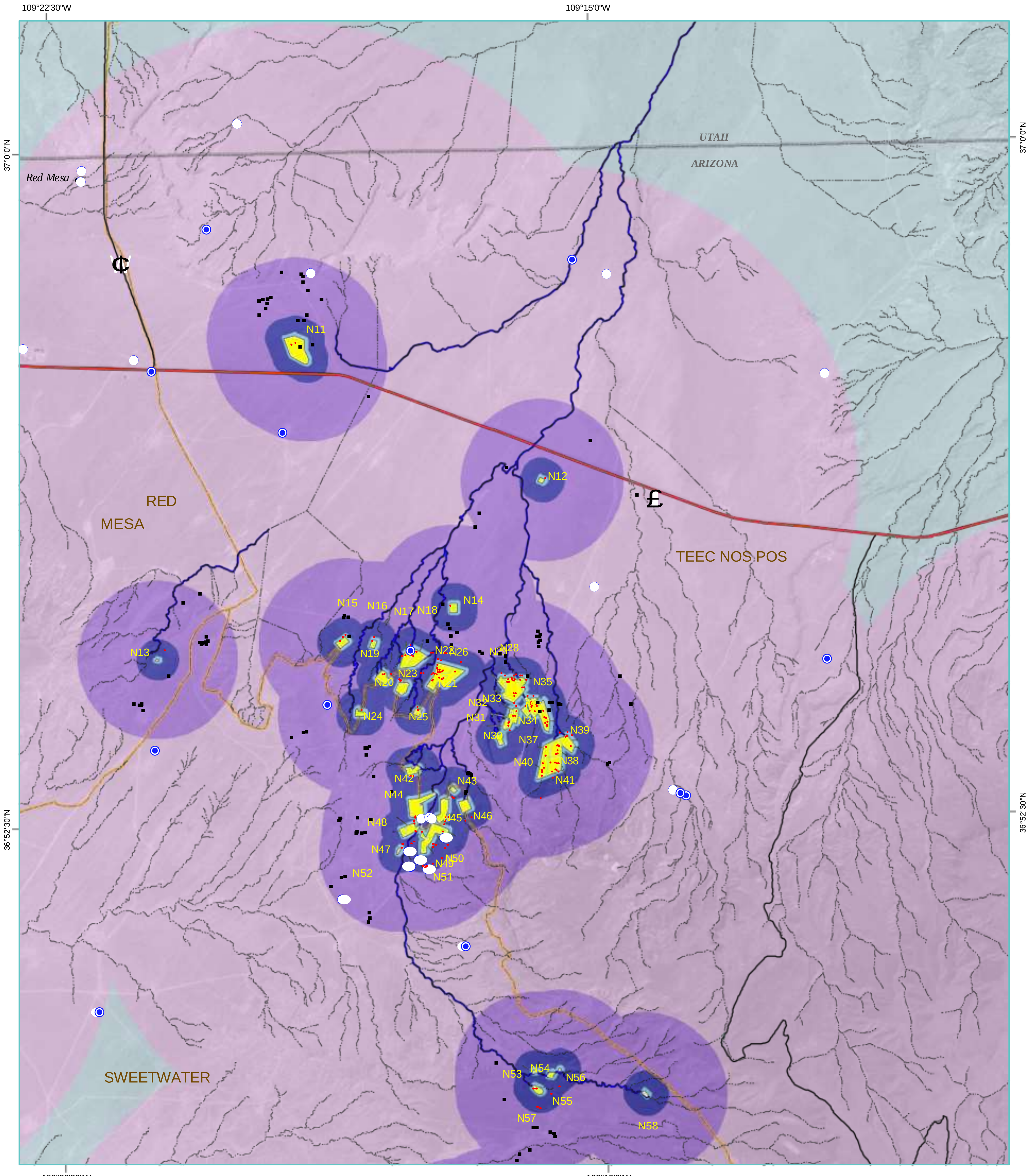
0 — 4 Miles

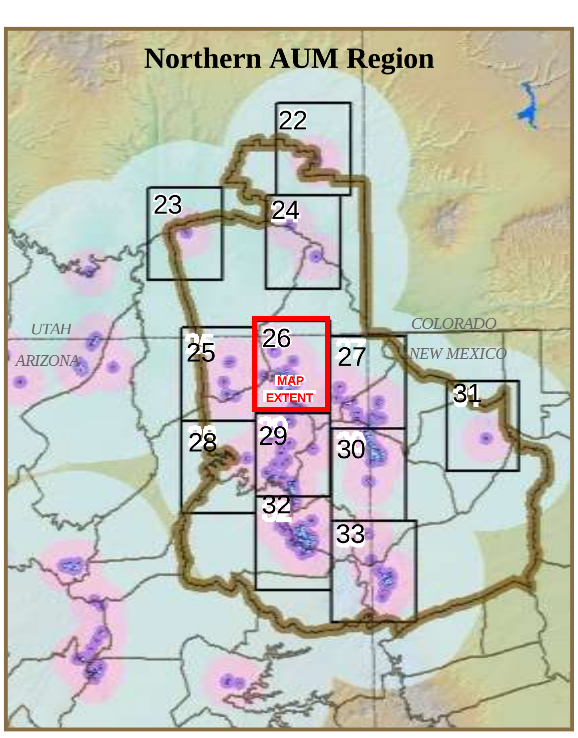
Map Scale 1:80,000

Legend

- N5 MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Intermittent Stream
- Northern AUM Region
- Chapter
- State
- Highway
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 25. Combined Pathways in the South Red Mesa Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - TSE TAH

0 — 4 Miles

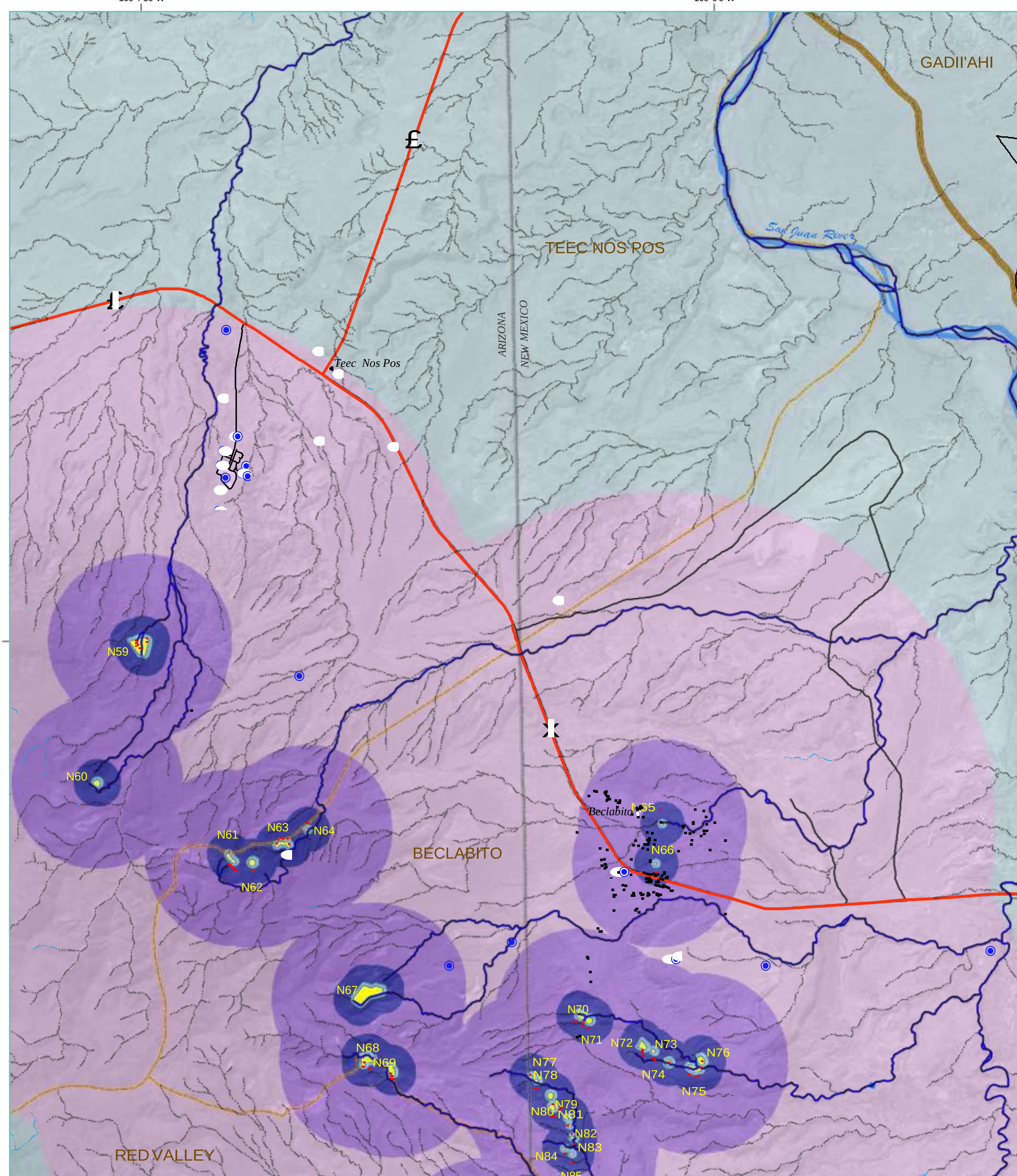
Map Scale 1:82,500

Legend

- N11 MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Intermittent Stream
- Northern AUM Region
- Chapter
- State
- Highway
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

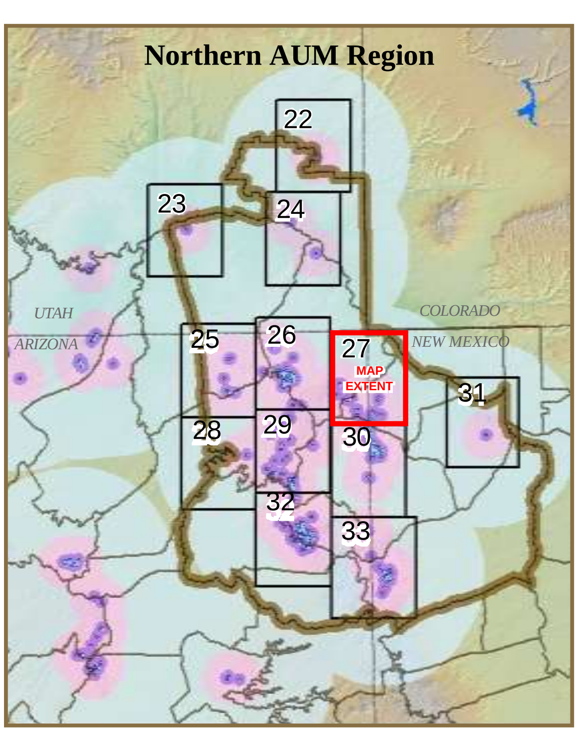
Figure 26. Combined Pathways in the Tse Tah Area.

109°7'30"W
109°0'0"W



36°52'30"N

109°7'30"W
109°0'0"W



ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NORTHEAST CARRIZO

0 4 Miles

Map Scale 1:80,000

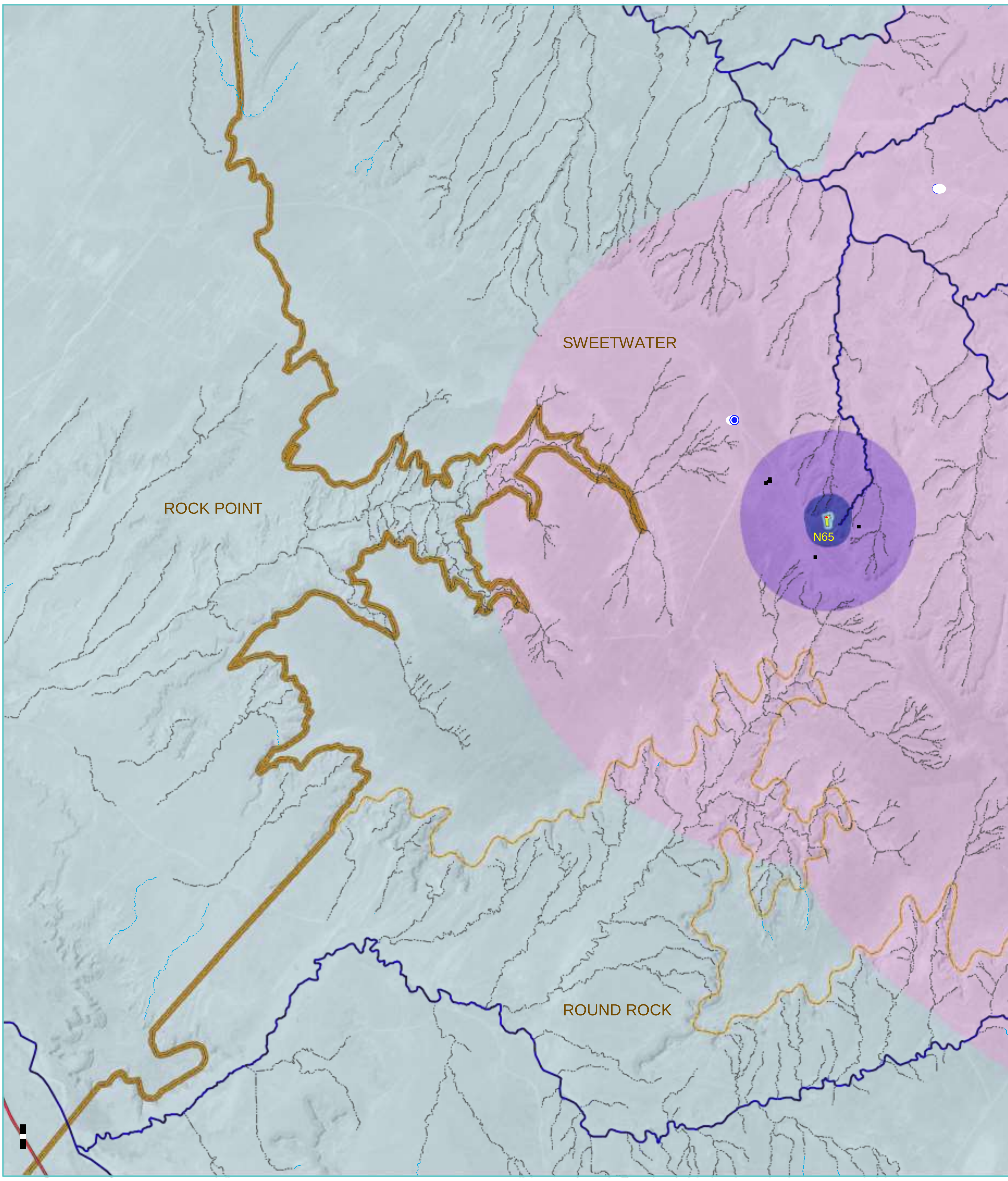
Legend

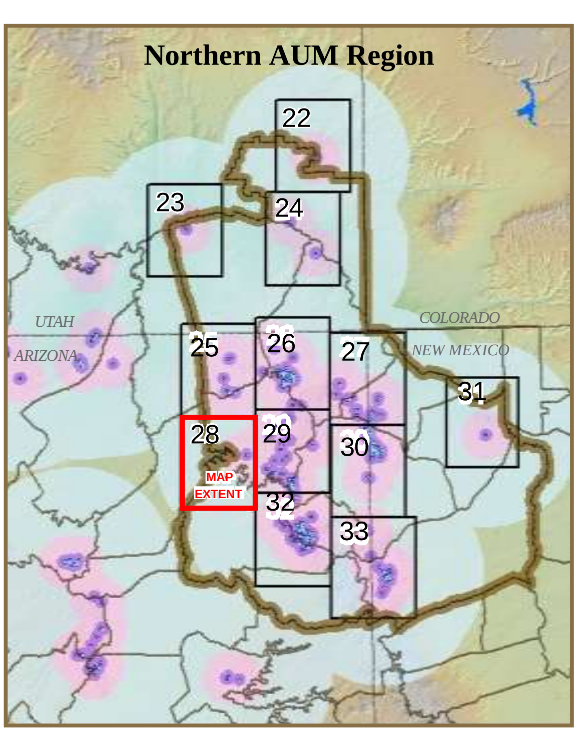
- MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Perennial Stream
- Intermittent Stream
- Northern AUM Region
- Chapter
- State
- Highway
- Paved Road
- Abandoned Uranium Mine

Mine Buffers

- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 27. Combined Pathways in the Northeast Carrizo Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - SOUTHWEST SWEETWATER

0 4 Miles

Map Scale 1:77,500

Legend

N86 MAP-ID

Mine Feature

Structure within 1 Mile

Well within 4 Miles

Downstream Water Pathway

Intermittent Stream

Northern AUM Region

Chapter

Highway

Abandoned Uranium Mine

Mine Buffers

200 Feet

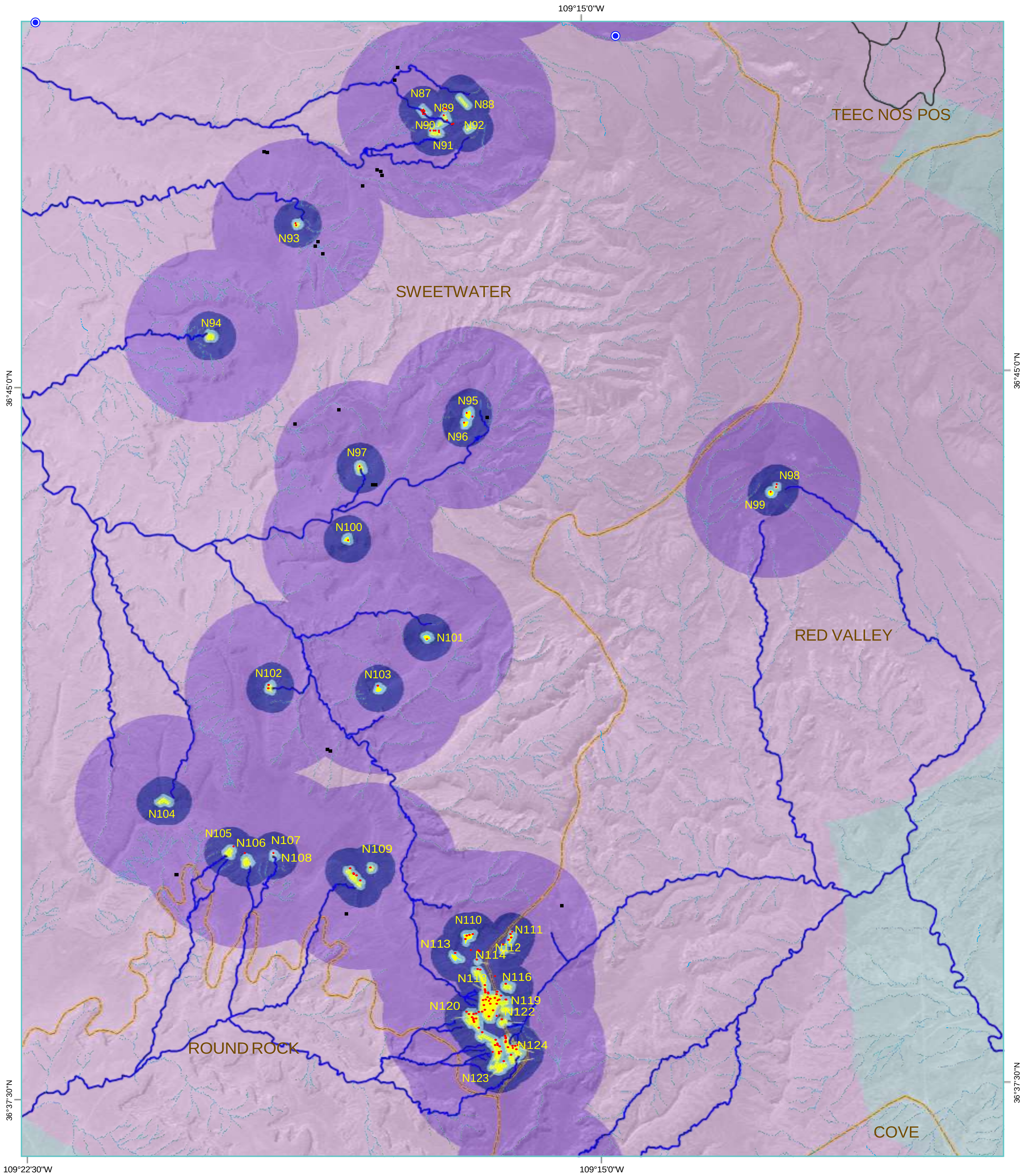
1/4 Mile

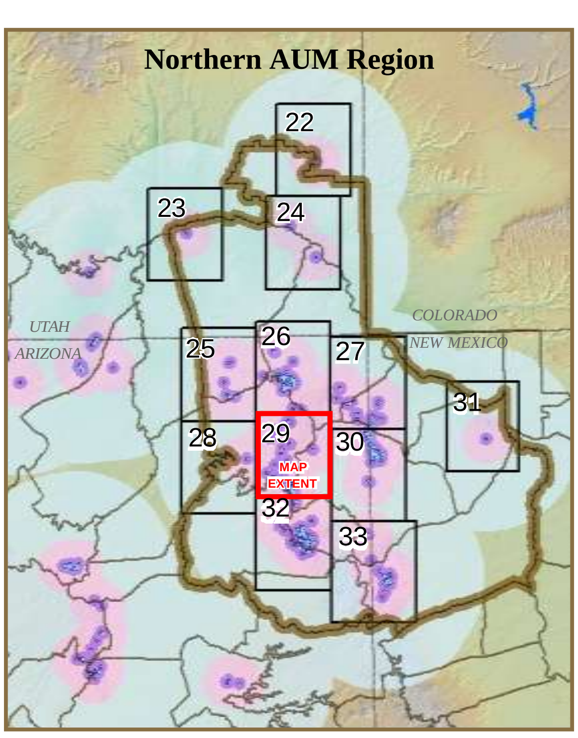
1 Mile

4 Miles

15 Miles

Figure 28. Combined Pathways in the Southwest Sweetwater Area.





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - WEST CARRIZO

0 — 4 Miles

Map Scale 1:77,500

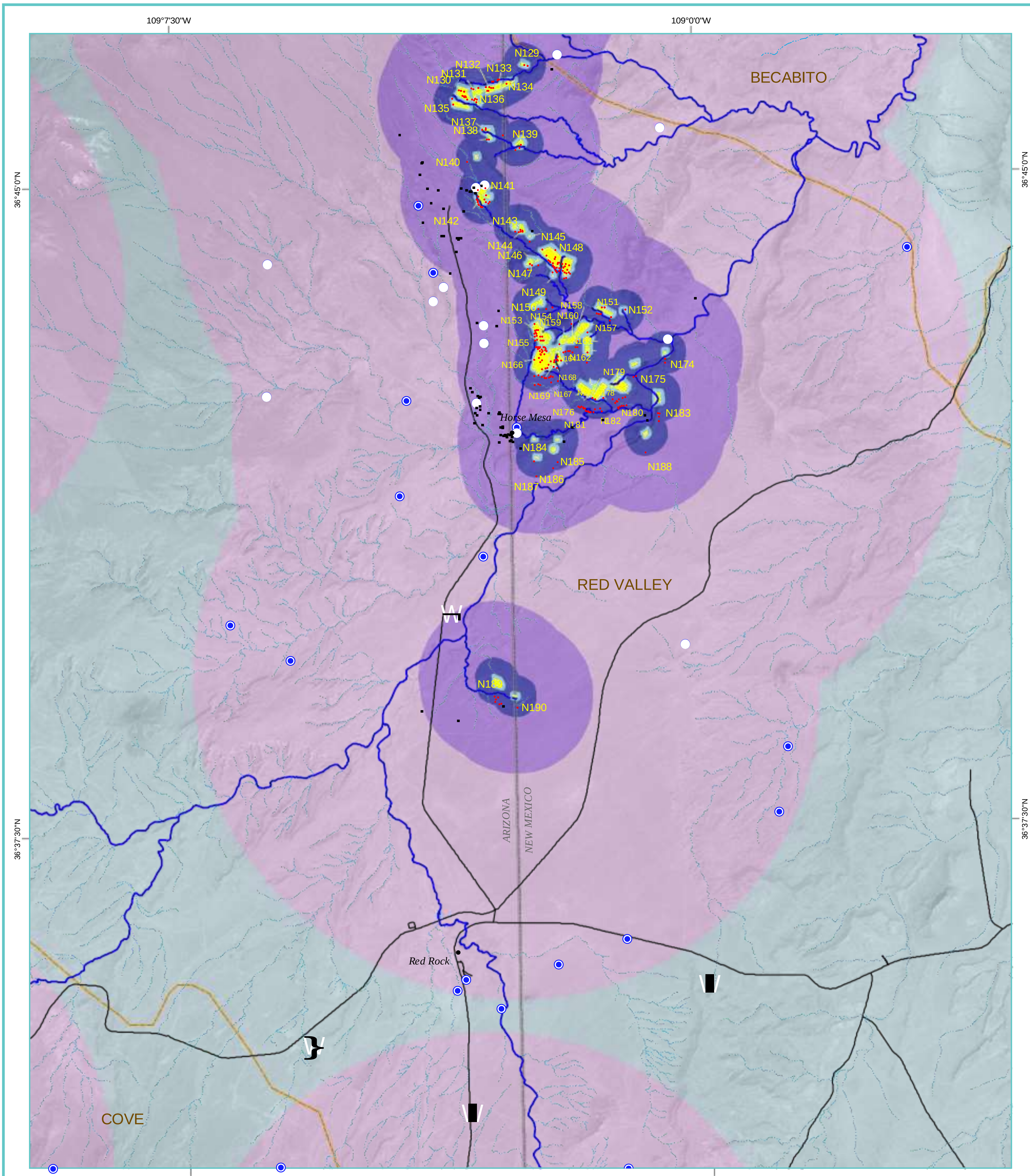
Legend

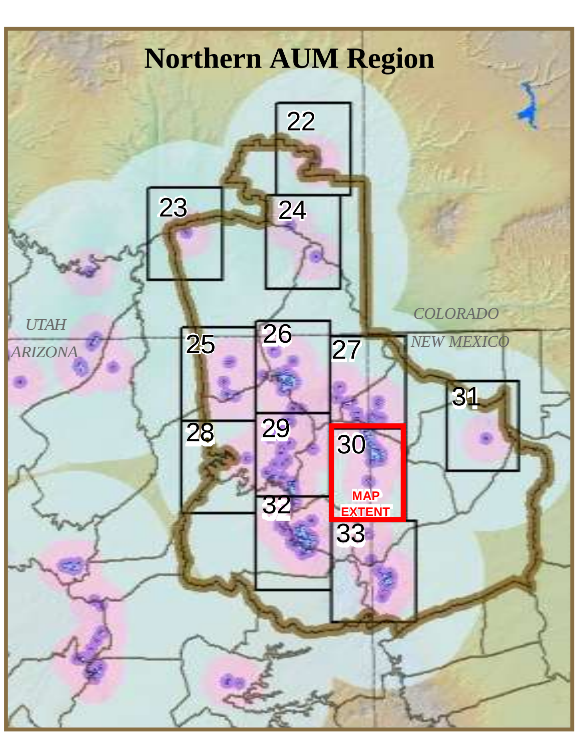
- N87 MAP-ID*
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Abandoned Uranium Mine
- Intermittent Stream
- Chapter
- Paved Road

Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

* MAP-IDs N115, N117, N121, and N125-128 deleted

Figure 29. Combined Pathways in the West Carrizo Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - EAST CARRIZO

0 4 Miles

Map Scale 1:85,000

Legend

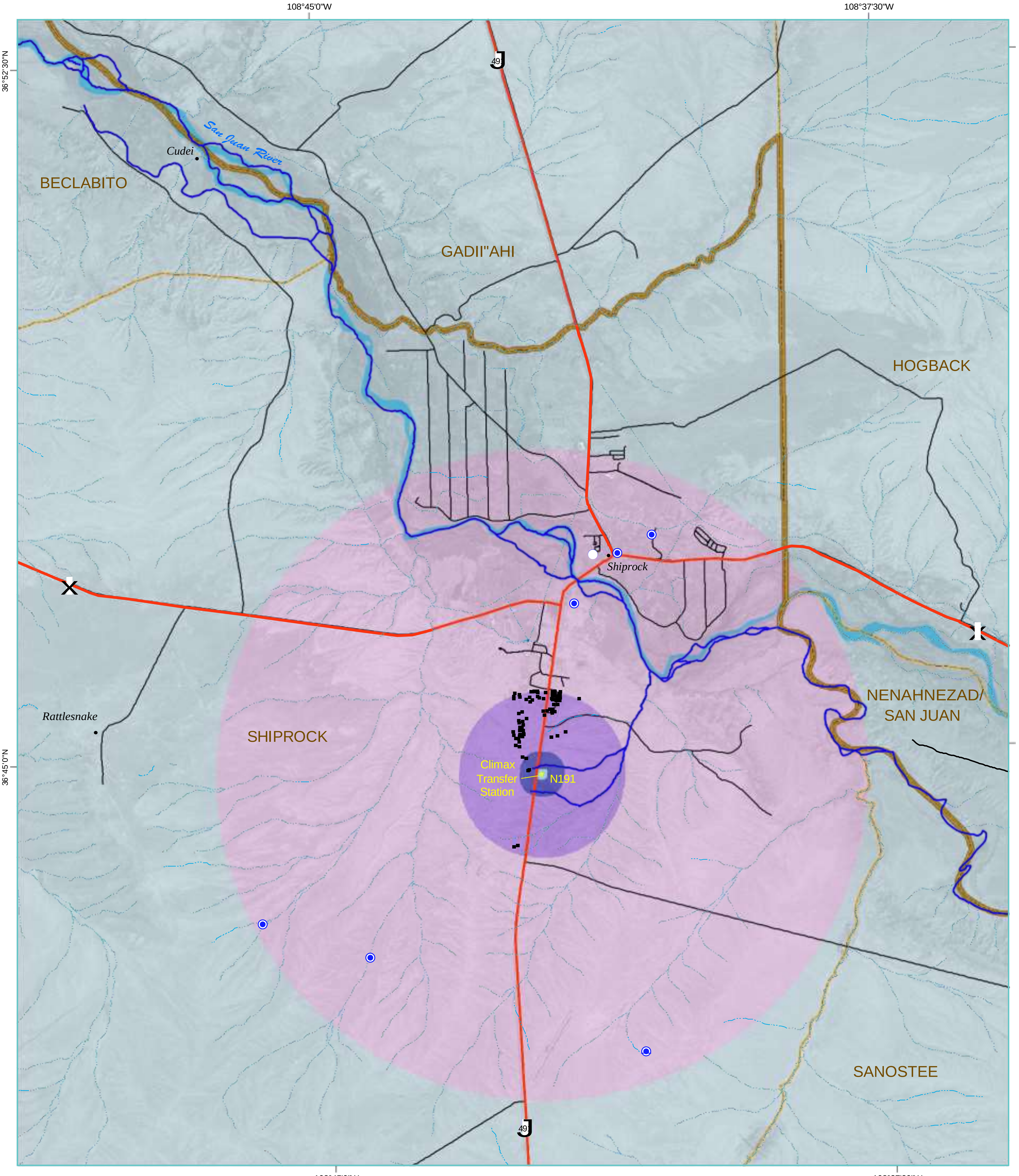
N129 MAP-ID*
Mine Feature
Structure within 1 Mile
Well within 4 Miles

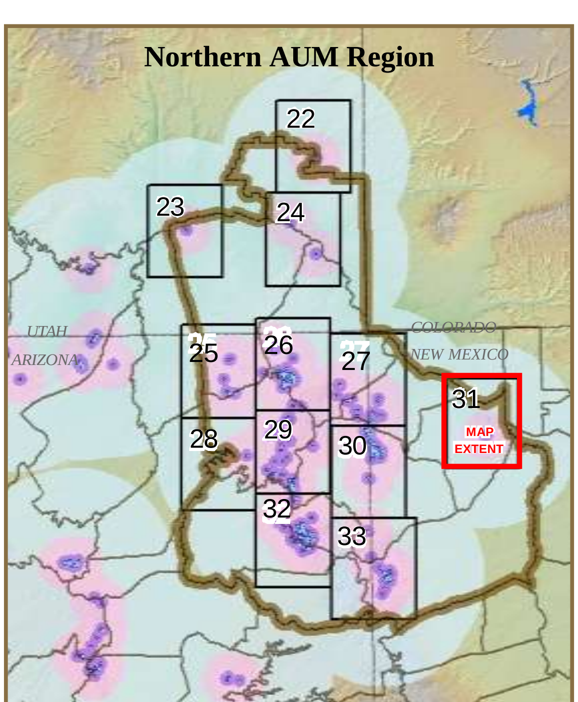
Downstream Water Pathway
Intermittent Stream
Chapter
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

* MAP-IDs N156, N163, N165, and N170-173 deleted

Figure 30. Combined Pathways in the East Carrizo Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - SHIPROCK

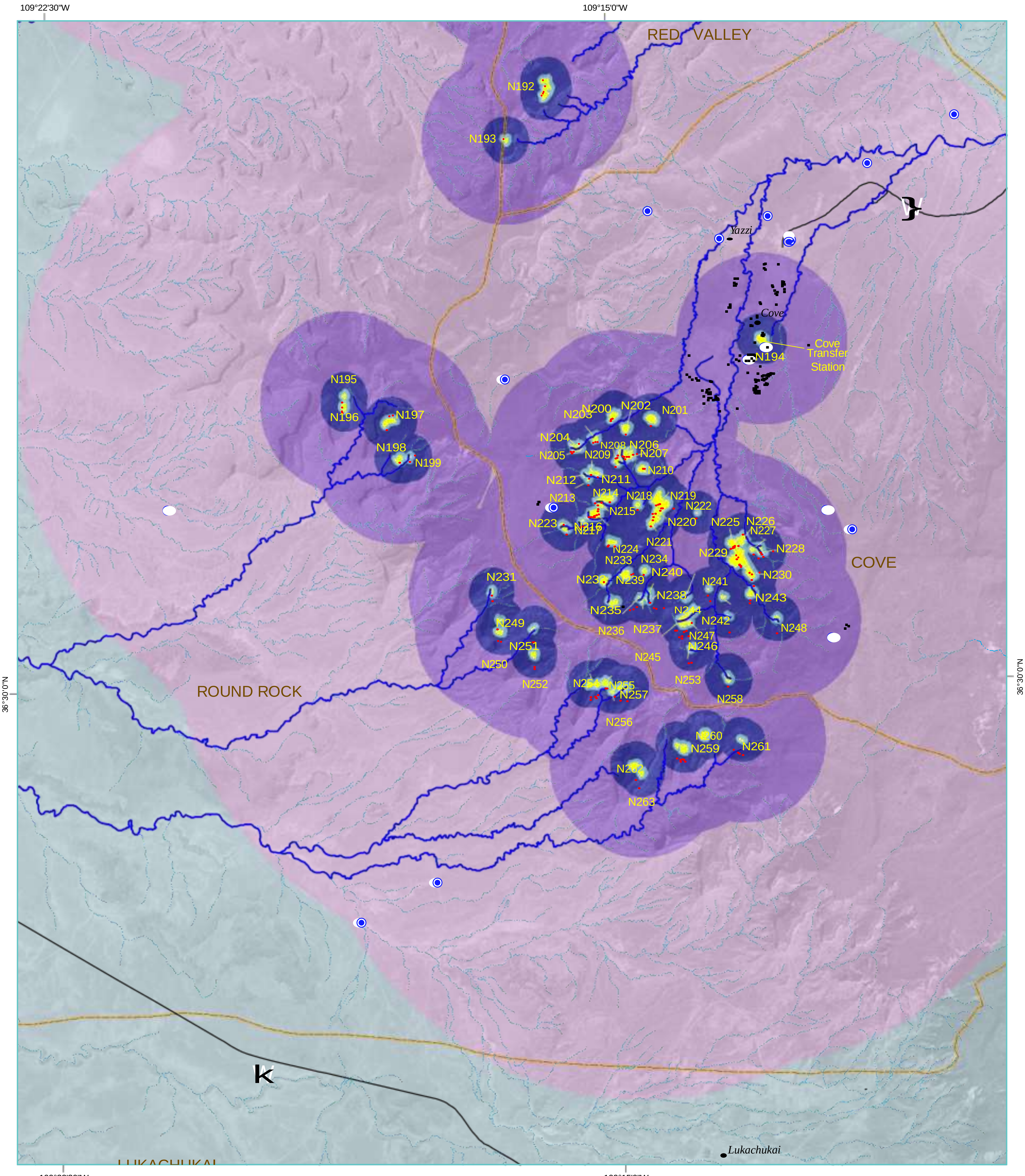
0 4 Miles

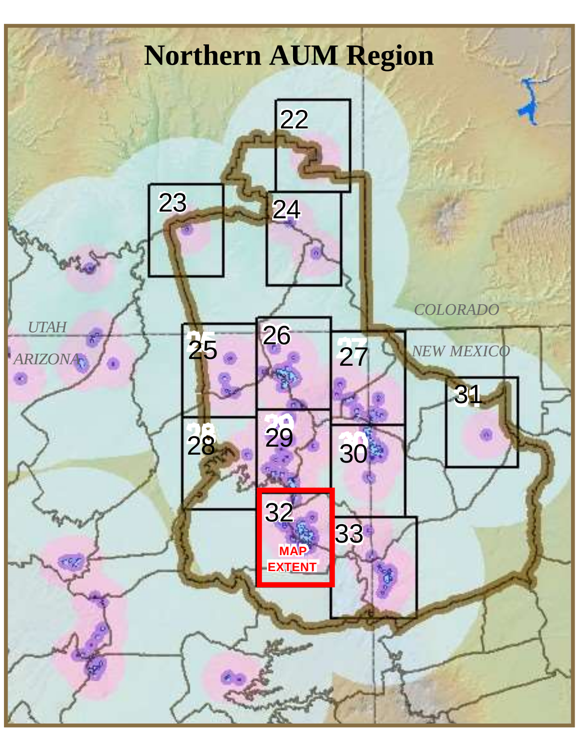
Map Scale 1:80,000

Legend

- N191 MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Intermittent Stream
- Northern AUM Region
- Chapter
- Highway
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 31. Combined Pathways in the Shiprock Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - LUKACHUKAI

N W E S

0 4 Miles

Map Scale 1:80,000

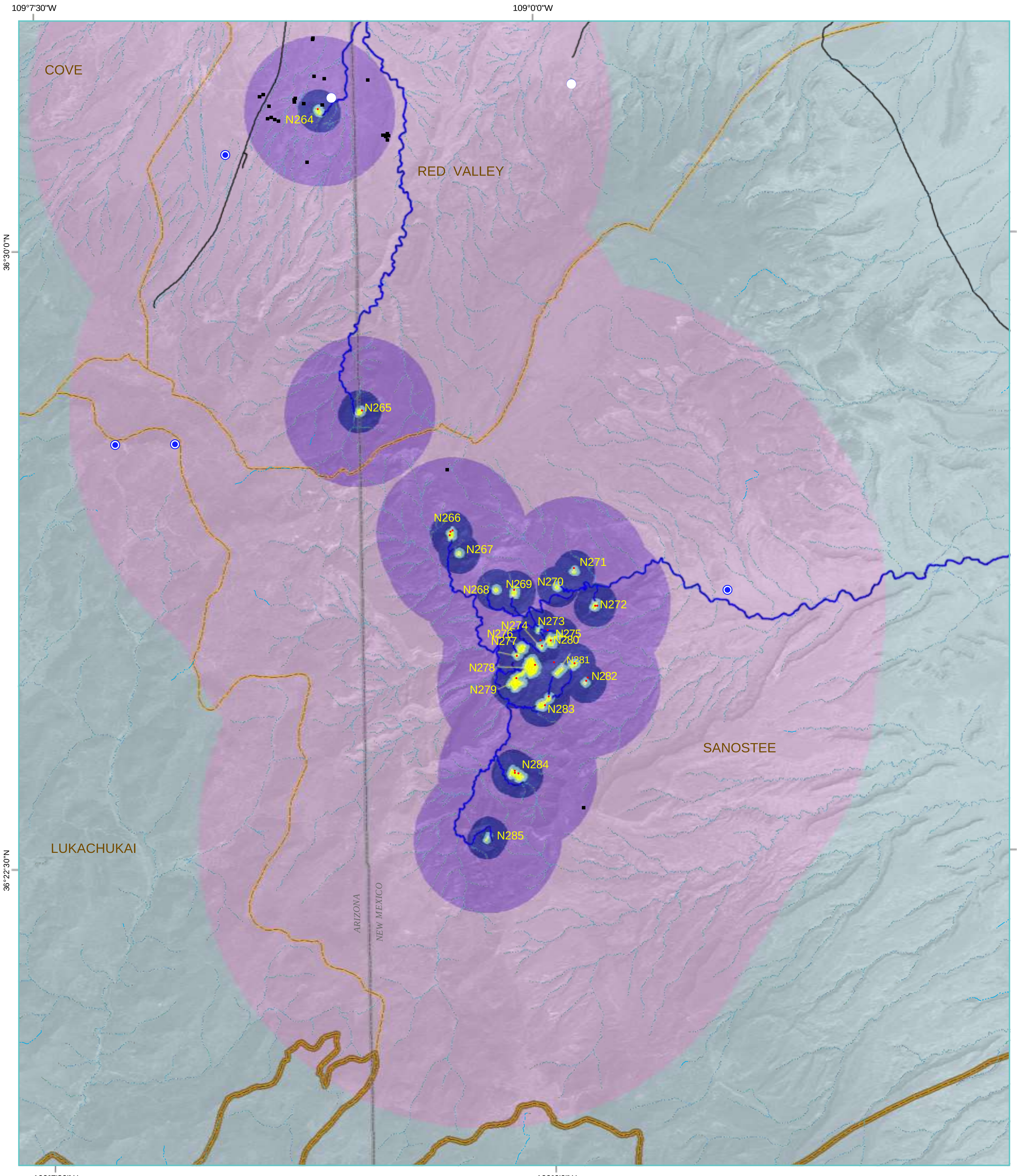
Legend

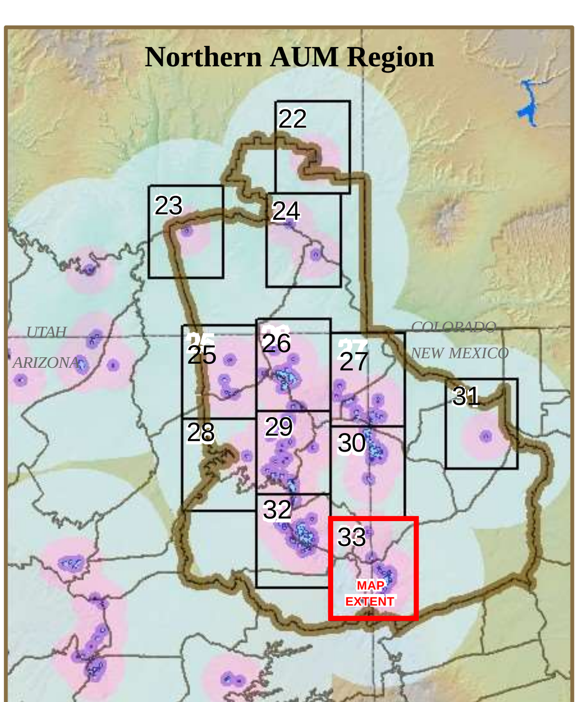
N192 MAP-ID
Mine Feature
Structure within 1 Mile
Well within 4 Miles

Downstream Water Pathway
Intermittent Stream
Chapter
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 32. Combined Pathways in the Lukachukai Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - CHUSKA

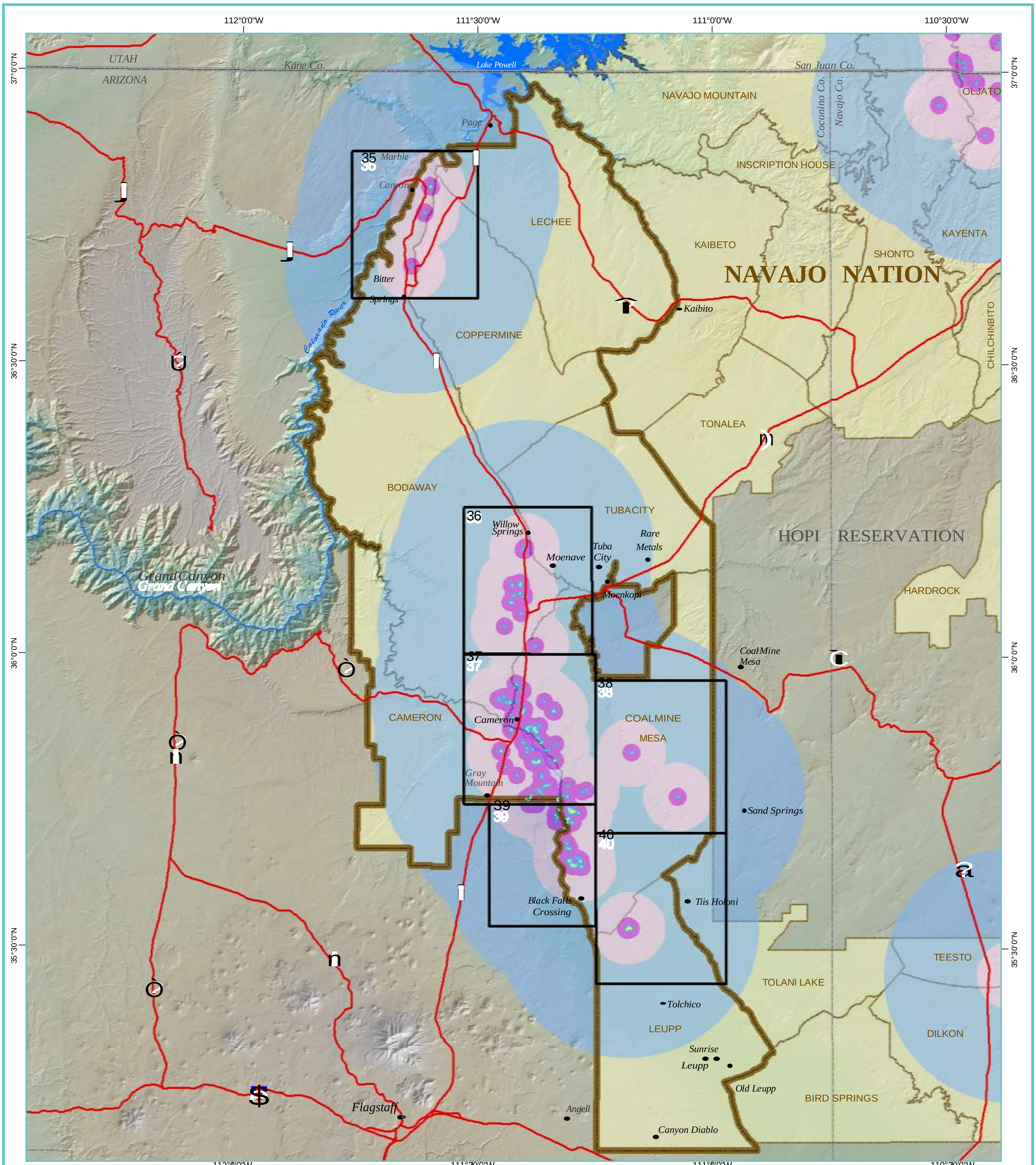
0 4 Miles

Map Scale 1:90,000

Legend

- N264 MAP-ID
- Mine Feature
- Structure within 1 Mile
- Well within 4 Miles
- Downstream Water Pathway
- Intermittent Stream
- Northern AUM Region
- Chapter
- State
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 33. Combined Pathways in the Chuska Area.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

WESTERN AUM REGION COMBINED PATHWAYS - MAP FIGURE INDEX

Sources

Abandoned uranium mine areas are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by several other sources. The Navajo Nation and Chapter boundaries are from the Navajo Land Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Selected Populated Places are from the USGS Geographic Names Information System (GNIS). Buffers were generated by TerraSpectra Geomatics. Map index figure outlines are approximate.

Map Index Area Designations

Figure

35 - Echo Cliffs
36 - Southeastern Bodaway/Gap
37 - Cameron
38 - Adeii Eechii Cliffs
39 - Southern Little Colorado
40 - East Black Falls

N W E S

0 20 Miles

Map Scale 1:750,000

Legend

Western AUM Region

Abandoned Uranium Mine

Mine Buffers

1/4 Mile

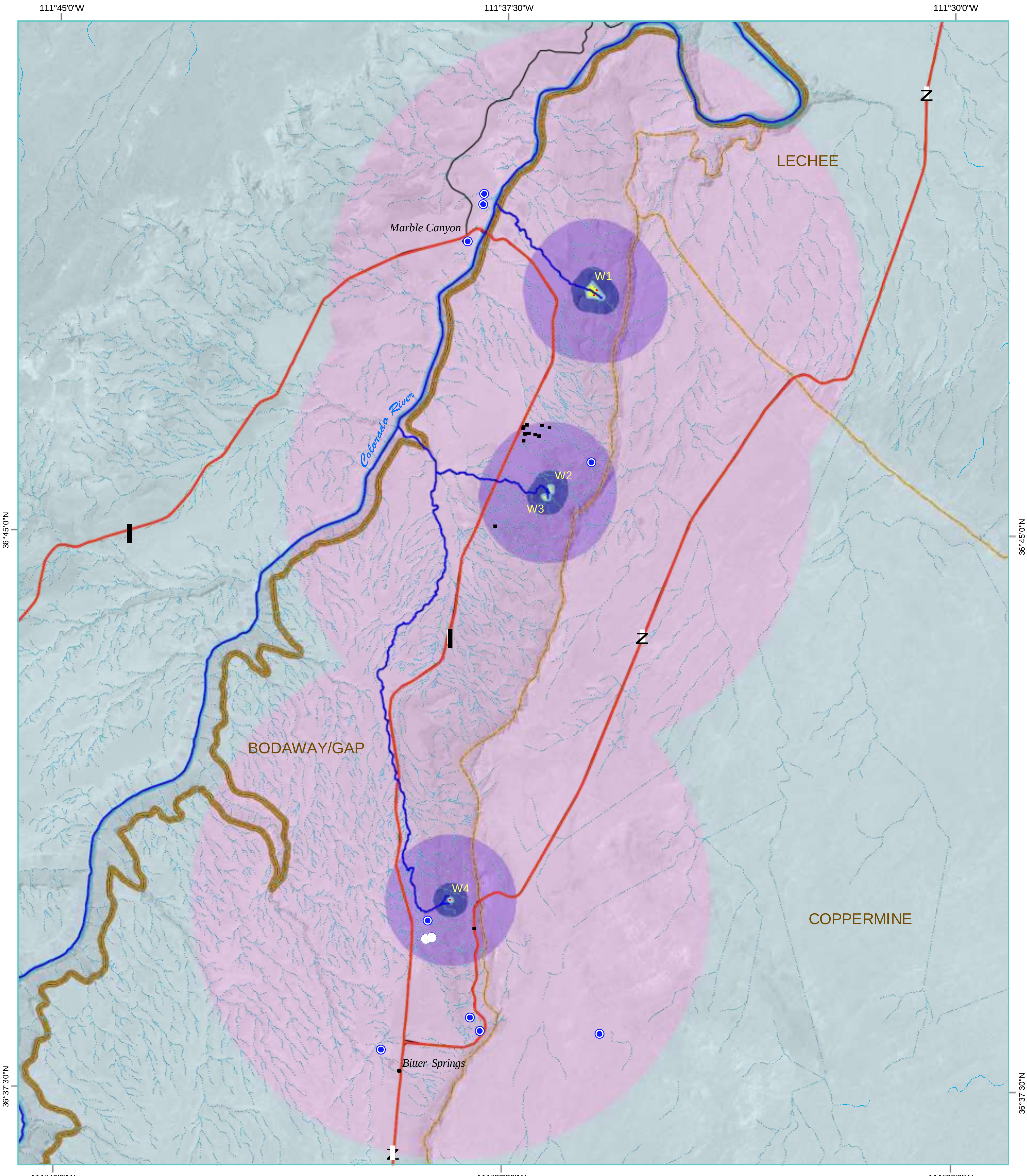
1 Mile

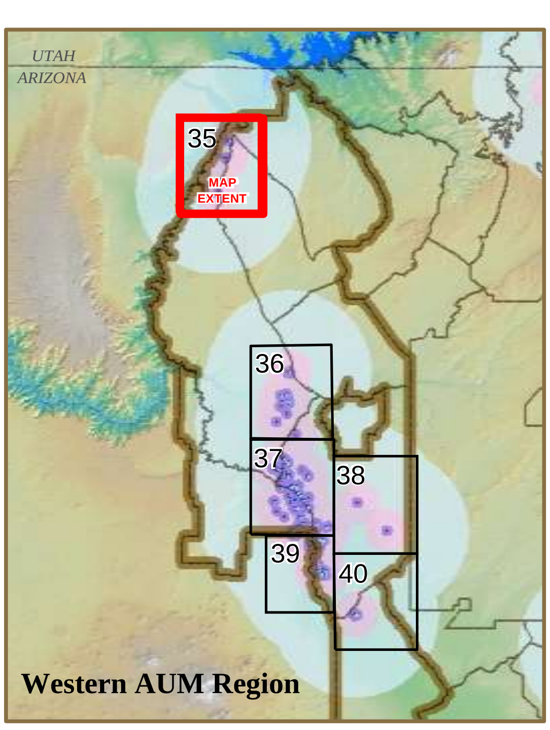
4 Miles

15 Miles

Populated Places

Highways





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - ECHO CLIFFS

0 4 Miles

Map Scale 1:100,000

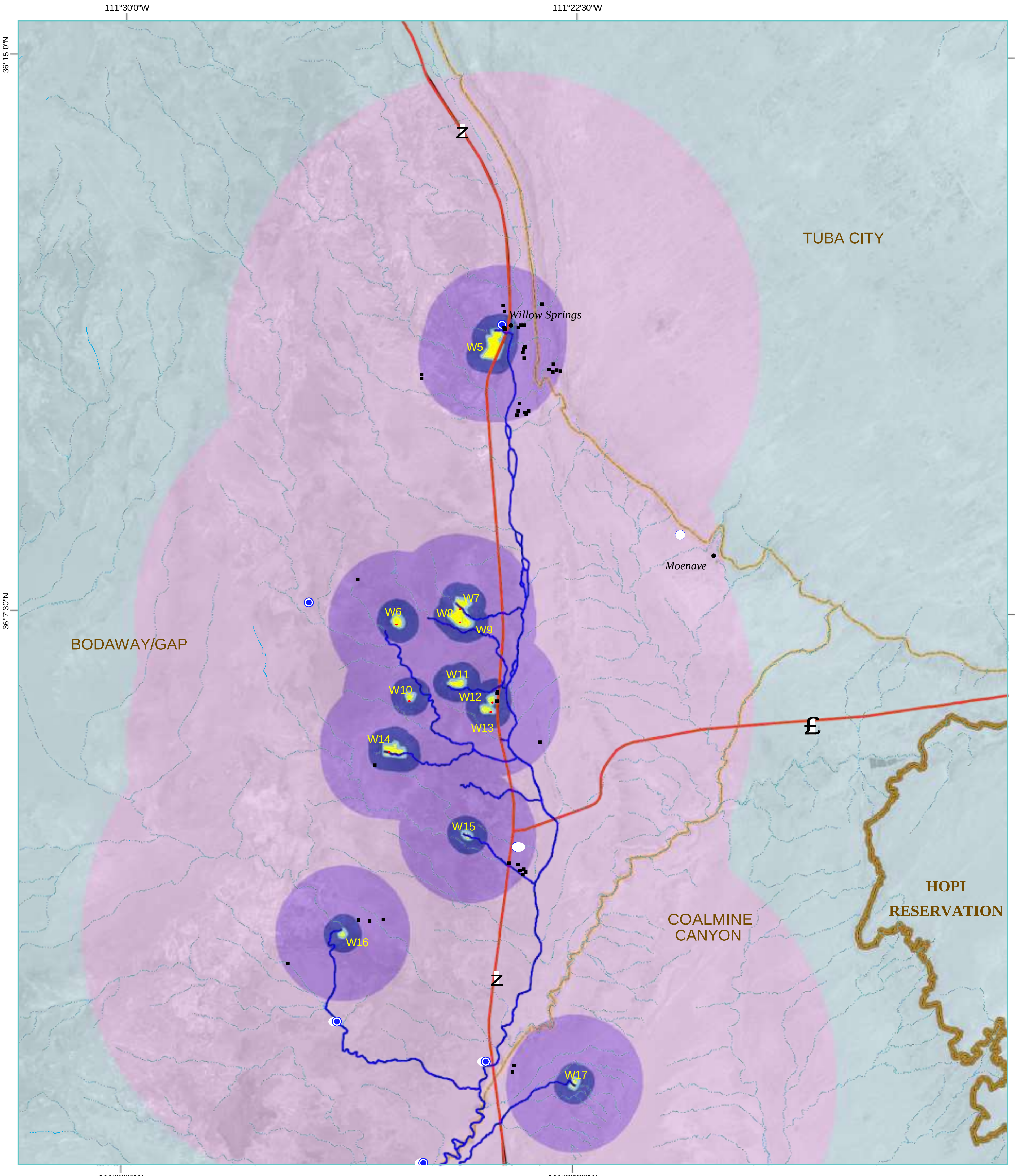
Legend

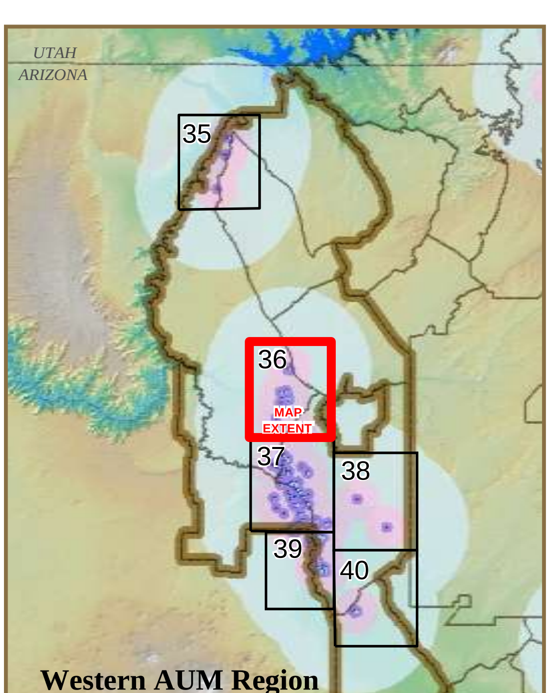
W1	MAP-ID
·	Mine Feature
▪	Structure within 1 mile
◉	Well within 4 miles
	Downstream Water Pathway
	Perennial Stream
	Intermittent Stream
	Western AUM Region
	Chapter
	Highway
	Paved Road
	Abandoned Uranium Mine

Mine Buffers

	200 Feet
	1/4 Mile
	1 Mile
	4 Miles
	15 Miles

Figure 35. Combined Pathways in the Echo Cliffs Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - SOUTHEASTERN BODAWAY/GAP

N W E S

0 4 Miles

Map Scale 1:100,000

Legend

W5 MAP-ID

Mine Feature

Structure within 1 mile

Well within 4 miles

Downstream Water Pathway

Intermittent Stream

Western AUM Region

Chapter

Highway

Abandoned Uranium Mine

Mine Buffers

200 Feet

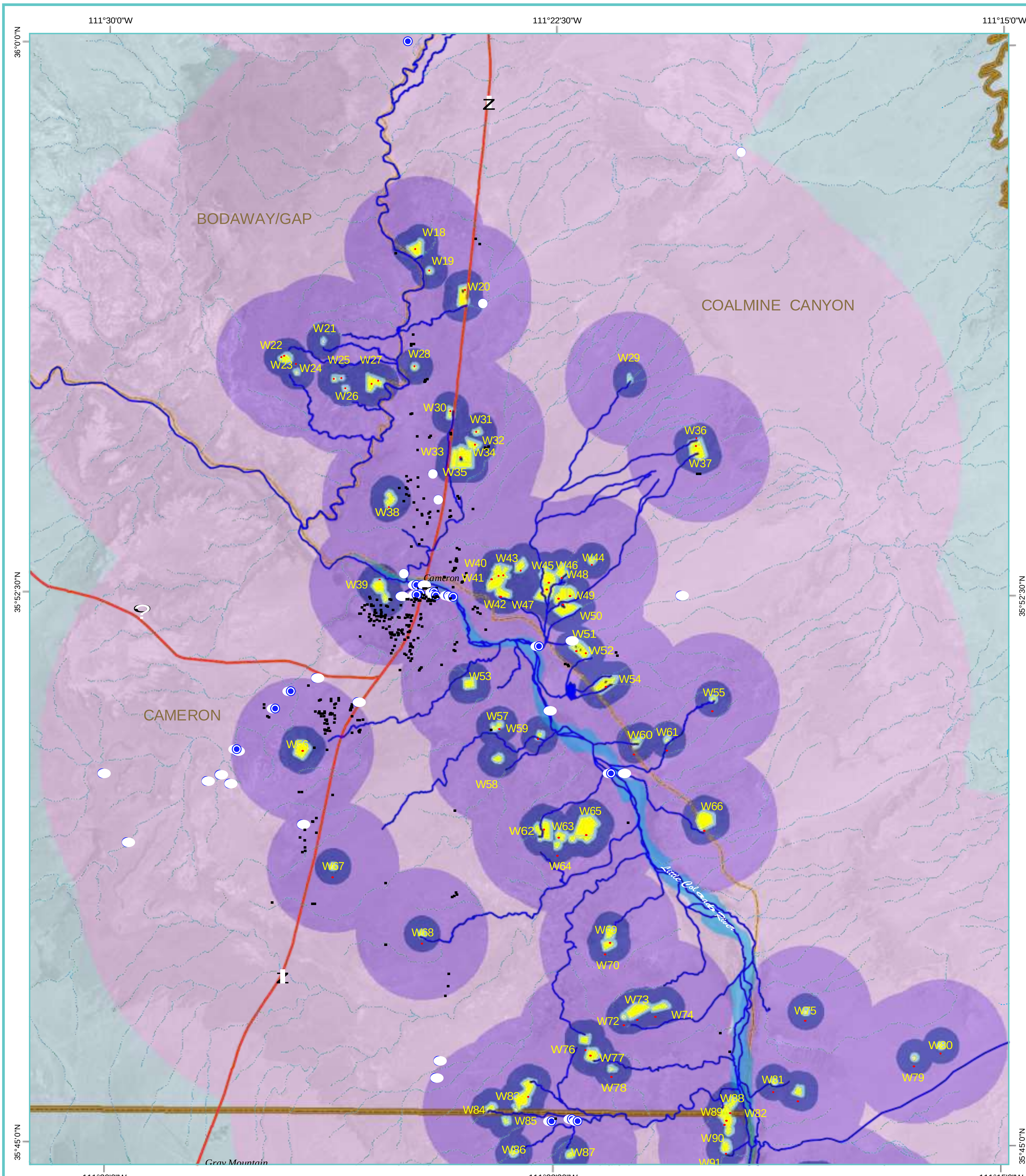
1/4 Mile

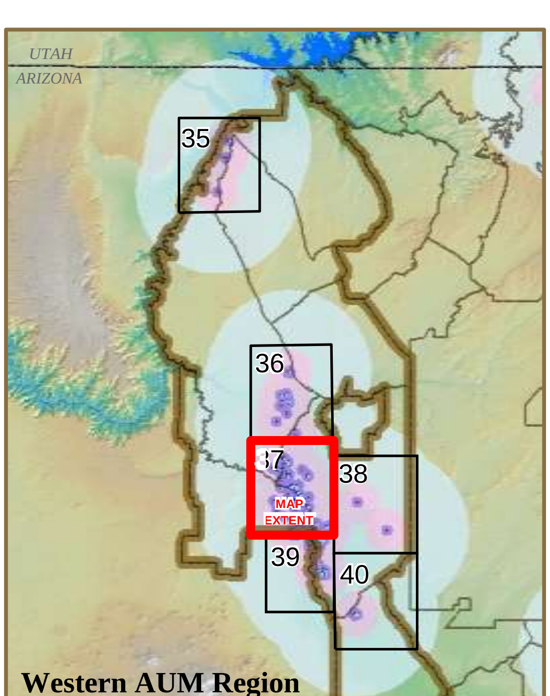
1 Mile

4 Miles

15 Miles

Figure 36. Combined Pathways in the Southeastern Bodaway/Gap Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - CAMERON

N
W E
S

0 4 Miles

Map Scale 1:100,000

Legend

- W18 MAP-ID*
- Mine Feature
- Structure within 1 mile
- Well within 4 miles
- Downstream Water Pathway
- Perennial Stream
- Intermittent Stream
- Western AUM Region
- Chapter
- Highway
- Abandoned Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

*MAP-ID W71 shown in Figure 38

Figure 37. Combined Pathways in the Cameron Area.

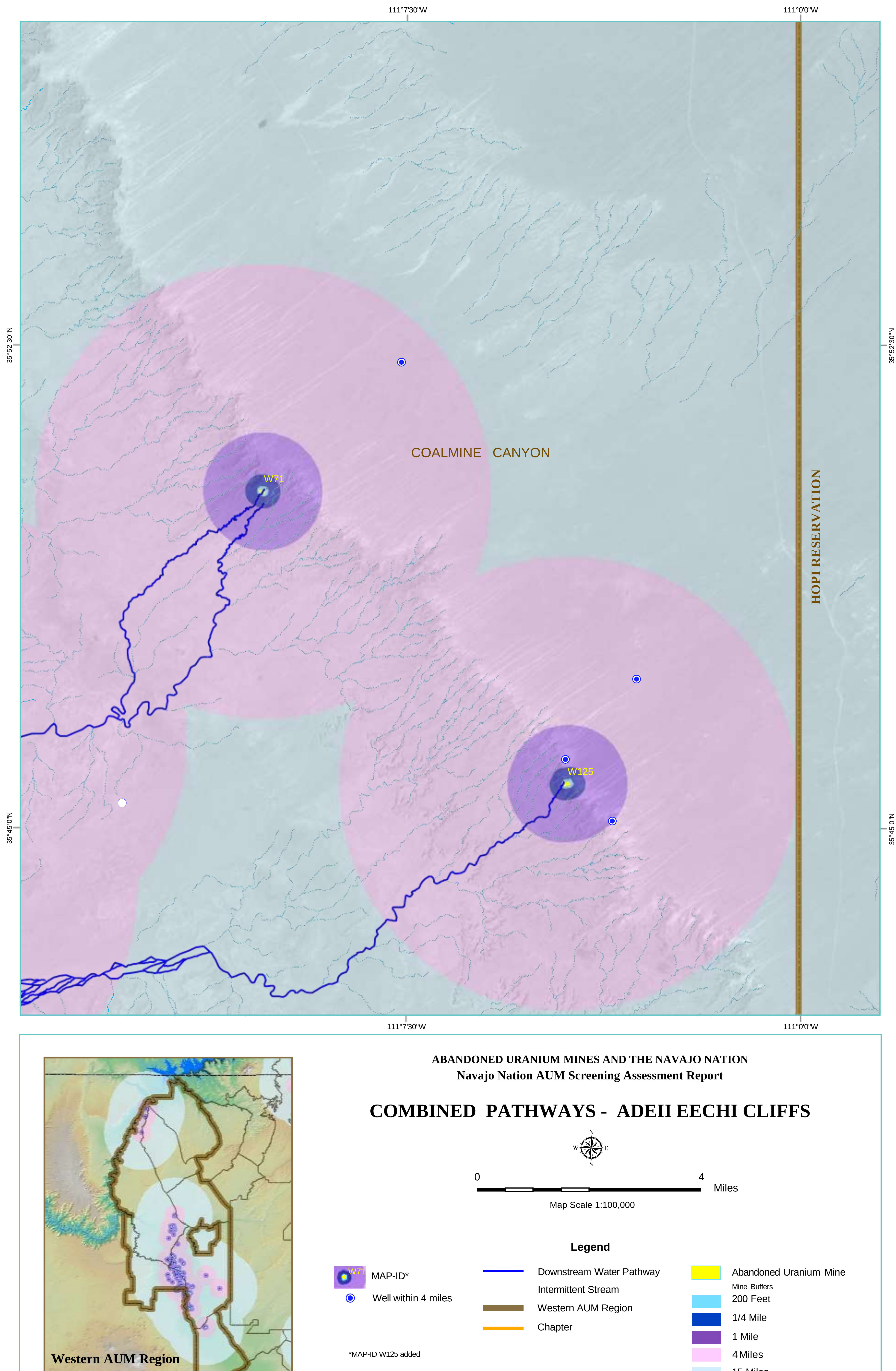
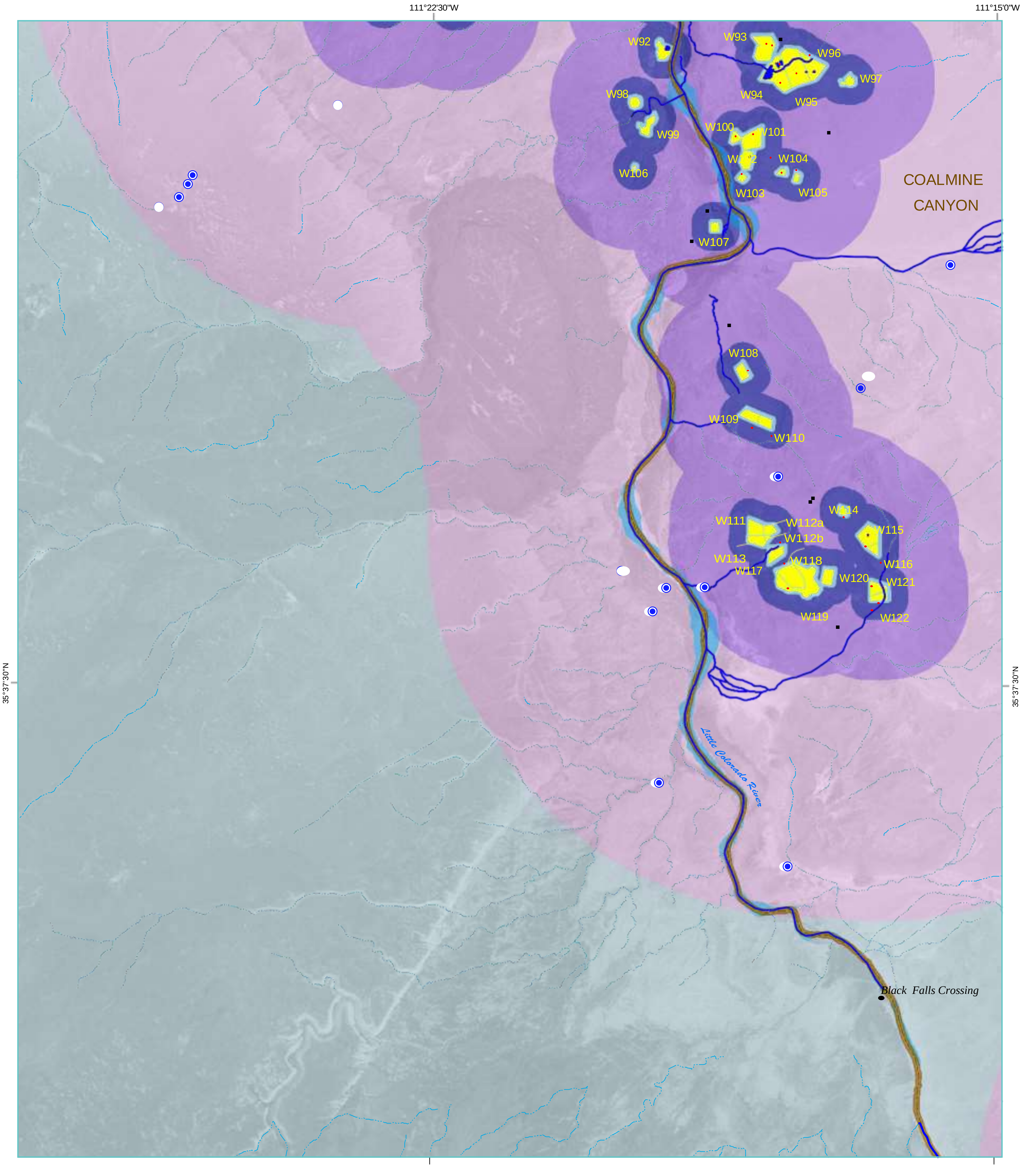
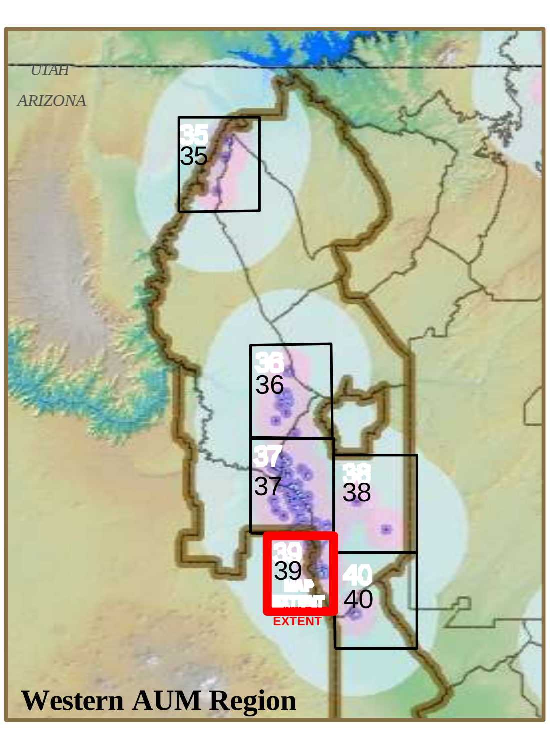


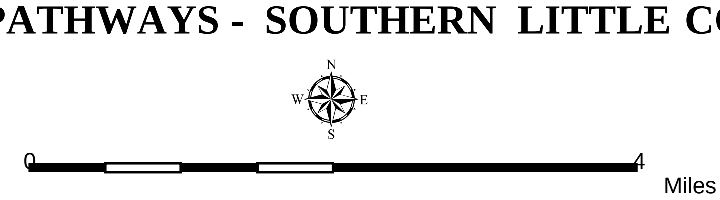
Figure 38. Combined Pathways in the Adeii Eechi Cliffs Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - SOUTHERN LITTLE COLORADO

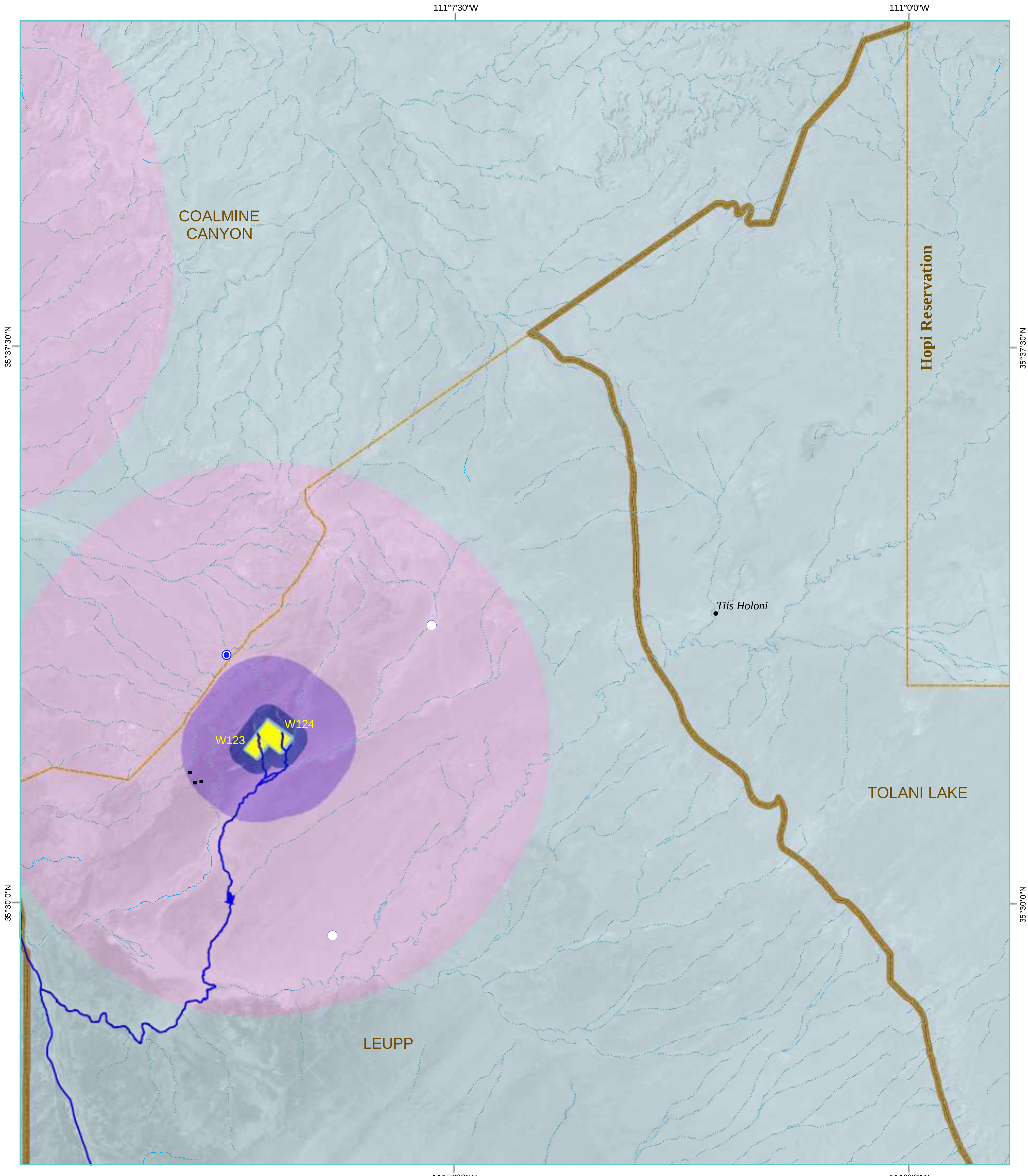


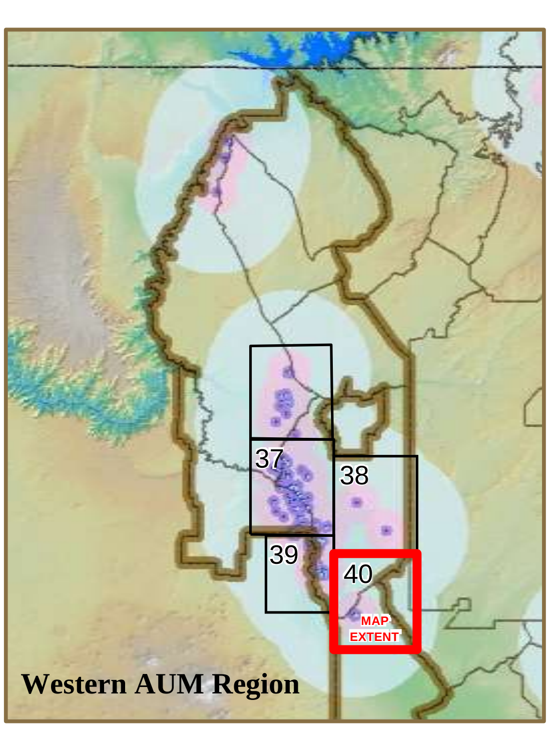
Legend

MAP-ID*	Downstream Water Pathway	Abandoned Uranium Mine
Mine Feature	Perennial Stream	Mine Buffers 200 Feet
Structure within 1 mile	Intermittent Stream	1/4 Mile
Well within 4 miles	Western AUM Region	1 Mile
	Chapter	4 Miles
		15 Miles

*MAP-ID W112 split into W112a and W112b

Figure 39. Combined Pathways in the Southern Little Colorado Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - EAST BLACK FALLS

0 4 Miles

Map Scale 1:100,000

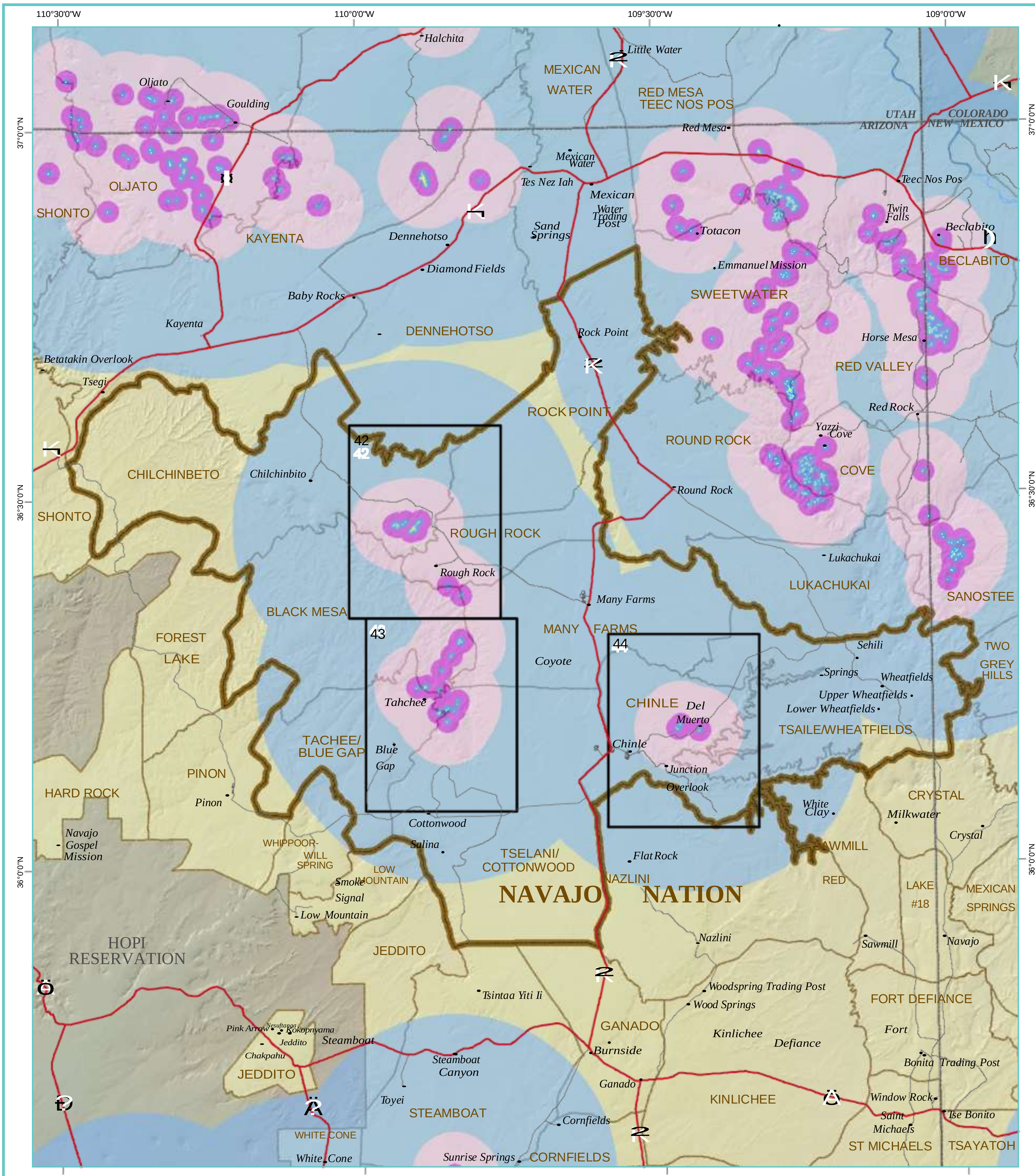
Legend

W123 MAP-ID
Structure within 1 mile
Well within 4 miles

Downstream Water Pathway
Intermittent Stream
Western AUM Region
Chapter

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 40. Combined Pathways in the East Black Falls Area.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

CENTRAL AUM REGION COMBINED PATHWAYS - MAP FIGURE INDEX

Sources

Abandoned Uranium Mine (AUM) locations are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by other sources. The Navajo Nation and Chapter boundaries are from the Navajo Land Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Buffers were generated by TerraSpectra Geomatics. Map index figure boundaries are approximate.

Map Area Designations

Figure

42 - Rough Rock
43 - Tachee
44 - Chinle

0 20 Miles

Map Scale 1:600,000

Legend

Central AUM Region

Abandoned Uranium Mine

Mine Buffers

1/4 Mile

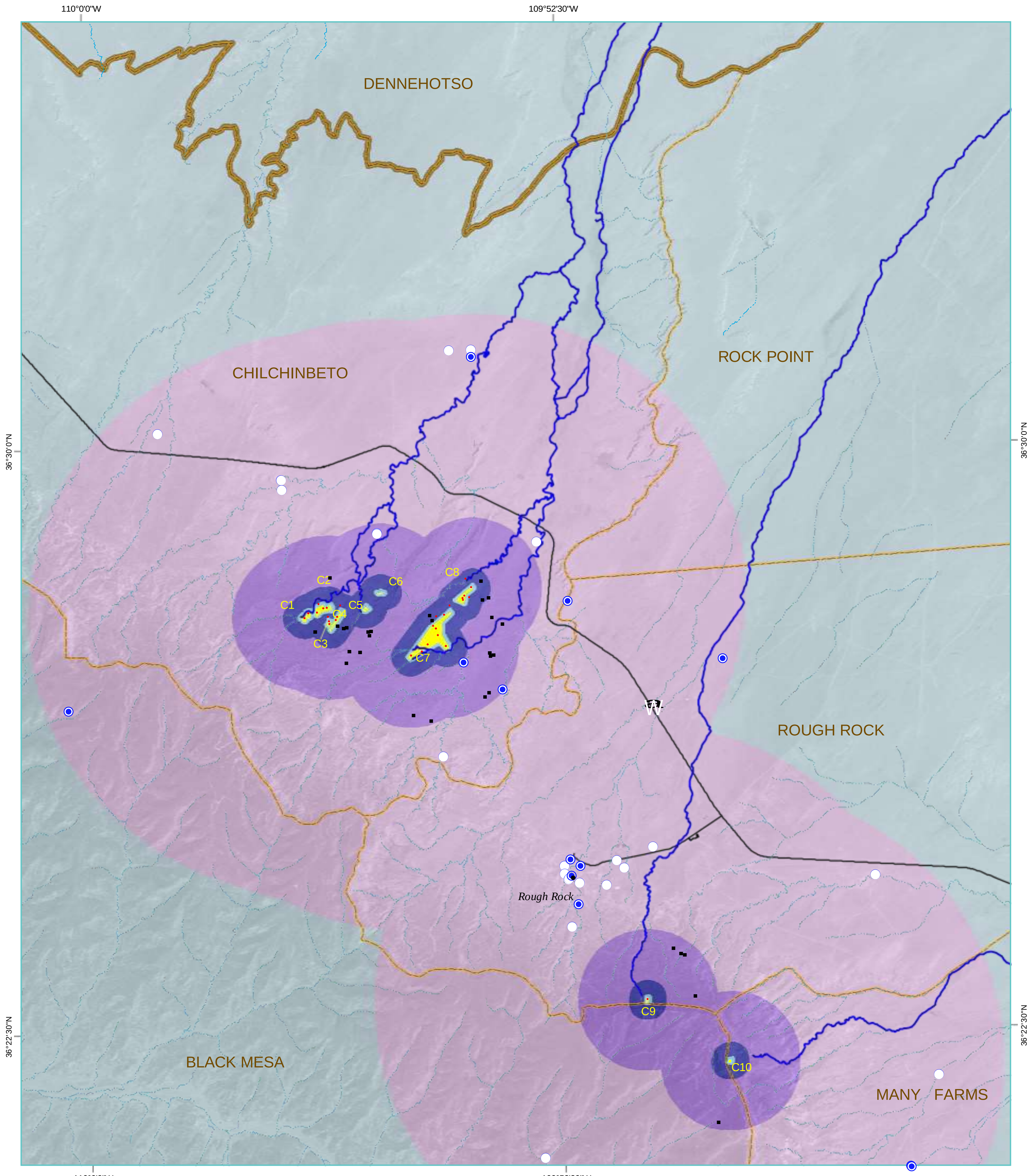
1 Mile

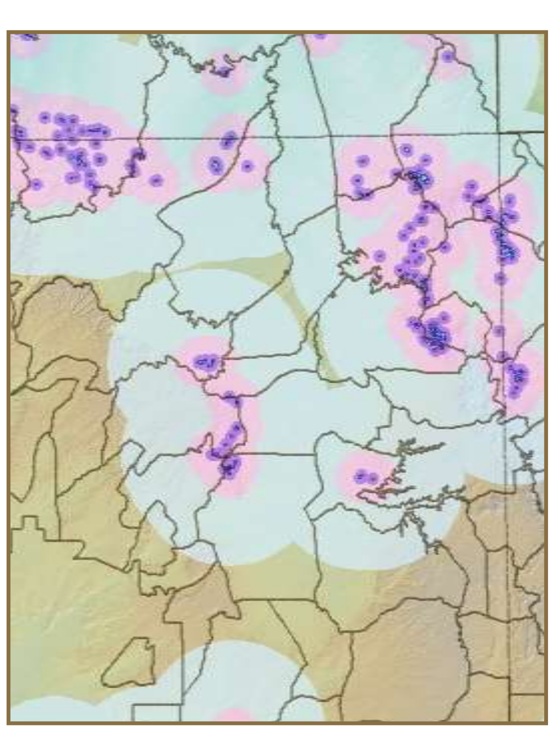
4 Miles

15 Miles

Populated Places

Highways





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - ROUGH ROCK

0 4 Miles

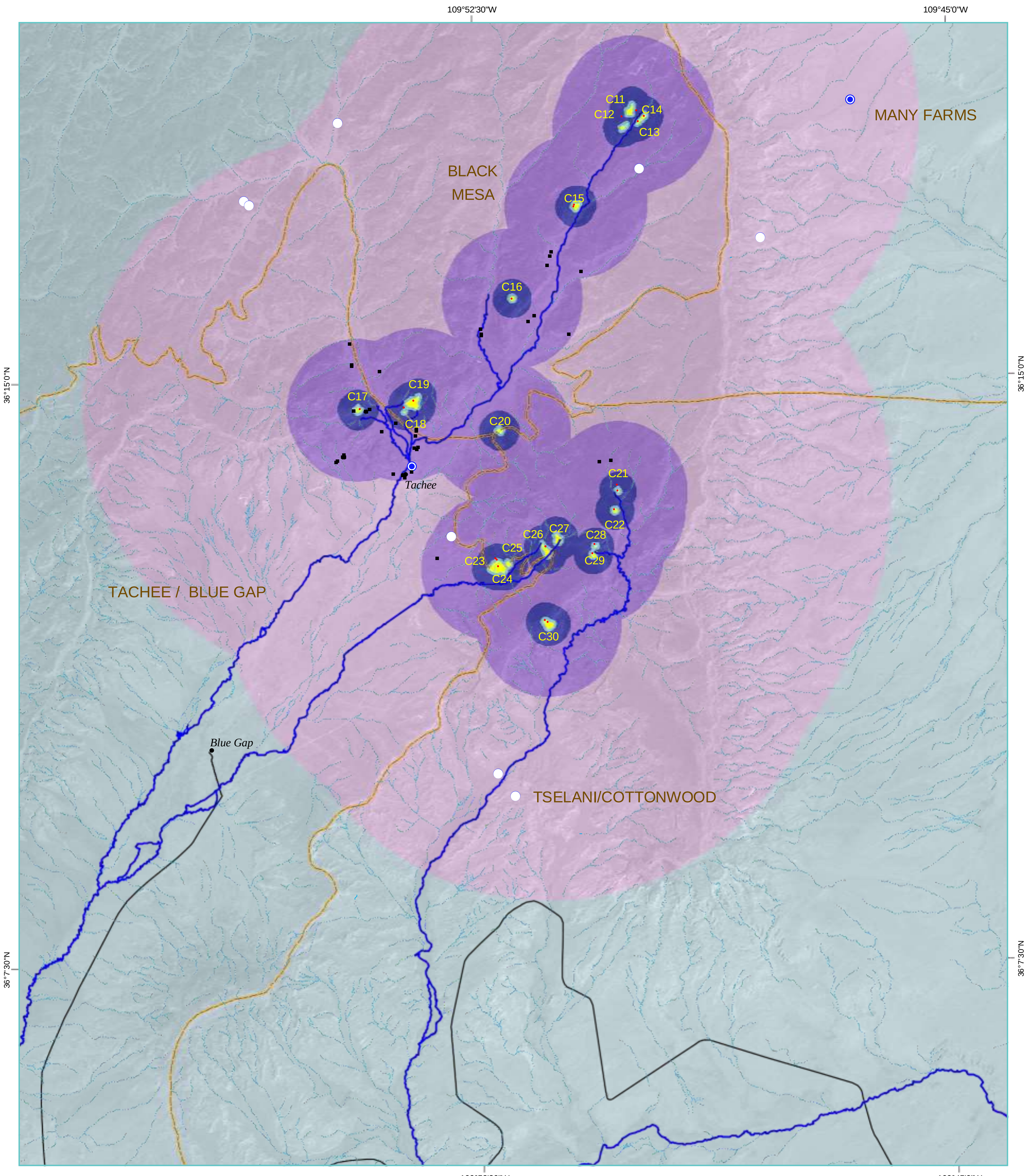
Map Scale 1:95,000

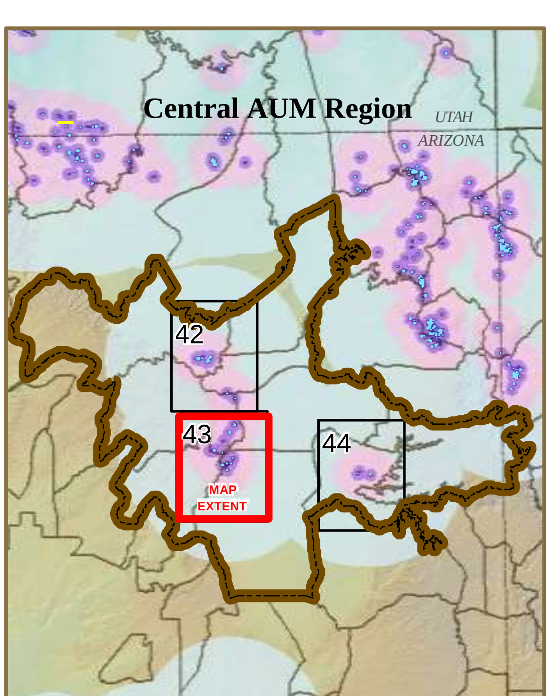
Legend

- C1 MAP-ID
- Mine Feature
- Structure within 1 mile
- Well within 4 milles
- Downstream Water Pathway
- Intermittent Stream
- Central AUM Region
- Chapter
- Paved Road
- Abandoned Uranium Mine

Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 42. Combined Pathways in the Rough Rock Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - TACHEE

N
W E
S

0 4 Miles

Map Scale 1:95,000

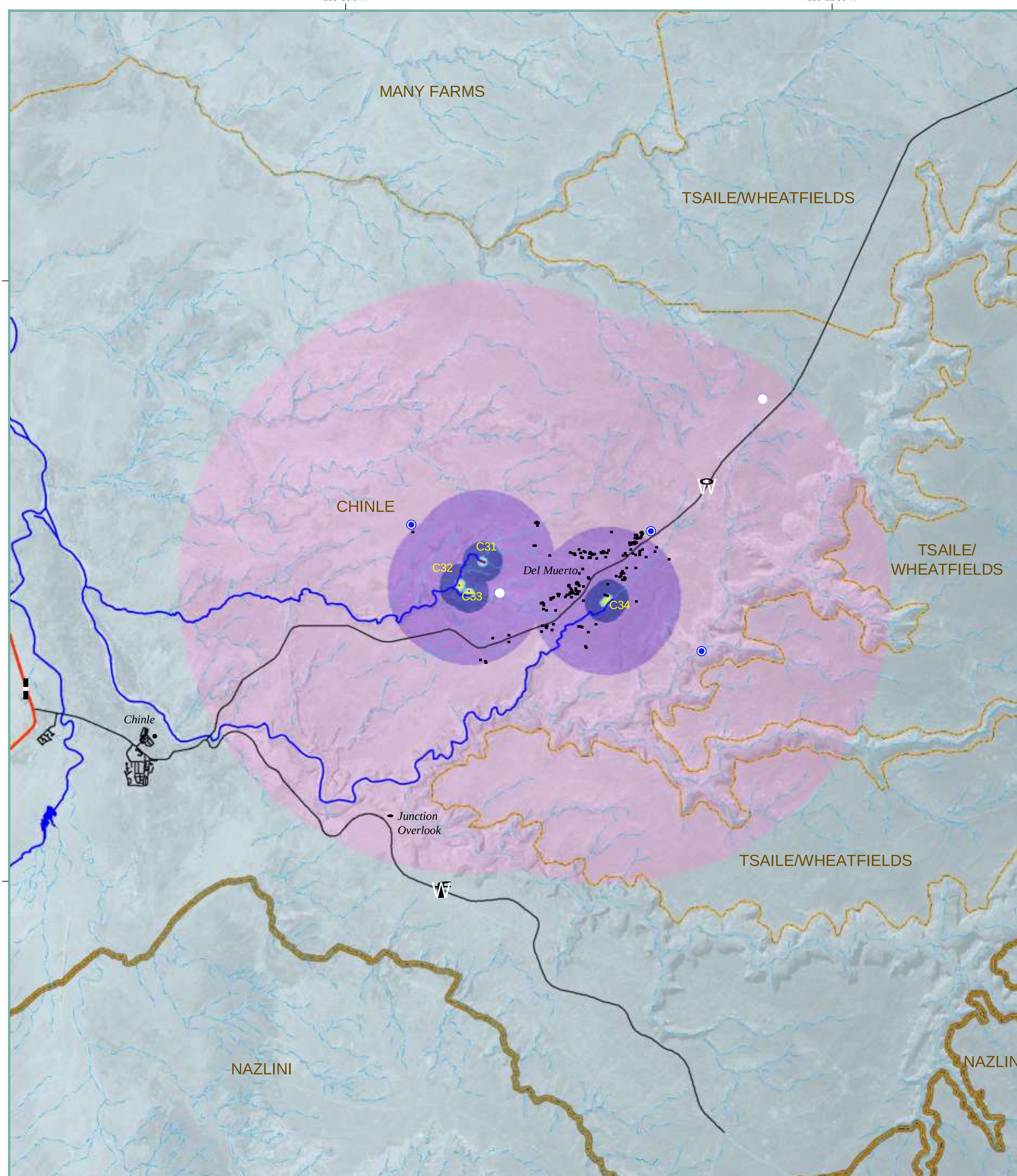
Legend

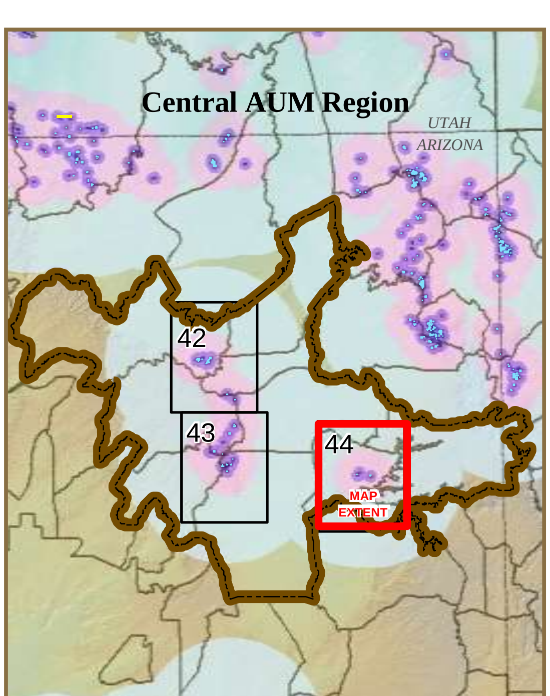
C11 MAP-ID
Mine Feature
Structure within 1 mile
Well within 4 milles

Downstream Water Pathway
Intermittent Stream
Chapter
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 43. Combined Pathways in the Tachee Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - CHINLE

0 4 Miles

Map Scale 1:95,000

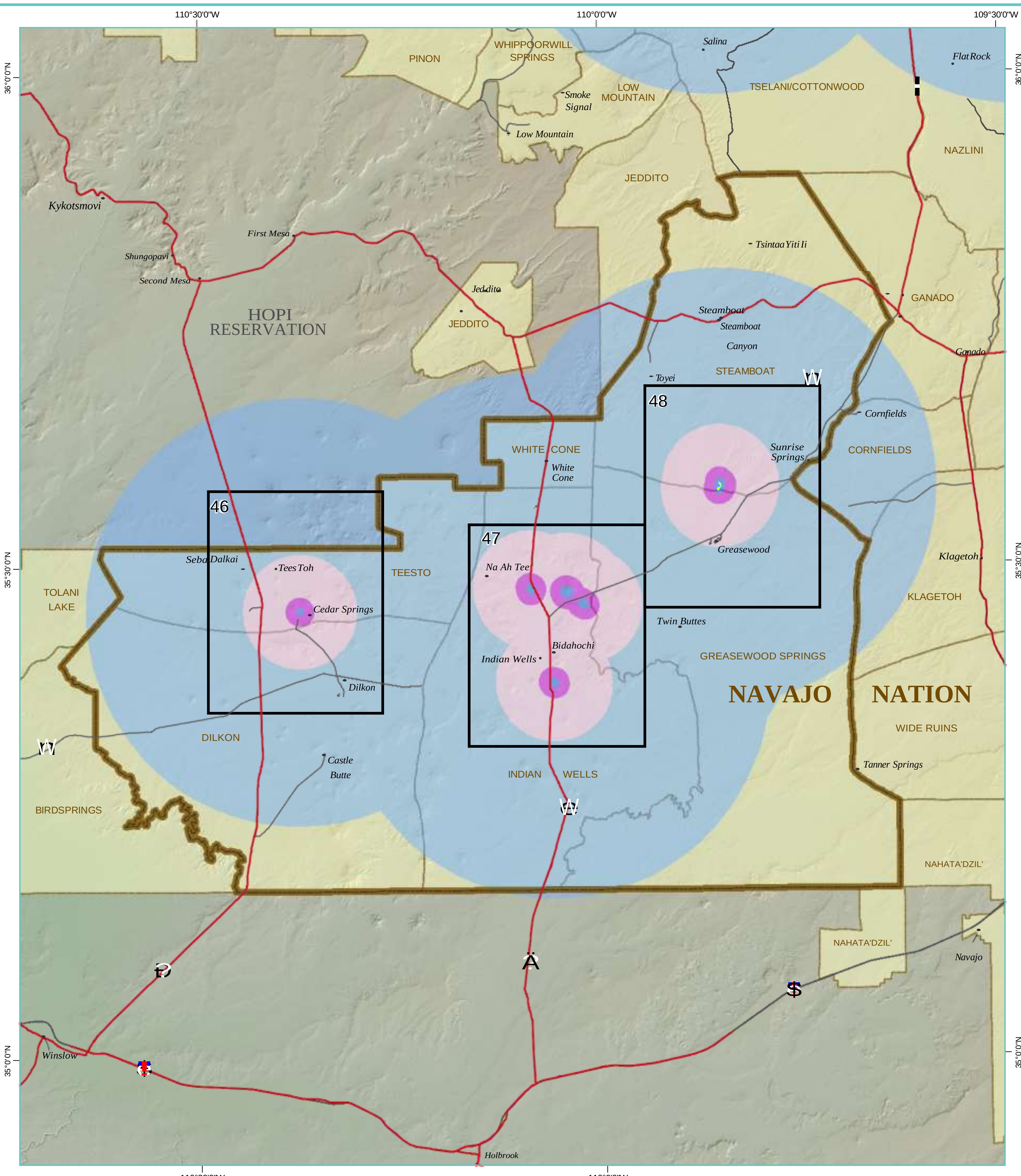
Legend

C31 MAP-ID
Mine Feature
Structure within 1 mile
Well within 4 milles

Downstream Water Pathway
Intermittent Stream
Central AUM Region
Chapter
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 44. Combined Pathways in the Chinle Area.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

SOUTHERN AUM REGION COMBINED PATHWAYS - MAP FIGURE INDEX

Sources

Abandoned uranium mine areas are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by other sources. The Navajo Nation and Chapter boundaries are from the Navajo Land Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Buffers were generated by TerraSpectra Geomatics. Map index figure boundaries are approximate.

Map Index Region Designations

Figure

46 - Cedar Springs
47 - Bidahochi
48 - Greasewood

0 10 Miles

Map Scale 1:450,000

Legend

Southern AUM Region

Chapter

Highways

Paved Roads

Populated Places

Abandoned Uranium Mine

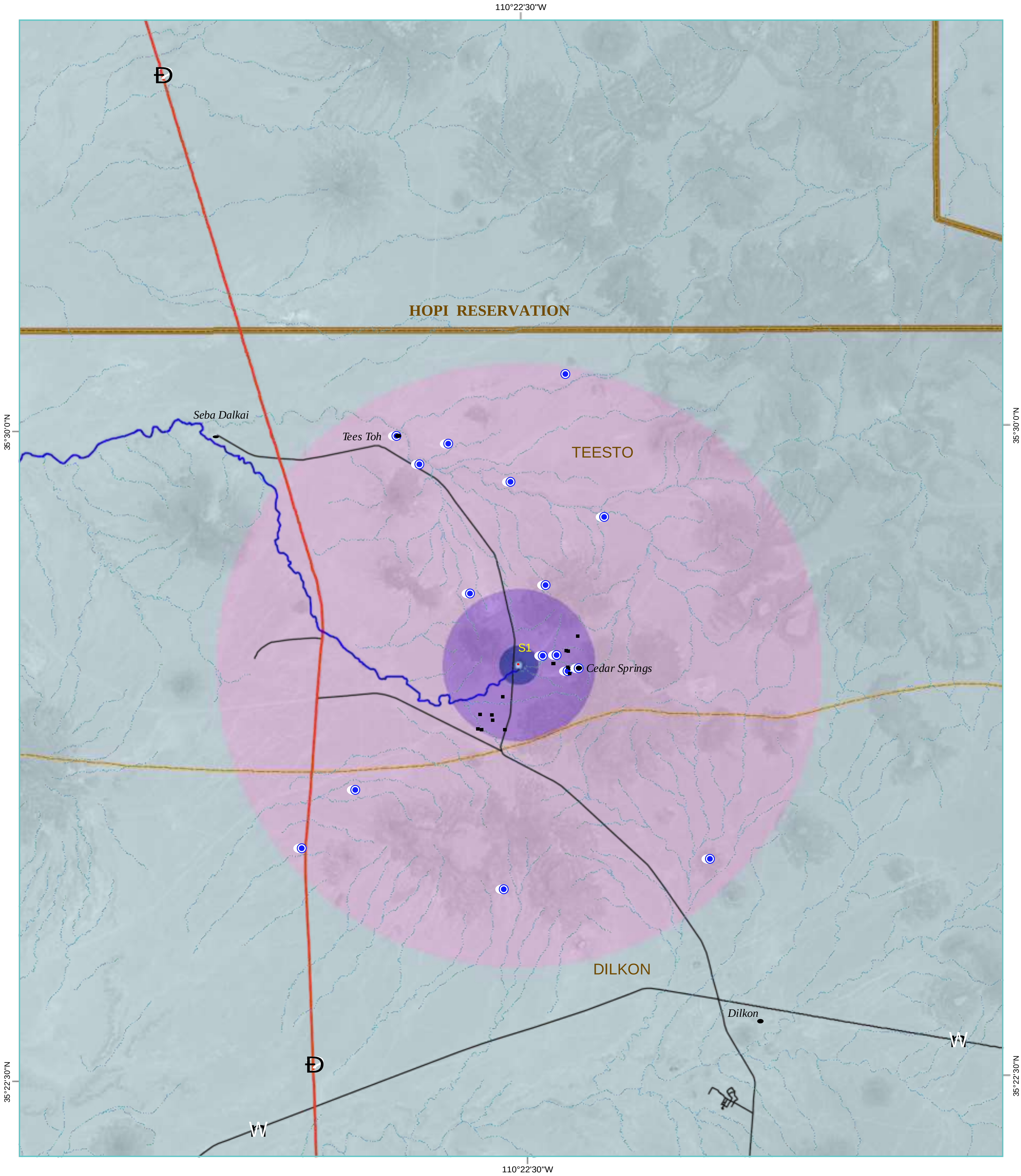
Mine Buffers

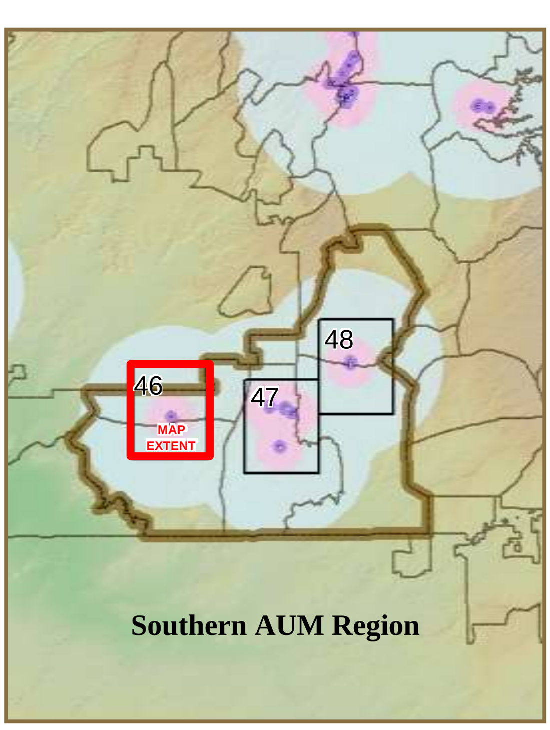
1/4 Mile

1 Mile

4 Miles

15 Miles





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - CEDAR SPRINGS

N W E S

0 4 Miles

Map Scale 1:85,000

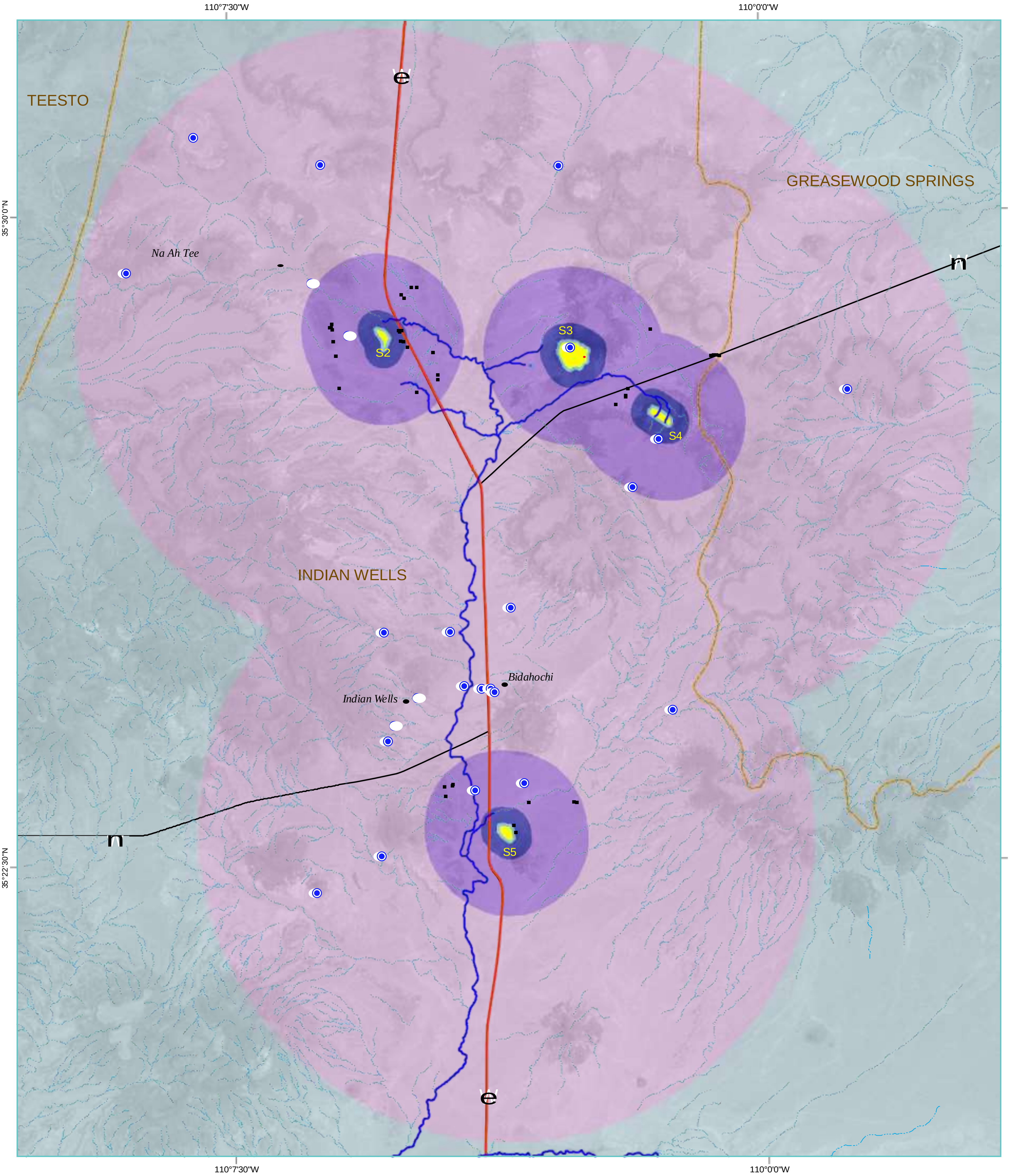
Legend

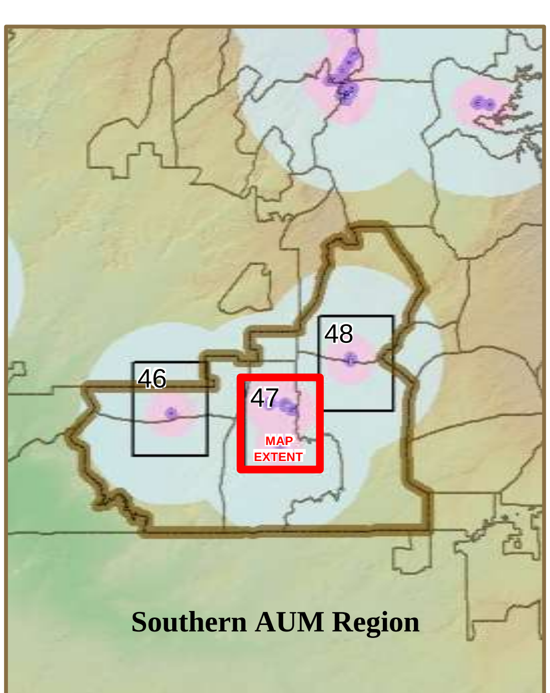
S1 MAP-ID
Mine Feature
Structure within 1 mile
Well within 4 milles

Downstream Water Pathway
Intermittent Stream
Southern AUM Region
Chapter
Highway
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 46. Combined Pathways in the Cedar Springs Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

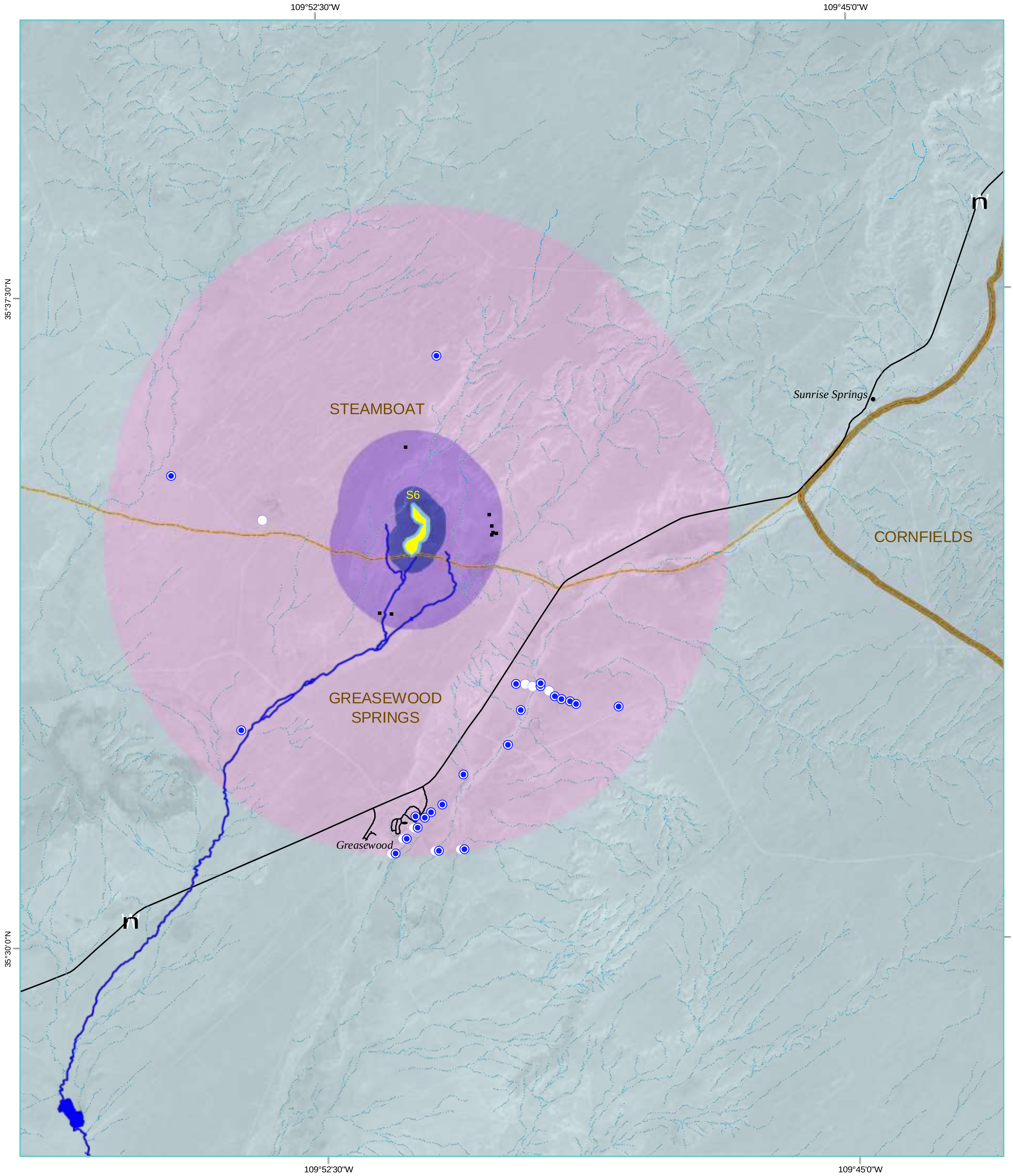
COMBINED PATHWAYS - BIDAHOCHI

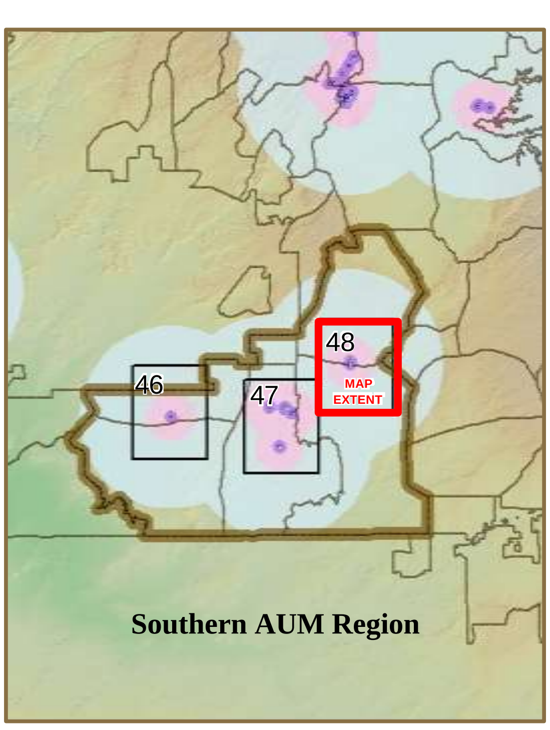
0 4 Miles
Map Scale 1:85,000

Legend

- S2 MAP-ID
- Mine Feature
- Structure within 1 mile
- Well within 4 milles
- Downstream Water Pathway
- Intermittent Stream
- Chapter
- Highway
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 47. Combined Pathways in the Bidahochi Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - GREASEWOOD

0 4 Miles

Map Scale 1:85,000

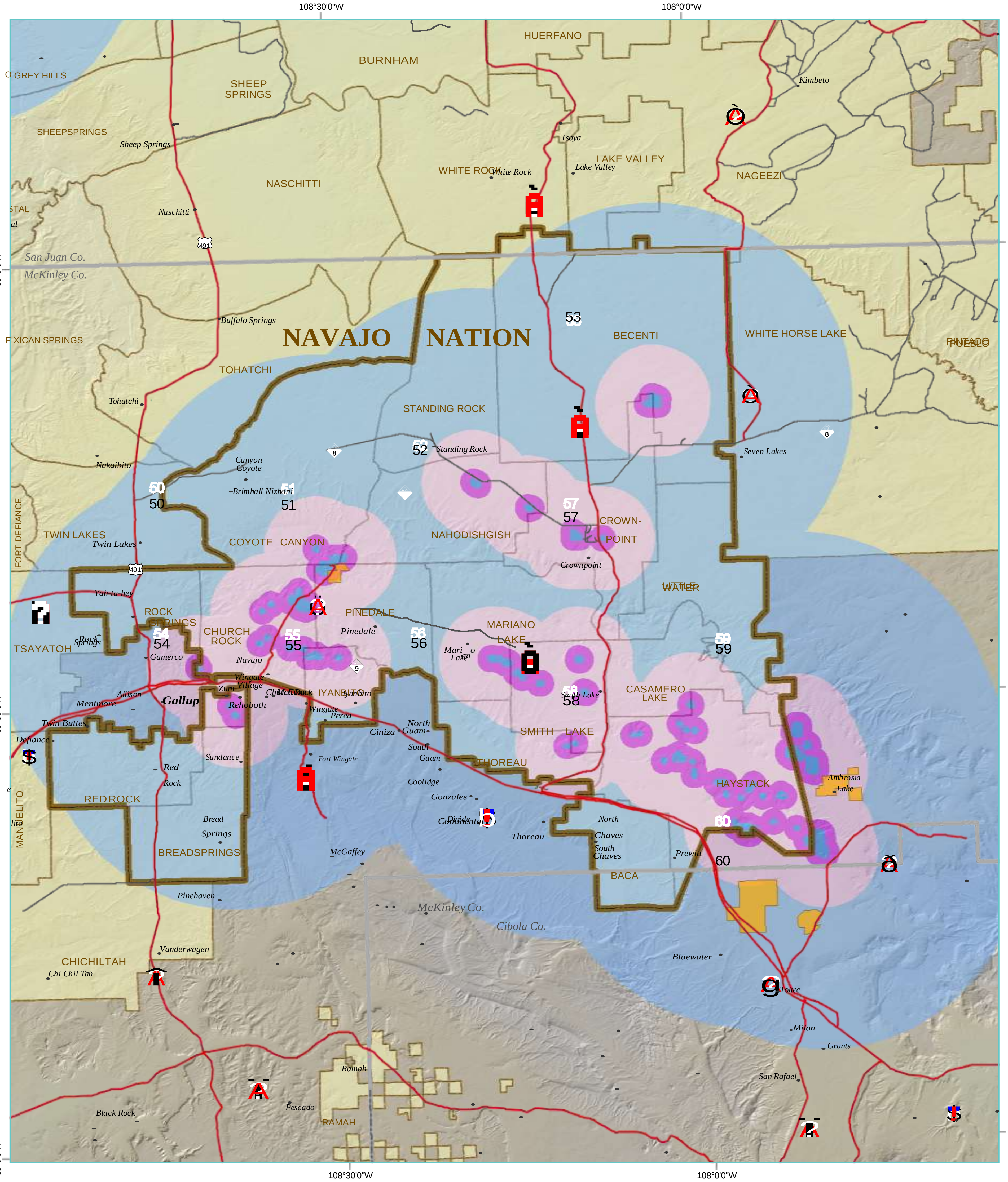
Legend

S6 MAP-ID
Mine Feature
Structure within 1 mile
Well within 4 milles

Downstream Water Pathway
Intermittent Stream
Southern AUM Region
Chapter
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 48. Combined Pathways in the Greasewood Area.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

EASTERN AUM REGION COMBINED PATHWAYS - MAP FIGURE INDEX

Sources

Abandoned uranium mine areas are from a variety of sources. The Navajo Nation and Chapter boundaries are from the Navajo Land Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Buffers were generated by TerraSpectra Geomatics. Map index area boundaries are approximate.

Map Index Area Designations

Figure

50 - NW Church Rock
51 - NE Church Rock
52 - Nahodishgish
53 - Becenti
54 - Church Rock
55 - Iyanbito
56 - Mariano Lake
57 - Crownpoint
58 - Baca/Prewitt
59 - Ambrosia Lake
60 - Haystack

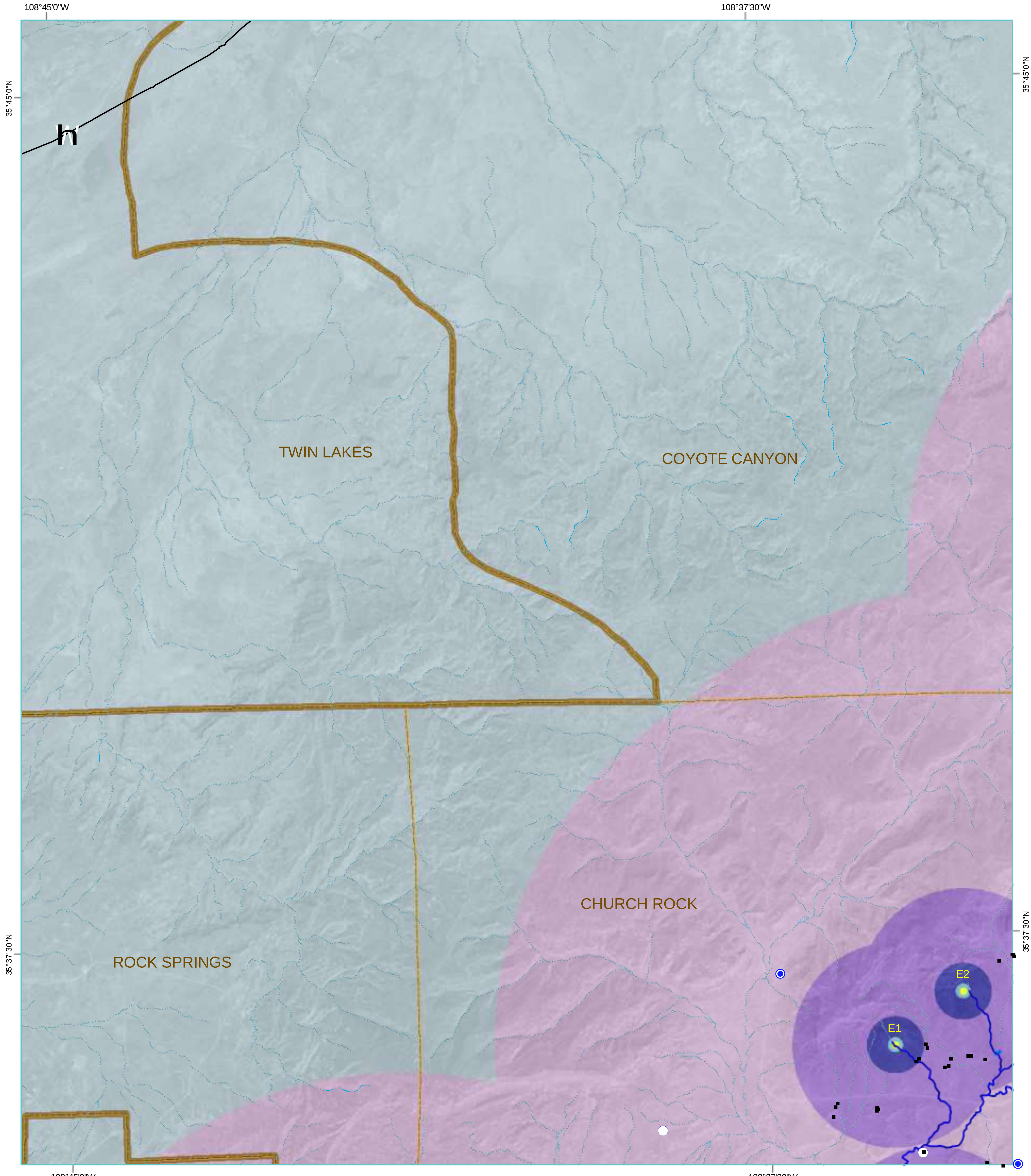
0 — 15 Miles

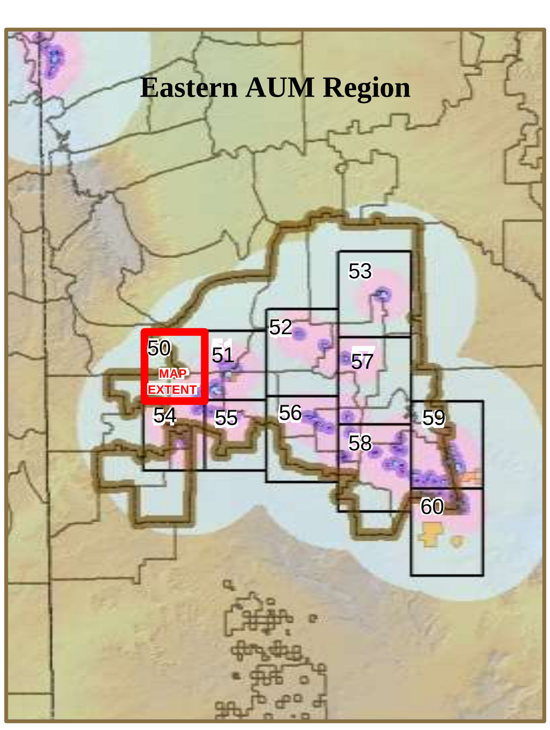
Map Scale 1:500,000

Legend

- Eastern AUM Region
- Chapter
- Highway
- Paved Road
- Populated Places
- Abandoned Uranium Mine
- Mine Buffers
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles
- Uranium Mill/ Reclamation Site

Figure 49. Eastern AUM Region Combined Pathways Map Figure Index.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NORTHWEST CHURCH ROCK

0 4 Miles

Map Scale 1:65,000

Legend

E1 MAP-ID

Structure within 1 mile

Well within 4 miles

Downstream Water Pathway

Intermittent Stream

Eastern AUM Region

Chapter

Paved Road

Abandoned Uranium Mine

Mine Buffers

200 Feet

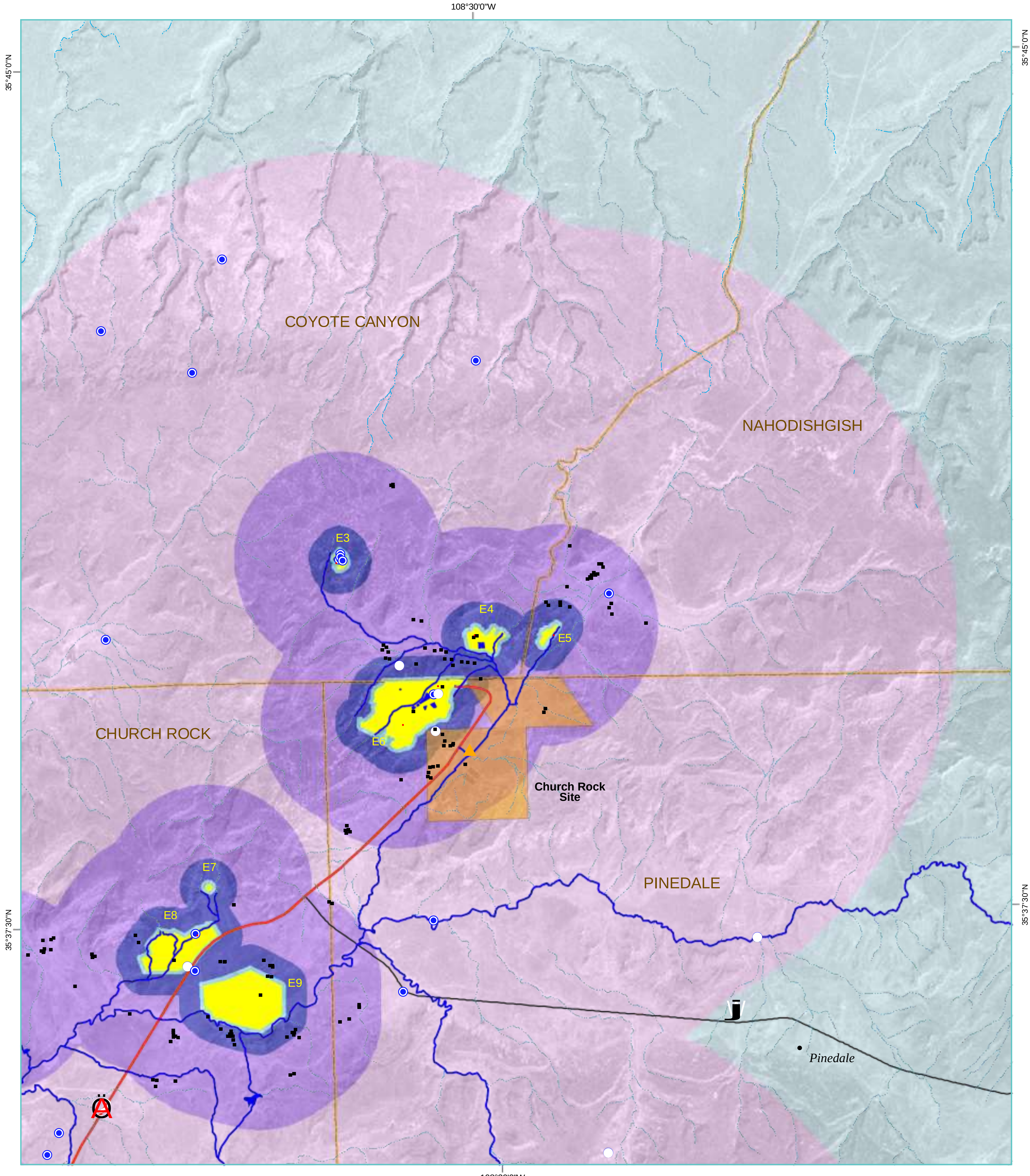
1/4 Mile

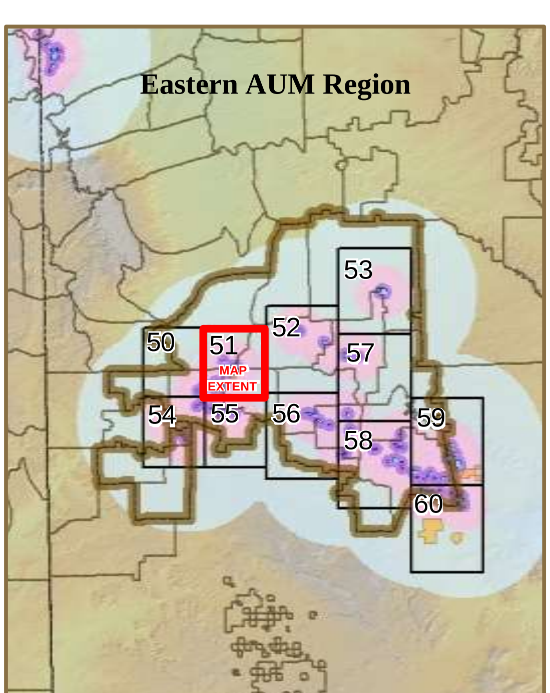
1 Mile

4 Miles

15 Miles

Figure 50. Combined Pathways in the Northwest Church Rock Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NORTHEAST CHURCH ROCK

N W E S

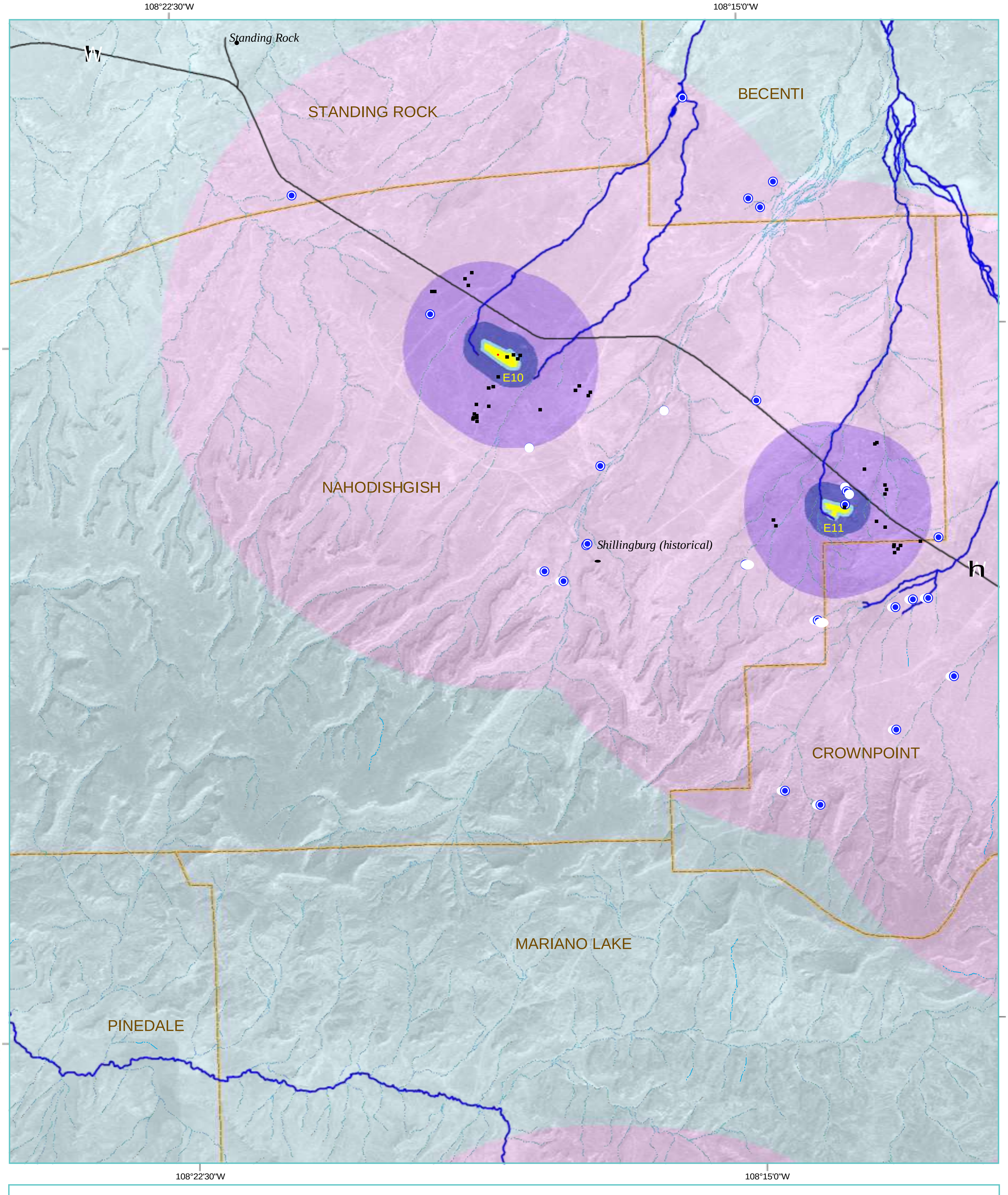
0 — 4 Miles

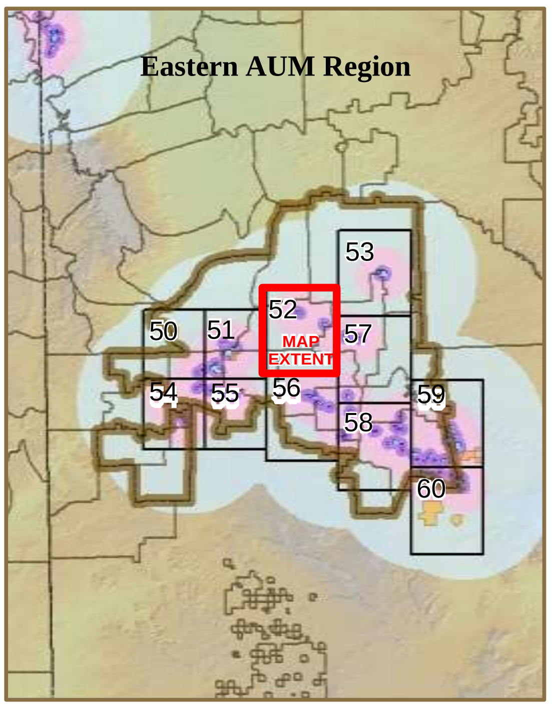
Map Scale 1:65,000

Legend

E3	Downstream Water Pathway ID
·	Mine Feature
▪	Structure within 1 mile
◉	Well within 4 miles
	Abandoned
	Intermittent Stream
	Chapter
	Highway
	Paved Road
	MAP-Uranium Mine
	Mine Buffers
	200 Feet
	1/4 Mile
	1 Mile
	4 Miles
	15 Miles
	Uranium Mill/ Reclamation Site

Figure 51. Combined Pathways in the Northeast Church Rock Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - NAHODISHGISH

N W E S

0 4 Miles

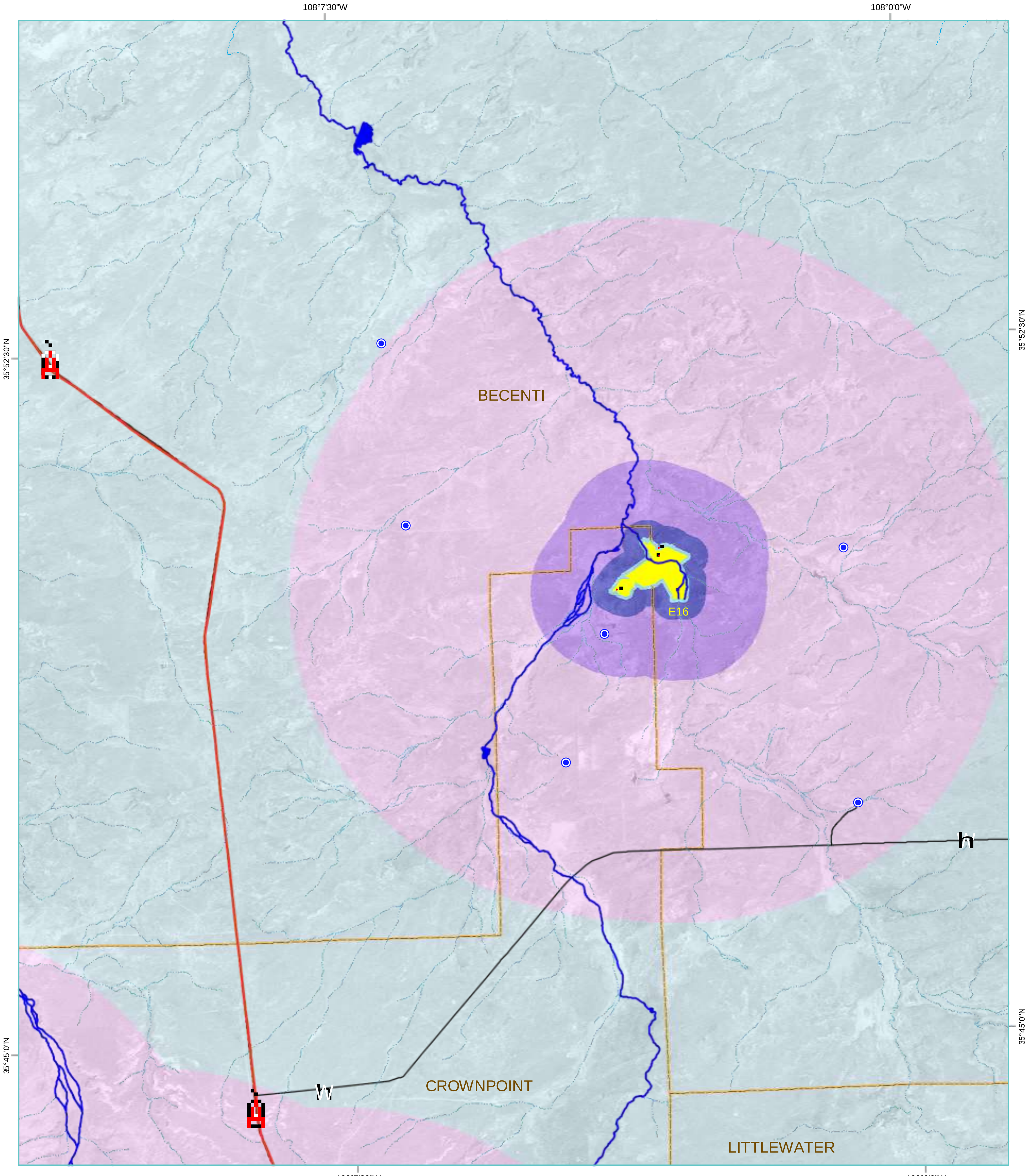
Map Scale 1:80,000

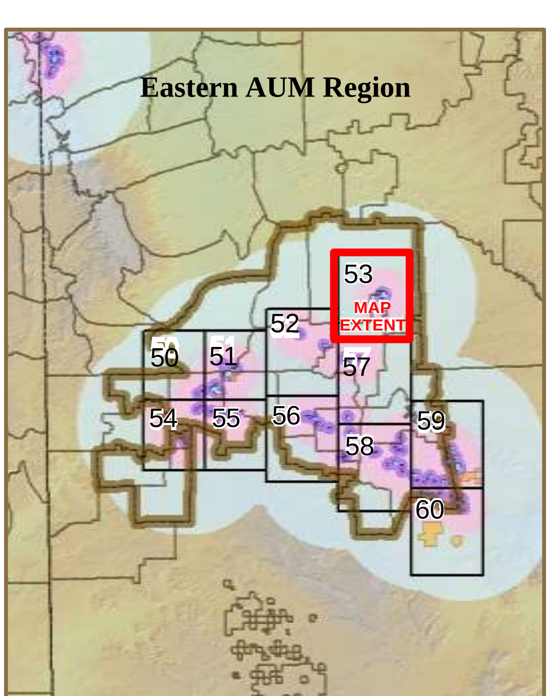
Legend

- MAP-ID*
- Mine Feature
- Structure within 1 mile
- Well within 4 miles
- Downstream Water Pathway
- Intermittent Stream
- Chapter
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

* MAP-IDs E12-E15 deleted

Figure 52. Combined Pathways in the Nahodishgish Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - BECENTI

N
W E
S

0 4 Miles

Map Scale 1:80,000

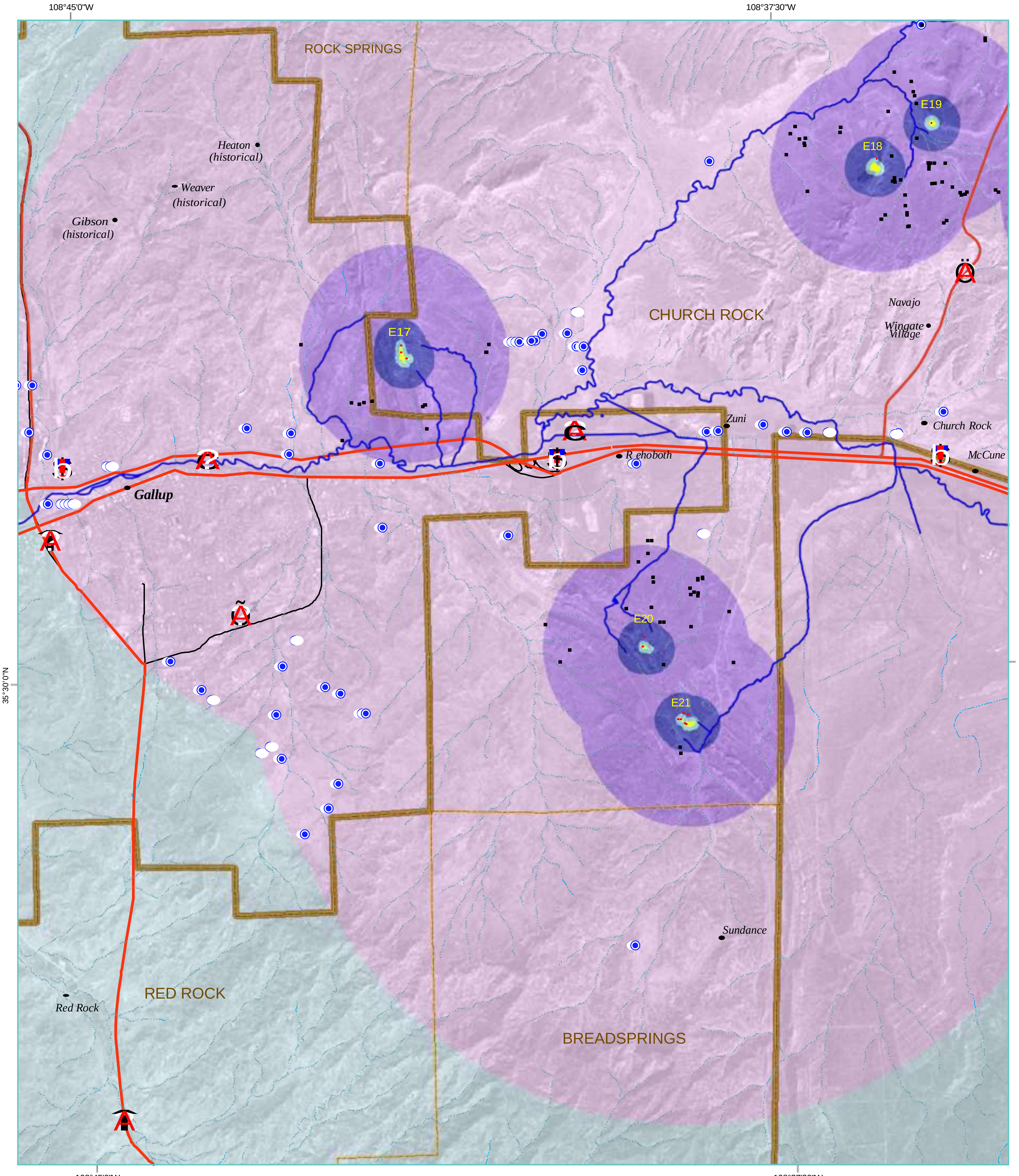
Legend

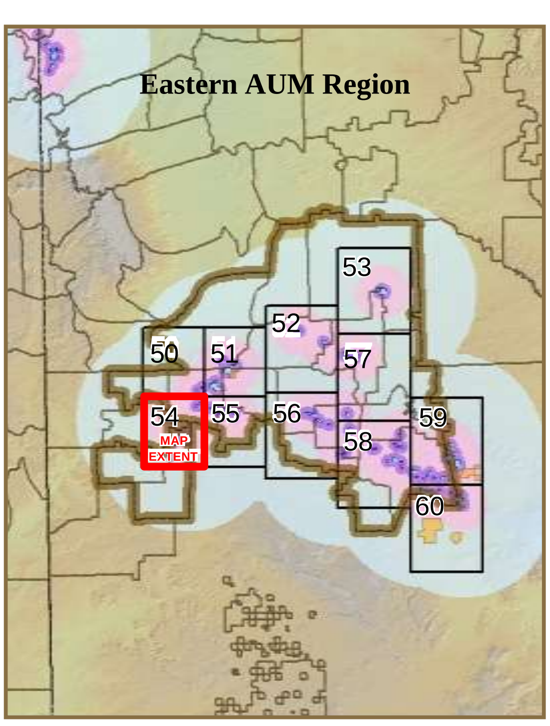
E16 ID
Downstream Water Pathway
Mine Feature
Structure within 1 mile
Well within 4 miles

Abandoned
Intermittent Stream
Chapter
Highway
Paved Road

MAP-
Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 53. Combined Pathways in the Becenti Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - CHURCH ROCK

N
W E
S

0 4 Miles

Map Scale 1:65,000

Legend

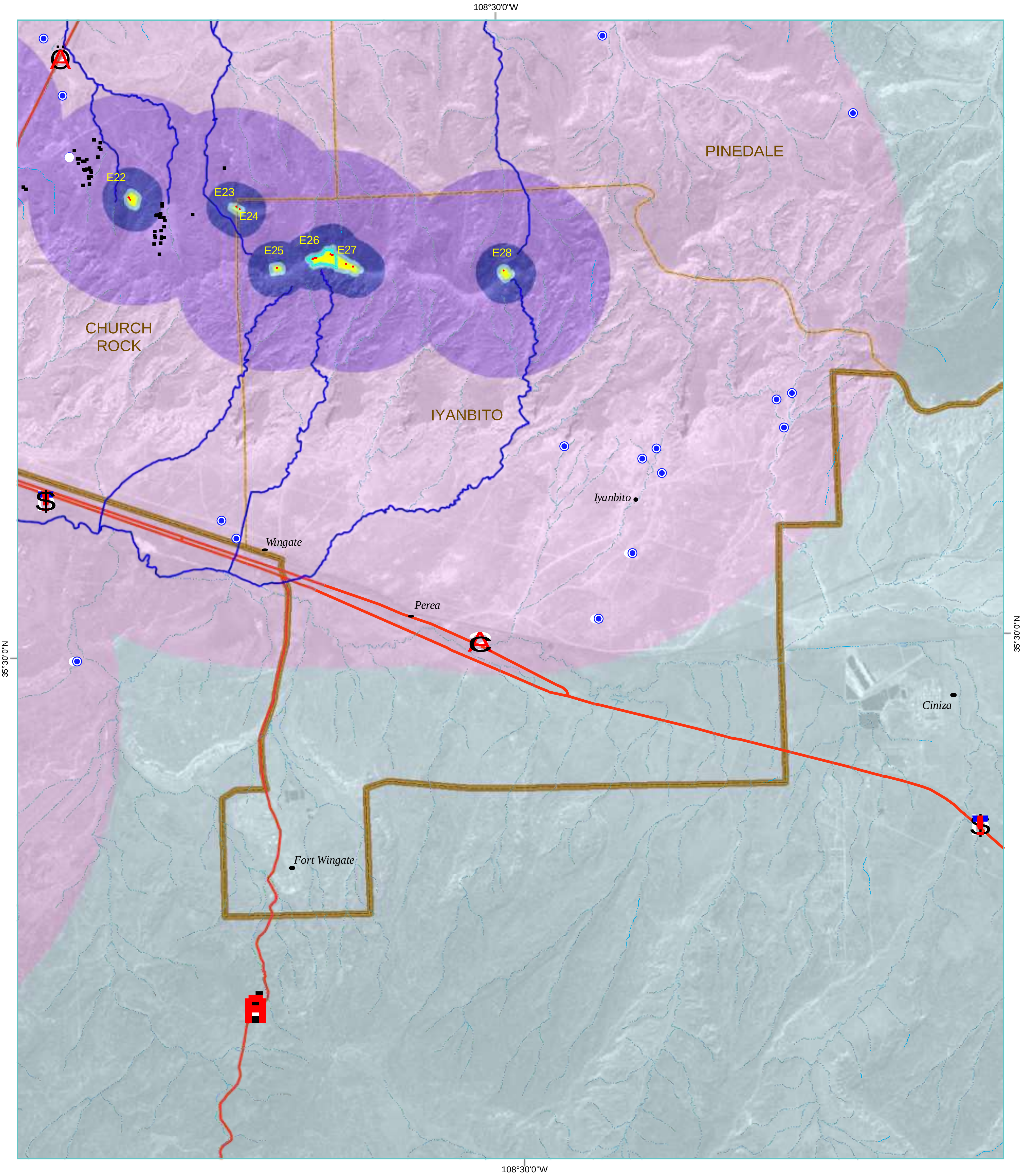
E17 Downstream Water Pathway ID
Mine Feature
Structure within 1 mile
Well within 4 miles

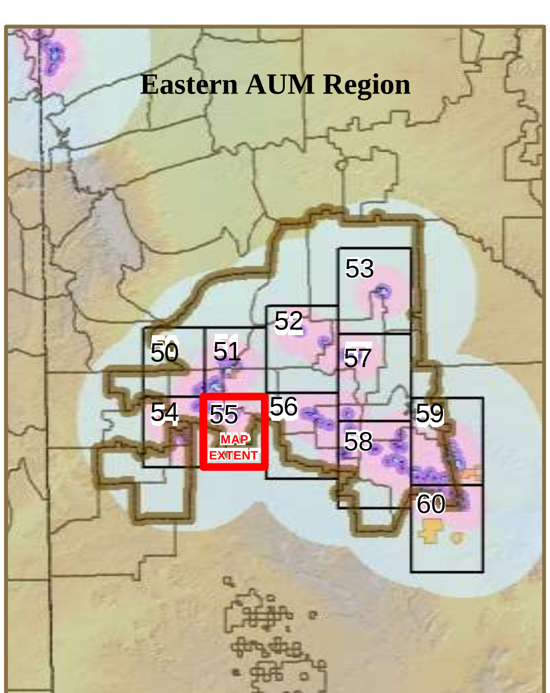
Abandoned
Intermittent Stream
Eastern AUM Region
Chapter
Highway
Paved Road

MAP-Uranium Mine

Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 54. Combined Pathways in the Church Rock Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - IYANBITO

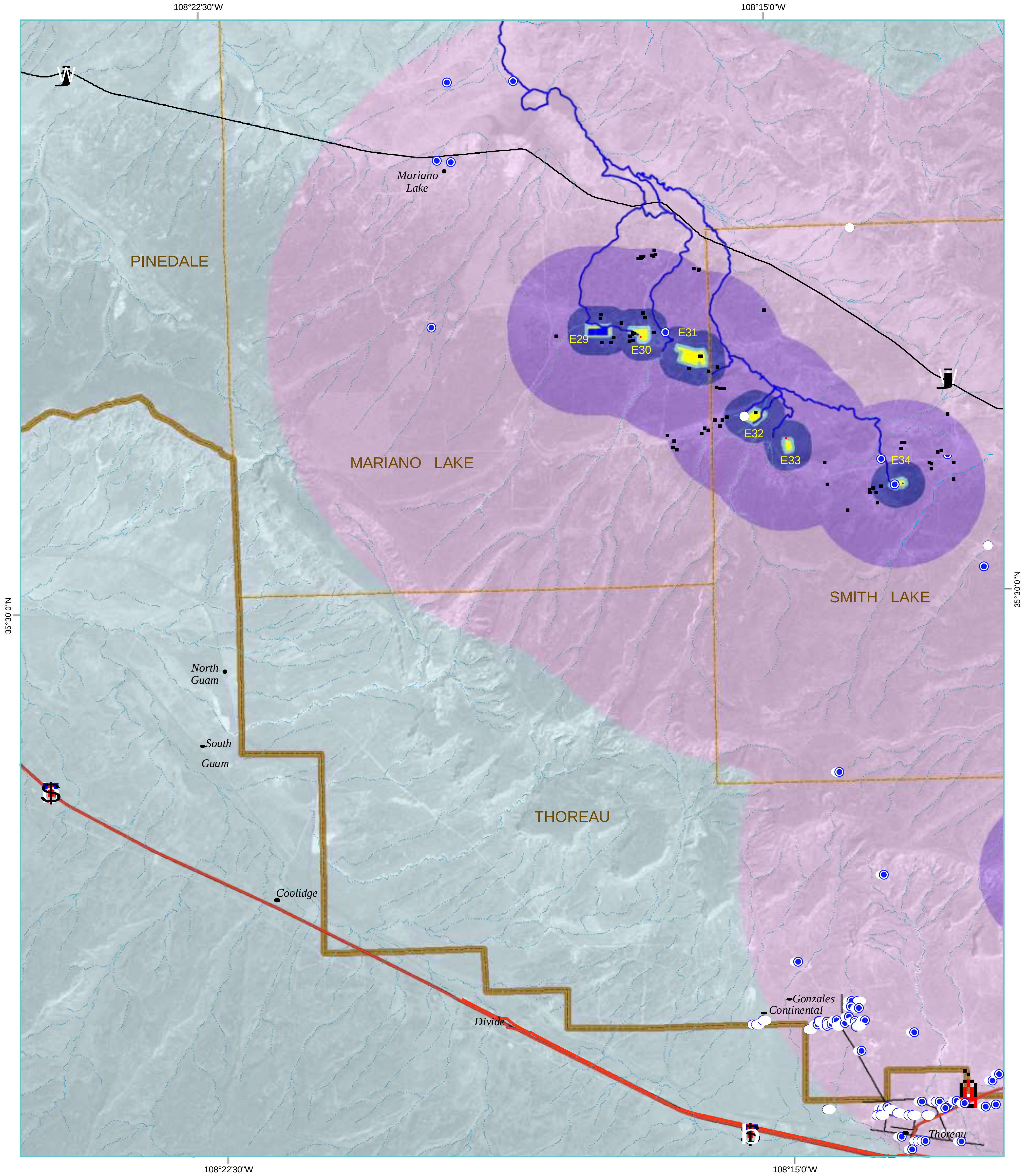
0 — 4 Miles

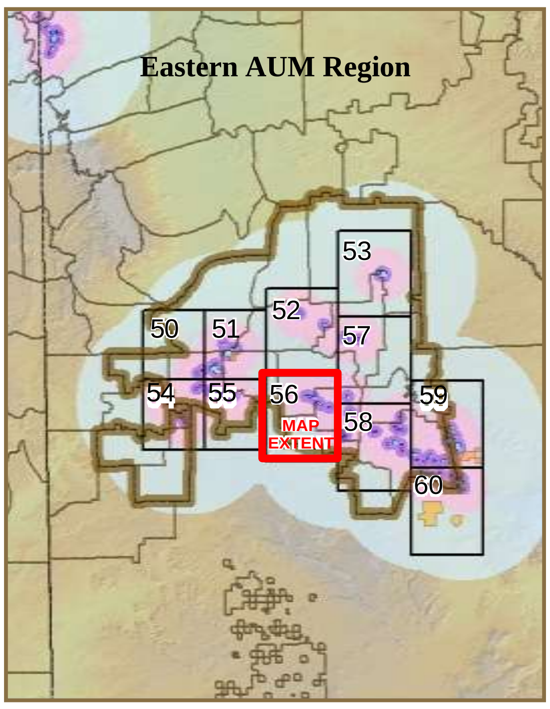
Map Scale 1:65,000

Legend

E22 MAP-ID	Downstream Water Pathway	Uranium Mine
Mine Feature	Abandoned	Mine Buffers
Structure within 1 mile	Intermittent Stream	200 Feet
Well within 4 miles	Eastern AUM Region	1/4 Mile
	Chapter	1 Mile
	Highway	4 Miles
		15 Miles

Figure 55. Combined Pathways in the Iyanbito Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - MARIANO LAKE

0 — 4 Miles

Map Scale 1:80,000

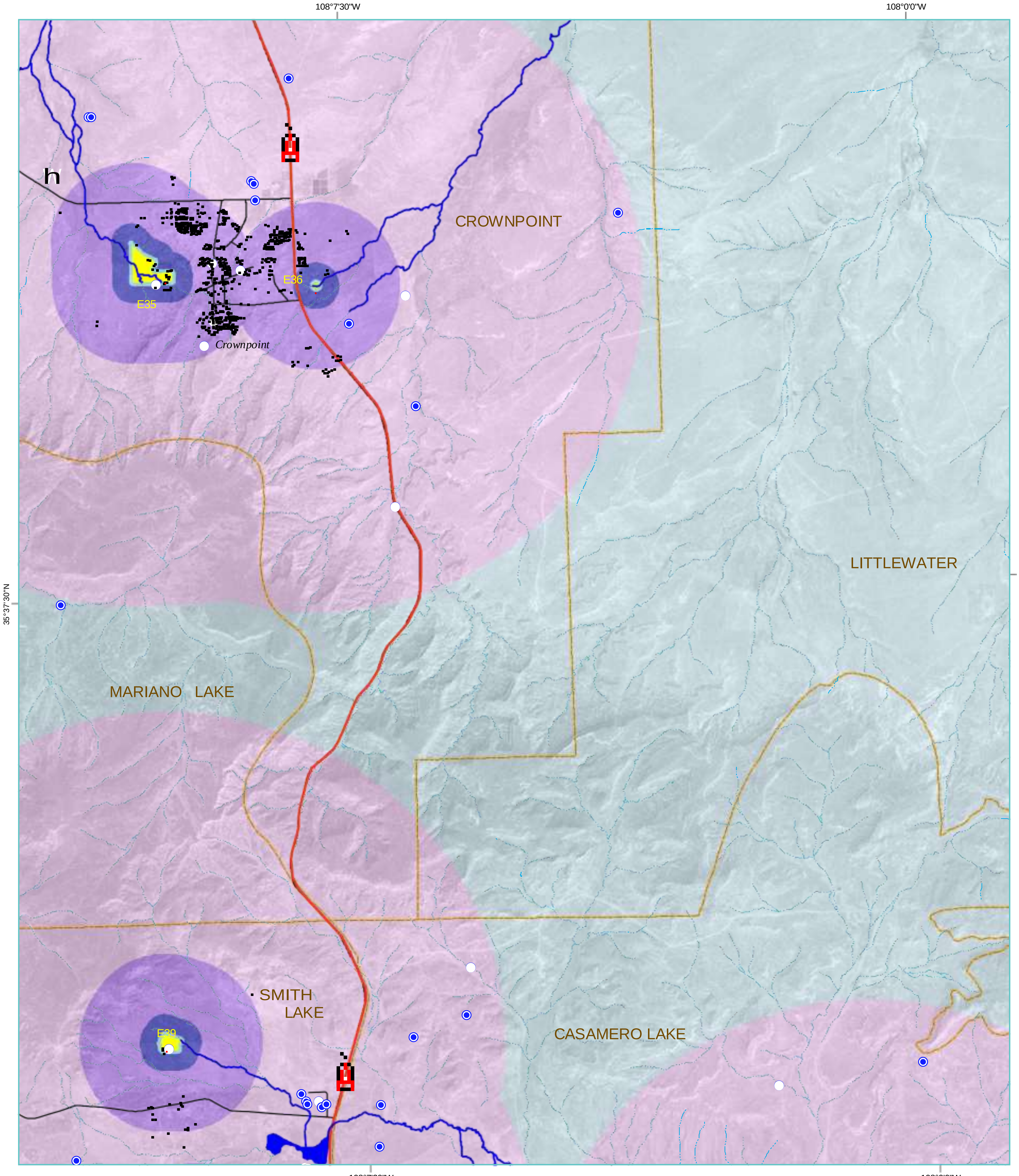
Legend

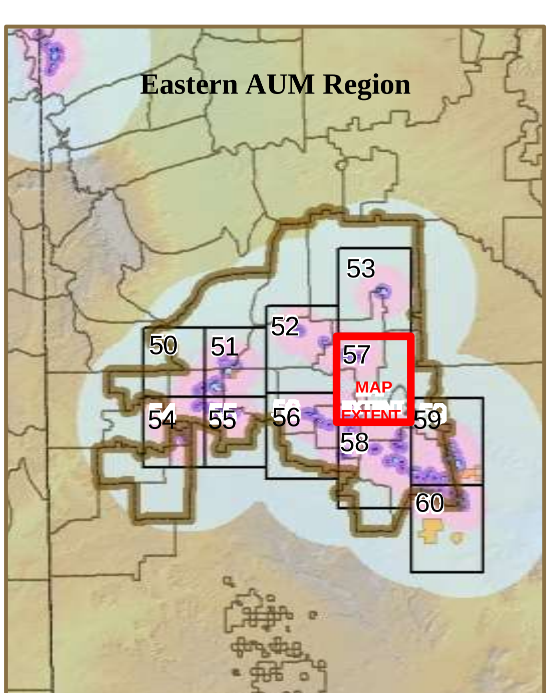
- E29 MAP-ID
- Mine Feature
- Structure within 1 mile
- Well within 4 miles
- Downstream Water Pathway Intermittent Stream
- Eastern AUM Region
- Chapter
- Highway
- Paved Road
- Abandoned Uranium Mine

Mine Buffers

- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 56. Combined Pathways in the Mariano Lake Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - CROWNPOINT

N W E S

0 4 Miles

Map Scale 1:80,000

Legend

E35 MAP-ID*

Mine Feature

Structure within 1 mile

Well within 4 miles

*MAP-IDs E37-E38 deleted

Downstream Water Pathway

Intermittent Stream

Chapter

Highway

Paved Road

Abandoned Uranium Mine

Mine Buffers

200 Feet

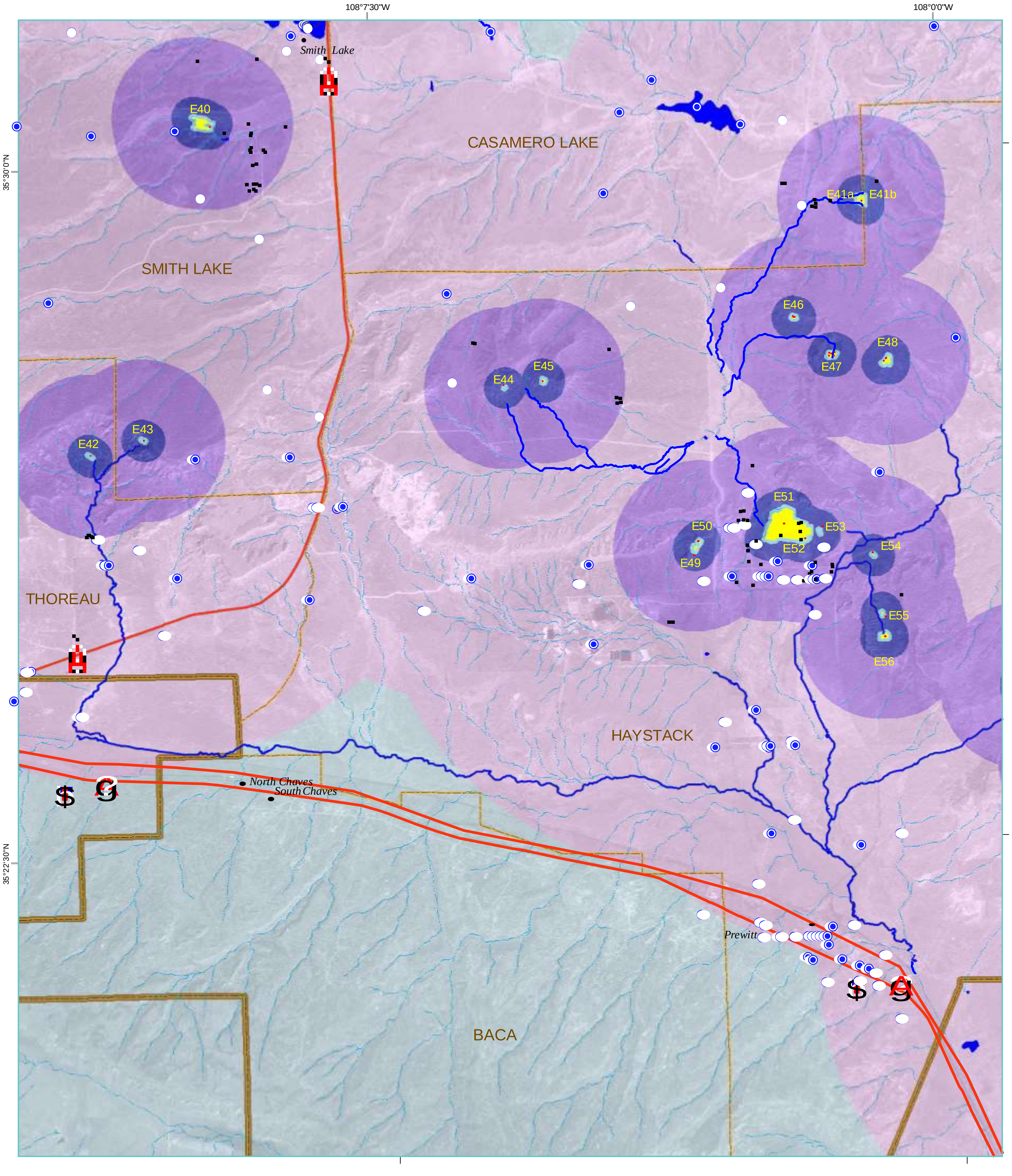
1/4 Mile

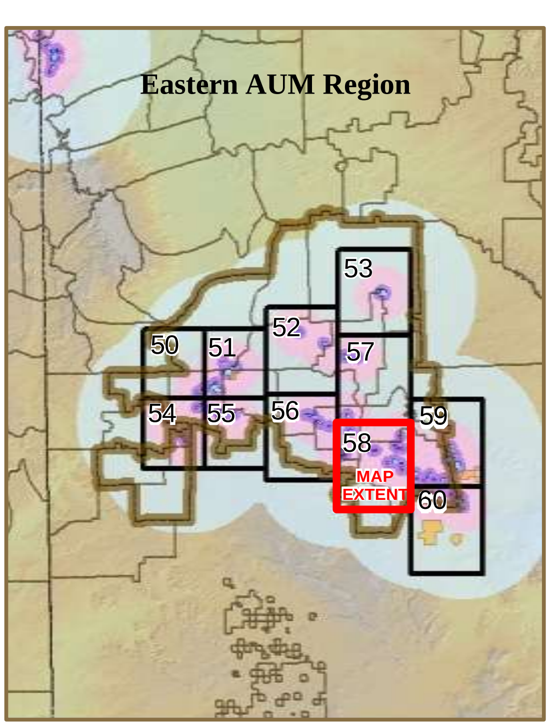
1 Mile

4 Miles

15 Miles

Figure 57. Combined Pathways in the Crownpoint Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - WESTERN HAYSTACK

0 4 Miles

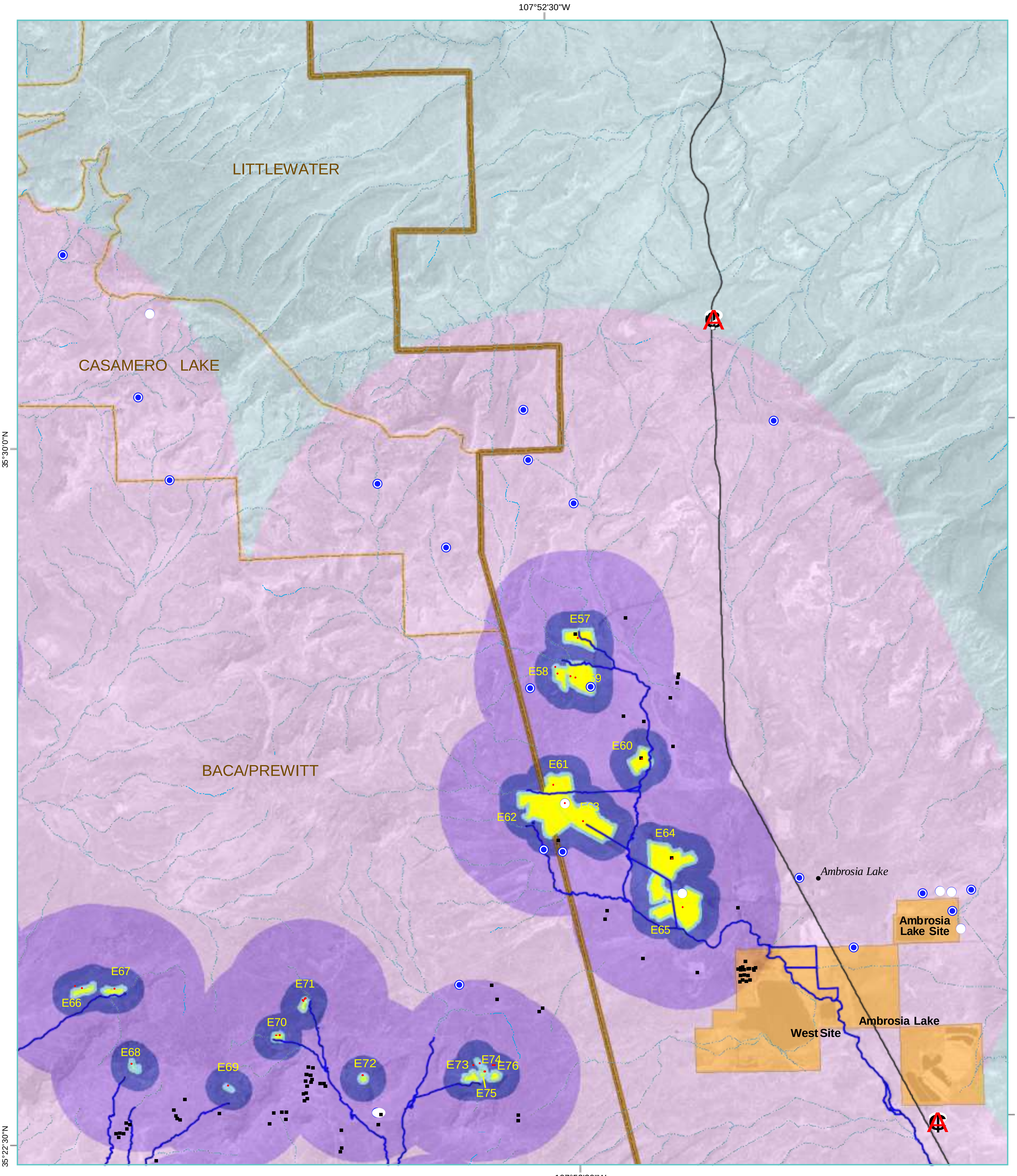
Map Scale 1:80,000

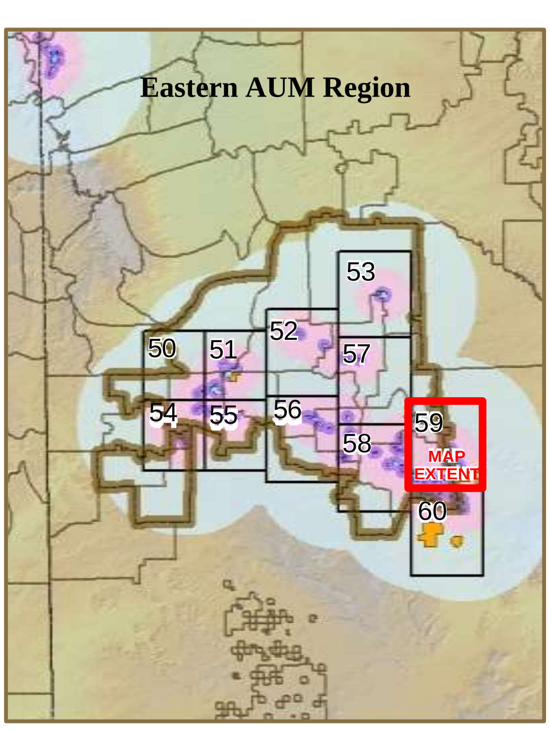
Legend

- E40 Downstream Water Pathway MAP-ID*
- Mine Feature
- Structure within 1 mile
- Well within 4 miles
- Abandoned
- Intermittent Stream
- Eastern AUM Region
- Chapter
- Highway
- Uranium Mine
- Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

*MAP-ID E41 divided into E41a and E41b

Figure 58. Combined Pathways in the Western Haystack Area.





ABANDONED URANIUM MINES AND THE NAVAJO NATION
Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - AMBROSIA LAKE

N W E S

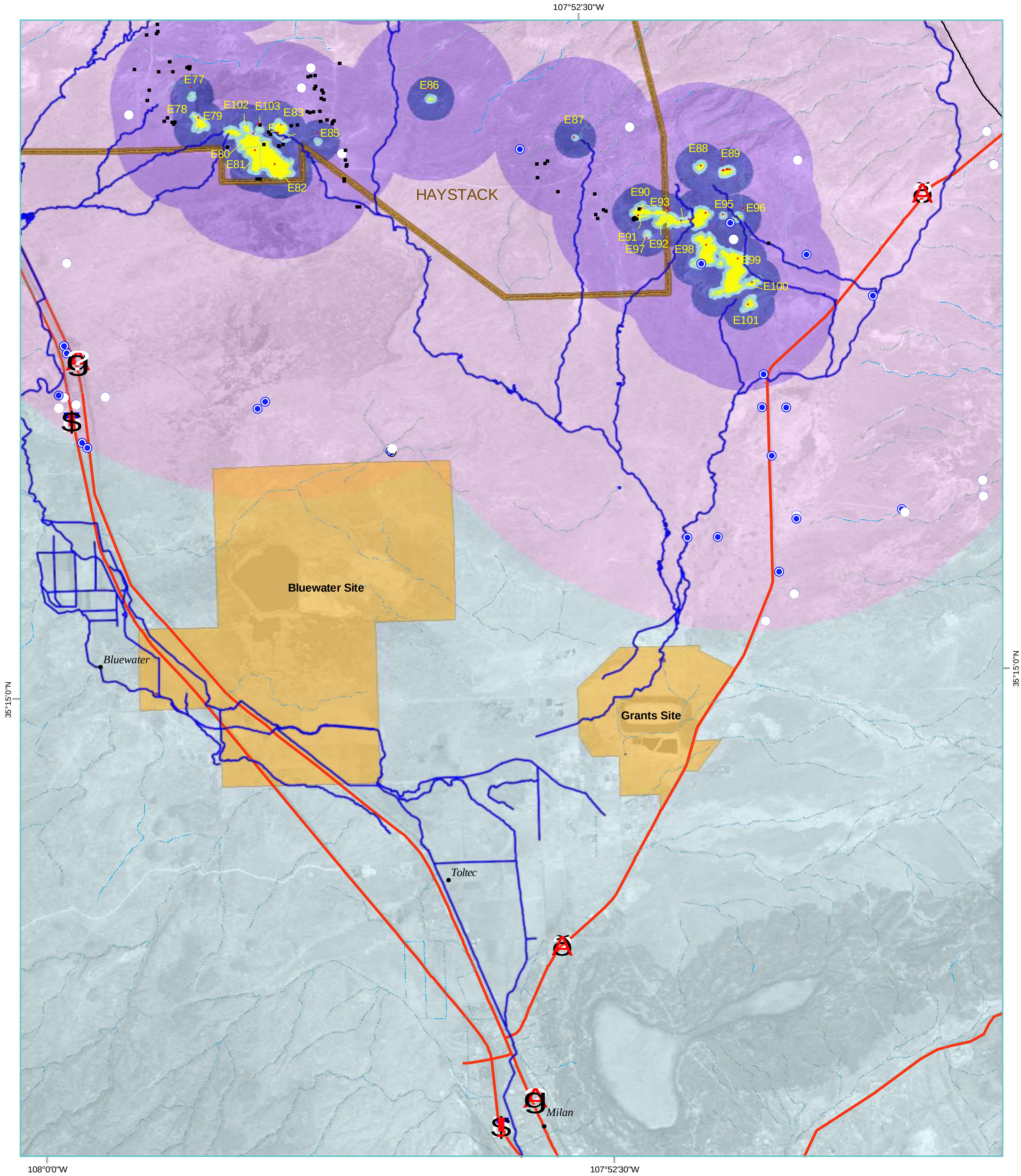
0 4 Miles

Map Scale 1:80,000

Legend

- E57 MAP-ID
- Mine Feature
- Structure within 1 mile
- Well within 4 miles
- Downstream Water Pathway
- Intermittent Stream
- Eastern AUM Region
- Chapter
- Paved Road
- Abandoned Uranium Mine
- Mine Buffers 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles
- Uranium Mill/ Reclamation Site

Figure 59. Combined Pathways in the Ambrosia Lake Area.



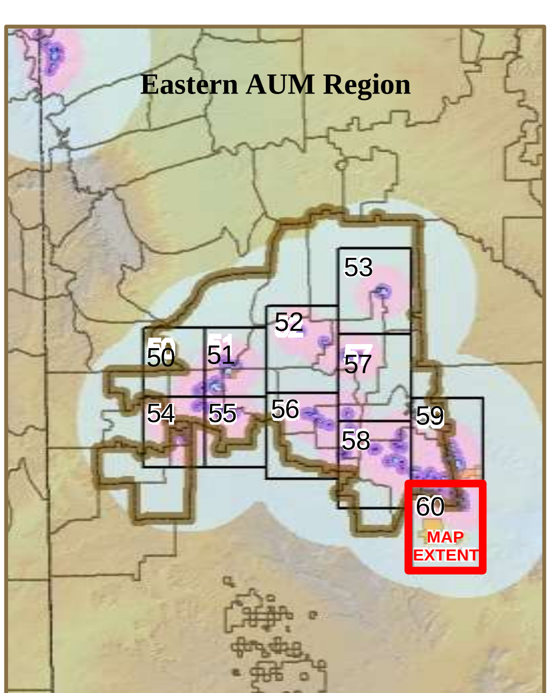


Figure 60. Combined Pathways in the Haystack Area.

ABANDONED URANIUM MINES AND THE NAVAJO NATION

Navajo Nation AUM Screening Assessment Report

COMBINED PATHWAYS - HAYSTACK

0 4 Miles

Map Scale 1:80,000

Legend

E77 MAP-ID
Mine Feature
Structure within 1 mile
Well within 4 miles

Downstream Water Pathway
Intermittent Stream
Eastern AUM Region
Chapter
Highway
Paved Road

Abandoned Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles
Uranium Mill/ Reclamation Site

*MAP-ID E94 deleted
MAP-IDs E102 and E103 added

DISCUSSION

This DISCUSSION section is organized by the six (6) AUM Regions. As noted earlier, the results from the scoring are not intended to identify actual risks, but are meant to provide a coarse screening of priority AUM sites for further investigation. The GIS approach facilitated a consistent and documented scoring process. The GIS cartographic tools also allowed flexible visualization of the data and analysis results.

NORTH CENTRAL AUM REGION SCREENING ASSESSMENT SCORE RESULTS

Review of the North Central AUM Region Combined Pathway Scores (Table 4) and Figure 61 “North Central AUM Region Combined Pathways - Three Score Ranges” show that three of the four highest scoring AUM sites in the region occur in the Monument Valley mining area on Oljato Mesa in the Oljato Chapter (Charles Keith, Rock Door No. 1, and Norcross). These three (3) AUMs have been reclaimed by NAMLRP. The fourth highest scoring site is located about one (1) mile north of the Mexican Hat bridge on Highway 163 and is off the Navajo Nation. This AUM-related site was a uranium ore transfer location.

Since the primary HRS criteria are counts of structures and wells at specified distances from the AUMs, areas with high occurrences of homes and wells proximal to the AUM sites scored high. The two highest scoring mines in the North Central AUM Region, Charles Keith mine (MAP-ID #NC15) and Rock Door No. 1 mine (MAP-ID #NC24) in the Oljato Chapter are examples of AUM sites that scored high (3,080 and 2,940 respectively) due to proximity of homes and wells. Conversely, remote AUM sites with sparse population and few wells score low. This can be seen in the generally low scores for the AUM sites in the western and southern Oljato, and west central Kayenta Chapters (shown in green on Figure 61).

High scoring AUMs were not necessarily high ore producers. The Rock Door No. 1 mine only had 25 tons of ore mined and produced 331 pounds of uranium and 937 pounds of vanadium (Chenoweth, 1991 - S03100502). Only 59 tons of ore were mined from the Charles Keith mine, which produced 237 pounds of uranium and 179 pounds of vanadium (Chenoweth, 1991 - S03100502). These are significantly smaller production numbers compared to the Bootjack AUM in Oljato Chapter (MAP-ID #NC48) that scored 330 but had 36,236 tons of ore mined with 331,010 pounds of uranium extracted (Chenoweth, 1993 - S10100222). The Monument No. 2 AUM (MAP-ID #NC66) in the Kayenta Chapter scored 980, but produced more uranium than any other mine in Arizona with 773,132 tons of ore mined and 5,276,093 pounds of uranium and 21,915,125 pounds of vanadium extracted (Gregg et al., 1989 - S10020208), and has an associated UMTRA cleanup site.

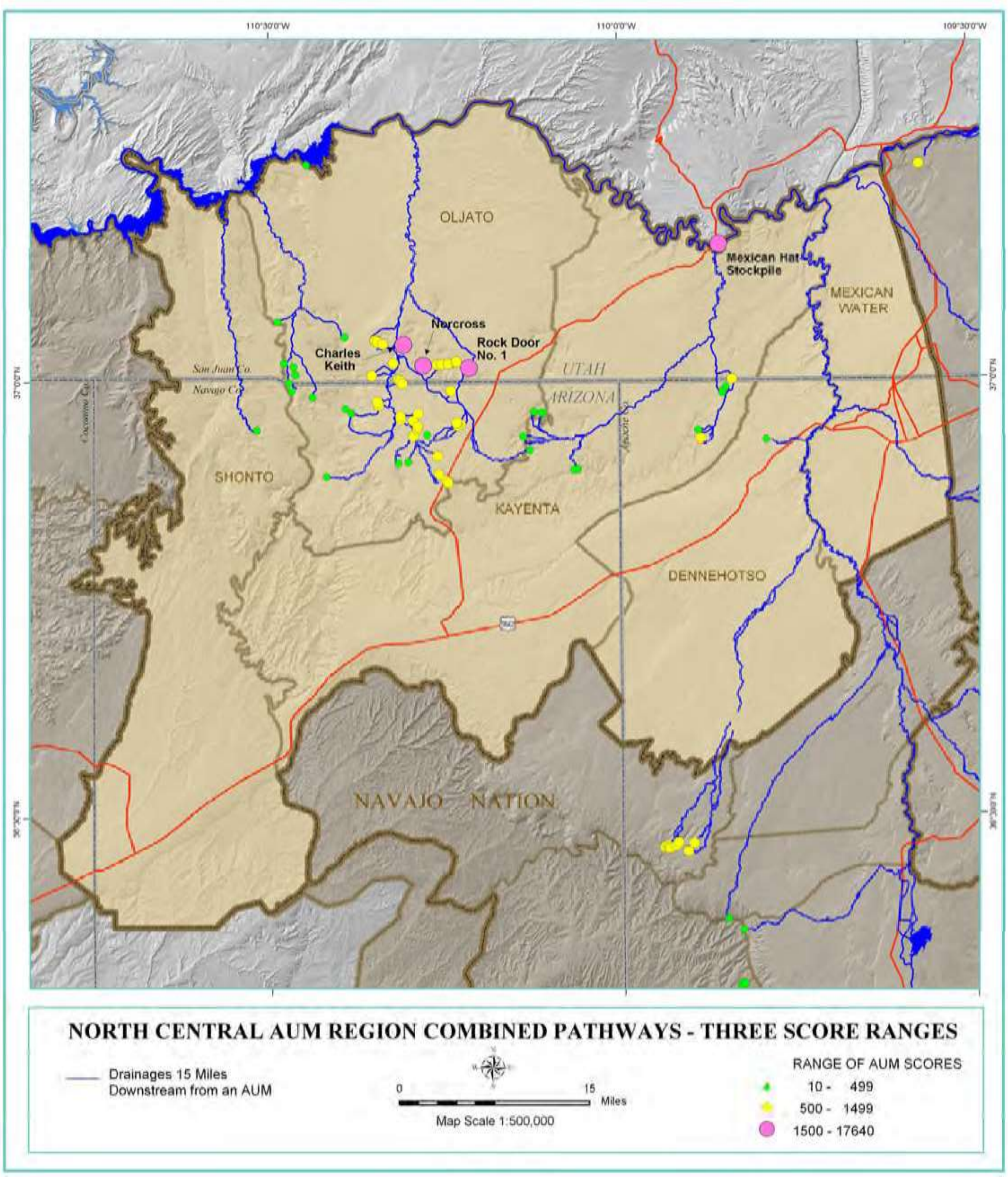


Figure 61. North Central AUM Region Combined Pathways Map with Three Score Ranges.

NORTHERN AUM REGION SCREENING ASSESSMENT SCORE RESULTS

Review of the Northern AUM Region Combined Pathway Scores (Table 5) and Figure 62 “Northern AUM Region Combined Pathway - Three Score Ranges” show that the highest scoring AUM sites occur in the Northeast Carrizo mining area of the Beclabito Chapter (NA-0420 and NA-0424), the Lukachukai mining area of Cove Chapter (Cove Transfer Station), the Climax Transfer Station south of the Shiprock community, the Oak Springs Mine (Gravel Cap) and Oak Springs Mine in the Red Valley Chapter, and the Plot 13 and Johnny McCoy 1 AUMs in the in Sweetwater Chapter. NA-0420 and NA-0424 are AUM sites that were reclaimed by the NAMLRP. NA-0420 is identified as a rim strip/pit feature, and NA-0424 is identified as a prospect. Uranium/vanadium production records could not be located for either of these sites. The Cove Transfer Station was not an AUM, but was used as a stockpile site. Uranium ore was trucked from the Kerr-McKee mines in the Lukachukai Mountains and dumped at the stockpile, then loaded onto larger trucks and transported to the Shiprock mill (Dare, 1961 - S10280202). Historical records could not be found for the Climax Transfer Station (MAP-ID #N191). William Chenoweth (2006 - S03010601) identified the site as a stockpile for ore mined at the Frank No. 1 Mine that was then transferred to the Climax Uranium Mill in Grand Junction. The Navajo Nation Environmental Protection Agency Superfund Program has recently conducted field assessments of the site (NNEPA, 2006 - S03030601). The Oak Springs Mine (Gravel Cap), Oak Springs Mine, Plot 13, and Johnny McCoy 1 were all productive mines that have been reclaimed by the NAMLRP.

Remote AUM sites with sparse population and wells scored low. This can be seen in the generally low scores for the AUM sites in the Chuska, Lukachukai, southwest Sweetwater, west Carrizo and portions of the northeast Carrizo mining areas (shown in green on Figure 62).

Rocky Spring Mine in the Chuska mining area (MAP-ID #N264) is an example of an AUM site that scored moderately high (1,070) due to proximity of homes and wells. However, this is an unreclaimed rim strip/pit site with limited production (a total of 11 tons of ore mined), and only 3 pounds of uranium and 62 pounds of vanadium extracted (Chenoweth, 1984 - S03130303). This is an insignificant production number compared to the Mesa II, Mine #1&2, P-21 AUM (MAP-ID #N245) that scored 250 but had 274,128 tons of ore mined with 1,284,853 pounds of uranium and 5,475,210 pounds of vanadium extracted (Chenoweth, 1988 - S10280203).

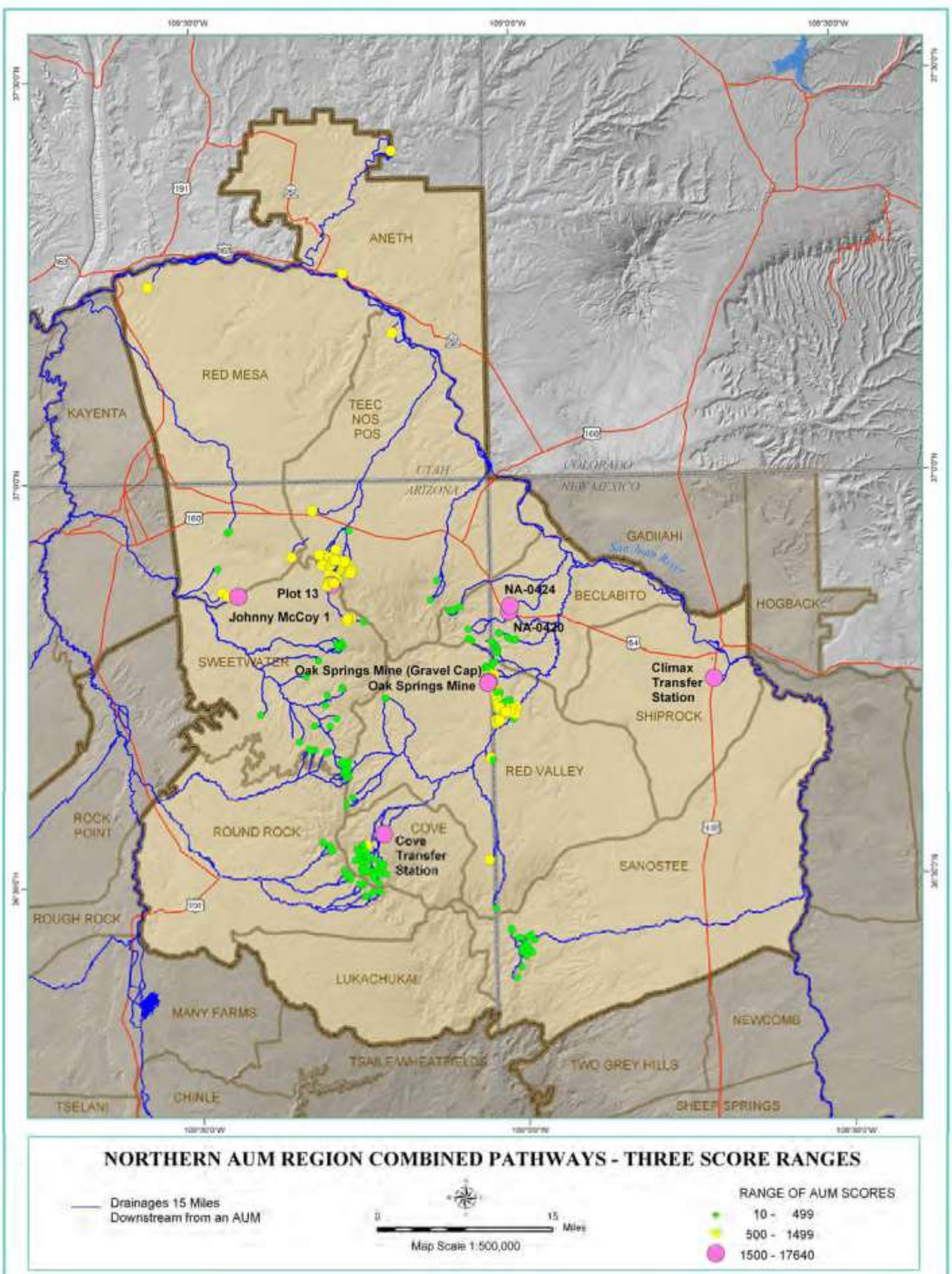


Figure 62. Northern AUM Region Combined Pathways Map with Three Score Ranges.

WESTERN AUM REGION SCREENING ASSESSMENT SCORE RESULTS

Review of the Western AUM Region Combined Pathway Scores (Table 6) and Figure 63 "Western AUM Region Combined Pathway - Three Score Ranges" show that the highest scoring AUM sites occur in the Little Colorado River mining area of the Cameron Chapter (A&B No. 2 and A&B No. 3) and Coalmine Canyon Chapter (Charles Huskon No. 1 and No. 12, and Jack Daniels Nos. 1, 4, and 5). All of these sites have been reclaimed by the NAMLRP.

AUM sites in the southwestern Coalmine Canyon, and southeastern and northern Bodaway/Gap Chapters generally scored low (shown in green on Figure 63). This is due to the remoteness of the AUMs with sparse populations and few wells.

Martin Johnson No. 4 mine in the Bodaway/Gap Chapter (MAP-ID #W5) is an example of an AUM site that scored moderately high (1,250) due to proximity of homes and wells. However, this AUM only had 38 tons of ore mined and produced 120 pounds of uranium and 23 pounds of vanadium. The A & B No. 3 mine (MAP-ID #W39) has the highest score (5,880) in the Western AUM Region. This was a producing mine, with 586 tons of ore mined and 1,458 pounds of uranium and 515 pounds of vanadium extracted. This is a significantly smaller production number compared to the Ramco No. 20 AUM (MAP-ID #W94) that scored 270 but had 22,642 tons of ore mined with 99,226 pounds of uranium and 19,259 pounds of vanadium extracted. Production numbers are from Chenoweth (1993 S10100239).

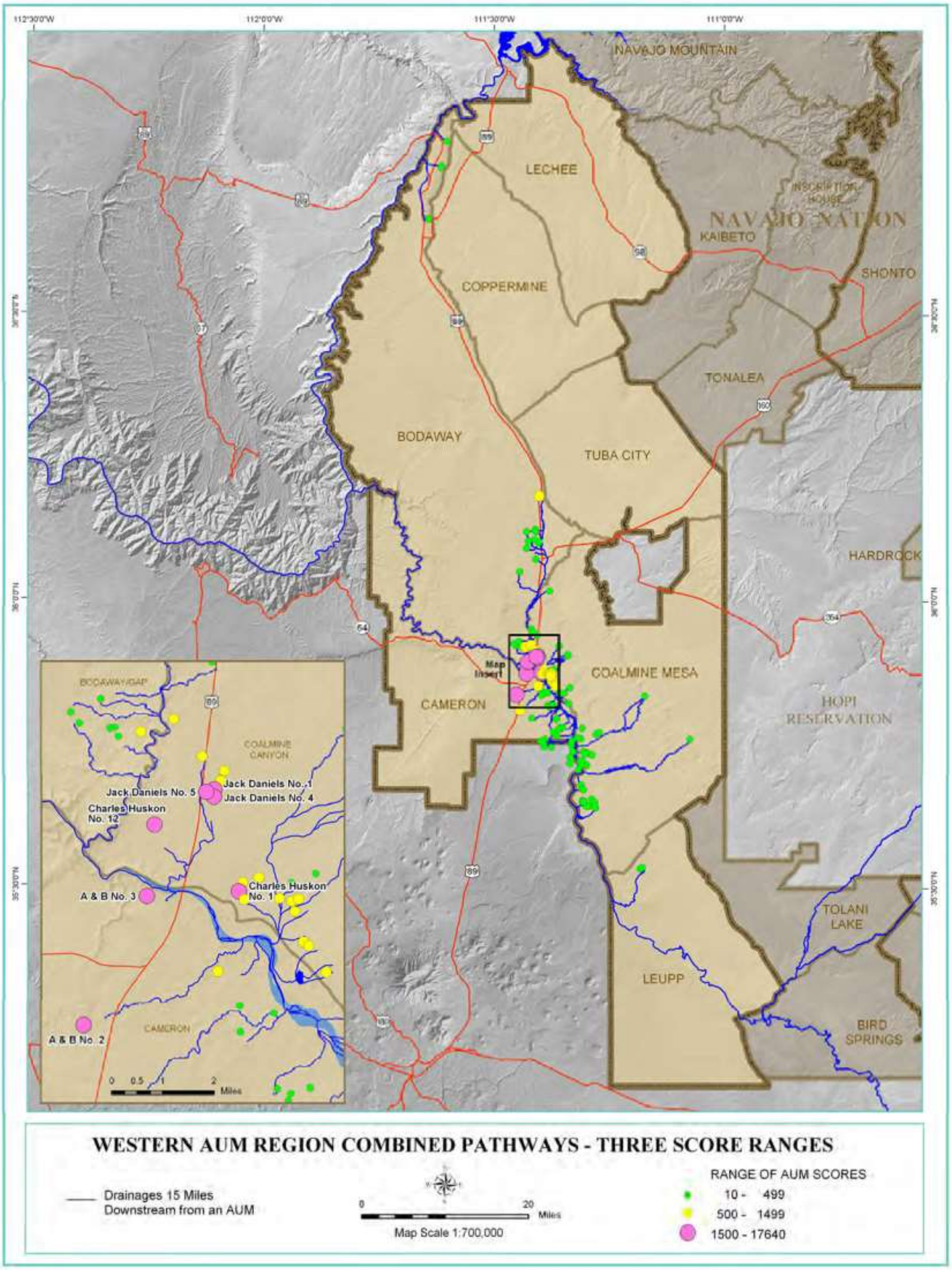


Figure 63. Western AUM Region Combined Pathways Map with Three Score Ranges.

CENTRAL AUM REGION SCREENING ASSESSMENT SCORE RESULTS

Review of the Central AUM Region Combined Pathway Scores (Table 7) and Figure 64 "Central AUM Region Combined Pathways - Three Score Ranges" shows that the Occurrence B AUM in the Chinle Chapter is the highest scoring AUM site. This AUM is an example of an AUM site that scored high (4,170) due to proximity of homes and wells. This AUM site is also proximal to the Canyon de Chelly National Monument, shown in orange in Figure 64.

Remote AUM sites with sparse population and few wells score low. This can be seen in the generally low scores for the AUM sites in the eastern Black Mesa, northeastern Tachee/Blue Gap, and northwestern Tselani/Cottonwood Chapters (shown in green on Figure 64).

High scoring AUMs did not necessarily produce large amounts of uranium. The Occurrence B AUM (MAP-ID #C34) did not have any reported production of uranium or vanadium. This occurrence was described as a stripped area (borrow pit) 500 feet by 700 feet across and 10 feet deep with radioactive rocks (up to 4 times background) (Chenoweth, 1990 - S10020207).

Conversely, one of the more significant uranium producing mines in the Central AUM Region was Claim 7 in Tselani/Cottonwood Chapter (MAP-ID #C24). The combined score for Claim 7 was 260, but it was one of the largest uranium producers in the region with 5,614 tons of ore mined and 14,594 pounds of uranium extracted (Chenoweth, 1990 - S10100236).

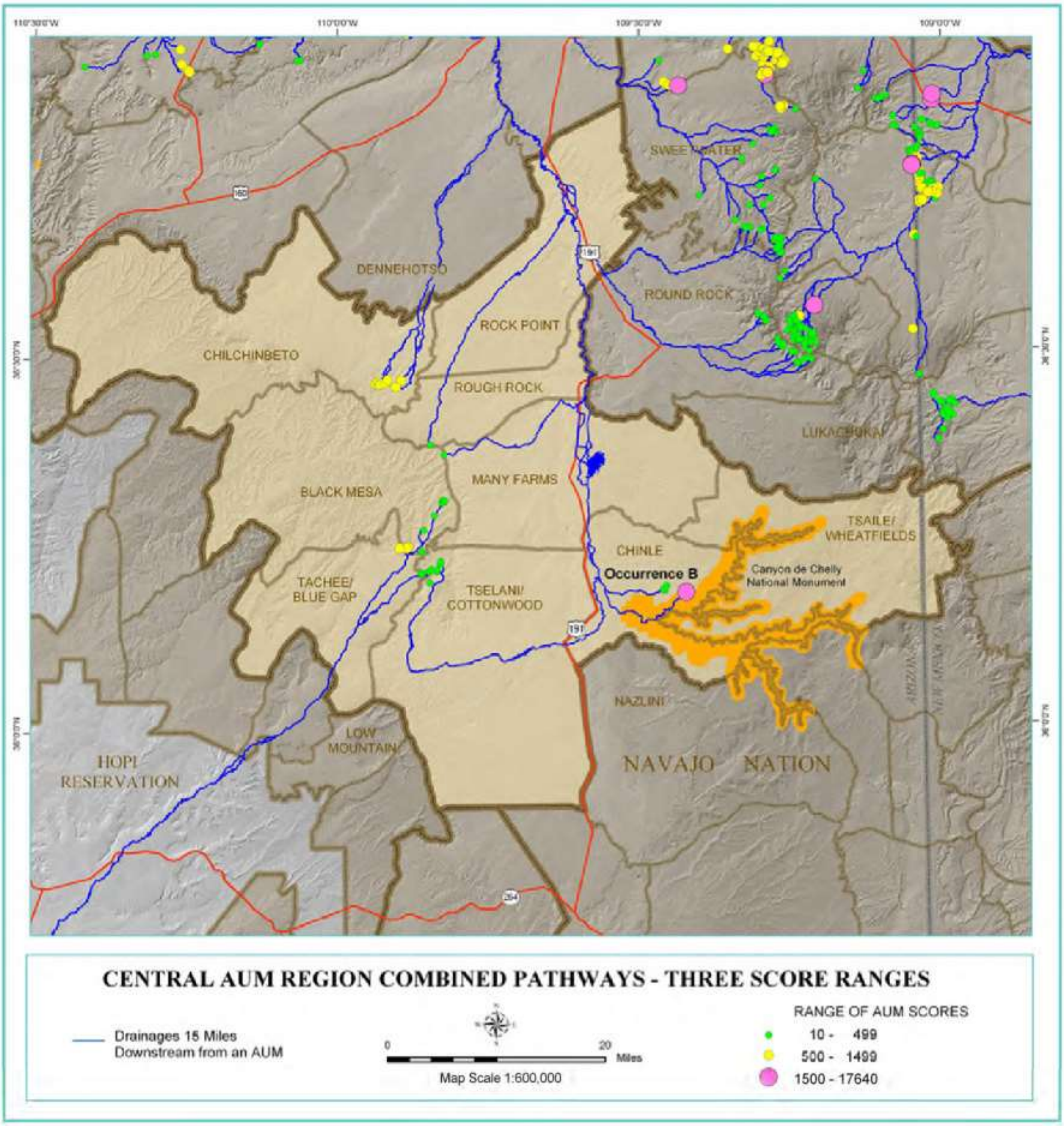


Figure 64. Central AUM Region Combined Pathways Map with Three Score Ranges.

SOUTHERN AUM REGION SCREENING ASSESSMENT SCORE RESULTS

Review of the Southern AUM Region Combined Pathway Scores (Table 8) and Figure 65 "Southern AUM Region Combined Pathways - Three Score Ranges" show the highest scoring AUM site occurs in the Indian Wells Chapter at the Mail Box Claim (MAP-ID #S2) with a score of 1,130.

There were no AUMs in the Southern AUM Region that scored above 1,500. The Mail Box Claim did not have any reported production of uranium or vanadium. The Morale Mine (shown in green) has the lowest combined pathway score at 450 (MAP-ID #S3). It was the only producing uranium mine in the Southern AUM Region, with 192 tons of ore mined, and 580 pounds of uranium and 162 pounds of vanadium produced (Chenoweth, 1990 - S10020205).

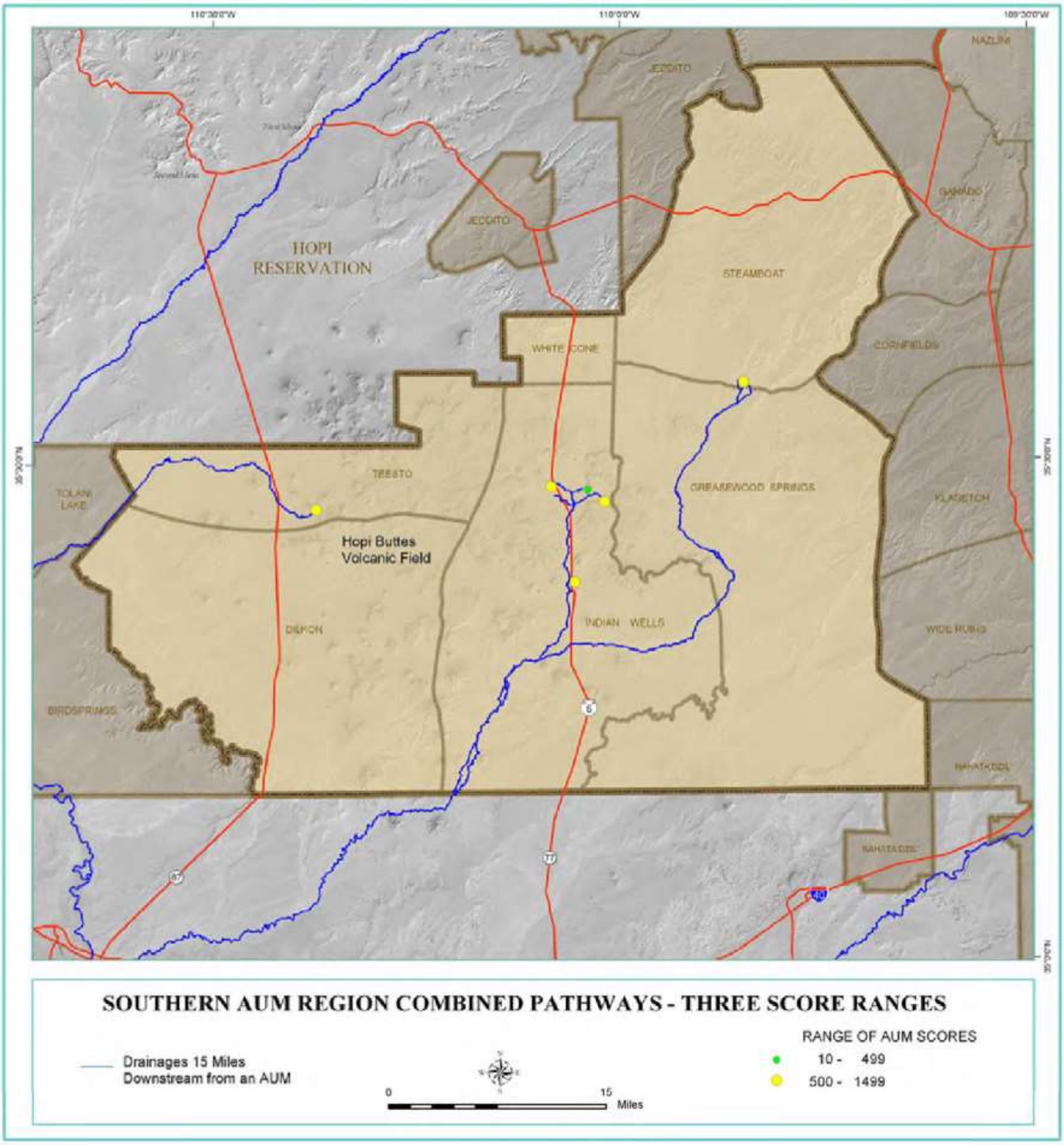


Figure 65. Southern AUM Region Combined Pathways Map with Three Score Ranges.

EASTERN AUM REGION SCREENING ASSESSMENT SCORE RESULTS

Much of the Eastern AUM Region is contained within the Grants Uranium District, the largest uranium producing area in the United States. Review of the Eastern AUM Region Combined Pathway Scores (Table 9) and Figure 66 “Eastern AUM Region Combined Pathways - Three Score Ranges” shows that there are twenty-four (24) AUM sites with scores that fall within the 1500 - 17,640 range. The highest scoring AUM site on the Navajo Nation is located in the Eastern AUM Region in the Crownpoint Chapter at the Crownpoint ISL (MAP-ID #E35). Since the primary HRS criteria are counts of structures and wells at specified distances from the AUMs, areas with high occurrences of homes and wells proximal to the AUM sites scored high. The highest scoring AUM in the Eastern AUM Region is an example of an AUM site that scored high (17,640) due to proximity of homes and wells (shown in pink on Figure 66). Conversely, remote AUM sites with sparse population and few wells score low. This can be seen in the generally low scores for the AUM sites in the Iyanbito and Smith Lake Chapters (shown in green on Figure 66).

The NE Church Rock mine (MAP-ID #E6) was the fifth highest scored AUM in the Eastern AUM Region (2,750). It was also the fifth highest producing mine on the Navajo Nation, with 3,398,648 tons of ore and 9,773,362 pounds of uranium. High scoring AUMs did not necessarily produce large amounts of uranium. An example is the highest scored Crownpoint ISL AUM (17,490), and the second highest scored Section 29-Conoco (5,850) with no uranium or vanadium production (McLemore et al., 2005 - S09290601). A mine site was developed at the Crownpoint ISL (see Figure 11 on page 18) and several warehouses and office buildings were constructed by Conoco in the 1970’s. Conoco completed at least 157 drill holes in the 1970’s, totaling about 316,750 drilled linear feet. Conoco began development of the uranium resource and constructed a plant facility, leach ponds, and three shafts were sunk to the mineralized horizons. Falling uranium prices in the early 1980’s resulted in the termination of the mine development. The mine plan called for underground extraction with surface processing (Myers, 2006 - S09300601).

Conversely, one of the more significant uranium producing mines in the Eastern AUM Region was the Dysart No. 1 AUM adjacent to the Haystack Chapter (MAP-ID #E59). The combined score for Dysart No. 1 was 540, but 891,922 tons of ore were mined, with 3,795,495 pounds of uranium and 47,438 pounds of vanadium produced (McLemore et al., 2005 - S09290601).

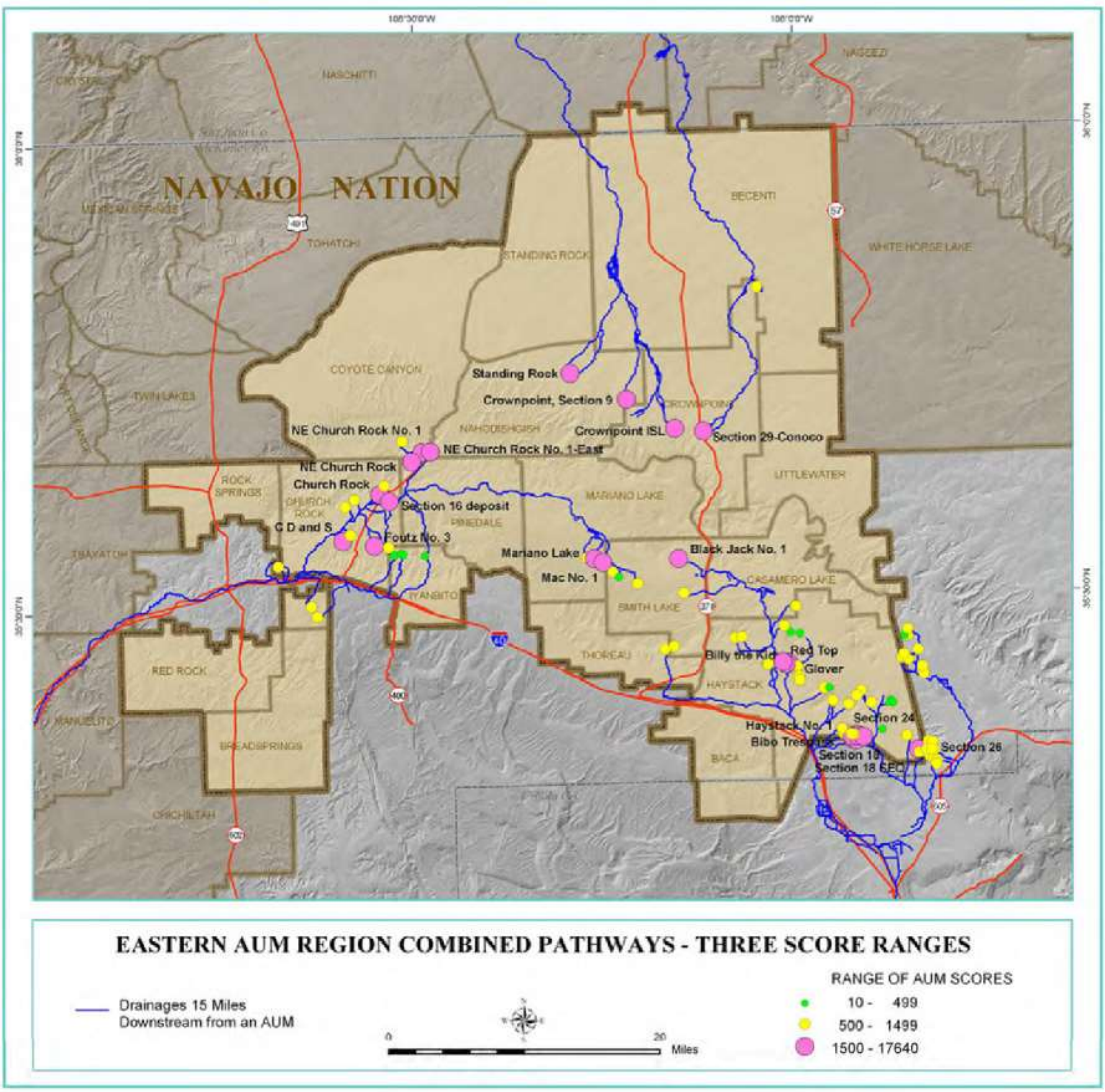


Figure 66. Eastern AUM Region Combined Pathways Map with Three Score Ranges.

RECOMMENDATIONS

Results from this modified screening process will be used to assist with identifying AUM sites for possible further investigation. There are several courses of action that may be used to remediate a site, including Removal Actions and Brownfields redevelopment. If the site is eligible for CERCLA assessments, then the site proceeds through the Preliminary Assessment stage and onward. If the site is not CERCLA eligible, the Site Screen recommendation is for No Further Remedial Action, in which the site may be referred to another party. The Site Screen may also recommend a Removal Action, though not necessarily detailed characterization, of the site contamination. Site specific characterization priorities should be established based on Navajo Nation priorities, AUM screening scores, resources, and site specific factors.

ADDITIONAL POSSIBLE SCORING FACTORS

Screening assessments at mine sites commonly require evaluation of exposures from multiple sources and exposures via multiple pathways (EPA, 2000 - S02200302). The modified HRS model used for this study was developed for the purpose of performing a coarse screening based on the presence of surface water drainages and the numbers of structures and wells proximal to AUM sites. Using existing GIS datasets, or by automating readily available data for the entire Navajo Nation, it may be possible to improve the analysis to better assess priority areas for further investigation. The following provides a list of existing or available datasets that could be used to develop additional factors that consider waste characteristics, likely transport pathways, and ecological targets.

- HRS factors related to uranium mine waste characteristics:
  - AUM reclamation sites with associated unreclaimed mine debris piles
  - AUM reclamation status (reclaimed versus unreclaimed)
  - AUM production (productive versus non-productive prospects)
  - Total uranium and/or vanadium production for each mine
  - The presence of host geologic formations for uranium ore
  - Water or stream sediment samples
  - Historic uranium haul routes, buying stations, and transfer stations
- HRS factors related to pathways and likelihood of release:
  - Surface or underground AUM extraction method (e.g., open pit or underground working)
  - Extent (size) of surface and/or underground workings
  - Perched water tables or documentation of infiltrated water in AUMs
  - Precipitation
  - Aquifer sensitivity
  - Slope proximal to AUM
  - Intersections of surface water pathway buffers with downstream targets (i.e., wetlands or structures)
- HRS factors related to targets:
  - Natural springs (undeveloped)
  - Sensitive habitats
  - Agricultural fields
  - Corrals and animal pens
  - Identification of schools, hospitals, Chapter houses, and community centers
  - Cumulative effects from multiple AUMs on targets (e.g.,several AUMs within 4 miles of a single well)

Inputs for many of these parameters have been processed and are presented in Part 2 of this document "Atlas with Geospatial Data." In order to provide spatial datasets that cover the entire Navajo Nation, many of the datasets are at regional scales (1:250,000 and smaller). While the spatial accuracies and detail of these regional datasets are not appropriate for detailed site investigations, they may provide useful information for regional assessments and site prioritizations for further study or remediation activities.

The following discussion provides several examples of how the data that has been collected could be used to augment and improve the AUM screening assessment.

NON-POTABLE WATER SAMPLES WITH URANIUM EXCEEDING MAXIMUM CONTAMINANT LEVELS

Water samples have been collected on the Navajo Nation for various programs and studies, and have in some cases included samples for for radionuclides, including uranium. Sites listed below in Tables 10, 11, and 12 have come to EPA's attention due to elevated radionuclide activity in water samples (EPA, 2000 - S02260102). As of December 8, 2003, the EPA Maximum Contaminant Level (MCL) for uranium is 30 micrograms per liter (µg/L)[1] or 20 pico-curies per liter (pCi/L)[2]. MCL is the maximum permissible level of a contaminant in water delivered to users of a public water system. Water samples from the following locations were sampled for Uranium-234, Uranium-235 and Uranium-238 and the summed total values were greater than 20 pCi/L (EPA, 2000 - S02260102). The locations of these water samples with elevated uranium levels are displayed on Figure 67 "Non-Potable Water Sample Locations with Elevated Uranium." The water sources cited were not sampled from Public Water Supply Systems (PWSS). The MCL's were used for comparison purposes only. The results for both studies were from one-time sampling events by EPA and the USGS and are not definitive with respect to attribution from mining related versus naturally occurring sources. Water sampling was conducted prior to NAMLRP reclamation activity and current conditions may differ. The Eastern AUM Region was not included in this sampling program.

Table 10. USACE Water Samples with Elevated Uranium.

REGION	USACE SAMPLE NAME	SAMPLE ID	SAMPLE DATE	SITE TYPE	TOTAL URANIUM (pCi/L)
Central	Benally Spring	KY981008CHS001	10/8/1998	Spring	47.1
Central	Burro Spring	KY981008CHS002	10/8/1998	Spring	60.1
Central	Cottonwood Spring	CH981123CHS001	11/23/1998	Spring	22.4
Central	Tank 10R-51	CH990316TCW004	3/16/1999	Wind Mill	22.3
Central	Tank 10T-533	CH981119TCW003	11/19/1998	Wind Mill	73.0
Central	Tinyehtoh Spring	KY981008CHS003	10/8/1998	Spring	39.9
Central	Waterfall Spring	CH981104BGS001	11/4/1998	Spring	61.7
Central	White Clay Spring	CH981124BGS002	11/24/1998	Spring	45.9
North Central	Baby Rock Spring 8-44	KY980901DES001	9/1/1998	Spring	36.3
North Central	Monument Pass Well	KY000112OLW014	1/12/2000	Well	40.0
North Central	Tank 8A-299	KY980902OLW001	9/2/1998	Wind Mill	171.9
Northern	9K216	RV990907SWW005	9/7/1999	Well	27.2
Northern	9T550	RV990907SWW004	9/7/1999	Well	32.3
Northern	9T586	RV990907SWW006	9/7/1999	Well	20.3
Northern	Alcove Canyon Springs	RV990330CVS010	3/30/1999	Spring	125.3
Northern	Area 1	RV990518CVS015	5/18/1999	Stream	51.3
Northern	Area 2	RV990518CVS017	5/18/1999	Stream	116.1
Northern	Area 4	RV990518CVS016	5/18/1999	Stream	148.8
Northern	Camp Mine	RV991026CVM013	10/26/1999	Mine	419.7
Northern	Cove Mesa 2	RV991020CVM012	10/20/1999	Mine	879.0
Northern	Ellison Wells	RV990517CVW004	5/17/1999	Well	34.7
Northern	P.H.S. 4-28-59	RV990329CVS005	3/29/1999	Spring	23.4
Northern	Pipe Mine	RV991019CVM010	10/19/1999	Mine	67.5
Northern	Sah Tah Spring	RV990317TNS001	3/17/1999	Spring	45.8
Northern	Slimwagon Well	RV990907SWW003	9/7/1999	Well	76.0
Northern	Thumb Rock Well	RV990519RVW005	5/19/1999	Well	30.4
Northern	Water Well 309	RV990519CVW005	5/19/1999	Well	83.7
Northern	West Thumb Rock Well	RV991201RVW013	12/1/1999	Well	32.8
Southern	Sheep Dip Spring	BI980702LGS002	7/2/1998	Spring	190.7
Southern	Tank 17T-517	BI980701LGW001	7/1/1998	Wind Mill	33.7
Western	Badger Spring	CT980729CMS004	7/29/1998	Spring	22.1
Western	Fivemile Wash Spring	CT000120CMS009	1/20/2000	Spring	28.4
Western	Lechee Spring	CT980811TCS001	8/11/1998	Spring	20.8
Western	Open Pit Mine	CT980722CAM003	7/22/1999	Mine	57.1
Western	Open Pit Mine	CT980722CAM002	7/22/1998	Mine	50.9
Western	Paddock Well	CT991130CAW007	11/30/1999	Well	46.4
Western	Tohachi Spring	CT980729CMS003	7/29/1998	Spring	84.2
Western	Tse To Baah Naali Spring	CT980729CMS005	7/29/1998	Spring	23.3

While this study is focused on elevated levels of uranium, it should also be noted that arsenic levels above the MCL were also detected in several of the water samples collected by the EPA from unregulated water sources in the Southern AUM Region, particularly in the Greasewood and Steamboat Chapters (EPA, 2000 - S02260102).

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[1] EPA, 2006 (S05190701). "List of Drinking Water Contaminants and MCL's" accessed on 2/28/06 at URL http://www.epa.gov/safewater/mcl.html#mcls.

[2] EPA, 2002 (S05030601). "EPA Implementation Guidance for Radionuclides." The total uranium mass measurements for the USACE water samples were converted to activity using a conversion factor of 0.67 pCi/µg.

In 2004 the Navajo Nation Surface and Ground Water Protection Department of the NNEPA conducted a study that was titled “Sanitary Assessment of Drinking Water used by Navajo Residents not Connected to Public Water Systems (Ecosystem Management, Inc., 2004 S05050701).” Thirteen (13) unregulated water sources were sampled for radionuclides, arsenic, pesticides, and coliform after being identified as potential sources of drinking water in the selected Chapters. Three of the samples had gross alpha results that were larger than the MCL of 15 pCi/L. The locations of these NNEPA water samples are listed below (Table 11).

Table 11. NNEPA Water Samples with Elevated Uranium.

REGION	CHAPTER	WELL NAME	GROSS ALPHA (pCi/L)
North Central	Kayenta	08T-522	25.7
Western	Coalmine Mesa	Box Spring	25.5
Western	Coalmine Mesa	Badger Tank Well	70.5

In 1991 the USGS, in cooperation with the NAMLRP, began a study to assess the chemical characteristics and hydraulic interaction of shallow ground water and mine water in AUMs in the Monument Valley and Cameron mining districts that had partially filled with water (Longsworth, 1994 - S02250302). Two AUMs in the Monument Valley mining district and six (6) AUMs in the Cameron mining district were studied. The AUMs in Monument Valley were the Moonlight and Radium Hill No. 1 mines. The Moonlight mine was an open pit that included two spoil piles and an oval shaped pit about 750 feet long by 525 feet wide and 134 feet deep. During this study about 5,000 square feet of the pit bottom was covered with as much as four feet of water. The Radium Hill No. 1 mine consisted of a drill hole approximately 2 feet in diameter and 96 feet deep, five spoil piles, and an inclined shaft. Water from these two mines contained large radionuclide activities.

Data in the Cameron area were collected from the 1) Jeepster No. 1 mine, an elliptical pit about 700 feet long by 200 feet at the widest point and ore was extracted from as deep as 60 feet below land surface; 2) Jack Daniels mine, consisted of one main pit approximately 450 feet by 250 feet and about 26 feet deep; 3) Manuel Denetsone No. 2 mine was sampled at a drill hole approximately 2 feet in diameter and 33 feet deep, and; 4) Ramco No. 20 mine at one of the smaller pits (200 feet by 400 feet and about 4 feet deep). Data were also collected from existing wells and springs. The locations of these USGS water samples with elevated uranium levels are listed below (Table 12) and are plotted on Figure 67 “Non-Potable Water Sample Locations with Elevated Uranium.”

Table 12. USGS Water Samples with Elevated Uranium.

					TOTAL URANIUM (Dissolved U^{238}, U^{234}, and U^{235} pCi/L)
Northern	Moonlight Mine (MVD-1)	Shallow well	10/15/1991	0.4	22,440
Northern	Moonlight Mine (MVD-2)	Shallow well	10/16/1991	0.2	28,530
Northern	Radium Hill No. 1 Mine	Mine drill hole	12/19/1991	86.8	450
Western	Jeepster No. 1 mine (JSW –1)	Open Pit	10/29/1991	4,225	52.8
Western	Jack Daniels Mine (JDD-1)	Shallow Well	11/01/1991	4,190	365.7
Western	Jack Daniels Mine (JDSW-1)	Open Pit	10/31/1991	4,190	25.4
Western	Manuel Denetsone No. 2 Mine	Mine drill hole	11/02/1991	4,159	418.9
Western	Ramco No. 20 NW	Open pit	11/06/1991	4,211	35.6
Western	Clay Well Spring	Spring box	11/05/1991	4,220	65.1
Western	Arizona Inspection Station Well	Well	12/19/1991	4,185	44.9

As part of the National Uranium Resources Evaluation (NURE) program (Smith, 2001 - S07250302), water samples were collected from springs, streams, and water wells by the Los Alamos Scientific Laboratory (LASL) between August and October, 1978 across the central and eastern portion of the Navajo Nation. The samples were analyzed by the LASL for elemental concentrations of uranium in water, in parts per billion, using fluorometry and delayed-neutron counting analysis techniques. Figure 67 shows the sample locations where results for concentration of uranium in water was greater than 30 parts per billion (ppb).

Review of these water sample results suggest that uranium mining may have affected the down-gradient watersheds. An area of interest is the Lukachukai mining area in the southwest portion of Cove Chapter. While the AUM scores are low, there are a series of 8 water samples that indicate elevated levels of uranium downstream from the Lukachukai AUMs, which were highly productive uranium and vanadium mines. Two of the AUMs in the Lukachukai mining area have highly elevated total uranium levels: Camp Mine (419.66 pCi/L) and Cove Mesa 2 (879.00 pCi/L). Based on notes and photos taken during water sampling field visits by the U.S. Army Corps of Engineers, both of these mines had wetland areas proximal to them.

Another area of interest is the Cove Mesa mines in the West Carrizo mining area. This is a highly productive uranium mining area with mines that score low due to their remote locations. The water sample at Alcove Canyon Spring resulted in a total uranium value of 125.34 pCi/L.

Two water sample sites have elevated radionuclide activity, but appear outside CERCLA authority:

- Thumb Rock Well - no apparent AUM nearby
- West Thumb Rock Well - no apparent AUM nearby

Water samples with elevated uranium levels should be evaluated for post-reclamation water sampling.

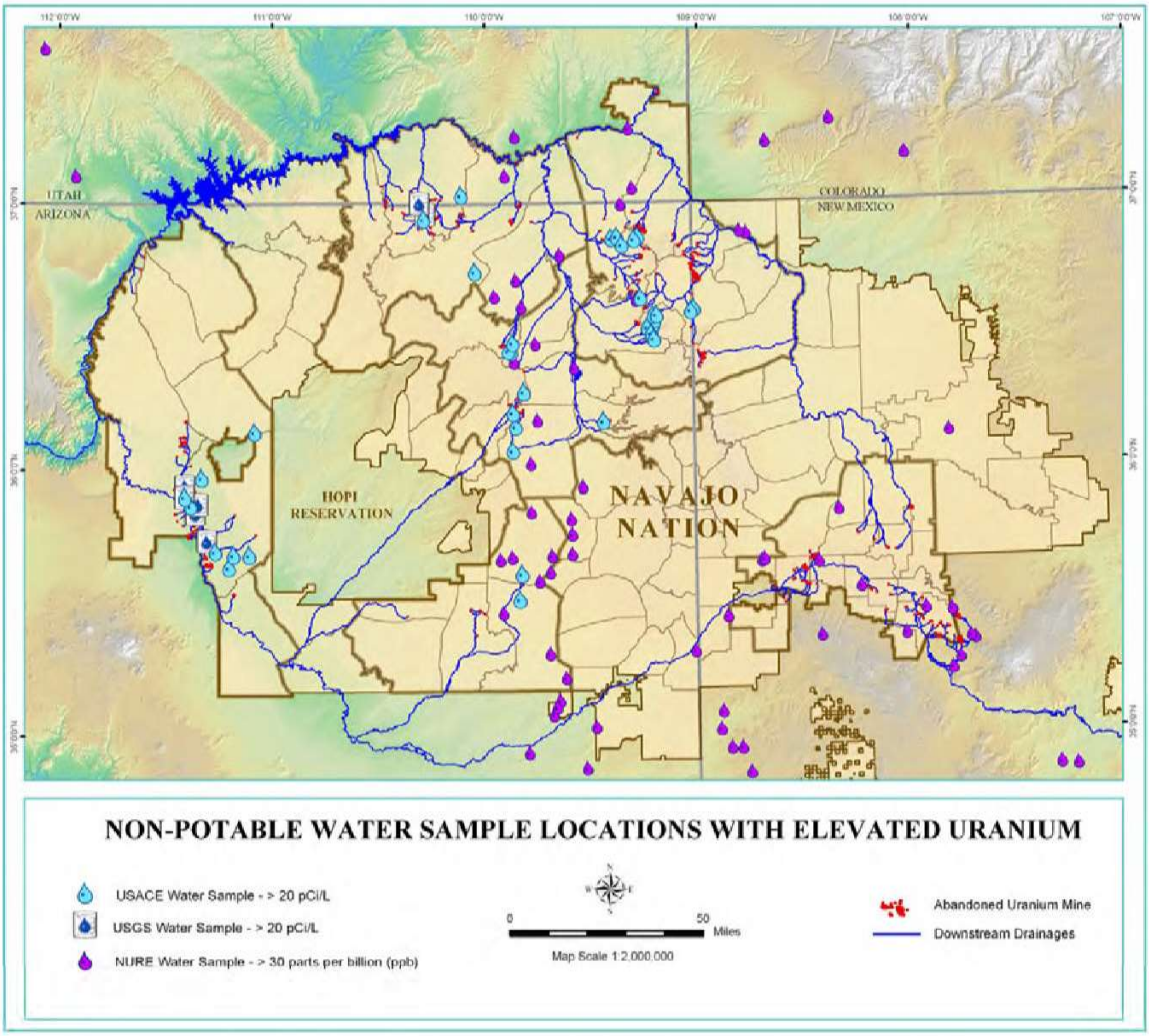

Figure 67. Water Sample Locations on the Navajo Nation with Elevated Uranium.

PERCHED OR SHALLOW WATER TABLES

Most of the mines in the North Central AUM region were extracting uranium from channel deposits in the basal Shinarump Member of the Chinle Formation. Perched water tables were present in the basal Shinarump conglomerate at many of the AUM sites. Bootjack Mine, the deepest uranium-ore deposit mined in the region was extremely wet. In 1959, ground water flowed into the workings at an average of 200 gallons per minute. This water was collected in the shaft sump and pumped to an evaporation pond on the surface (Chenoweth, 1993 - S10100222). Ground water, at the rate of 50 gallons per minute, seeped into the mine workings at the Alma-Seegan Mine (Chenoweth, 1994 - S10100230), Big Four No. 2 Mine (Chenoweth, 1994 - S10100228), Fern No. 1 Mine (Chenoweth, 1994 - S10100227) Firelight No. 6 Mine (Chenoweth, 1992 - S10100224) and Starlight Mine (Chenoweth, 1997 - S10100233). Water flowed into the mine workings at the Big Chief Mine at approximately 80 gallons per hour (Chenoweth, 1992 - S10100223). A sump and pump was required at the Moonlight Mine due to water seepage (Chenoweth, 2003 - S08250503). Perched water was encountered during mining at the Utah No. 1 Mine (School Section 36) (Chenoweth, 1991 - S03100502). Mining at the C-3 mine was in wet ground because a perched water table was encountered in the basal Shinarump (Chenoweth, 1991 - S03100502). Results from the water samples taken at the Moonlight and Radium Hill mines suggests that AUMs that partially fill with water may concentrate radionuclide activities and other dissolved constituents. Collection and analysis of additional hydrologic data would be necessary to determine shallow ground water flow characteristics and thus the implications of radionuclide mobilization near mines in the Monument Valley mining district (Longsworth, 1994 - S02250302).

MINE WATER EXTRACTION

In the Eastern AUM Region uranium was recovered from mine water. Mine water recovery is also referred to as Old Stope-Leach Projects and are described by Holen and Hatchell (1986 - S08200601) as another form of In Situ Leach (ISL) mining. Surface or recirculated mine waters, along with air to facilitate oxidation, were pumped through injection drill holes into old uranium mine stopes (an underground excavation from which ore is extracted). These water solutions were then pregnant with leached uranium, and were collected in sumps within the mine workings and pumped to the surface into open settling and holding ponds. After settling, these waters were passed to an Ion Exchange facility to remove the uranium. The extracted waters were either used for recirculation, discharged to surface waters, or were used in nearby uranium mills as process water. In some cases natural mine water flow, where underground mines were flooded below the water table, was pumped to the surface and its dissolved uranium was extracted in an Ion Exchange facility. This method of mining was used extensively at the large mines in the Ambrosia Lake area. It was also used at the Church Rock and the Mariano Lake mines where the settling and holding ponds and fences are readily visible on orthophotos. However, these pregnant solutions ponds were not mapped everywhere and have not been characterized for exposure risk. McLemore and Chenoweth (1991 - S03030608) reported that 893,787 pounds of uranium oxide were recovered from mine waters of Kerr McGee, Homestake Sapin Partners, and United Nuclear mines throughout the entire Grants Uranium District.

Table 13 lists productive AUMs that were determined to have workings below the water table or were considered wet mines that required pumping. It also shows AUMs that were not mined, but the ore deposits occur below the water table, and would likely require pumping if mined.

Table 13. AUMs With Uranium Ore Deposits Below the Water Table.

MINE NAME	PRODUCER	TONS	U3O8_LBS	START_YEAR	END_YEAR	WATER TABLE * If Mined	REGION
Crownpoint, Section 9	No					Below*	Eastern
NE Church Rock No. 2	No					Below*	Eastern
Nose Rock No. 1	No					Below*	Eastern
Section 13	No					Below*	Eastern
Section 29-Conoco	No					Below*	Eastern
Black Jack No. 2	Yes	247,613	1,129,004	1959	1970	Below	Eastern
Church Rock	Yes	292,604	883,580	1960	1982	Below	Eastern
Church Rock ISL	No					Below	Eastern
Crownpoint ISL	No					Below	Eastern
Grace Insitu Leach	Yes	9	201	1975	1975	Below	Eastern
Homestake Sapin Mine No. 23	Yes	4,811,351	17,520,976	1959	1989	Below	Eastern
Homestake Sapin Mine No. 25	Yes	3,145,969	9,960,150	1959	1983	Below	Eastern
Kermac Mine No. 22	Yes	3,851,523	13,471,257	1958	1985	Below	Eastern
Kermac Mine No. 24 and 26	Yes	2,894,860	15,365,512	1959	1983	Below	Eastern
Mariano Lake	Yes	505,489	2,265,405	1977	1982	Below	Eastern
NE Church Rock	Yes	3,498,648	9,773,362	1972	1982	Below	Eastern
NE Church Rock No. 1	Yes	836,570	2,953,673	1976	1985	Below	Eastern
NE Church Rock No. 1-East	Yes	322,602	1,234,784	1978	1983	Below	Eastern
Section 16 deposit						Below	Eastern
Alma-Seegan	Yes	6,769	25,541	1965	1966	Below	North Central
Big Chief	Yes	32,834	151,221	1959	1961	Below	North Central
Big Four No. 2	Yes	3,930	20,444	1963	1963	Below	North Central
Bootjack	Yes	36,236	331,010	1957	1966	Below	North Central
Fern No. 1	Yes	9,582	126,703	1956	1961	Below	North Central
Firelight No. 6	Yes	2,141	7,611	1959	1960	Below	North Central
Moonlight	Yes	223,237	1,177,501	1956	1966	Below	North Central
Radium Hill No. 1 and Utah No. 1	Yes	12,776	87,737	1955	1962	Below	North Central
South Sunlight	Yes	28,645	171,460	1962	1965	Below	North Central
Starlight	Yes	40,378	231,731	1958	1961	Below	North Central
Starlight East	Yes	45,990	289,378	1961	1964	Below	North Central
Sunlight	Yes	55,024	291,462	1958	1964	Below	North Central

Figure 68 shows two areas near the Bootjack Mine with above-background levels of excess Bismuth-214 (see page 91). The radiation contour area to the northeast corresponds to the location of the evaporation ponds (shown in Figure 69) where water in the mine was pumped to the surface. AUMs with underground workings that had histories of water infiltration and pumping may warrant additional examination for possible radionuclides or concentrations of other dissolved constituents.

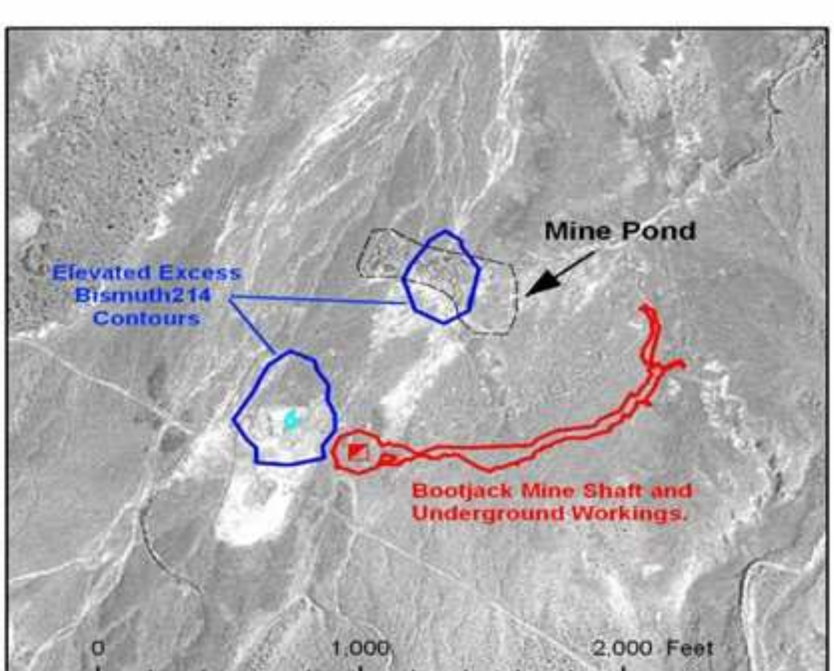

Figure 68. Bootjack Mine Surface and Underground Workings and Proximal Areas with Excess Bismuth-214.

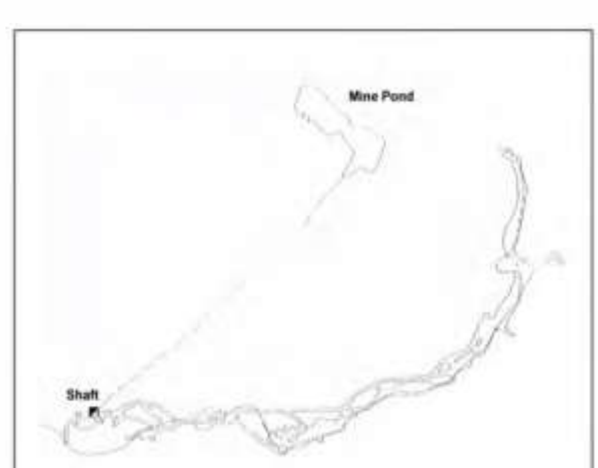

Figure 69. Plan Map of the Underground Workings and Surface Features of the Bootjack Uranium Mine (Chenoweth, 1993 - S10100222).

AUMS WITH SURFACE WATER PATHWAYS TO WATER SOURCES

Two of the AUMs in the North Central AUM region are located upstream and adjacent to major water sources - San Juan River and Lake Powell. The Whirlwind Mine is on the south bank of the San Juan River (Glen Canyon National Recreation Area) approximately 16 miles northwest of Oljato Trading Post (Chenoweth, 1991 - S03100502). The Whirlwind Mine operated from 1950 to 1966 and extracted 15,777.8 tons of ore with 69,403.5 pounds of uranium and 277,779.1 pounds of vanadium recorded. Figure 70 shows the location of the Whirlwind Mine on a natural color orthophotograph (left) generated from 2004 imagery during drought conditions. The outline of the Whirlwind Mine is shown in red and from this image it can be seen that the Whirlwind Mine is directly upstream from the San Juan River (approximately 2000 feet upstream). The USGS topographic map on the right was developed in 1987 during non-drought conditions, and shows that the Whirlwind Mine drained directly into a drainage within 400 feet of Lake Powell's shore.

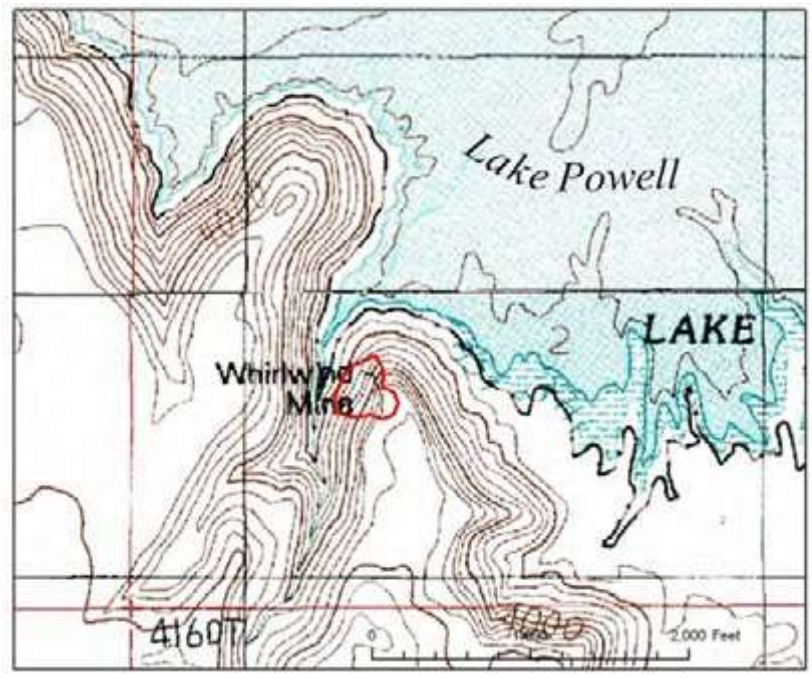

Figure 70. Whirlwind Mine on the South Bank of Lake Powell. Natural color image (left) acquired in 2004 and USGS topographic map (right) dated 1987.

Mexican Hat Stockpile (Figure 71) is an AUM-related site located in a drainage that flows directly into the San Juan River, which is located less than 1/2 mile downstream. During the late 1940's and 1950's, the Vanadium Corporation of America (VCA) and individual Navajo's mining in the vicinity of VCA's Monument No. 2 mine stockpiled their ore at this location in ore bins along the wash on both sides of the highway (Chenoweth, 2006 - S04200601). Companies mining on Oljato Mesa and on Monitor Butte also stockpiled their ores here. This was done because the small, narrow, suspension bridge across the San Juan River at Mexican Hat at that time could not support large trucks. Ores were hauled from the mines in five-ton trucks to the stockpile area and then 21-ton semi-trailer trucks were used to haul the ore to the AEC ore-buying station at Monticello, Utah or the VCA mill at Durango, Colorado (Chenoweth, 1994 - S10100221). The wagon road from Cane Valley over Comb Ridge connecting Kayenta to Shiprock road (now US Highway 160) was not improved by the Atomic Energy Commission until 1952 (Chenoweth, 1989 - S10100213). When completed, this route greatly reduced the mileage to Durango, Colorado and eliminated the Mexican Hat stockpiling.

There may be other sites like the Mexican Hat Stockpile. Donald Bayles, a uranium ore hauler living in Blanding, Utah, stated in an oral history interview:

"I hauled ore from Mexican Hat which is Monument Valley One [sic] Mine. They hauled the ore up and would put the ore in a bin on the other side of the bridge. Then from there they'd have a little truck to take it across the bridge. They'd take it up on this side of Mexican Hat to a little creek. Then they'd take it on top. They had some little chutes they'd dump it in. When we'd come down and load it, we'd just open the chutes. They'd keep trucking it across the bridge there because the bridge wasn't made for too much weight."

This statement suggests there may have been another uranium ore transfer point on the south side of the bridge. Ore was loaded into a bin where it was stockpiled to load into smaller trucks to cross the bridge and dump at the Mexican Hat Stockpile (Tate, 2001 - S05310703). AUMs located upstream from water sources and/or associated riparian/wetland areas such as these sites may warrant additional study.

Figure 71. Mexican Hat Stockpile.

MINE SUBSIDENCE IN THE EASTERN AUM REGION

The Eastern AUM Region has also experienced mine subsidence, which was likely an unintended result of retreat mining underground. This can happen when a mine collapses as pillars separating stopes are extracted. Holmquist (1970 - S01140711) describes surface subsidence of 2-3 feet over thicker stopes at the Dysart No. 1 mine. The ore was 320-370 feet below the surface. At the Homestake Sapin Mine No. 15, caving above mine stopes collapsed to the surface. At the Kermac Mine No. 22 two large stopes caved to the surface creating holes 60 feet deep. The ore was at a level of 360 feet below the surface. At this mine, uranium mill tailings were run underground to prevent further caving to the surface. At the Homestake Sapin Mine No. 23, surface sand was injected via a drillhole to prevent collapse. In this area some mines were below the water table and flowed up to 1,600 gallons per minute. The environmental impact of these various mining occurrences has not been characterized.

EXPLORATION DRILLING

Navajo prospectors were the first to discover uranium mineralization in the Lukachukai Mountains (Chenoweth, 1988 - S10280203), on Black Mesa (Chenoweth, 1990 - S10100236), and in the Cameron area (Chenoweth, 1993 - S10100239). It was a Navajo sheepherder whose discovery in the Todilto Limestone triggered the boom in the Grants uranium district (Chenoweth, 1985 - S08020601). The earlier discoveries in the Carrizo Mountains and these successful prospecting efforts were followed by extensive drilling and stripping programs across the Navajo Nation by the Atomic Energy Commission (AEC) and private companies. These activities would penetrate uranium mineralization at depth or at the surface, opening additional pathways to uranium ore deposits.

Chenoweth (1990 - S10100236) describes how bulldozers were used by the AEC in the Black Mesa area of the Central AUM Region to expose uranium mineralized outcrops after ground and aerial reconnaissance revealed promising outcrops. Later these exposed outcrops and nearby areas were typically drilled to search for and define uranium ore bodies. Some were eventually mined and others left exposed. An inspection of the DOE aerial radiation surveys in this area shows strong correlation with these unexploited but radioactive outcrops.

In the Cameron area of the Western AUM Region Chenoweth (1993 - S10100239) provides an extensive description of drilling activities. He reports that from 1953 through 1962 approximately 1,005,000 feet of surface drilling occurred at about 20,000 holes that rarely exceeded 100 feet in depth. They were drilled around known mines and typically in a 500 foot grid pattern decreasing to a 50 foot grid in promising areas. Drilling was also performed at the locations of aerial radiometric anomalies.

Extensive drilling programs were conducted by the AEC in the Northern AUM Region. Exploration occurred in the eastern Carrizo Mountains (Chenoweth, 1984 - S03130303), the northern and western Carrizo Mountains (Chenoweth, 1985 - S10020203), and the Lukachukai Mountains (Chenoweth, 1988 - S10280203). It was noted that mining companies also ran some drilling programs.

In numerous locations within the North Central AUM Region there is evidence of previous uranium exploration activities. An example is the Tract 10 and Tract 11 area where there is significant surface expression of exploration drilling evident on the photos. Figure 72 shows a grid of roads used to access and lay out exploration drilling sites. Phillips Petroleum Company conducted an extensive exploration program on Tracts 10 and 11, known as the Strategic Minerals Project 68 (Chenoweth, 1991 S03100502). This drilling included 245 holes with 40,000 feet of total linear drilling. The exploration resulted in locating an ore body at a depth of 200 feet with an average thickness of 5 feet that was reported to contain 8,300 tons of uranium. The potential impacts of these exploration activities as a migration pathway may warrant further investigation.

Malan (1964 - S04290701) prepared a map locating exploratory drilling projects of Monument Valley for Arizona and Utah. Figure 73 below shows the greater extent of exploratory drilling areas (shown in yellow) that were mapped by Malan in comparison to the extent of AUMs (shown in red).

Figure 72. Exploration Drilling in the Tracts 10 and 11 Area of the North Central AUM Region.

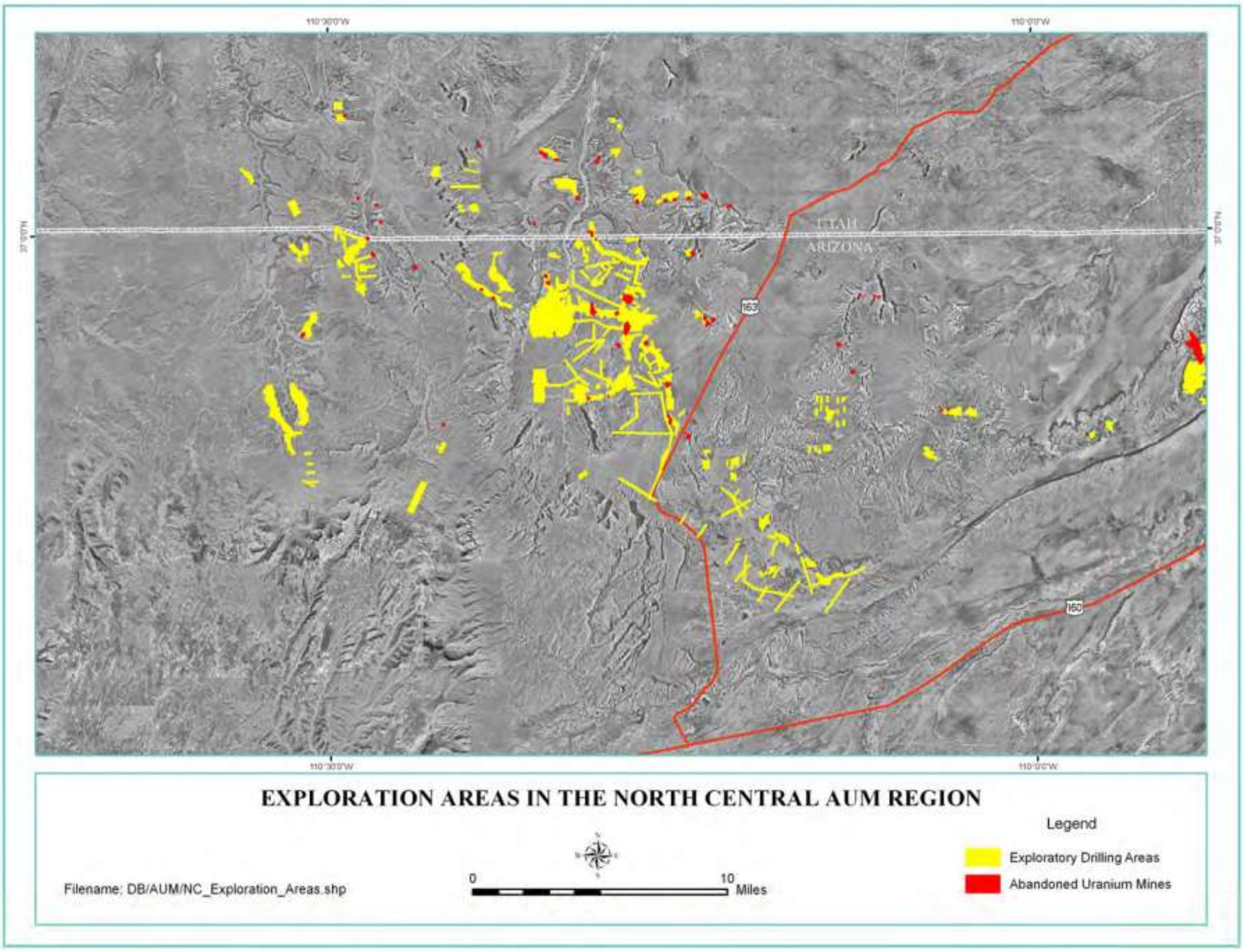

Figure 73. Exploration Areas in the North Central AUM Region.

AERIAL RADIATION SURVEY—EXCESS BISMUTH-214 AREAS

The aerial radiological surveys that were flown over portions of the Navajo Nation proved to be a useful tool for locating AUMs and AUM-related areas, like the Cove Transfer Station shown in Figure 74. See Part II, Section 2, "Aerial Radiation Survey" for more information. These types of surveys allow characterization of large areas to identify where higher spatial resolution ground-based measurements may be required. The acquisition of new high resolution aerial radiation surveys may help locate ore transfer stations, ore haulage routes, or AUMs in areas that were not flown during the 1994 - 1999 surveys, such as the Eastern AUM Region.

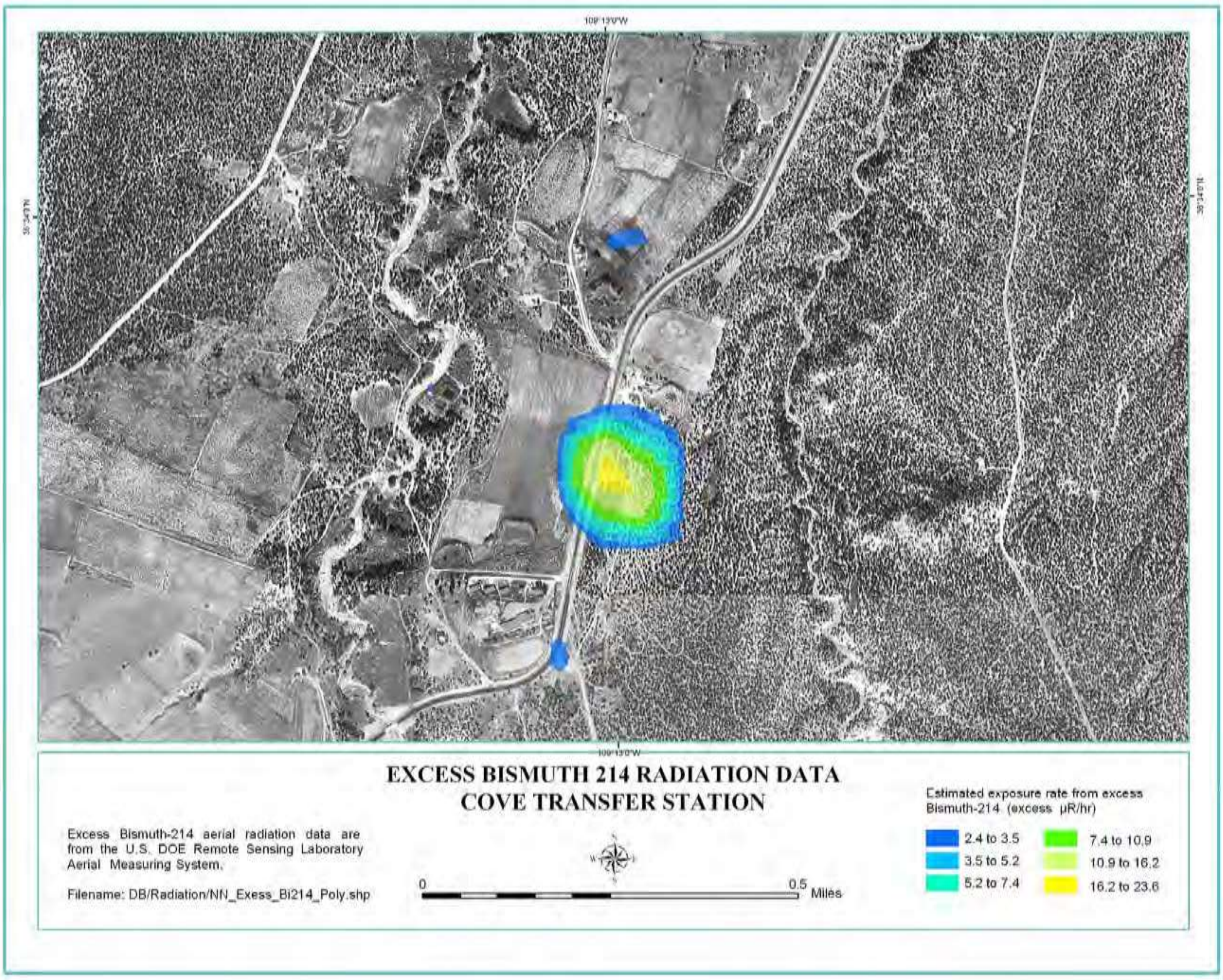

Figure 74. Cove Transfer Station. Location of this site was established by the DOE aerial gamma radiation survey.

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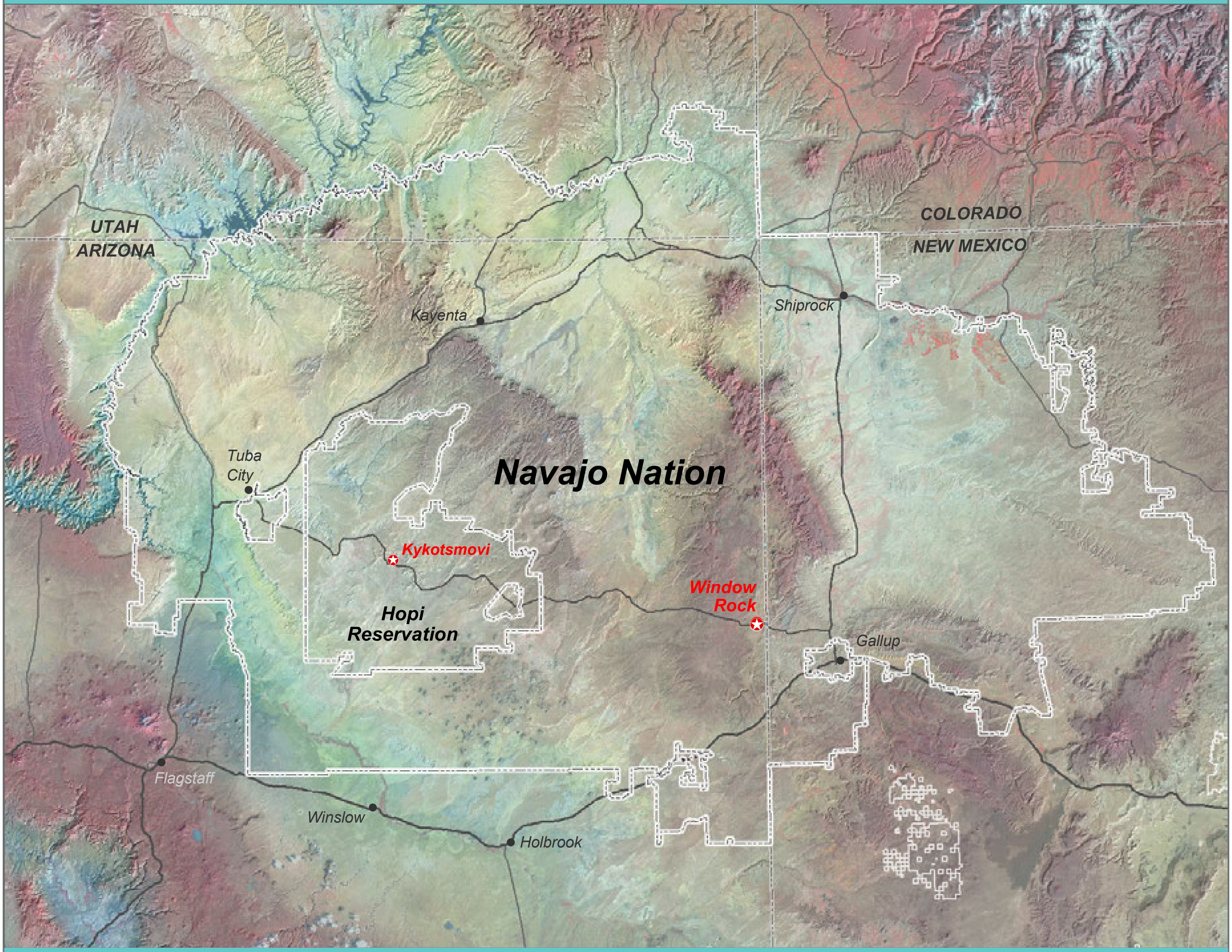
ABANDONED URANIUM MINES AND THE NAVAJO NATION

PART II

ATLAS WITH GEOSPATIAL DATA



Section 1

MINING HISTORY AND MINE SITE INFORMATION

Section 2

MINE WASTE CHARACTERISTICS

Section 3

ENVIRONMENTAL SETTING

CONTENTS

Page Number

PART II - ATLAS AND GEOSPATIAL DATA

CONTENTS

Page Number

A standard set of symbols for administrative boundaries, transportation, and cultural features were used for this Atlas, where possible. This allowed minimizing the legend area to include only the map's specific set of thematic symbols. The standard map legend symbols used throughout this Atlas are shown below.

MAP LEGEND

ROADS AND ROUTE SHIELDS

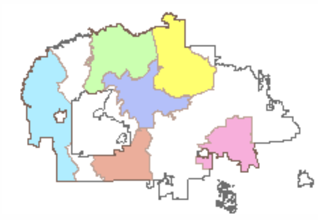
- 40 — U.S. Interstate Route
- 191 — U.S. Route
- 264 — Arizona State Route
- 371 — New Mexico State Route
- 262 — Utah State Route
- 13 — Indian Service Route

BUILDINGS AND RELATED FEATURES

- *Shiprock* — Populated Place Name

BOUNDARIES

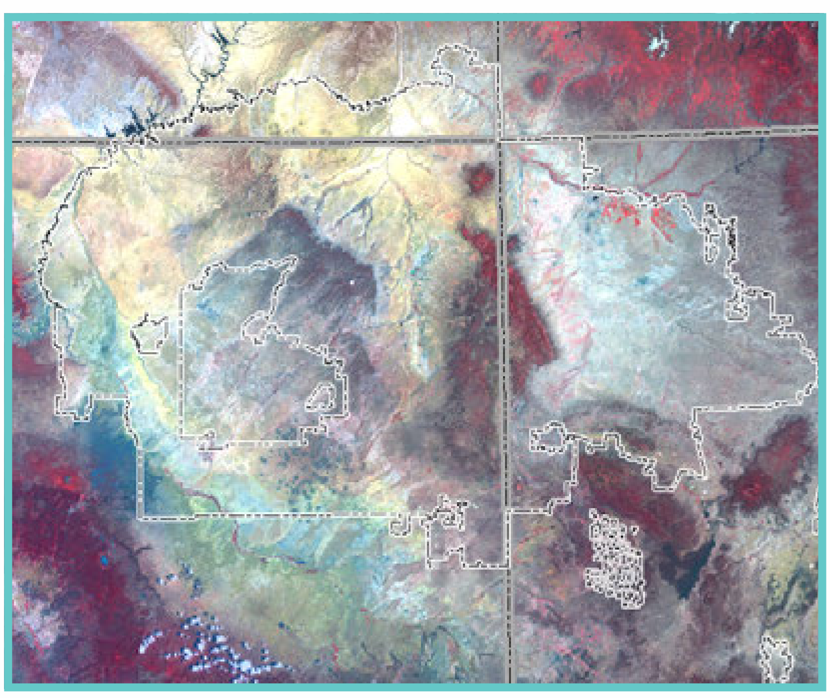
- Navajo Nation Boundary
- Shonto / Oljato — Navajo Chapter Boundary
- ARIZONA / NEW MEXICO — State Boundary
- Navajo Co. / Apache Co. — County Boundary



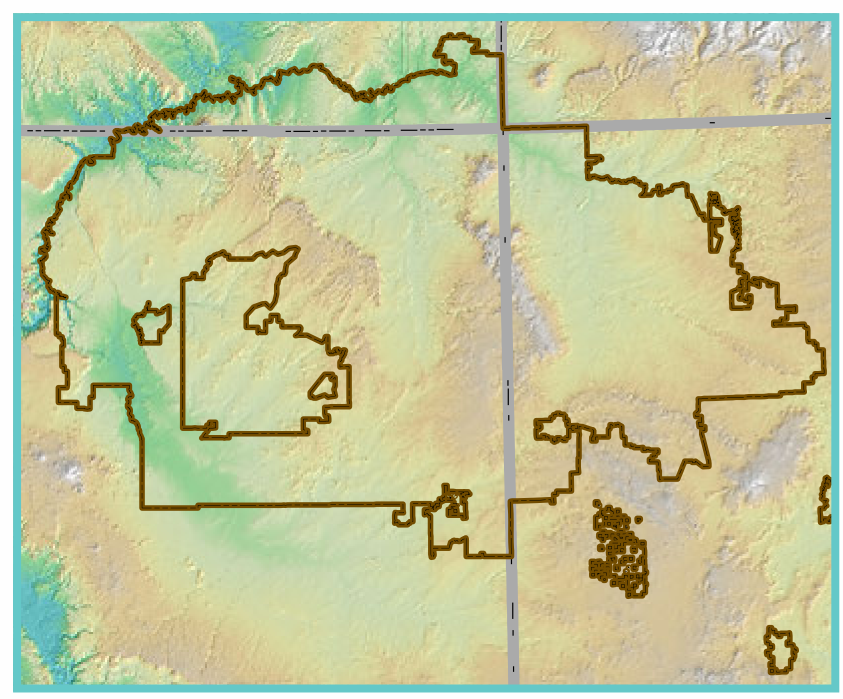
Abandoned Uranium Mine Regions

- Central AUM Region
- Eastern AUM Region
- North Central AUM Region
- Northern AUM Region
- Southern AUM Region
- Western AUM Region

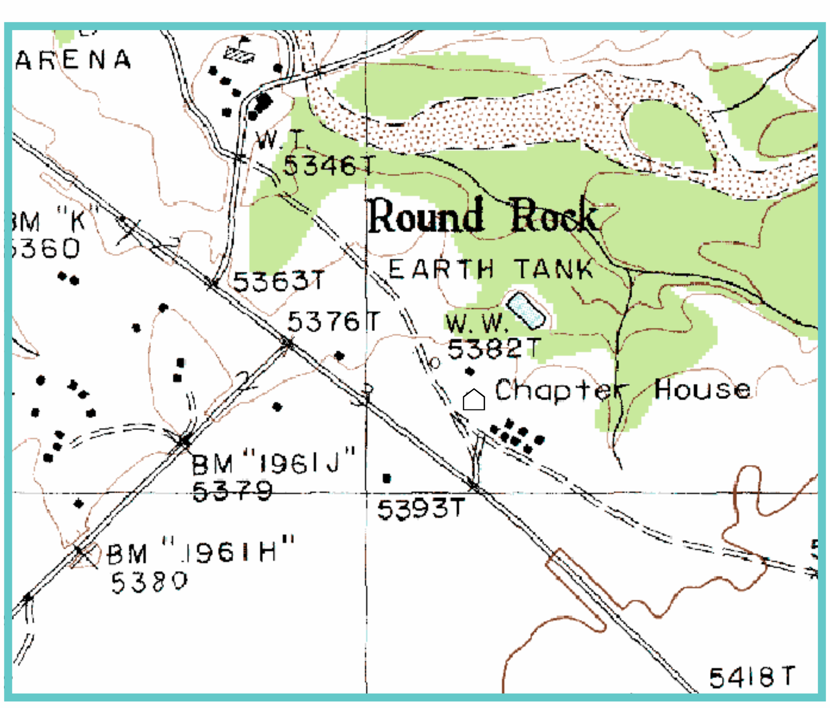
A series of Navajo Nation basemap images were generated for this Atlas. These include scanned U.S. Geological Survey (USGS) topographic quadrangle maps, orthographic-corrected aerial photographs (orthophotographs), computer-generated terrain images, and satellite imagery. Examples of the basemaps and imagery are shown below.



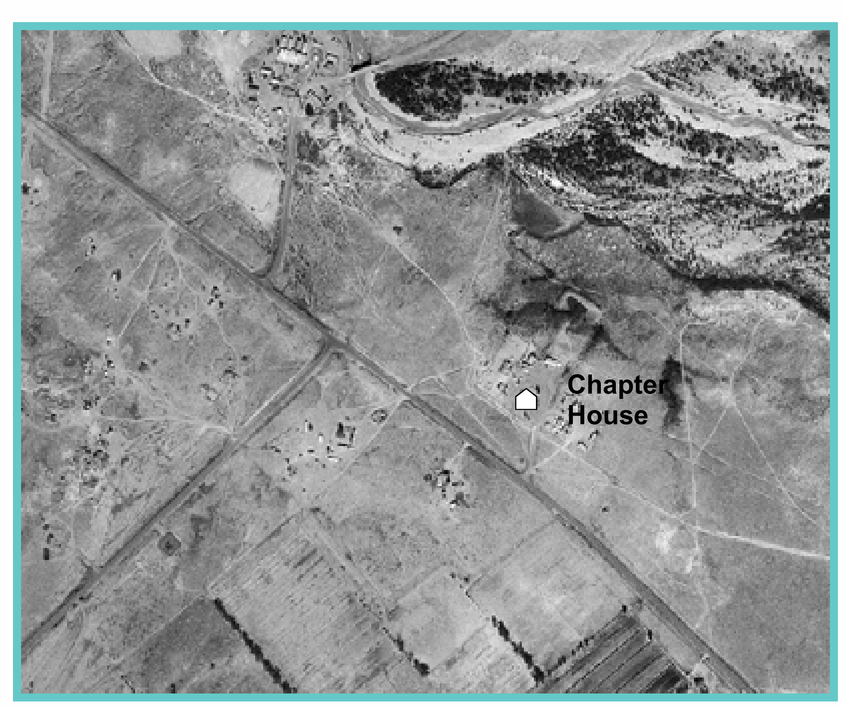
A Landsat Multispectral Scanner (MSS) satellite image mosaic covering the Navajo Nation was generated from four images that were acquired between June 2 and September 7, 1992. The imagery has a ground resolution of 60 meters. The bands used to generate the mosaic are band 4 (near-infrared), band 2 (red) and band 1 (green). In addition, a Landsat 7 Enhanced Thematic Mapper satellite image (band 8, 15 meter panchromatic band) was also processed and used throughout this Atlas as an image base.



A shaded relief image for the Navajo Nation was generated using 30-meter resolution data from the U. S. Geological Survey (USGS) National Elevation Dataset (NED). Elevation is shown as a range of colors, from white for higher elevations to blue for lower elevations.



USGS 7.5 minute 1:24,000-scale topographic quadrangle maps were scanned to produce Digital Raster Graphic (DRG) maps. These DRGs were used by the Natural Resources Conservation Service (NRCS) to create county-wide mosaics. The mosaics were compressed to a ratio of about 1:20 to save on storage requirements and to accelerate computer processing and display. In the example above, a portion of a DRG for the community of Round Rock is shown. DRGs show elevation contours, and transportation and various cultural features. These county-wide DRG mosaics are provided for the entire Navajo Nation in MrSID compressed format.



USGS Digital Orthophoto Quarter Quadrangles (DOQQ) are 1-meter ground resolution images that were used by NRCS to create county-wide mosaics. Like the DRGs, the DOQQ mosaics were compressed to a ratio of about 1:20. The example above shows the community of Round Rock (same area as shown left) and illustrates that orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. These county-wide DOQQ mosaics (photos taken in 1997 and 1998) are provided for the entire Navajo Nation in MrSID compressed format.

Section 1

MINING HISTORY AND MINE SITE INFORMATION

MINING HISTORY

An extensive review of records and literature was conducted in an effort to identify the locations of uranium mining activities within the Navajo Nation and to reconstruct production histories for these mines. Significant assistance in determining the locations of abandoned uranium mines (AUMs) was provided by the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and Mr. William Chenoweth, who previously worked with the Atomic Energy Commission and the U. S. Department of Energy's Grand Junction Office. This section presents information about the history of uranium mining within the United States, and focuses on the mining areas, leasing and permitting history, and location and production statistics of AUMs on the Navajo Nation.

URANIUM MINING HISTORY IN THE UNITED STATES

To understand uranium mining on the Navajo Nation it is useful to review the history of uranium mining and the interrelation between uranium, radium, and vanadium. The discovery of radium by Marie and Pierre Curie in 1898 resulted in the realization that all uranium ores contained this new element. Carnotite is a uranium-vanadium mineral with colorful red and yellow ores that had been used as body paint by early Navajo and Ute Indians. Carnotite was found on the Colorado Plateau to contain uranium, vanadium, and trace amounts of radium (Utah History Encyclopedia, 2005 - S09190504). This co-product relationship allowed many mines to survive even after the radium content of their ores was no longer economic (Hahne, 1989 - S09190503).

The history of uranium mining in the U.S. can be divided into four periods, as shown in Table 1. After 1905, interest in mining uranium ore for radium recovery led to an expansion of mining on the Colorado Plateau. The U.S. dominated the world radium market from 1912 to 1922, until high grade ore from the Belgian Congo entered the market, which by 1925 ended the radium period in the U.S. On the Navajo Nation, John F. Wade, working with local Navajos, located carnotite-bearing outcrops in the Carrizo Mountains. From 1920 to 1923, three leases were issued in the Carrizo Mountains to mine carnotite ore for its radium content (Chenoweth, 1991 - S02020701). In 1920, twenty (20) tons of radium ore was mined from a lease in the northeastern Carrizo Mountains (Chenoweth, 2007 - S07110701).

Table 1. U.S. General Uranium Mining Periods.

1905 - 1925	Radium
1925 - 1947	Vanadium
1947 - 1970	Uranium (Government)
1970 - present	Uranium (Commercial)

From 1925 to 1947, vanadium was extracted from the tailings of the radium mines. When added to molten steel vanadium greatly increases its tensile strength and elasticity. This, and the armaments industry of World War II, made the vanadium industry flourish. During this period, prospecting and mining increased and expanded geographically as the demand for vanadium increased (Hahne, 1989 - S09190503).

As a result of the atomic age and subsequent arms race of the Cold War, uranium that was previously considered a waste product of vanadium mines, came into demand as a key element for nuclear weaponry. Beginning in World War II, almost 90 percent of the uranium supply for the U.S. was imported from the Belgian Congo and Canada. The Manhattan Project, tasked with development of an atom bomb, instituted a program to extract uranium from the radium and vanadium mill tailings on the Colorado Plateau and sent geologists to explore the region in search of new uranium sources.

With the end of World War II, the Atomic Energy Commission (AEC) was established by the Atomic Energy Act of August 1, 1946. The AEC was a civilian agency created to ensure continued development of atomic energy. The AEC constructed roads into the back country, promised $10,000 bonuses for new lodes of high-grade ore, guaranteed minimum prices, constructed mills, and helped with haulage expenses. The AEC also provided geologic data for promising areas found by federal geologists using airborne scintillometers and other radiation detection instruments (Utah History Encyclopedia, 2005 - S09190504).

As a result of federal inducements, the Four Corners area was filled with prospectors. They concentrated on exposed outcroppings along canyon rims, where they searched primarily for the Salt Wash Member of the Morrison Formation. When a likely claim was located, they used diamond drills to core test holes to determine if mineable ore was present. By 1955 there were approximately 800 mines producing high-grade ore on the Colorado Plateau. By 1967, however, the uranium mining industry almost came to a standstill. The AEC, holding ample reserves, announced an eight-year limited program and finally stopped buying uranium in 1970. Private industry triggered a brief second boom when nuclear power plants came on line in the mid-70s; but foreign competition, federal regulations, and nuclear fears virtually put an end to domestic uranium mining (Utah History Encyclopedia, 2005 - S09190504). In New Mexico the extensive high grade uranium ores in the Grants Uranium District on and near the Navajo Nation were mined until at least 1989 (McLemore and Chenoweth, 1989 - S08200608).

New interest in uranium is occurring as prices are increasing and demand is exceeding supply worldwide. The New Mexico Bureau of Geology and Mineral Resources (NMBGMR, 2007 - S05200701) reports that in 2006 four mining companies submitted exploration permit applications to the State Mining and Minerals Division for the Grants Uranium District. The Navajo Nation Diné Natural Resources Protection Act of 2005 forbids uranium mining on the Navajo Nation (Navajo Nation, 2005 - S09300605).

URANIUM MINING AREAS ON THE NAVAJO NATION

Uranium mining occurred across the Navajo Nation in six (6) AUM Regions (shown on Figure 2). On the Western AUM Region the major mining area is Cameron, although mining ranged from Bitter Springs in the north to Grand Falls in the south and as far east as the Ward Terrace. The Morale Mine among the Hopi Buttes was the only productive mine in the Southern AUM Region. The Central AUM Region was dominated by the mines on the east side of Black Mesa, with a few mines located at the foot of Black Mesa near Rough Rock. Mining in Monument Valley straddled the Arizona-Utah border in the North Central AUM Region. The Whirlwind mine was a significant outlier on the San Juan River. In the Northern AUM Region mining areas encircled the Carrizo Mountains in Arizona. The eastern Carrizo Mountains mines straddled the Arizona-New Mexico border. To their south was Cove Mesa and further south were the Lukachukai Mountains.[1] The mines of the Sanostee area were solely in New Mexico. The Eastern AUM Region is where much of the productive Grants Uranium District is located, stretching from the Church Rock area in the west, through Smith Lake to Ambrosia Lake on the east.

[1] The cover photo is the Kerr-McGee Mesa II, P-21 mine in the Lukachukai Mountains taken in 1956. Photo courtesy of William Chenoweth.

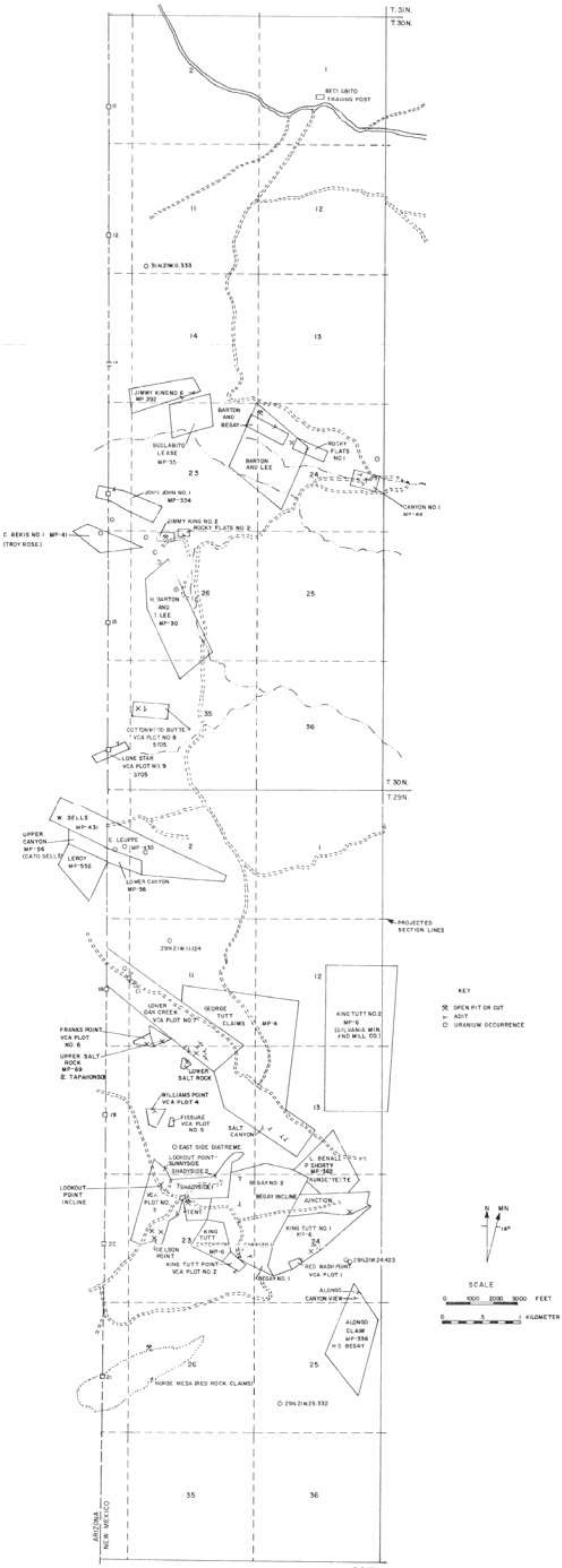


Figure 1. Map of Uranium Mines and Claims in the Eastern Carrizo Mountains. McLemore (1983 - S12110202).

LEASES AND MINING PERMIT HISTORY

In order to locate and identify uranium mines on the Navajo Nation, it was necessary to understand that the mining lease and permit process was complex and evolved over time. The following provides a chronology of significant events that impacted the Navajo Nation lease and mining permit process.

The U.S. Congressional Act of June 30, 1919 opened the Navajo Reservation to mining and prospecting in the same manner as prescribed in the U.S. Mining Law of 1872. If a discovery was made, land could then be leased from the Office of Indian Affairs. Due to the lack of mining activity when the radium market collapsed, the Navajo Reservation was closed to prospecting and mining by the Secretary of Interior on March 25, 1936, thereby canceling any existing leases (Chenoweth, 1997 - S03310301).

Due to the demand for vanadium, the Secretary of Interior was asked to open the Navajo Reservation for prospecting and mining. The Congressional Act of May 11, 1938 reopened the Navajo Reservation to mining under new procedures; prospectors could no longer enter the Navajo Reservation and stake a mining claim under regulations similar to those of the U.S. Mining Law. With the approval of the Secretary of the Interior, the Navajo Tribal Council could now enter into leases with mining companies. Leases were limited to a period of 10 years, which could be extended by production. The new regulations provided for a base 10% royalty with escalating annual rentals and bonding requirements (Chenoweth, 1991 - S02020701).

On April 9, 1941 the Navajo Tribal Council requested the Secretary of the Interior to lease lands for mining purposes to the highest bidder. Mining leases were written for large areas and were subsequently reduced in acreage at the end of a specified time period. The net effect of this type of lease was that a prospecting permit was issued to the highest bidder, who then had the right to lease up to 960 acres within the permit area (Chenoweth, 1991 - S02020701).

After World War II, the AEC was established to ensure the continued development of atomic energy. In 1949 the Secretary of Interior and the Navajo Tribal Council developed new regulations that permitted individual Navajos to prospect and hold unnumbered Tribal Mining Permits upon discovery of a resource. On September 19, 1951, additional regulations permitted non-Navajos to prospect, but still required that only Navajos could hold unnumbered mining permits for a renewable two year period. Permits could be assigned to non-Navajo individuals or companies to explore and mine. Permits and assignments were subject to approval by the Navajo Tribal Council and the U.S. Bureau of Indian Affairs (BIA). Both the Navajo Nation and the permittee received royalties (Chenoweth, 1997 - S03310301). The Navajo Nation and the permittee also received royalties on the vanadium in the ores, as well as copper, and any AEC bonuses received for new discoveries (Chenoweth, 2007 - S07110701).

Drilling and exploration permits were also issued for a non-renewable period of 120 days. The number of Navajos applying for permits was so large that in April 1952, the Navajo Tribal Mining Department began to issue numbered mining permits (Chenoweth, 1995 - S10100231). The BIA encouraged permitted mine operators to convert assignments to 10-year leases upon development of large amounts of ore (Chenoweth, 1993 - S10100239).

Figure 1 is an example of a claim map for the east Carrizo Mountains covering an area from Horse Mesa in the south, to the Beclabito Trading Post to the north (McLemore, 1983 - S12110202). This is one of many maps that were reviewed, scanned, and georeferenced to assist with identifying uranium mines, leases, and mining permits. Most maps were schematic and were based largely on older, less accurate surveys of the Public Land Survey System, as shown by dashed section lines in Figure 1.

ABANDONED URANIUM MINES (AUM)

URANIUM MINING

The excavation of uranium ore bodies is associated with hazards due to both physical conditions and radiation exposure. Although outcrops of radioactive minerals exist throughout much of the Navajo Nation, the areas where ore was extracted and deposited in mine waste piles exhibits higher radiation levels than most undisturbed natural areas. Radiation is particularly hazardous because it cannot be seen or detected without the aid of specialized equipment. The result is that radiation exposure or contamination is not readily apparent. Hazards associated with AUMs include open portals, adits, vertical openings, inclines and declines, pits, radioactive waste piles, radioactive dust, rim cuts, high walls, and embankments (OSM, 1999 - S05070313). Figure 2 shows the locations of AUMs that were mapped on or within one (1) mile of the Navajo Nation. These AUMs are discussed in the following text by AUM Region:

North Central AUM Region: Uranium and vanadium was mined in this region from the Monument Valley mining area, which is located in the southern portion of the Monument Upwarp in the west-central part of the Colorado Plateau. The uranium host rock crops out around the perimeter of the Monument Upwarp and also caps the many mesas and buttes within Monument Valley (Chenoweth, 1991 - S03100502). Uranium mines throughout this region were primarily located in ore bodies formed in channel deposits of the Shinarump Member of the Chinle Formation. These paleochannels range from 5 to 200 feet deep and from 10 to 2,000 feet wide (Black and others, 1962 - S04220602). However, not all paleochannels in the area were mineralized by uranium-bearing fluids. In a few mines, (e.g., Moonlight) ore extended downward as much as 15 feet into underlying beds of the Moenkopi Formation. The deposits also contain variable amounts of vanadium and copper. Shallow deposits at or near an outcrop were mined by adit or open pit, depending on the size of the deposit. Deeper deposits were developed and mined by shafts or inclines. Forty-one (41) separate properties produced uranium or uranium-vanadium ores from 1942 through 1969. However, the location of the productive Harvey Lee Sampson No.s 1 and 9 mine is unknown (Chenoweth, 1991 - S03100502). The Mexican Hat Stockpile was located within one (1) mile of the Navajo Nation.

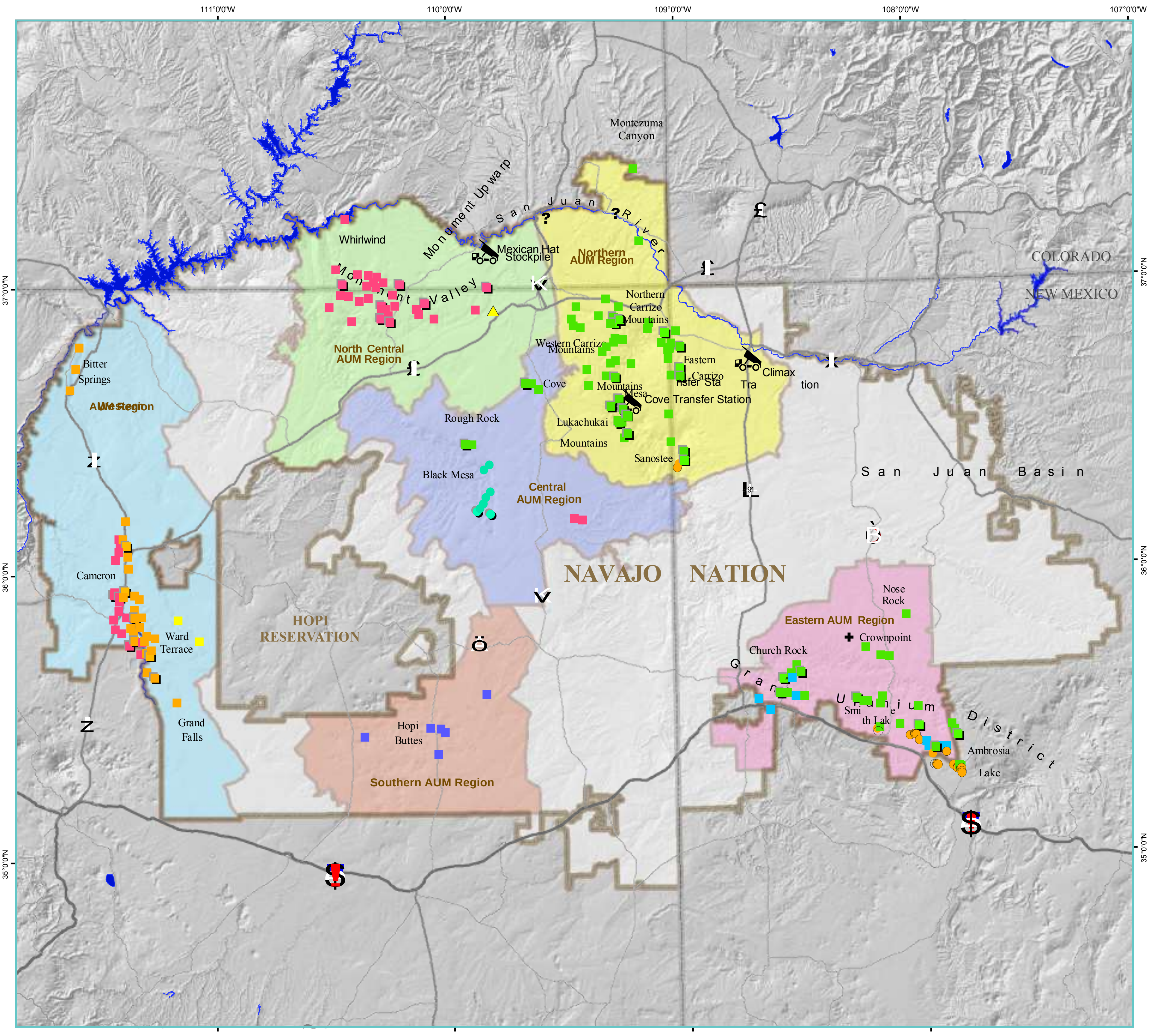
Northern AUM Region: From the late-1940s through 1967 uranium ore in the Northern AUM Region was mined mostly from mesa tops, rims, and from canyon walls. The Enos Johnson 3 mine in the Sanostee area was the one mine that produced until 1982 into the post-AEC period (Chenoweth, 1985 - S08250504). Ore bodies at or near the surface of mesa tops were excavated from relatively shallow pits or trenches. Often the pits were less than 10 feet deep, with unexcavated lower grade ore (protore) at the base and a protore debris pile on the surface. Buried ore bodies and ore bodies exposed on canyon walls were mined by digging down to the ore, or into the face of a hillside or canyon wall, creating mine entrances (e.g., shafts, inclines, declines, and/or adits). The debris pile/talus slope of protore emits gamma radiation at the surface where none may have been emitted before mining (EPA, 1999 - S12120285). Higher grade ores were transported to buying stations and processing mills and the waste rock consisting of overburden and protore was left behind in debris piles. For example, ore was transported from the Lukachukai mines by loading the ore onto dump trucks and driving down steep, winding dirt roads to the Cove Transfer Station, where the ore was dumped and stockpiled. The ore was then reloaded onto larger trucks to haul the ore to the Shiprock mill (Dare, 1961 - S10280202). Two transfer stations were mapped, Cove Transfer Station at the northern base of the Lukachukai Mountains, and the Climax Transfer Station just south of the town of Shiprock, New Mexico. Uranium was produced from 174 properties and 55 properties were not productive.

Western AUM Region: Uranium mining in this region was active from 1951 through 1963. Most of the mining was from open pits, which ranged in size from a shallow trench containing a single fossil log to pits as deep as 130 feet. Uranium ore was produced from 98 properties. The bulk of the ore (98%) was mined from the Petrified Forest Member of the Chinle Formation, about 2% of the uranium was mined in the Shinarump Member of the Chinle Formation, and the Kayenta Formation produced a minor amount (approximately 550 pounds) of uranium (Chenoweth, 1993 - S10100239).

Central AUM Region: Uranium in this region was mined on Black Mesa, a southwest dipping cuesta capped by the Upper Cretaceous Mesaverde Group. The uranium deposits occur on the east side of Black Mesa in the Toreva Formation. Ore was mined from shallow open pits, rim cuts, and underground (Chenoweth, 1990 - S10100236). A small amount of uranium was mined from the Salt Wash Member at the foot of Black Mesa near the Rough Rock Trading Post. Mining at this location was by rim stripping and shallow bulldozer cuts (Chenoweth, 1989 - S10100212). Uranium was produced from 1954 through 1968 from 15 properties in the Toreva Formation and two in the Morrison Formation. Uranium occurrences were prospected in the Chinle Formation near the village of Chinle in Apache County, Arizona. The workings in this area consisted of rim stripping, bulldozer cuts, prospect pits, and small open pits (Chenoweth, 1990 - S10020207).

Southern AUM Region: Uranium was discovered in the Southern AUM Region within the Hopi Buttes volcanic field in the early 1950's. The Hopi Buttes volcanic field is characterized by eroded dikes, necks, diatremes, flows, and tuff of Pliocene and Miocene age (8-4 million years ago). More than 300 diatremes have been located in the Hopi Buttes volcanic field. Many of the diatremes are expressed on the surface as maars that were often filled by localized lakes believed fed by rising thermal solutions. Anomalous concentrations of uranium are located only in those diatremes containing maar lakes with ephemeral lake deposits (Wenrich-Verbeek and Mascarenas , 1982 - S06280601). The Morale mine was the only productive AUM, and was mined between 1954 and 1959 (Chenoweth, 1990 - S10020205). Five non-productive AUMs were also mapped in the Southern AUM Region.

Eastern AUM Region: Uranium was mined in the Eastern AUM Region from the Grants Uranium District from 1951 to at least 1989. The Grants Uranium District is located in the southern San Juan Basin in northwestern New Mexico. The district spans the area from Gallup in the west to Laguna in the east, mostly north of Interstate 40 in the south and to north of Crownpoint. It produced more than 240,600,000 pounds of uranium (McLemore and Chenoweth, 2003 - S03030608), and for three decades was the largest uranium district in the world (NMBGMR, 2007 - S05200701). This region covers the western half of the Grants Uranium District. The 1950 discovery of uranium near Haystack Butte initiated the development of the Grants Uranium District. Uranium was produced from the Todilto Limestone in the Haystack Chapter (Chenoweth, 1985 - S08020601). Most uranium in the Grants Uranium District was produced from underground mines in the Westwater Canyon and Brushy Basin Members, or Poison Canyon Sandstone of the Jurassic Morrison Formation (McLemore and Chenoweth, 2003 - S03030608). Grace In Situ Leach near Church Rock was the one mine that produced using In Situ methods. Leaching solution was injected underground via injection wells, the uranium was dissolved and pumped to the surface via production wells and then extracted by an ion exchange process. Another method was to pump a leaching solution into old underground mines, then pump the water out to surface settling and holding ponds, and finally process via ion exchange. The Church Rock and Mariano Lake mines used this method, as did many mines in the Ambrosia Lake area (Holen and Hatchell, 1986 - S08200601). The Cretaceous Dakota Sandstone was another significant uranium host rock for uranium mines in the southern part of the Eastern AUM Region. Most of the mines were developed at the surface, but the largest production was from underground workings (Chenoweth, 1989 - S08020602).



ABANDONED URANIUM MINES AND THE NAVAJO NATION

ABANDONED URANIUM MINES

N W E S

0 50 Miles

Map Scale 1:1,750,000

Legend

Abandoned Uranium Mine Host Rock

- Tertiary Bidahochi Formation
- Cretaceous Dakota Sandstone
- Cretaceous Toreva Formation
- Cretaceous Point Lookout Sandstone
- Cretaceous Dakota Sandstone and Jurassic Morrison Formation
- Jurassic Morrison Formation
- Jurassic Kayenta
- Jurassic Navajo
- Jurassic Todilto Limestone
- Triassic Petrified Forest Member, Chinle Formation
- Triassic Shinarump Member, Chinle Formation
- Transfer Station
- ? Unknown

Source

Abandoned Uranium Mine locations and host rock types were produced from Navajo Abandoned Mine Lands Reclamation Program maps, and sources by William L. Chenoweth, Virginia McLemore, US Atomic Energy Commission/US Department of Energy Documents, and other sources.

Filenames: DB/AUM/NN_AUM_Production_Pts.shp

Tyuyamunite at the VCA Plot 2, West Reservation Lease Pit. Photo courtesy of William Chenoweth.

Figure 2. Abandoned Uranium Mines Shown by Geologic Host Rock Formation.

ABANDONED URANIUM MINES (continued)

METHOD FOR DETERMINING POINT MINE FEATURE LOCATIONS

Since May 1990, the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) has worked to reclaim eligible AUMs on the Navajo Nation. Their initial efforts involved compiling information about each reported occurrence of past uranium activity on the Navajo Nation. NAMLRP then conducted field inventories and investigations to develop a more comprehensive inventory of the AUM sites.

Initially, the NAUM Project concentrated on the AUMs located in the Red Valley Chapter within the Northern AUM Region. NAMLRP prepared a set of USGS topographic maps with mapped AUM feature locations for the Red Valley Chapter. These mine features were automated into a GIS point dataset and compared to those developed from georeferenced mine sketch maps from William Chenoweth's multiple publications covering the East Carrizo Mountains area of Arizona and New Mexico. NAMLRP mine features were also compared with USGS digital orthophoto quarter quadrangles (DOQQ) and USGS 7.5 minute topographic maps. In consultation with Chenoweth (2003 - S07100301) and using a GIS overlay process, it was determined that most NAMLRP mine features were accurately positioned at the 1:24,000 scale and would be used as the primary source for mine feature locations.

For the remainder of the Navajo Nation, NAMLRP prepared multiple sets of USGS topographic maps, covering their inventory areas in the North Central, Northern, Western, Central, and Southern AUM Regions. These maps located all inventoried mine features and coded them by mine feature type (e.g., portal, shaft, prospect, rim strip, and pit). For each AUM region these maps were georeferenced and a GIS point dataset was developed. There are 1,265 mine features mapped on or within one (1) mile of the Navajo Nation. These mine features are provided on the GIS Data DVD (DB/AUM/NN_AUM_Pt_Features.shp). The number of mine feature types by AUM Region is shown in Table 2.

Table 2. Mine features by AUM Region.

Mine Site Feature/AUM Region	Central	Eastern	North Central	Northern	Southern	Western	Total
Drillhole	0	0	0	1	0	0	**1**
Portal	4	53	55	417	1	3	**533**
Prospect	5	4	1	135	1	11	**157**
Rim Strip / Pit	44	44	29	302	0	84	**503**
Vertical	0	36	12	9	0	2	**59**
Waste Pile	1	6	1	4	0	0	**12**
Total	**54**	**143**	**98**	**868**	**2**	**100**	**1265**

Most of the mine features (1,126) were mapped from sources provided by NAMLRP. The remaining 139 mine features were mapped from other sources, and 122 of these were mapped in the Eastern AUM Region. NAMLRP only mapped twenty-one (21) mine features in the Eastern AUM Region, which were associated with the Christensen, Foutz No. 1, Foutz No. 2, Foutz No. 3, and Rats Nest mines north of the town of Church Rock, New Mexico. This was primarily due to NAMLRP's authorization to reclaim only those AUMs that fall within Tribal Trust Lands. Land ownership in the Eastern AUM Region is significantly mixed (see Section 3, page 3-4). The other mine features were mapped in the Eastern AUM Region using reports and maps from multiple literature sources in conjunction with USGS 7.5 minute topographic maps and DOQQ imagery.

There were seventeen (17) mine features added to the other AUM Regions that were not mapped by NAMLRP. These were mapped from other literature sources, USGS 7.5 minute topographic maps, and DOQQ imagery. These additional mine features included: four (4) in the Central AUM Region, six (6) in the North Central AUM Region, and seven (7) in the Northern AUM Region. Eleven (11) of these additional mine features were portals or vertical shafts that were added based upon mine entrances shown on underground mine sketches.

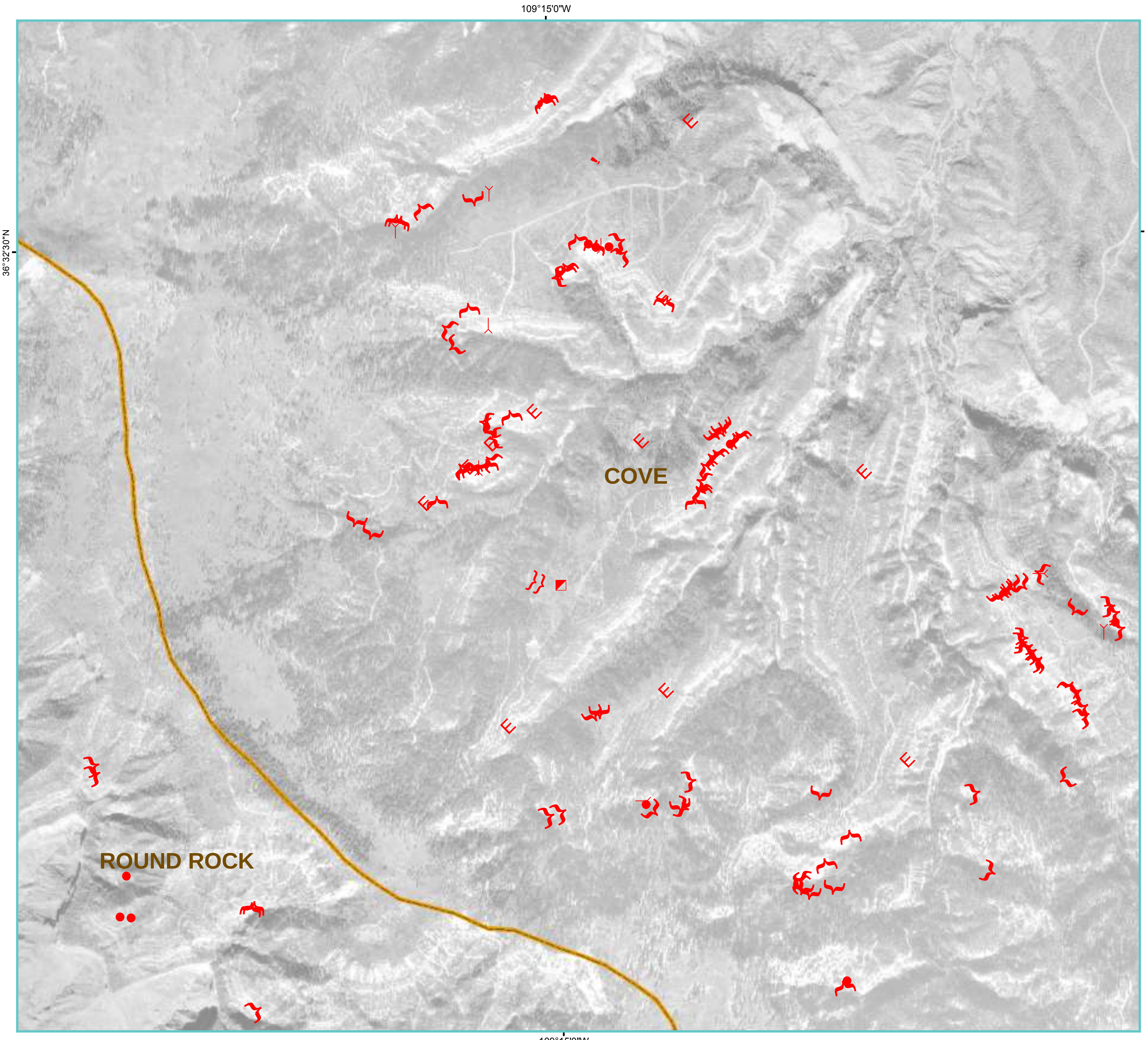
Some NAMLRP mine feature positions were adjusted. These are documented in the "COMMENTS" attribute of the GIS dataset (NN_AUM_Pt_Features.shp). The location source attribute "LCTN_SRC" provides a reference for mine features that were added from sources other than NAMLRP, or for NAMLRP mine feature positions that were adjusted.

Seventy four (74) AUM sites do not have mapped mine features. Sixty three (63) of these AUM sites were not mapped by NAMLRP, and no specific mine feature was present on available maps, interpreted from imagery, or found in the literature. Eleven (11) AUM sites were originally mapped by NAMLRP as single NAMLRP Project sites that were subsequently split into multiple named AUM sites. The splits did not result in mapping any additional mine features.

The "SITE_ID" attribute provides identifiers for the mine features. The NAMLRP mine features use a three character abbreviation for the NAMLRP Problem Area in which they are located[1], followed by a three integer number that was arbitrarily assigned during field inventories. Sometimes there is a character following the three integers. For the mine features added from non-NAMLRP sources, the identifier provided by the source was used for the SITE-ID. In cases where a source identifier was not available for added mine features, a two character abbreviation designating the Chapter was used. For mine features that were located off the Navajo Nation, two XX's were used. These two characters were followed by a two integer sequential number.

Figure 3 provides an example of mine features in an area of the Lukachukai Mountains, Apache County, Arizona. Mine features are shown in red and they have been symbolized by the type of feature. The inset location map shows the distribution of mine features (shown in black) in an overview of the Navajo Nation.

[1] For the NAMLRP mine features at the Christensen, Foutz No. 1, Foutz No. 2, Foutz No. 3, and Rats Nest mines, the identifiers used by McLemore and others (2002 - S12160205) were adopted.



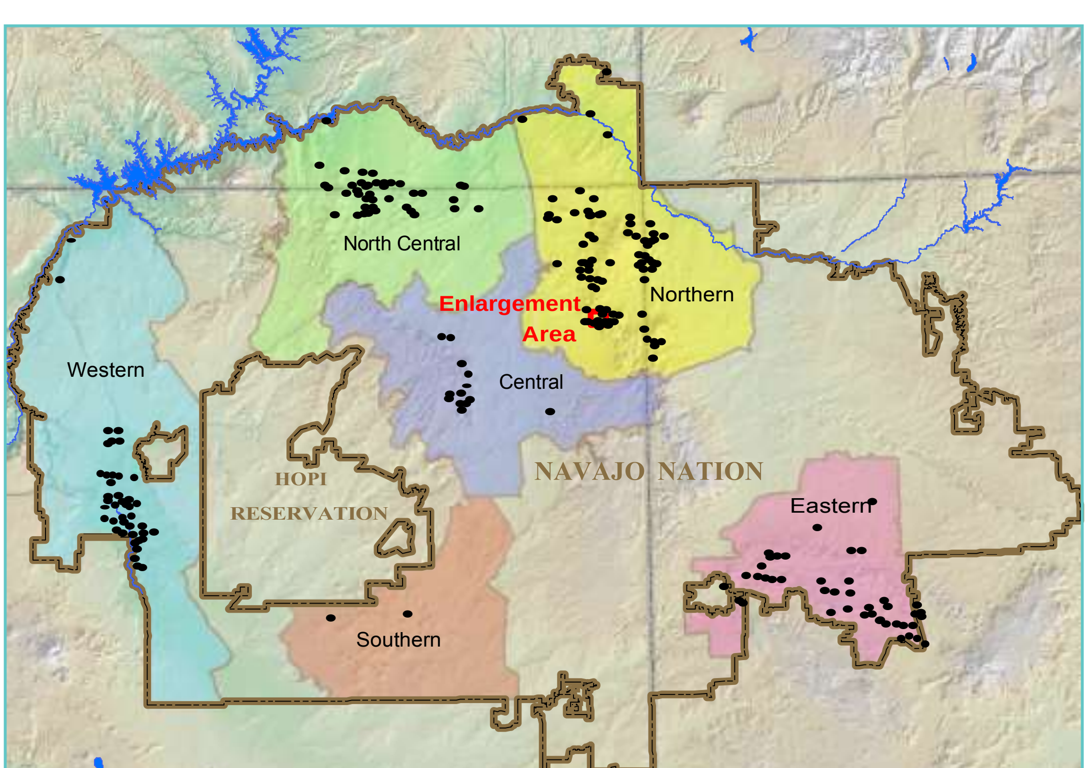
ABANDONED URANIUM MINES AND THE NAVAJO NATION

MINE FEATURES OF THE LUKACHUKAI MOUNTAINS

N
W E
S

0 1 Miles

Map Scale 1:24,000



Overview of Mine Feature Locations Across the Navajo Nation.

Legend

Mine Features

- Portal
- Prospect
- Rim Strip / Pit
- Vertical

Source

Abandoned Uranium Mine feature locations are from Navajo Abandoned Mine Lands Reclamation Program maps, and sources by William L. Chenoweth, Virginia McLemore, USGS 7.5 minute topographic maps, Digital Orthophoto Quarter Quads (DOQQs), and other sources.

Filename: DB/AUM/NN_AUM_Pt_Features.shp

Figure 3. Mine Features on the Lukachukai Mountains.

ABANDONED URANIUM MINES (continued)

ABANDONED URANIUM MINE POLYGON DELINEATION

NAMLRP provided maps showing the location of NAMLRP Reclamation Project Areas for the North Central, Northern, Western, Central, and Southern AUM Regions. NAMLRP provided coordinates from Global Positioning System (GPS) measurements for the location of AUM project areas in the North Central and Western AUM Regions. Seven (7) of 51 NAMLRP AUM reclamation project areas in the North Central AUM Region were mapped using GPS and 83 of 86 NAMLRP AUM reclamation project areas in the Western AUM Region were mapped using GPS. NAMLRP inventories were conducted on Navajo Nation Trust Lands; therefore, maps were not provided in the Eastern AUM Region outside the area of the Christensen, Foutz No. 1, Foutz No. 2, Foutz No. 3, and Rats Nest mines. NAMLRP project areas generally included groups of mine features that were associated with one or more mining operations. They encompass the mapped mine features, smaller unmapped features of a mining operation, and a buffer around the mining operations by about 50 feet. These NAMLRP AUM reclamation project polygons provide excellent mine operation locations and extents and are provided on the GIS Data DVD (DB/AUM/NN_AUM_Project_Sites.shp).

AUM polygons were also generated for mine features and unreclaimed mine waste piles that were not reclaimed by NAMLRP. These AUM polygons were generated by creating a 200 foot buffer around the feature. In some cases, it was possible to further refine the AUM boundaries by including NAMLRP unreclaimed mine waste piles, airborne radiological anomalies, and/or photo-interpreted mine-related surface disturbances. Many AUMs across the Navajo Nation occur in areas of high relief, characterized by flat-topped mesas with vertical or near vertical cliffs. Mine waste was often pushed down these cliffs forming potentially radioactive mine waste talus slopes. These mine waste piles were not individually mapped; however, they were identified by NAMLRP and coded into the mine features GIS dataset. In these areas, the boundaries of NAMLRP project polygons were extended down-slope 200 feet.

Some NAMLRP project boundaries were modified based on aerial radiation data collected by the U.S. Department of Energy's Aerial Measuring System (Hendricks, 2001 - S03310309). NAMLRP project boundaries were enlarged where the excess Bismuth-214 7.4 µR/hr contour levels extended beyond these boundaries. This contour level was chosen because it represents about twice the background excess Bismuth-214 expected across the Navajo Nation. DOQQ imagery was inspected around NAMLRP projects. Boundaries were extended where distinct AUM related disturbances could be photo-interpreted and mapped contiguous with NAMLRP projects. Some NAMLRP projects encompassed more than one mine. In these cases the project polygons were split or merged to enable the separate representation of AUMs. All of the modifications to the NAMLRP project boundaries were documented in the metadata, and resulted in a new GIS dataset of AUM boundaries.

For the Eastern AUM Region, NAMLRP AUM Reclamation Project Areas and field inventories were used to develop six (6) AUM polygons. Eighty five (85) AUMs were identified from McLemore's database of point locations for uranium and thorium occurrences in New Mexico (McLemore et al., 2002 – S12160205). Locations for eight (8) AUM polygons were added from other reports and documents (Chenoweth, 2007 - S01150706; DOE, Unpublished - S08020610; Holen and Hatchell, 1986 - S08200601; and McLemore and Chenoweth, 1991 - S03030608). Most AUM polygons were developed using point locations and/or mine claim or permit boundaries from these and other supporting literature. They were further developed using USGS 1997 black and white and 2005 color DOQQs and USGS 7.5 minute topographic maps. The aerial radiation survey did not cover the Eastern AUM Region.

Mine names were identified for most AUMs. Some AUM polygons have the same mine name because a mine may have more than one associated area of disturbance. The final boundaries for the AUMs are provided on the GIS Data DVD (DB/AUM/NN_AUM_Poly_Surf.shp), and represent the AUM surface extents. These were used as the basis for generating buffers for the Soil, Air and Surface Water Pathway analyses.

Underground AUM Workings

North Central AUM Region: Thirty-seven (37) of the AUMs in the North Central AUM Region had documented underground workings, although most uranium mines in this region were mined underground. Many historical reports contained sketches of the underground workings of the mines, which were used to develop polygon boundaries representing the extents of the underground workings.

Northern AUM Region: A significant number of the AUMs had extensive underground workings, particularly those in the Lukachukai and Cove Mesa area.

Central AUM Region: Four (4) AUMs in the Black Mesa area of the Central AUM Region used underground methods (Claim 7, Dan Taylor No. 1, Etsitty No. 1 and Rough Rock Slope No. 9) (Chenoweth, 1990 – S10100236). With the exception of Claim 7, historical reports did not contain sketches of the underground workings of the mines. The sketch for Claim 7 could not be georeferenced, so no polygon boundaries representing the extents of the underground workings were developed.

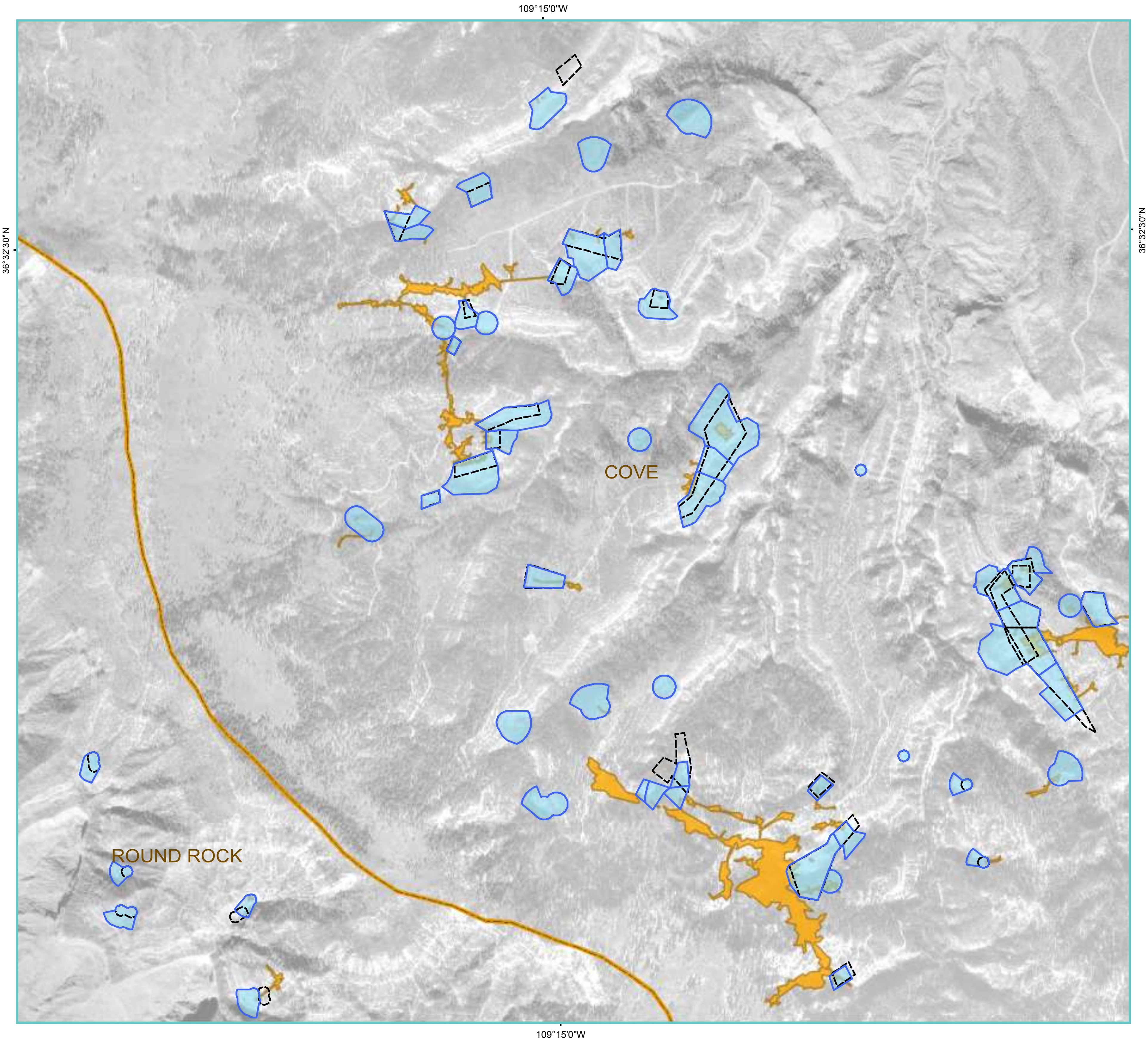
Southern AUM Region: The Morale mine was the only productive mine in the Southern AUM Region, and it used underground methods (Chenoweth, 1990 – S10020205). However, no map for the underground workings was located.

Western AUM Region: There was no significant underground mining in the Western AUM Region. However, it is known that at the base of some large pits (e.g., Ramco 20 and 21) adits were dug into pit walls in order to follow minor ore trends (Chenoweth, 1993 – S10100239). These minor underground workings were not mapped or entered into the GIS database.

Eastern AUM Region: Most mines in the Eastern AUM Region were underground mines. Seven (7) underground mine maps were automated. Eighty-five (85) ore body extent polygons were automated. These represent areas of ore bodies known to have been mined; however, precise underground mine workings are unknown. Many AUMs with underground mines are unmapped due to the lack of literature sources.

A GIS dataset with the polygons for these compiled underground AUM mine workings is provided on the GIS Data DVD (DB/AUM/NN_AUM_Poly_Undrgnd.shp). The combined area of the surface and underground AUM boundaries were used to generate the buffers used for the ground water pathway analyses.

Figure 4 shows the spatial distribution of surface and underground AUMs for an area of the Lukachukai Mountains, Apache County, Arizona. For a comparison, the original NAMLRP reclamation project sites are shown as dashed polygons.



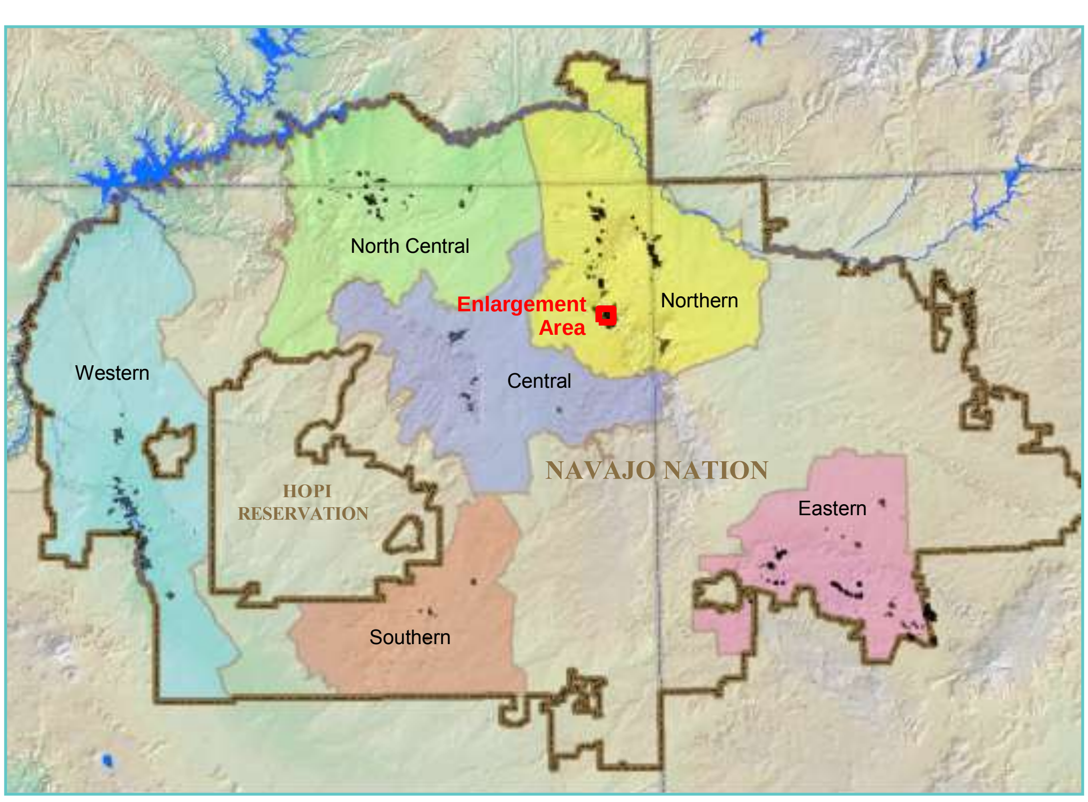
ABANDONED URANIUM MINES AND THE NAVAJO NATION

SURFACE AND UNDERGROUND AUMS OF THE LUKACHUKAI MOUNTAINS

N W E S

0 1 2 Miles

Map Scale 1:24,000



Overview of AUM Locations Across the Navajo Nation.

Legend

NAMLRP Reclamation Project Sites

Underground AUMs

Surface AUMs

Sources

Reclamation Project Sites are from Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) maps. Abandoned Uranium Mine site locations are from NAMLRP maps, and sources by William L. Chenoweth, Virginia McLemore, USGS 7.5 minute topographic maps, Digital Orthophoto Quarter Quads (DOQQs), and other sources. Mapped underground AUM extents are from various sources.

Filenames:
DB/AUM/NN_AUM_Pt_Features.shp
DB/AUM/NN_AUM_Project_Sites.shp
DB/AUM/NN_AUM_Poly_Surf.shp
DB/AUM/NN_AUM_Poly_Undrgnd.shp

Figure 4. Surface and Underground AUMs of the Lukachukai Mountains.

ABANDONED URANIUM MINES (continued)

PRODUCTION

Production Data Development

William Chenoweth reported that the documentation of ore production records is indebted to the AEC's requirement for monthly reports from the uranium ore processing mills (DeVoto and Huber, 1982 – S10020206). These monthly ore receipts were compiled on a quarterly basis and included the following information: name of property and shipper, mining district, state and county, AEC license number, and usually the number of miles from the mine to the mill or ore buying station. They also contained the following production data: dry tons of ore; contained pounds and the calculated percents of uranium oxide (U_3O_8), vanadium oxide (V_2O_5), and calcium carbonate ($CaCO_3$). These records were subsequently compiled for the U.S. Claims Court, Navajo Tribe vs. United States, Docket Nos. 69 and 299 (copper, vanadium, uranium, sand, rock and gravel claims) held in Albuquerque, New Mexico, February 24 through March 4, 1983 by the General Services Administration (GSA, 1981 – S03210322). Chenoweth has continued to publish uranium mine and production history for uranium-vanadium mines across the Navajo Nation to the present. Chenoweth has maintained a comprehensive library on the uranium history of the Four Corners states, as well as an extensive personal experience and memory of the uranium history of the region from the 1950s to the present. This report's documentation of uranium and vanadium production has benefited from numerous personal communications with William Chenoweth that permitted the compilation of production data from various unpublished records. A major source of archived unpublished uranium and vanadium production records were the Atomic Energy Commission and the Department of Energy records held at the U.S. National Archives and Records Administration (NARA), National Record Group 434-00-287, Rocky Mountain Region at the Denver Federal Center, Colorado.

Working with William Chenoweth to build this extensive set of publication data also improved development of the AUM datasets. The work led to the discovery of additional documents, or Chenoweth's recollections of mine site visits, which resulted in the development of a few new AUMs or refinement of existing AUMs. This facilitated separating production estimates for individual mines in cases where the records reported production statistics as a combined total for an entire lease. In the Northern AUM Region, the Vanadium Corporation of America's (VCA) East and West Reservation Lease production records were not recorded by Plot (claim) where individual mines were located, but by total production for each lease. Chenoweth was also invaluable in documenting post-AEC production for the Grants Uranium District in the Eastern AUM Region. McLemore and Chenoweth (1991 - S03030608) and McLemore et al., (2002 - S12160205) previously reported post-AEC (after 1970) production statistics as large ranges, due to company confidential records. Since that time, Chenoweth has been able to access now public NARA records up to about 1983. These production statistics are documented in this report. A few mines in the Ambrosia Lake area likely produced after 1983, but any production after 1983 is not included in this report.

In some cases, production for multiple mines on a lease was reported as a single combined production value for all those mines. During the period 1942-1947 production for the 12 Plots (or claims) of VCA's East Reservation Lease (I-149-IND-5705), the 16 Plots of VCA's West Reservation Lease (I-149-IND-5456), the 12 Plots of the AEC Lease (I-149-IND-6197, also known as the Curran Brothers and Wade Lease), the 3 Plots of the Wade, Curran, and Co. Lease I-149-IND-3798, and the 2 Plots of the Wade, Curran, and Company Lease I-149-IND-4225, all had production recorded by Lease and not by individual Plot (Chenoweth, 1991 – S02020701). Further, the East Reservation Lease had combined production reported for the period 1948-1950 (Chenoweth, 1985 – S03130303), as did the West Reservation Lease for the period 1948-1952 (Chenoweth, 1984 – S10020203). This happened during the period 1942-1947 when these mines were operated as vanadium mines, and when the shipper or operator of all the mines on a lease were the same company. Separate production values for these mines was estimated based upon ore tonnage and grade estimates for vanadium in various Chenoweth reports and personal communications (Chenoweth, 2007 – S01150701). Unlike the other Plots of the East Reservation Lease, a further separation of production was performed for Plot 3, because at this time it had four producing mines: Shadyside No. 1, Shadyside No. 2, Lookout Point and Nelson Point. Actual production for each of these four mines was used to estimate the relative ratio of production. This ratio was applied to the estimated Plot 3 production for the period 1942-1945 and 1948-1950 to produce estimated production of tons of ore and pounds of vanadium oxide.

During World War II, production from these Northern AUM Region vanadium mines was used to extract uranium for the atom bomb. Uranium oxide production (U_3O_8) was estimated based upon the uranium to vanadium ratio for each lease (Chenoweth, 1991 – S02020701).

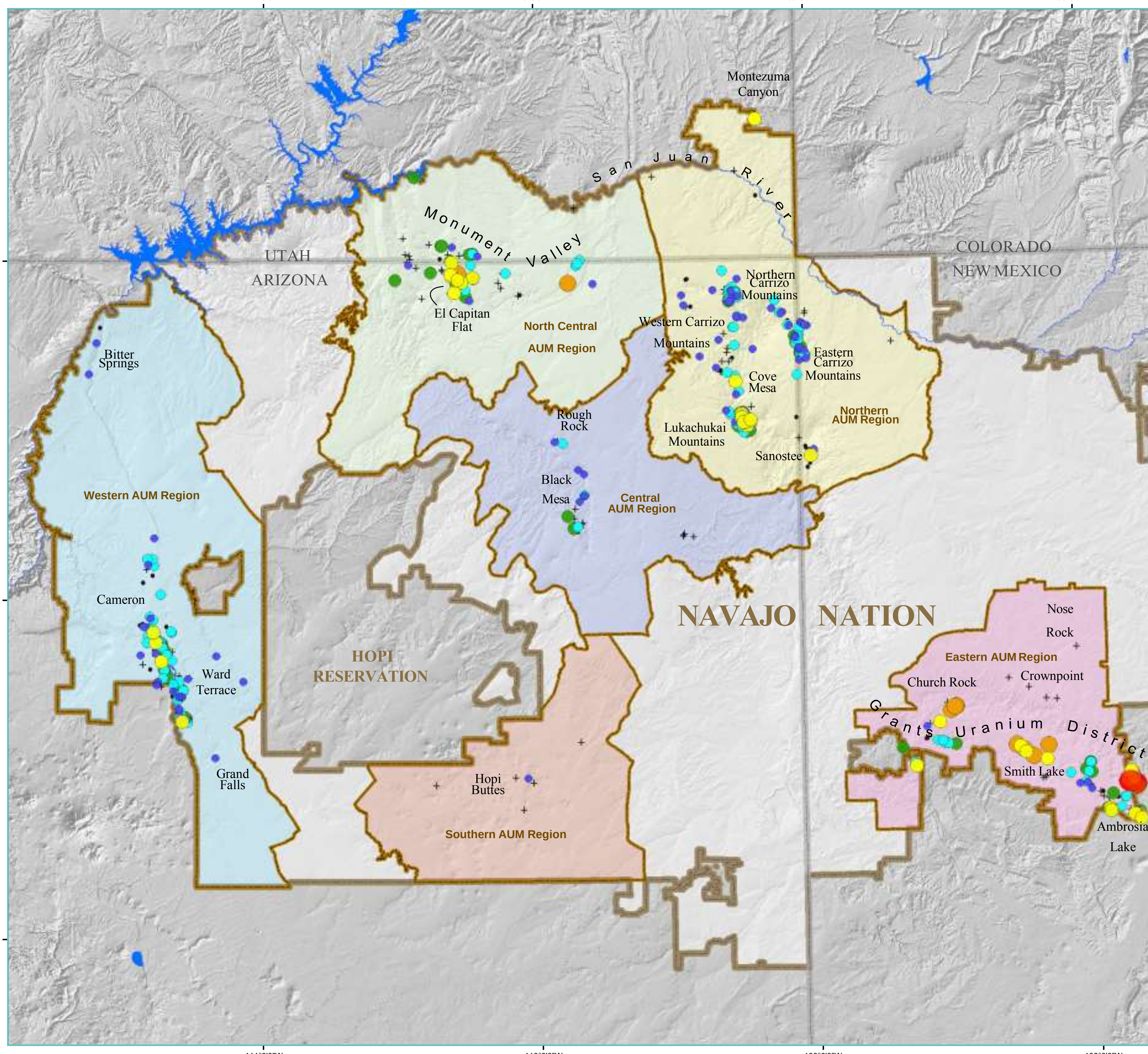
In 1962, production at the C-3 and Taylor Reid No. 1 mines was reported as combined production under the same mine operator, Dumont Development (Chenoweth, 1991 – S03100502). Also, during 1956 and the period 1964-1965, production for the Shadyside No. 1 and Shadyside Incline mines was reported as combined production by VCA under the name Shadyside Mines (Chenoweth, 1996 – S03240304). Separate mine production was estimated based on the ratio of actual production of the two mines during the years that production was reported separately.

The estimated values for tons of ore and pounds of uranium and vanadium oxide discussed above are included in the final total production reported in the GIS datasets provided on the GIS Data DVD (DB/AUM/NN_AUM_Production_Pts.shp and DB/AUM/NN_AUM_Production.shp). Notes about actual versus estimated ore production values will be found in the "COMMENT" field of the two production GIS datasets.

Figure 5 presents the results of the compiled and estimated uranium oxide (U_3O_8) production on and within one (1) mile of the Navajo Nation. The ranges of uranium production are symbolized on a base ten logarithmic scale where each higher production range is a magnitude larger than the previous production range. The largest producing mines are shown as red circles (>10,000,000 pounds of U_3O_8) and orange circles (1,000,001 to 10,000,000 pounds U_3O_8). Fourteen (14) of these sixteen (16) large mines are located mostly in the Grants Uranium District of the Eastern AUM Region, with the largest AUM located in the Ambrosia Lake area. Outside the Eastern AUM Region there are two (2) mines that produced more than 1,000,000 pounds U_3O_8: the Monument No. 1 and Moonlight mines, both located in Monument Valley within the North Central AUM Region.

Mines that produced in the range of 100,001 to 1,000,000 pounds of U_3O_8 are shown as yellow circles. These include: thirteen (13) mines across the Eastern AUM Region; eight (8) mines in the El Capitan Flat area of Monument Valley in the North Central AUM Region; six (6) mines in the Lukachukai Mountains, three (3) mines on Cove Mesa, at the south end of Montezuma Canyon, and in Sanostee in the Northern AUM Region; and four (4) mines within the Western AUM Region.

The largest producer in the Central AUM Region is Claim 28 (17,327 pounds U_3O_8). The only producing mine in the Southern AUM Region was the Morale mine (580 pounds U_3O_8).



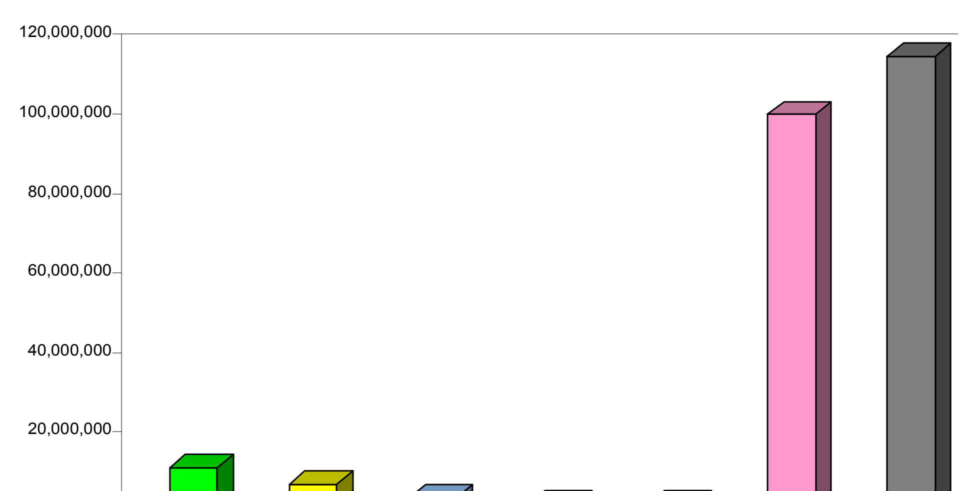
ABANDONED URANIUM MINES AND THE NAVAJO NATION

ABANDONED URANIUM MINE PRODUCTION

0 50 Miles

Map Scale 1:1,525,000

Pounds U_3O_8 by AUM Region
Produced On or Within One Mile of the Navajo Nation



	North Central	Northern	Western	Central	Southern	Eastern	Total
TOTAL	8,828,143	4,650,939	1,206,413	57,562	580	97,584,814	112,328,451

AUM Region

Legend

Abandoned Uranium Mine Production
Pounds U_3O_8

- 10,000,001 - 17,520,976
- 1,000,001 - 10,000,000
- 100,001 - 1,000,000
- 10,001 - 100,000
- 1,001 - 10,000
- 101 - 1,000
- 1 - 100
- No Production

Source

Uranium production was compiled primarily from published reports and personal communications by William L. Chenoweth.

Filename: DB/AUM/NN_AUM_Production_Pts.shp

Figure 5. Uranium (U_3O_8) Production on the Navajo Nation.

ABANDONED URANIUM MINES (continued)

PRODUCTION (continued)

Production Polygon GIS Dataset Development
AUM polygons with total production were developed and are provided as a GIS dataset on the GIS Data DVD (DB/AUM/NN_AUM_Production.shp). Figure 6 shows the AUM polygons for an area of the Lukachukai Mountains, Apache County, Arizona. These mine polygons are symbolized using the same color scheme and production ranges as shown on Figure 5 for AUM points. They were developed by merging and dissolving the surface (NN_AUM_Poly_Surf.shp) and underground (NN_AUM_Poly_Undrgnd.shp) AUMs by all Mine-IDs that comprised a single productive mine. The polygon includes the full known productive extent of a mine.

Frank No. 1 Mine (yellow polygon) and the Frank No. 2 Mine (white polygon) are shown in the top map of Figure 6 at the center of the red outlined box. The Frank No. 1 Mine and Frank No. 2 Mine can also be seen in the inset map enlargement on Figure 6. In the inset map there are three blue surface polygons for the Frank No. 1 Mine (i.e., North, East, and South Portals), and three yellow polygons that represent the underground workings from each portal. These polygons are all associated with the same mine, which was operated by Frank Natcheenbetah and Climax Uranium (Chenoweth, 1988 - S10280203). These six (6) surface and underground polygons comprise the single yellow mine polygon for the Frank No. 1 shown on the top map of Figure 6.

Production Point GIS Dataset Development
The point production GIS dataset was developed from centroids of the production polygons GIS dataset. These centroid points are located at the center weighted average for all polygons that comprise a single AUM. Most AUMs are single polygons and the centroids fall within them. An example is shown in the Figure 6 inset map with the blue point representing the centroid of the Frank No. 2 Mine. In cases where there are multiple polygons comprising a single AUM site, the centroid point will not necessarily fall within the center of one of the polygons. An example is shown in the Figure 6 inset map where the centroid (red dot) is located at the center weighted location between all of the surface and underground polygons comprising the Frank No. 1 Mine. The production points GIS dataset is provided on the GIS Data DVD (DB/AUM/NN_AUM_Production_Pts.shp).

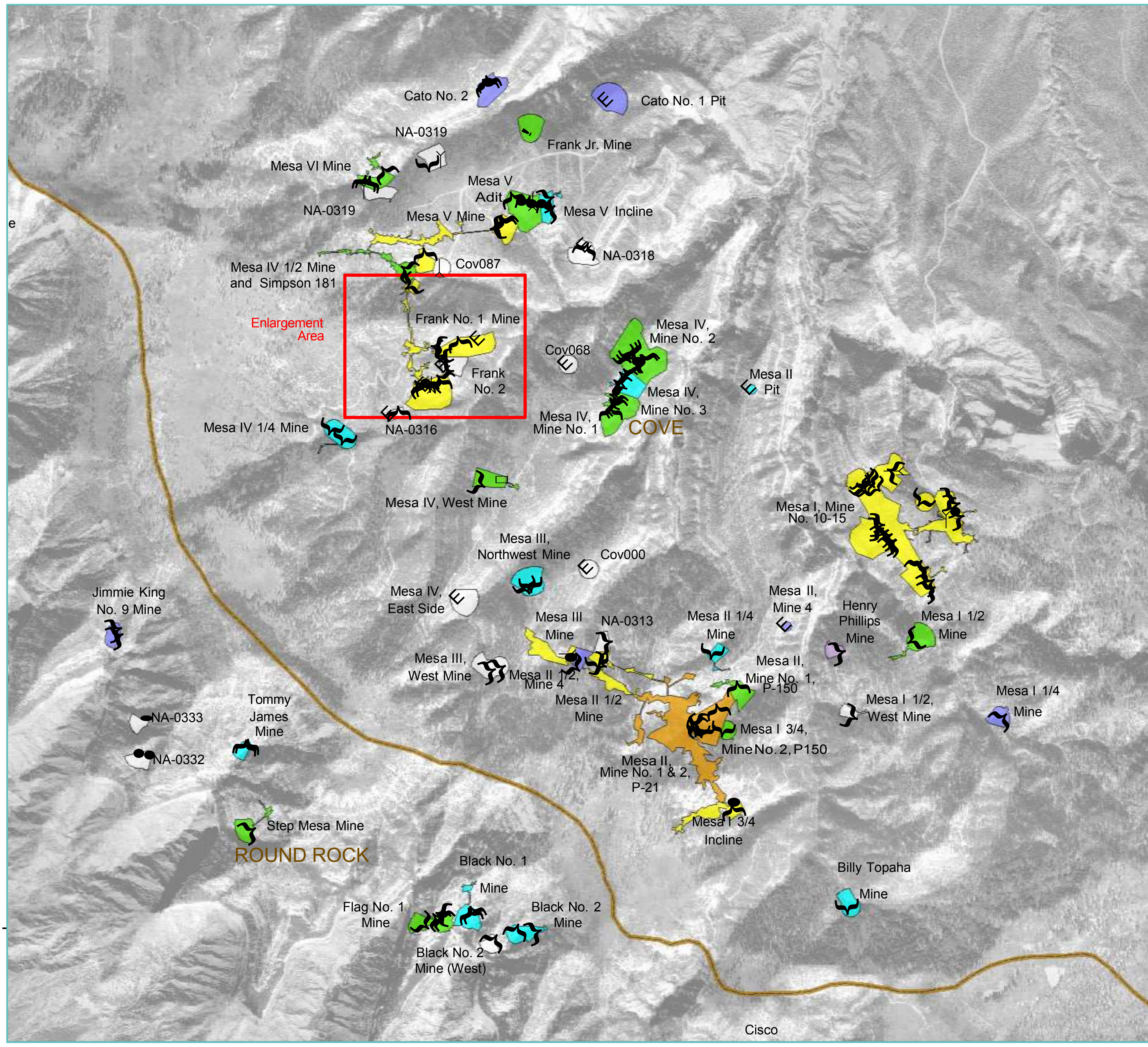
Production Tabulation
The production data attributes collected for each AUM are listed in Table 3 below. This is an example from the production point GIS dataset for the Frank No. 1 Mine. Note that the single Frank No. 1 Mine has three AUM polygons (e.g., three IDs under "AllMineIDs"). This is also represented in the "COMMENTS" field where it is stated that the Frank No. 1 Mine is comprised of three portals. These attributes are included in the two production GIS datasets (DB/AUM/NN_AUM_Production.shp and DB/AUM/NN_AUM_Production_Pts.shp). The grades presented are actual grades for periods of production.

Table 3. Example Production Record for Frank No. 1 Mine.

NN_AUM_Production_Pts
Frank No. 1 Mine

Location: (-109.251112 36.529669)

Field	Value
FID	81
Shape	Point
Mine_ID	106
AllMineIDs	106, 505, 509
Mine_Name	Frank No. 1 Mine
Aliases	South Portal, 48 Mine; North Portal, 1207 Mine; East Portal, 709 Mine
Stratum	Surface and Underground
PRODUCER	Yes
TONS	75739
U308_LBS	373141
U308_PRCNT	0.25
V205_LBS	1738347
V205_PRCNT	1.15
START_YEAR	1951
END_YEAR	1967
PROD_SRC	S10280203
COMMENT	Includes the South Portal (48 Mine), East Portal (709 Mine), and North Portal (1207 Mine).
HOST_ROCK	Jmsw
HOST_SRC	S10280203
SURF_UNDER	S & U
S_U_SRC	S06220502
WTR_TABLE	Above
WTRTBL_SRC	S03190701
REGION	Northern



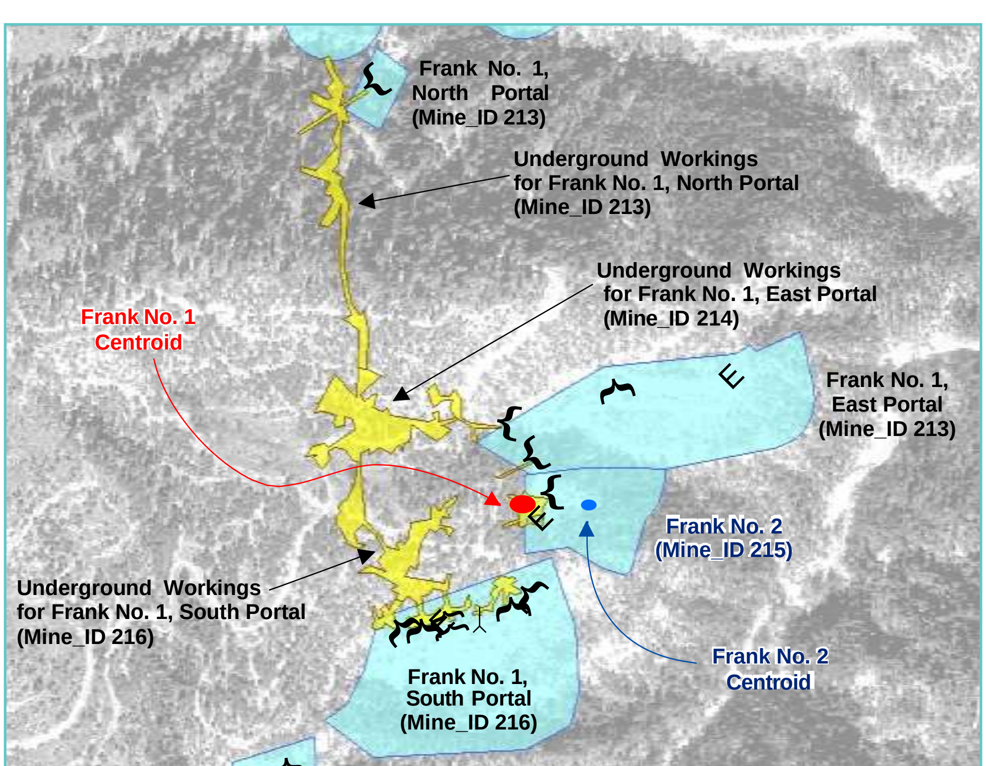
ABANDONED URANIUM MINES AND THE NAVAJO NATION

MINE PRODUCTION FOR THE LUKACHUKAI MOUNTAINS

N W E S

0 1 Miles

Map Scale 1:30,000



Map of surface (cyan) and underground (yellow) workings for the Frank No. 1 and Frank No. 2 Mines. The red dot is the centroid for the combined surface and underground workings for Frank No. 1 mine. The smaller blue dot is the centroid for Frank No. 2. Production from these mines is designated by color-coding in the map above this enlargement (red box outline).

Legend

Abandoned Uranium Mine Production

Pounds U3O8

- 1,000,001 - 17,520,976
- 100,001 - 1,000,000
- 10,001 - 100,000
- 1,001 - 10,000
- 101 - 1,000
- 0 - 100
- No Production

Mine Features

- Portal
- Prospect
- Rim Strip / Pit
- Vertical

Source

Uranium production was compiled from published reports and personal communications by William L. Chenoweth.

Filename: DB/AUM/NN_AUM_Production.shp

Figure 6. Uranium (U_3O_8) Production for the Lukachukai Mountains.

URANIUM MILLS ON THE NAVAJO NATION

Some AUM Regions had uranium mills sited on or near the Navajo Nation (shown on Figure 7). The Tuba City Mill is in the Western AUM Region. The Mexican Hat Mill along the San Juan River, and the Monument Valley Upgrader Site that serviced only the Monument No. 2 mine, was in the North Central AUM Region. In the Northern AUM Region was the Shiprock Mill. The Church Rock Mill is the only mill in the Eastern AUM Region on the Navajo Nation. Nearby, however, were also the Ambrosia Lake, Rio Algom, Blue-water, and Homestake Mining Company Mills. There were no mills near the mines within the Central and Southern AUM Regions.

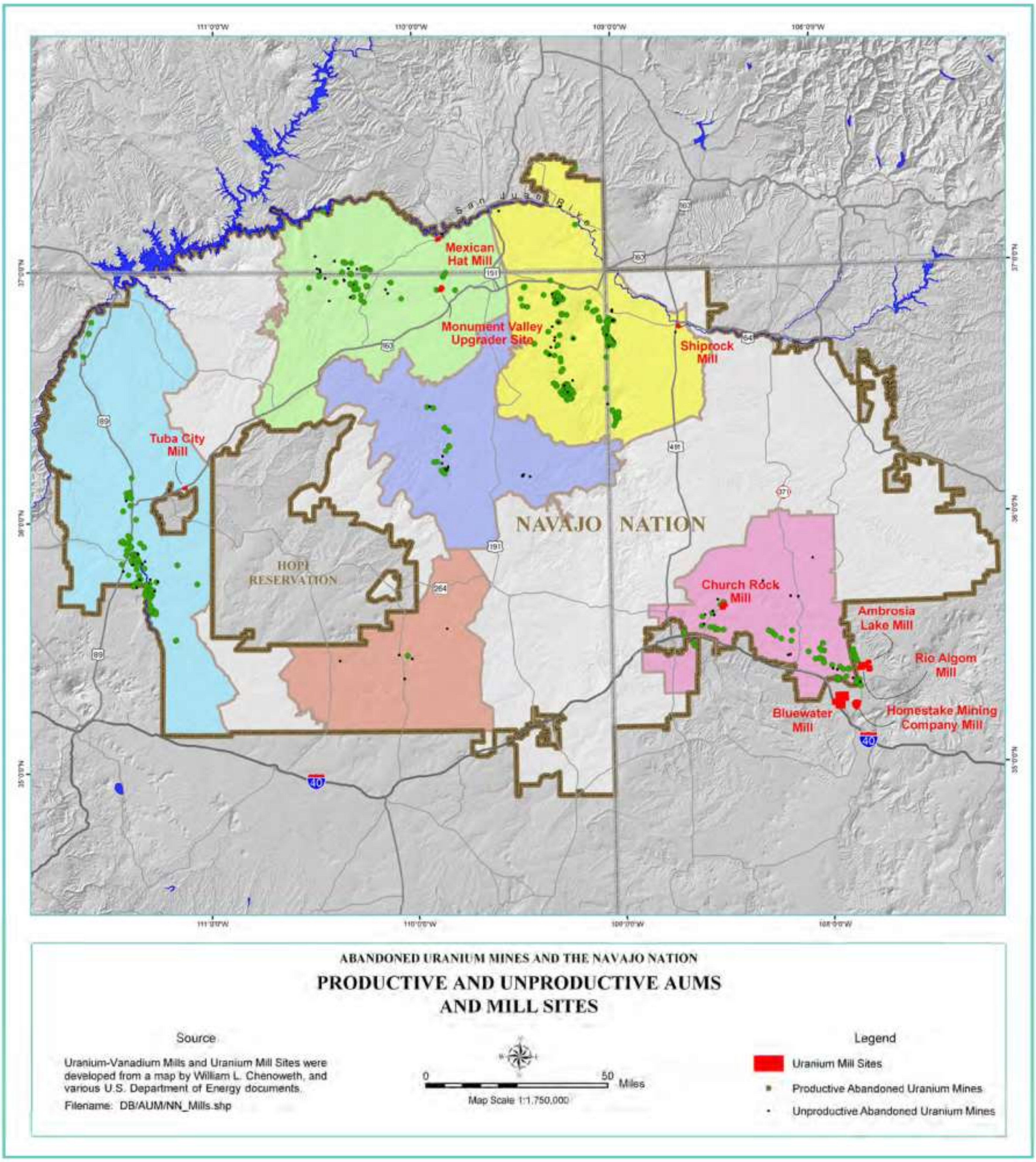


Figure 7. Mill Sites on or Near the Navajo Nation.

Section 2

MINE WASTE CHARACTERISTICS

ABANDONED URANIUM MINE WASTE CHARACTERISTICS

Two important waste characteristics, the location and the types of AUM features (e.g., portals, shafts, rim strips, prospects and waste piles), have been presented in Section 1 - Mining History and Mine Site Information. Another key characteristic of waste is the estimated quantity of potential wastes associated with the mine features. As part of the planning and reclamation process, volumes of uranium mine waste piles were estimated by the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP).

Further characterization of AUM waste requires analytical sampling data. These sampling data should be designed to identify hazardous substances at the AUM sites and to determine the presence or absence of these hazardous substances in environmental media and at targets. This requires a sufficient number of samples, of sufficient quality, to show that any substances found are above background levels and are a result of activities at the AUM sites (EPA, 1991 - S01230301).

This section presents existing sampling and survey data that have been collected on the Navajo Nation, including radiation surveys, field surveys and samples, and reclamation data. These data must be examined carefully with respect to their suitability for drawing conclusions about hazardous substance releases and target exposures. While these data may provide useful insights about the types, levels, and areal distribution of hazardous substances, there are also limitations that should be considered (EPA, 1991 - S01230301):

- Previous sampling efforts may not have been conducted for purposes that are compatible with site assessment objectives.
- Previous sampling may not have been extensive enough to fully characterize the site and the possibility of a release.
- Previous sampling may be limited to one-time sampling events (e.g., water samples).
- Laboratory protocols and standards may not be known.
- Conditions may have changed since the site was last sampled/surveyed. This is a key limitation since most of the AUM sites have been reclaimed since the data samples/surveys were conducted.
- There are inaccessible mine waste piles that were too difficult and hazardous to reclaim or to collect data.

RADIATION SURVEYS

NAUM AERIAL RADIATION SURVEYS

Aerial radiation surveys were flown over the Navajo Nation during October 1994 through October 1999, and covered areas where there was known uranium mining activities. The surveys were conducted by the U.S. Department of Energy's (DOE) Remote Sensing Laboratory (RSL) to assist with locating and characterizing AUMs. The surveys were flown using a helicopter-based acquisition platform equipped with 2 x 4 x 16 inch sodium iodide (NaI[Tl]) scintillation detectors. Aircraft position was established using a real-time differential global positioning system (GPS) and a radar altimeter.

The surveys were flown at a nominal altitude of 150 feet above the terrain, resulting in a footprint of about 300 feet, and a line spacing of 300 feet. Radiation sensor measurements were integrated and recorded at one-second intervals. Each measurement provided an average radiation level for the entire ground sample area (i.e., the 300 feet diameter footprint under the helicopter as shown in Figure 1). This means the data does not pinpoint the radiation levels within the ground sample area. For each ground sample area, the radiation source could be evenly distributed or it could be made up of a combination of radiation sources, such as a higher-level mine waste debris pile placed on soil that had lower regional background radiation levels. Obtaining finer detail measurements for individual radiation sources requires additional ground-based measurements.

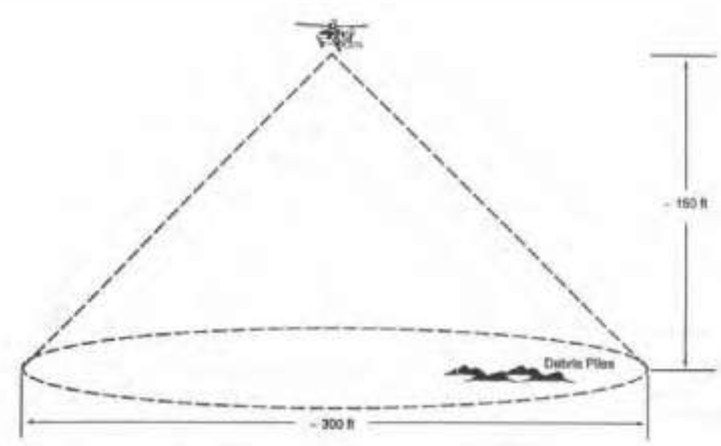


Figure 1. Aerial Radiation Survey Footprint Diagram.

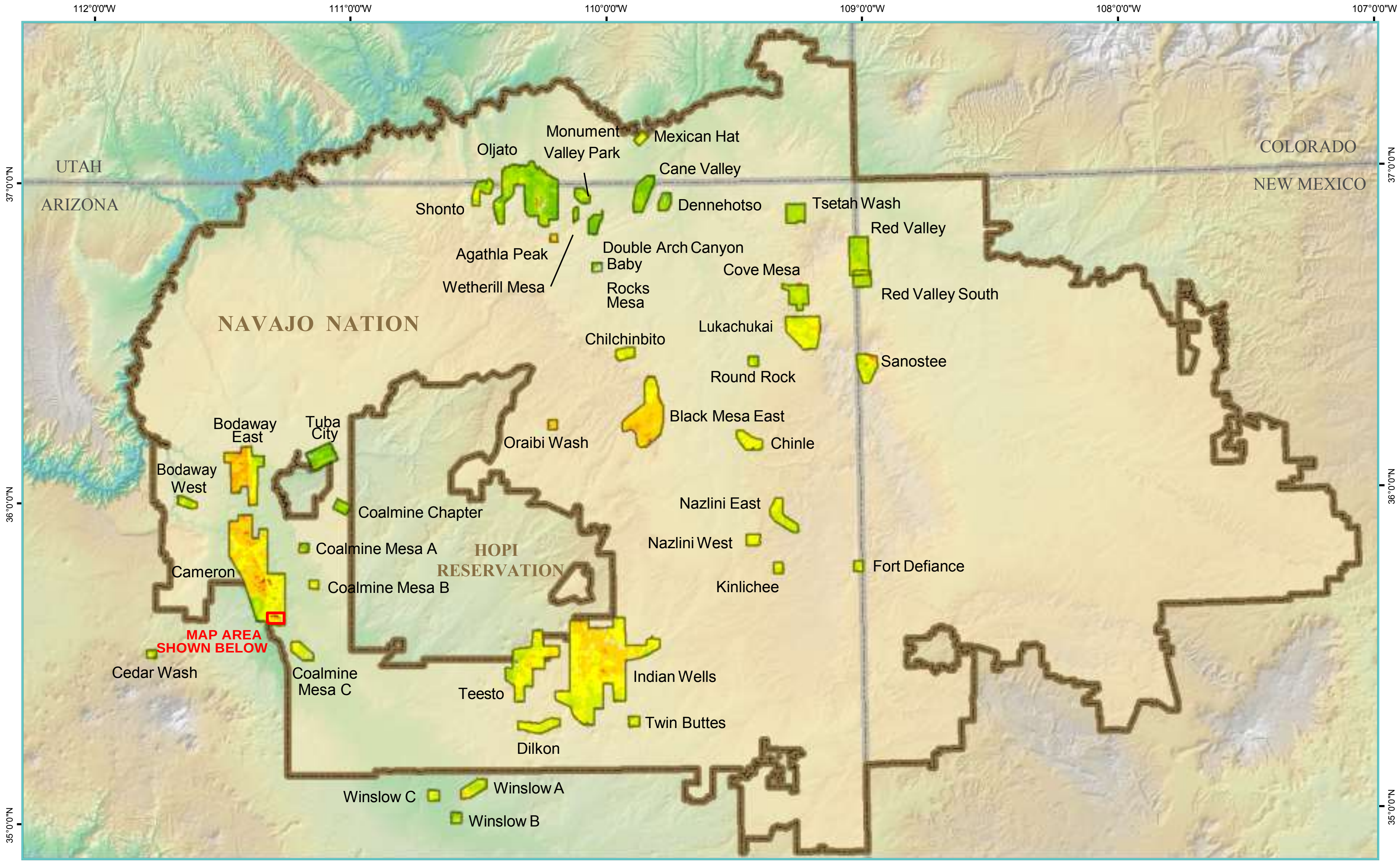
Aerial radiation surveys were flown over forty-one (41) uranium mining areas on the Navajo Nation (Figure 2). Aerial radiation surveys were not conducted over the Eastern AUM Region. A spreadsheet with summaries of the survey parameters for all areas is provided on the GIS Data DVD (DB/Radiation/NAUM_Radsurveys.xls).

Gross count and excess Bismuth-214 data were derived from the measured gamma spectral information. Gross count measures total terrestrial gamma activity, without considering its source, much like a Geiger counter. Aerial gross count data documents the wide range of radioactivity present, even in areas not associated with uranium mining activities. The gross count radiation contours are shown in Figure 2 for the entire Navajo Nation.

Bismuth-214 radiation is associated with the presence of uranium, making it a good indicator of old mines and mining related activities. The Bismuth-214 response, rather than a uranium response, is used because its unique photo peak can be readily distinguished from other radiation. The Bismuth-214 radiation polygons are shown in Figure 2 for an area in the Western AUM Region. These aerial radiation contours were used as an aid in locating and defining the surface extents of AUMs, which are also shown on Figure 2.

These GIS datasets are provided on the GIS Data DVD (DB/Radiation). Aerial radiation survey boundaries (NN_Flight_Areas.shp) and radiation contour data files were converted to GIS-compatible digital files by the DOE RSL for gross count (NN_Gross_Count_Contours.shp) and excess Bismuth-214 (NN_Excess_Bi214_Contours.shp). Additional processing was performed under the NAUM Project to convert the vector contours to polygons (NN_Gross_Count_Polys.shp and NN_Excess_Bi214.shp).

For a more comprehensive explanation of the acquisition and processing methods used for the aerial radiation measurements, a report was developed by the DOE's RSL titled "An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation." (Hendricks, 2001 - S03310309). Two other aerial radiation surveys were conducted by the DOE RSL on the Navajo Nation for the Shiprock, New Mexico Uranium Mill Tailings Site (Jobst, 1981 - S10290208), and the Rio Puerco River downstream from the Church Rock Uranium Tailings Spill (Burson, 1979 - S10280211). GIS data were not provided, but scanned versions of the reports are provided on the References DVD. These surveys were flown to provide information to help guide the planning of ground-based surveys in the vicinity of the AUM sites and to evaluate the effectiveness of any cleanup efforts.



AERIAL RADIATION SURVEY AREAS AND GROSS COUNT RADIATION CONTOURS

Survey areas and gross count aerial radiation contour data are from the U.S. DOE Remote Sensing Laboratory Aerial Measuring System.

Filenames: DB/Radiation/NN_Flight_Areas.shp
DB/Radiation/NN_Gross_Count_Contours.shp

N W E S

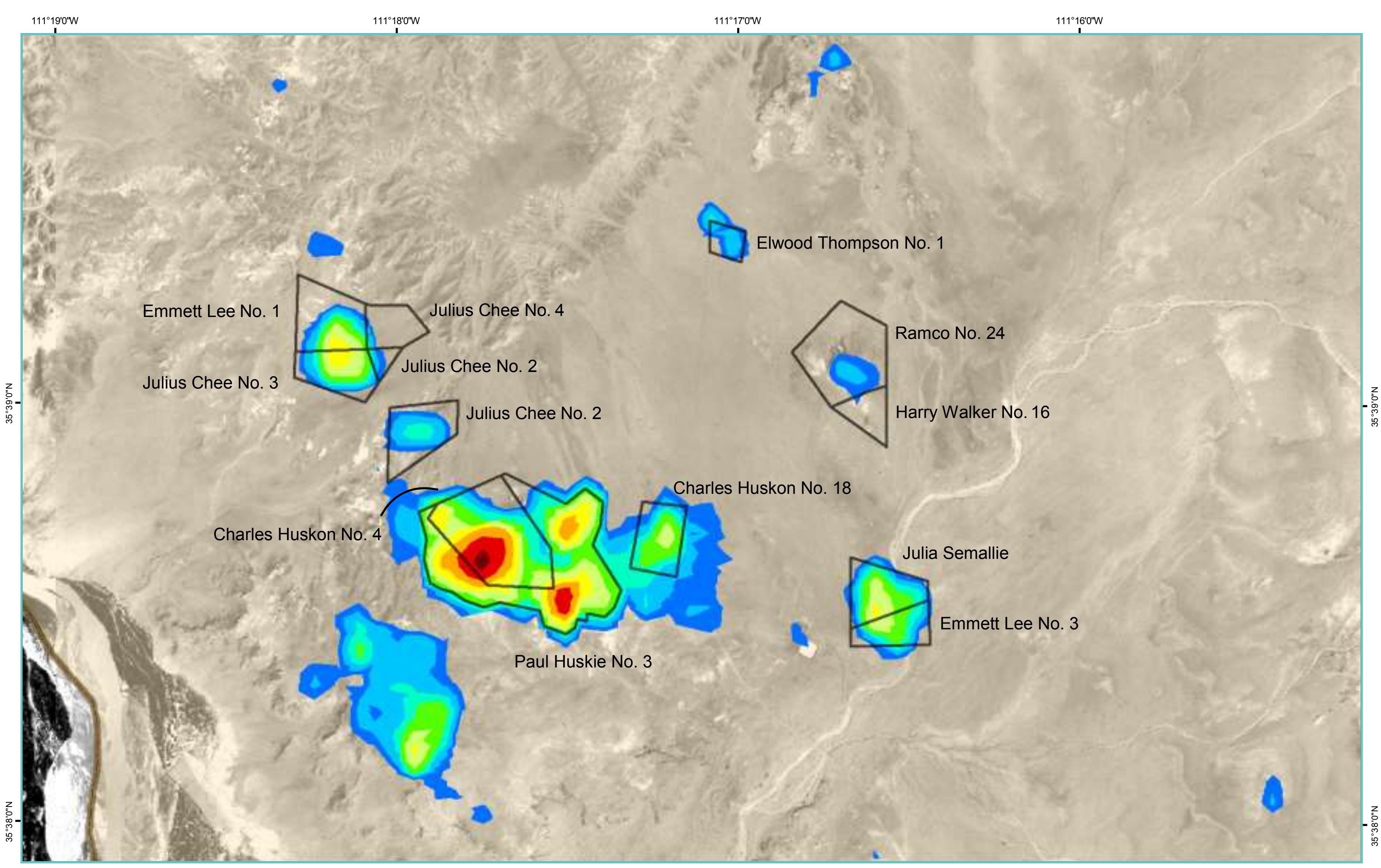
0 50 Miles

Map Scale 1:1,900,000

Aerial Survey Boundary

Radiation Contours - Units in μR/hr.

2	9
3	12
4	16
5	24
6	37
7	60



EXCESS BISMUTH 214 RADIATION DATA SOUTH AREA OF CAMERON SURVEY AREA

Excess Bismuth-214 aerial radiation data are from the U.S. DOE Remote Sensing Laboratory Aerial Measuring System.

Filename: DB/Radiation/NN_Excess_Bi214_Poly.shp

N W E S

0 0.5 Miles

Map Scale 1:24,000

Abandoned Uranium Mine

Estimated exposure rate from excess Bismuth-214 (excess μR/hr)

2.4 to 3.5	16.2 to 23.6
3.5 to 5.2	23.6 to 34.9
5.2 to 7.4	34.9 to 52.4
7.4 to 10.9	>52.5
10.9 to 16.2	

Figure 2. NAUM Project Aerial Radiation Survey Data.

RADIATION SURVEYS (continued)

NATIONAL URANIUM RESOURCE EVALUATION (NURE) AERIAL GAMMA RAY SURVEYS

One of the earliest uranium characterization programs conducted on the Navajo Nation was the National Uranium Resource Evaluation (NURE) program. NURE was initiated by the Atomic Energy Commission (AEC) in 1973 with a primary goal of identifying uranium resources in the United States. From 1974 to 1980, the NURE program systematically evaluated uranium resources of the United States by conducting airborne radiometric and magnetic surveys and by collecting hydrogeochemical and stream sediment samples (Smith, 2001 - S07250302). Aerial gamma-ray data can be used to quantify and describe the radioactivity of rocks and soils. The majority of the gamma-ray signal is derived from the upper 20-25 cm of surficial materials. A gamma-ray detector is mounted in an aircraft and flown at relatively low altitudes. Aerial gamma-ray surveys measure the flux of gamma rays emitted as a result of the radioactive decay of the naturally occurring radioactive elements K-40 (potassium), U-238 (uranium), and Th-232 (thorium). Equivalent uranium (eU) is calculated from the counts received by a gamma-ray detector in the energy window corresponding to Bismuth-214.

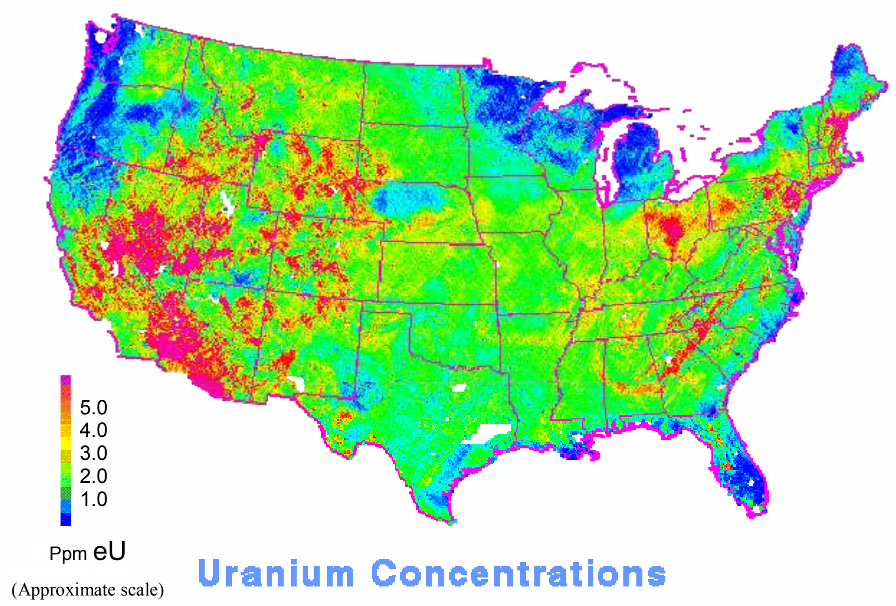


Figure 3. Equivalent Uranium Map for the Conterminous United States

Figure 3 shows an image of the equivalent uranium for the Conterminous United States. This image was generated from NURE aerial gamma-ray data presented in United States Geological Survey Digital Data Series DDS-9, "National Geophysical Data Grids: Gamma-Ray, Magnetic, and Topographic Data for the Conterminous United States," by J.D. Phillips, J. S. Duval, and R. A. Ambrosiak, 1993. Data can be requested from the USGS at *http://energy.cr.usgs.gov/radon/orderinfo.html.*

CHURCH ROCK GAMMA SCAN

In October 2003, EPA's Radiation and Indoor Environment's National Laboratory conducted a truck-mounted gamma radiation scan along transportation corridors in the Church Rock area (Shura, 2003 - S07120501). The scan chart (graph) and corresponding image shown in Figure 4 can be used together to locate the anomalous areas.

The graph shows the counts per second (Y axis) and channel number (X axis) for each second of acquired gamma flux. The green, yellow, and red coloring represents a level of the gamma rate every second as the scanner van traveled about 5 miles per hour along the scan route.

The green represents the average (plus 2 standard deviations) or lower gamma rate of the area background in counts per second. The red (average plus 7 standard deviations) represents an anomaly compared to the background rate. This anomaly may be NORM (Naturally Occurring Radioactive Material) which has a higher flux rate in dense materials such as concrete, rocks and soils in direct line of sight of the scanner van's collimated detector. Or it might be an indication of the elevated gamma flux from mining activity or similar activities or both. NORM is generally easily determined by visual examination, health physics hand held instrument surveys or laboratory analysis. The scanner van is just one tool used in an area characterization.

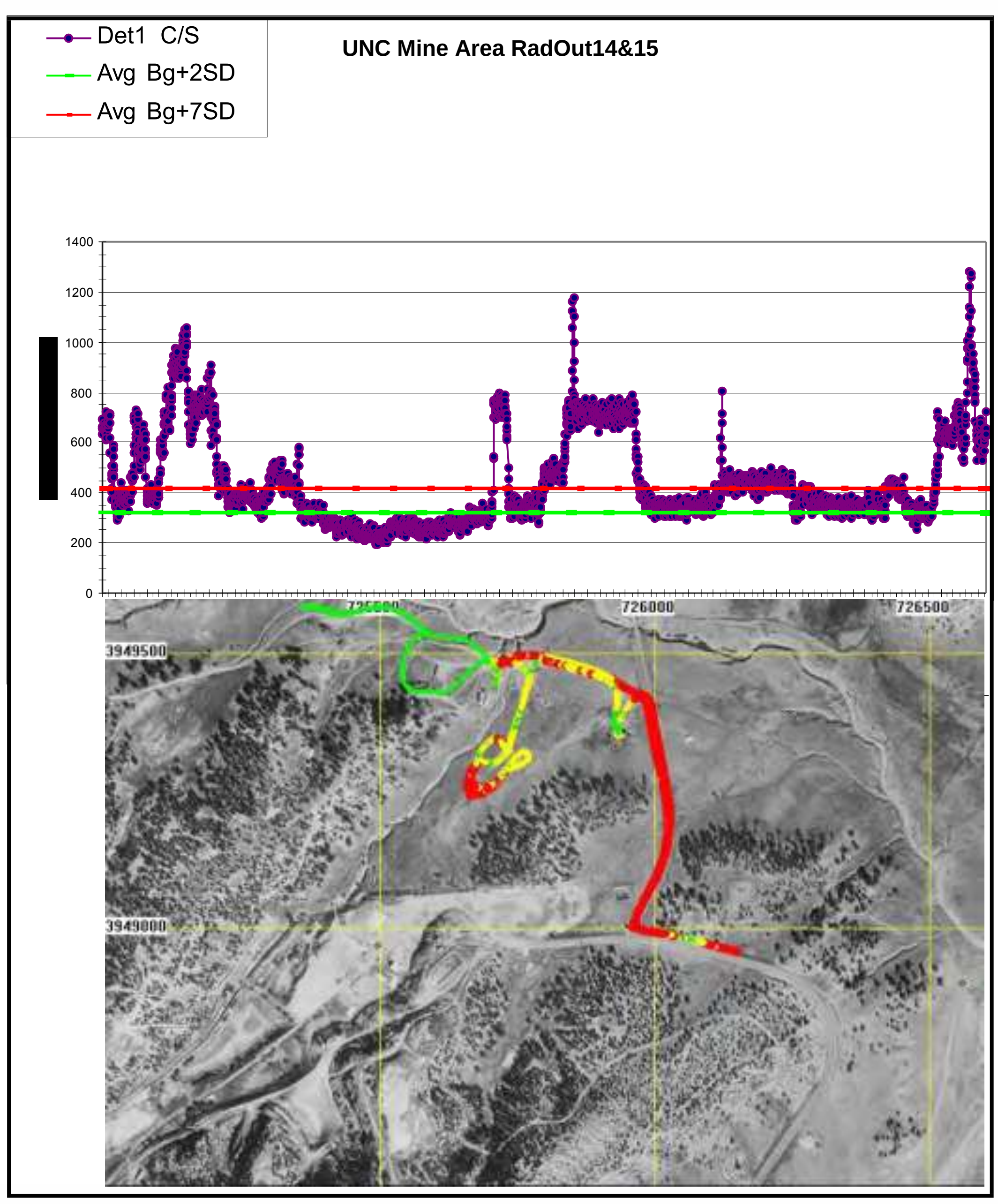


Figure 4. Truck Mounted Gamma Survey Near the United Nuclear Corporation Mine

WATER AND SEDIMENT SAMPLES

NURE HYDROGEOCHEMICAL AND STREAM SEDIMENT RECONNAISSANCE (HSSR) DATA

Systematic sampling of water and sediments over the entire United States began in 1976 under the NURE HSSR Program. Responsibility for the sampling was assigned to four DOE National Laboratories (Smith, 2006 - S06010701). Water and sediment samples on the Navajo Nation were collected by the Los Alamos National Laboratory and the Savannah River Laboratories. The results are presented on a 1° x 2° quadrangle basis. Figure 5 shows the quadrangles that cover the Navajo Nation. Some quadrangles were never completed. For example, the Marble Canyon and Flagstaff quadrangles were not sampled on Hopi Tribal Lands or much of the Navajo Nation. Originally, all samples were only analyzed for uranium. Analyses for up to 42 additional elements were authorized in 1977 and many early samples were reanalyzed. The NURE program effectively ended in 1984.

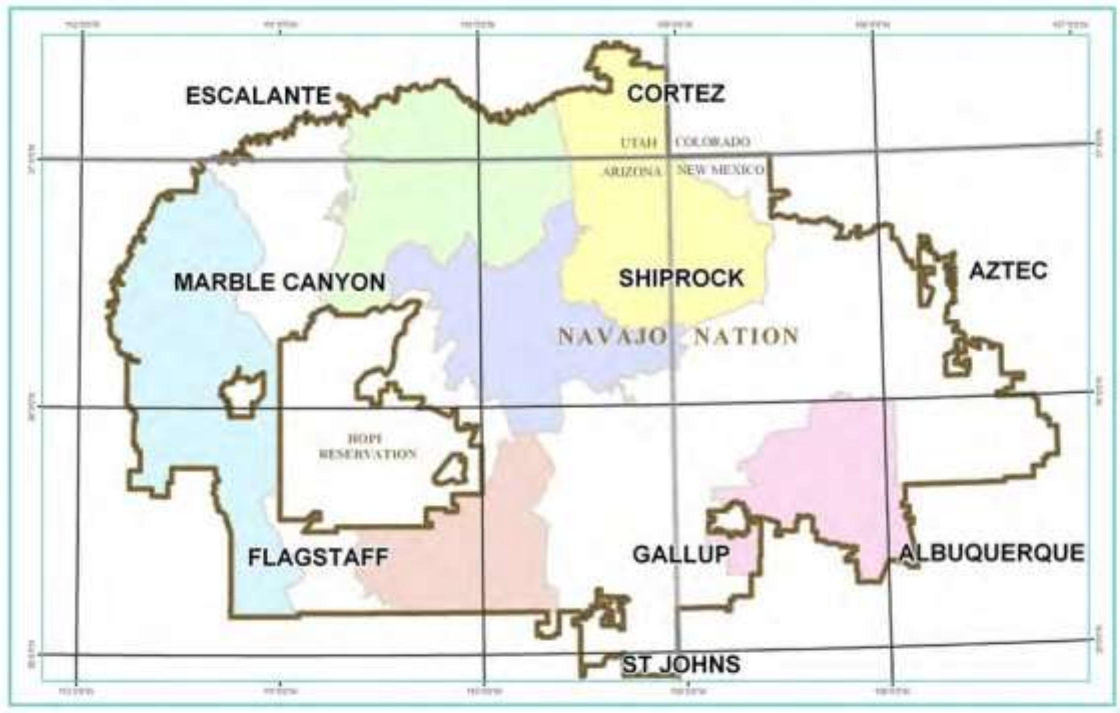


Figure 5. NURE Quadrangles Covering the Navajo Nation.

Sediment samples were collected between July 1975 and December 1979 from locations on the Navajo Nation. These data are provided as a GIS dataset on the GIS Data DVD (DB/Sampling/NN_NURE_Sediments.shp). Figure 6 below shows the distribution of the NURE sediment samples collected on the Navajo Nation. Sediment sample locations are symbolized by the source from which the sample was taken (e.g., pond, soil, spring, or stream).

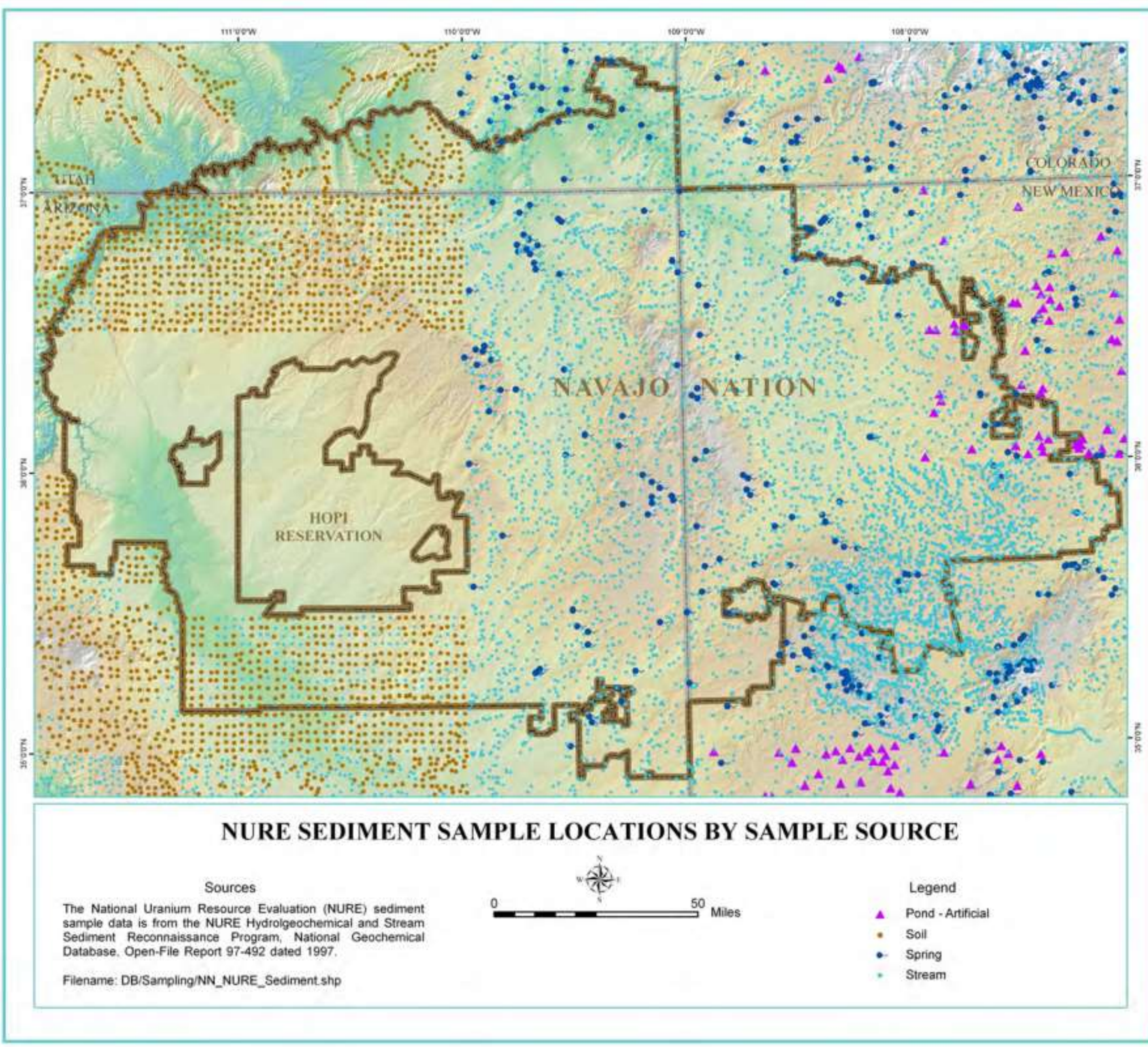


Figure 6. NURE Sediment Sample Locations by Sample Source.

WATER AND SEDIMENT SAMPLES (continued)

Water samples have been collected on the Navajo Nation for various programs and studies, and have in some cases included samples for radionuclides, including uranium. Many of these water samples were not collected from public drinking water systems and are one-time sampling events; therefore they are not definitive with respect to attribution from anthropogenic versus naturally occurring sources. Most of the samples were taken prior to NAMLRP reclamation activities and current conditions may differ. However, these radionuclide data have been included in this Atlas as data sources that may provide some useful information about where elevated levels of uranium have been found in non-public drinking water sources on the Navajo Nation. Figure 7 shows the locations of these water samples on the Navajo Nation.

NATIONAL URANIUM RESOURCE EVALUATION (NURE) WATER SAMPLES

Water samples were collected on the Navajo Nation from May 1976 through November 1979 as part of the NURE Hydrogeochemical and Stream Sediment Reconnaissance Program. Sampling was conducted in the Central and Eastern portion of the Navajo Nation, but no water samples were collected in the western 1/3 of the Navajo Nation, nor on any of the Hopi Tribal lands. 1,014 water samples were collected, with 4 from artificial ponds, 113 from springs, 33 from streams, and 864 from wells. Water samples were analyzed for uranium concentration using two methodologies: delayed neutron counting (results ranged from 0.15 ppb to 1,007.4 ppb) and fluorescence spectroscopy (results ranged from 0.01 ppb to 35.78 ppb). These data have been provided on the GIS Data DVD (DB/Sampling/NN_NURE_Water.shp).

NAVAJO ABANDONED URANIUM MINES STUDY WATER SAMPLES

In March 1998, EPA Region 9 signed an inter-agency agreement with the USACE for technical assistance on the NAUM. The USACE formed a team to investigate the effects of AUMs on the ground water. As part of the effort to assess whether uranium mining on the Navajo Nation had affected water quality, 226 locations were sampled for 23 metals and 11 radionuclides. Chapter officials selected the water sources to be sampled. Samples were taken from point of service, meaning no purging was conducted, to address the most likely exposure scenarios. Results are summarized in the NAUM Phase I Project Atlas (USEPA, 2000 - S02260102). Water sample analyses results for stable metals and radionuclide activity are provided on the GIS Data DVD (DB/Sampling/NN_USACE_Samples.shp). The water sampling performed to date is considered preliminary because it was a one-time sampling event. As a one-time sampling event, it does not take into account fluctuation in concentrations resulting from seasonal and hydrological variability. As a preliminary characterization, the primary goal was to identify areas of potential concern based on the levels of metals and radionuclides measured in the water source.

U.S. GEOLOGICAL SURVEY WATER SAMPLES

In 1991 the USGS, in cooperation with the NAMLRP, began a study to assess the chemical characteristics and hydraulic interaction of shallow ground water and mine water in AUMs in the Monument Valley and Cameron mining districts that had partially filled with water (Longsworth, 1994 - S02250302). Two (2) AUMs in the Monument Valley mining district and six (6) AUMs in the Cameron mining district were studied. Results showed that uranium-238 activities in shallow ground water from AUMs ranged from 150 to 14,000 picocuries per liter (pCi/L). Uranium-238 activities in pit water from AUMs ranged from 11 to 22 pCi/L. Radionuclide activities in well and spring water generally were less than in shallow ground water and pit water. Water from Clay Well spring, which is about 1.9 miles from the nearest AUM, had a uranium-238 activity of 27 pCi/L. Radionuclide activities in well and spring water may result from naturally occurring mineralization in water-bearing rock units. The effects of mining could not be determined from chemical analyses of well and spring water. Results from the water sampling for radionuclide activity are presented on the GIS Data DVD (DB/Sampling/USGS_Longsworth_Samples.shp)

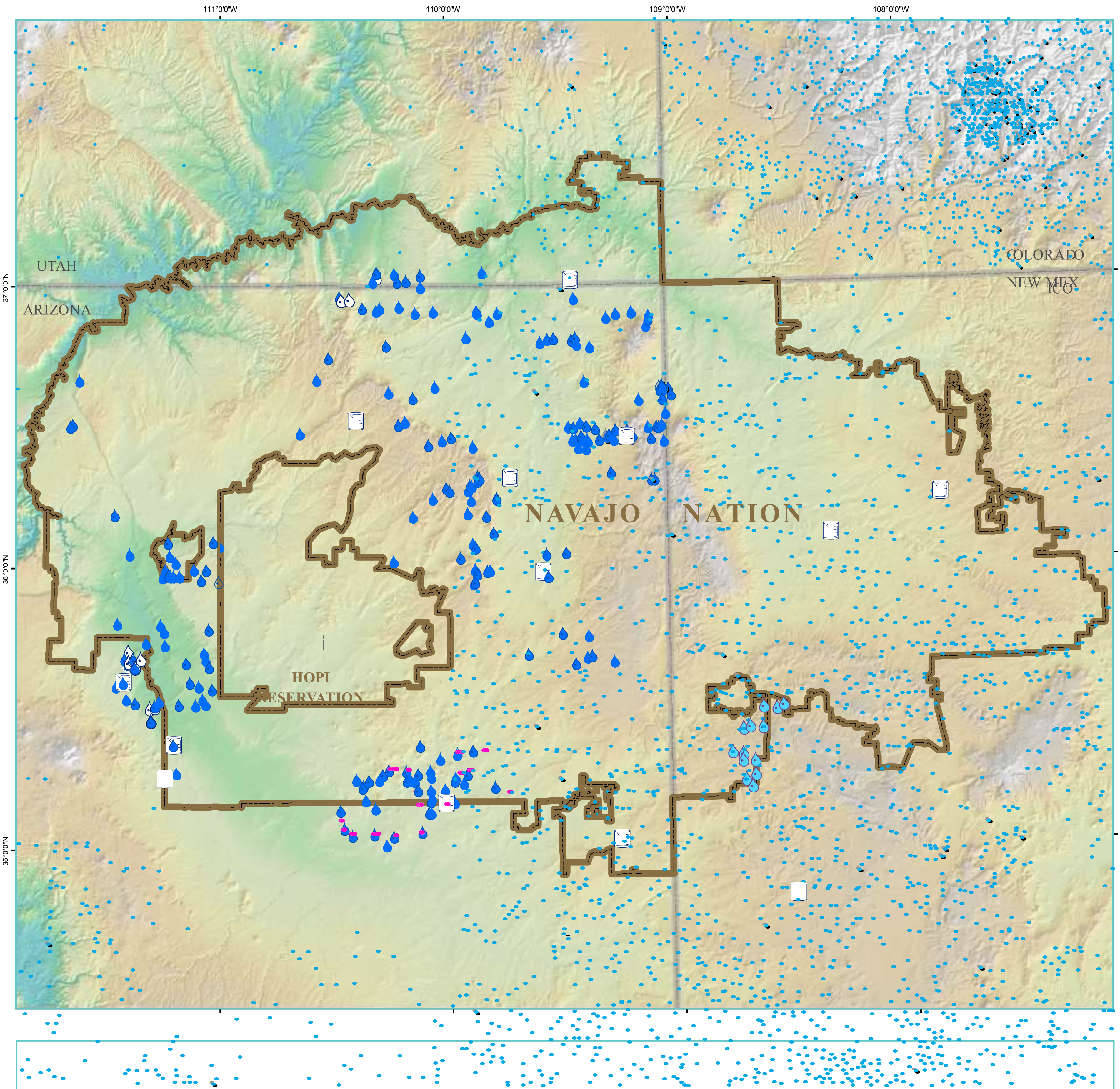
Eighteen (18) water sample locations in the Hopi Buttes area, that were previously sampled by the USACE, were resampled by George Breit and Margaret Hiza, USGS. Water samples were collected during six sampling periods (6/2001, 9/2001, 10/2001, 7/2002, 5/2003, and 6/2004). Results for 35 samples (several locations were sampled up to three times) were provided for: temperature, specific conductance, pH, aluminum; antimony, arsenic, barium, beryllium, cadmium, calcium, cobalt, chromium, copper, iron, lead, potassium, magnesium, manganese, mercury, nickel, selenium, silver, sodium, thallium, thorium, uranium, vanadium, and zinc. Uranium concentrations are reported in units of µg/L, and range from 0.02 - 17.0 µg/L. The original spreadsheet provided by George Breit is on the GIS Data DVD (DB/Sampling/USGS_Breit_Sampling_COE_5-28-07.xls), which contains notes on the methods used for the analyses. A GIS dataset was developed for the data and is provided on the GIS Data DVD (DB/Sampling/USGS_Breit_Samples.shp). No unit conversions were made to these data.

NAVAJO NATION ENVIRONMENTAL PROTECTION AGENCY WATER SAMPLES

In 2004 the Navajo Nation Surface and Ground Water Protection Department of the NNEPA conducted a study "Sanitary Assessment of Drinking Water used by Navajo Residents not Connected to Public Water Systems (Ecosystem Management, Inc., 2004 - S05150701)." Thirteen (13) unregulated water sources were sampled for radionuclides, arsenic, pesticides, and coliform after being identified as potential sources of drinking water in the selected Chapters. Three of the samples had gross alpha results that were larger than the MCL of 15 pCi/L. Results of the water sample analysis are provided on the GIS Database DVD (DB/Sampling/NNEPA_Samples.shp). A GIS dataset was developed for the data and is provided on the GIS Data DVD (DB/Sampling/NNEPA_Samples.shp).

CHURCH ROCK URANIUM MONITORING PROGRAM WATER SAMPLES

Water samples were collected in August and October 2003 by the Church Rock Uranium Monitoring Program (CRUMP) Water Assessment Team for thirteen (13) wells in the Church Rock area (CRUMP, 2003 - S01140501). Twelve (12) of the thirteen (13) wells were sampled for total uranium. Total uranium results for eleven (11) of the samples ranged from 0.04 to 9.94 pCi/L. One sample (16-4-10) had a total uranium result of 46.48 pCi/L. A GIS dataset was developed for the summary of selected radionuclides and is pro- vided on the GIS Data DVD (DB/Sampling/CRUMP_Samples.shp).



ABANDONED URANIUM MINES AND THE NAVAJO NATION

WATER SAMPLES WITH ANALYSES FOR RADIONUCLIDES

0 50 Miles

Map Scale 1:1,750,000

Sources

The National Uranium Resource Evaluation (NURE) water sample data is from the NURE Hydrogeochemical and Stream Sediment Reconnaissance Program, National Geochemical Database, Open-File Report 97-492 dated 1997.
Filename: DB/Sampling/NN_NURE_Water.shp

U.S. Geological Survey (USGS) water sample data is from the report titled "Geohydrology and Water Chemistry of Abandoned Uranium Mines and Radiochemistry of Spoil-Material Leachate, Monument Valley and Cameron Areas, Arizona and Utah," Water Resources Investigations Report 93-4226 by S.A. Longsworth dated 1994.

Filename: DB/Sampling/USGS_Longsworth_Samples.shp

U.S. Environmental Projection Agency (EPA) water sample data was collected by the U.S. Army Corps of Engineers (USACE) and is from the report titled "Abandoned Uranium Mines Project, Arizona, New Mexico, Utah - Navajo Lands 1994 - 2000, Project Atlas" dated 2000.
Filename: DB/Sampling/NN_USACE_Samples.shp

USGS water sample data was collected at 18 locations in the Hopi Buttes area that were previously sampled by the USACE. USGS collected samples during the period from June 2001 through June 2004. Data were provided by George Breit, USGS, Denver.
Filename: DB/Sampling/USGS_Breit_Samples.shp

Navajo Nation Environmental Protection Agency water sample data is from the report titled "Sanitary Assessment of Drinking Water Used by Navajo Residents Not Connected to Public Water Systems" by Ecosystem Management, Inc. dated December, 2004.
Filename: DB/Sampling/NNEPA_Samples.shp

Church Rock Uranium Monitoring Project (CRUMP) water sample data is from a spreadsheet "CRCWellsWaterQuality2003" provided by Andrew Bain, EPA Region 9 in January, 2005.

Legend

- National Uranium Resource Evaluation (NURE)
- U.S. Geological Survey - Longsworth
- U.S. Geological Survey - Breit
- U.S. Environmental Protection Agency
- Navajo Nation Environmental Protection Agency
- Church Rock Uranium Monitoring Project

Cameron Open Pit Mine (Field Filtering Sample)

AUM RECLAMATION

The NAMLRP has the authority and responsibility to reclaim uranium mines within the jurisdiction of the Navajo Nation that were left abandoned or inadequately reclaimed prior to August 3, 1977. This authority is granted under the Surface Mining Control and Reclamation Act (SMCRA) of 1977, Public Law 95-87 and the approved Navajo Reclamation Plan and Reclamation Code. The reclamation projects were designed to minimize the need for maintenance, promote landscape stability, enhance re-establishment of natural vegetation, enhance wildlife (where it is consistent with adjacent land uses), and most importantly, adequately safeguard the physical and radioactive hazards. NAMLRP is only authorized to perform reclamation activities on “tribal trust lands.” A prioritization scheme for non-coal mine sites was established by the NAMLRP. Priority 1 sites exhibit extreme physical hazards, easy access, and danger to life and property. Priority 2 and 3 sites have less physical dangers, more difficult access, and lower visitation (NAMLRP, 2000 - S07220301). AUM “Problem Areas” were identified by NAMLRP, which were used for mine feature and reclamation project identifiers (Table 1). For example, “COV127” designates the 127th inventoried mine feature in the Cove Problem Area. “NA-0307” is a reclamation project in the Cove Problem Area.

Table 1. NAMLRP Problem Areas and Associated Naming Convention Designations.

PROBLEM AREA	PROJECT RANGE	MINE FEATURE		PROBLEM AREA	PROJECT RANGE	MINE FEATURE
Cameron	NA-0100	CAM		Sanostee	NA-0600	SAN
Monument Valley	NA-0200	MON		Black Mesa	NA-0700	BLK
Cove	NA-0300	COV		Bidahochi	NA-0750	BID
Beclabito	NA-0400	BEC		Oak Springs	NA-0800	OAK
Sweetwater	NA-0500	SWT		Tse Tah	NA-0900	TSE

NAMLRP conducted inventories of non-coal mine features and established priorities during the period August 1988 through October 1990 (NAMLRP, S02230324). Problem Area inventory field logs were maintained for each mine feature included in the inventory. Field observations were recorded that included parameters such as: the date of the field visit, mine feature type, description of mine feature, dimensions, drainages, evidence of visitation, impacted area estimate, spoil volume, and accessibility. Field logs are available from NAMLRP. Mine features include uranium mine portals, rimstrips, open pits, highwalls, and radioactive waste piles with low-level radioactivity. The portals and shafts are open or partially open and located on the mesa ridges/edges and flat areas. The highwalls, or mine related cliffs, are associated with portals and rimstrips. The waste piles are usually located on the flats and on steep slopes. NAMLRP inventoried over 1,000 AUM features on the Navajo Nation.

After the prioritization process, NAMLRP initiated reclamation projects. Each reclamation project started with a description of the technical specifications, including general information about the required reclamation work, mine closure methods, earthwork requirements, incidental work (e.g., mobilization, site grading to re-establish drainage patterns, access road improvement, demobilization), site specific work scope details with maps and drawings, radiological clean-up guidelines and worker safety, and cultural and fish and wildlife resources protection.

Figure 8 is an example of one of the technical specification drawings that was developed for a planned reclamation site. These drawings are available from the NAMLRP and provide valuable information about the number and type of AUM features, acreages, and estimated waste volumes. Figure 9 shows the NAMLRP Problem Areas and Priority 1, 2, or 3 AUM features. There are four (4) reclaimed AUM features in the Eastern Agency that do not have assigned priorities.

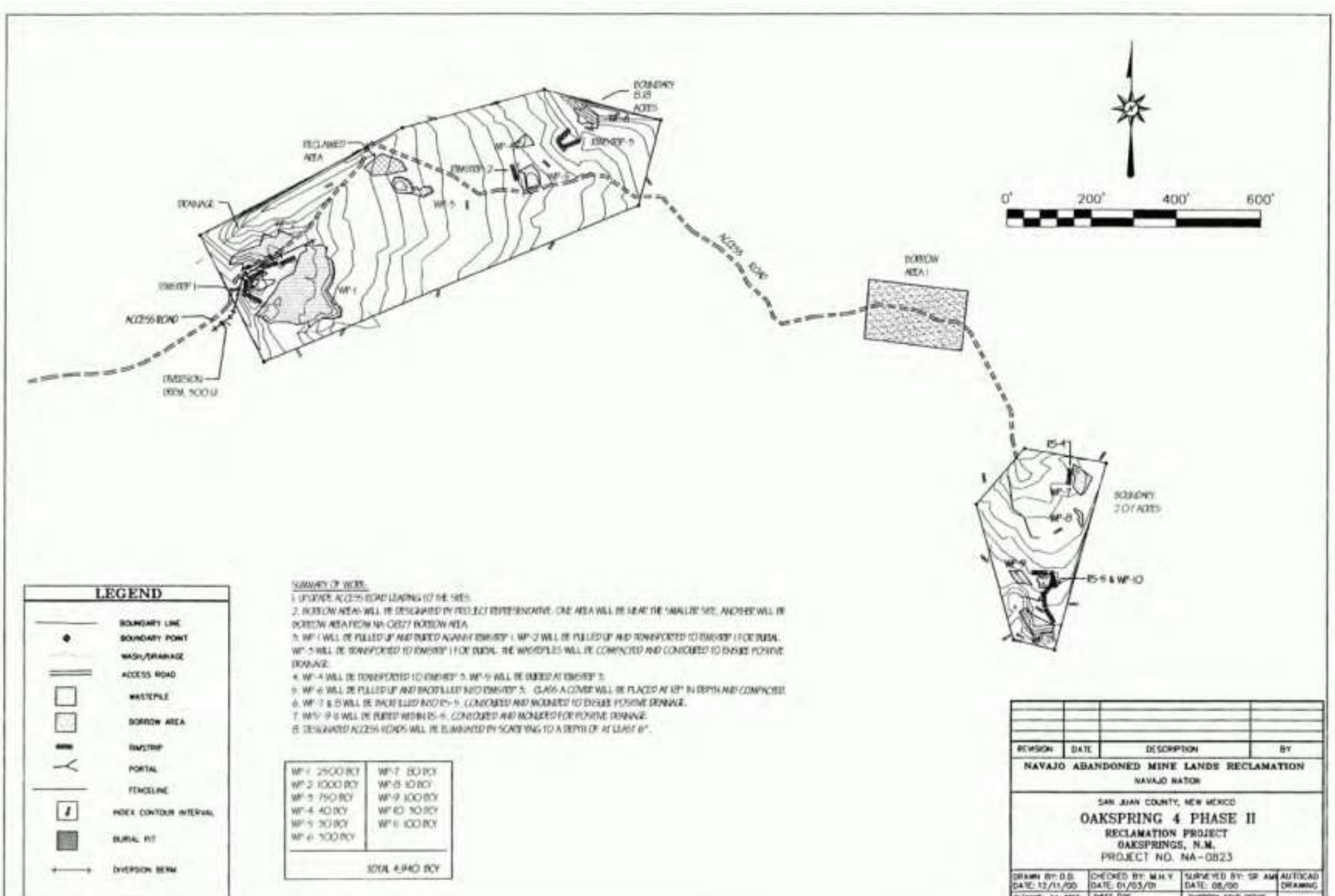
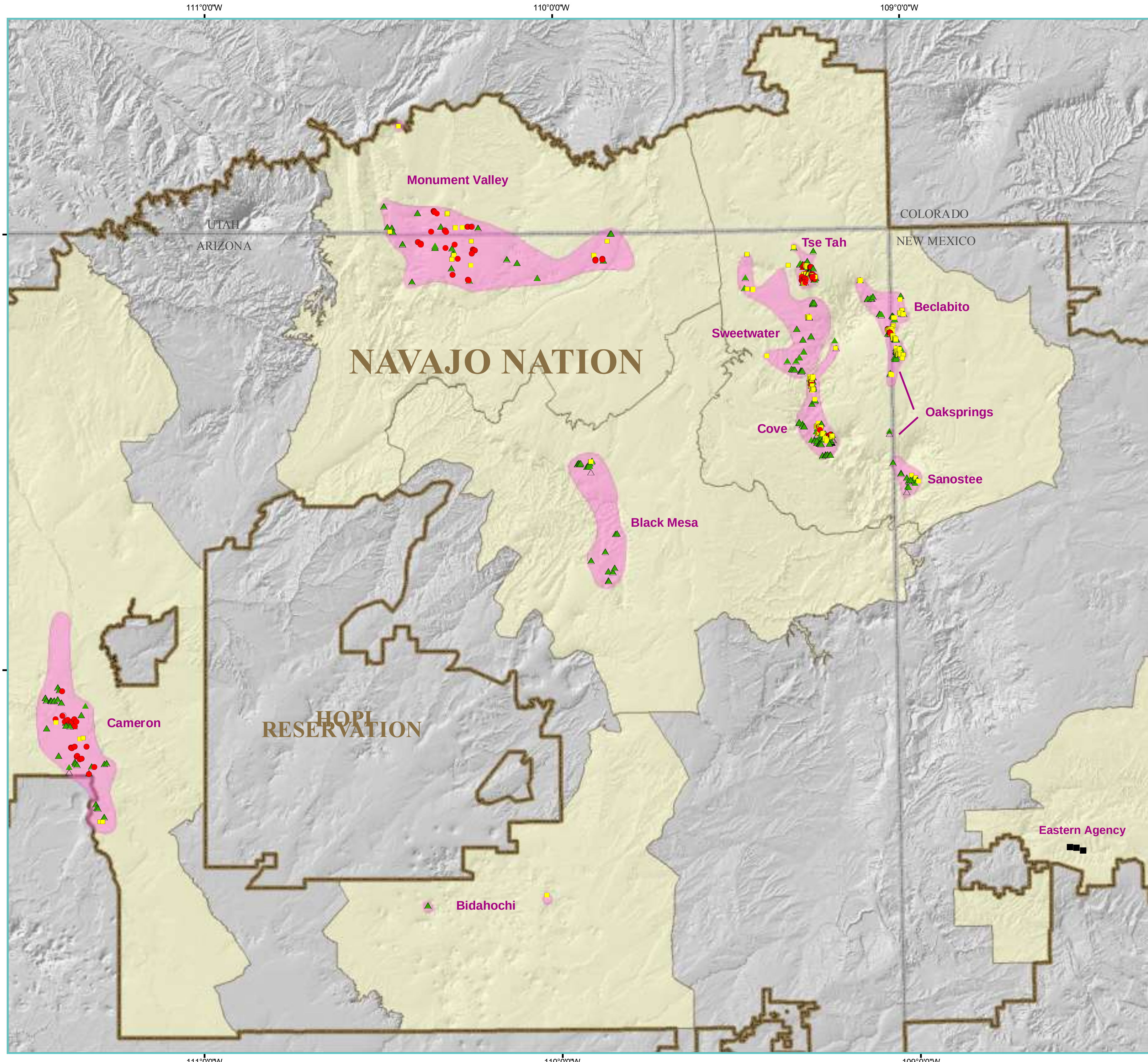


Figure 8. Example of an NAMLRP AUM Reclamation Project Site Technical Specification Drawing.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

NAMLRP RECLAMATION PROBLEM AREAS WITH AUM FEATURES BY PRIORITY

0 50 Miles

Map Scale 1:1,185,000

Legend

PRIORITY
- 1 = Highest Priority
- 2 = Medium Priority
- 3 = Lowest Priority
- Unknown Priority
- NAMLRP Problem Areas
- AUM Regions

NAMLRP reclamation site NA-0804 at Lookout Point Incline Mine. This photo shows a loader hauling Class A cover and a bulldozer placing it on a reclaimed waste pile. Photo courtesy NAMLRP.

Sources

Problem area boundaries and Priority 1, 2, and 3 sites for the Navajo Nation were developed by the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP). Priority 1 and 2 category sites meet criteria that concern the protection of public health and safety. Priority 3 sites meet conditions that concern environmental degradation.

Filenames:
DB/AUM/NN_AUM_Problem_Areas.shp
DB/AUM/NN_AUM_Pt_Features.shp.

Figure 9. NAMLRP Reclamation Problem Areas with Prioritized AUM Features.

AUM RECLAMATION (continued)

Site evaluation and design of reclamation projects typically involved characterization of the mine feature(s) and associated waste piles at the site. Preliminary radiometric readings were taken at mine feature locations (e.g., rimstrips, adits, pits, etc.) during the site inventories and were recorded in field logs. Prior to beginning significant reclamation activities, gamma radiation surveys were conducted. General maps were prepared for the mine site vicinity including: the mine, waste piles, protore piles, structures, and surface water drainage (NAMLRP, S05110504). Field logs and ground gamma radiation surveys are available from the NAMLRP.

During reclamation, portals and shafts were generally closed by either backfilling, by polyurethane foam (PUF) plugs, or cinderblock bulk heads (Figure 10). The rimstrips and open pits were backfilled with a combination of mine waste piles (Class B and C) and Class A cover. The waste piles were used to backfill the portals and rimstrips to a certain point, then any excess was excavated out, hauled to designated areas, placed in burial pits, and then covered with a minimum 18 inches thick compacted Class A cover (NAMLRP, 2000 - S02230328). Generally a buffer zone of clean material is placed at the bottom of the waste disposal area, then the highest levels of radioactive materials are placed on top of the buffer zone material, and the less radioactive materials are subsequently placed over them. Topsoil or non-radioactive materials (Class A) from the surrounding area are used as cover material. All radioactive waste disposal areas are located away from surface and ground water in order to prevent contamination to the local hydrology. Generally the reclaimed sites are revegetated using a suitable native seed mix (OSM, 1998 - S07220302). Work that was performed at each reclamation site included:

- Improve access roads for reclamation work
- Stabilize mine openings before closure
- Backfill or excavate any radiological "hot spots"
- Eliminate the mine feature and any related physical hazards
- Regrade all disturbed areas to ensure positive drainage around and off the reclaimed areas
- Roughen reclaimed surfaces
- Eliminate access roads at completion of reclamation.

Figure 10. Polyurethane Foam (PUF) Closure on an Open Portal. Photo courtesy NAMLRP**.**

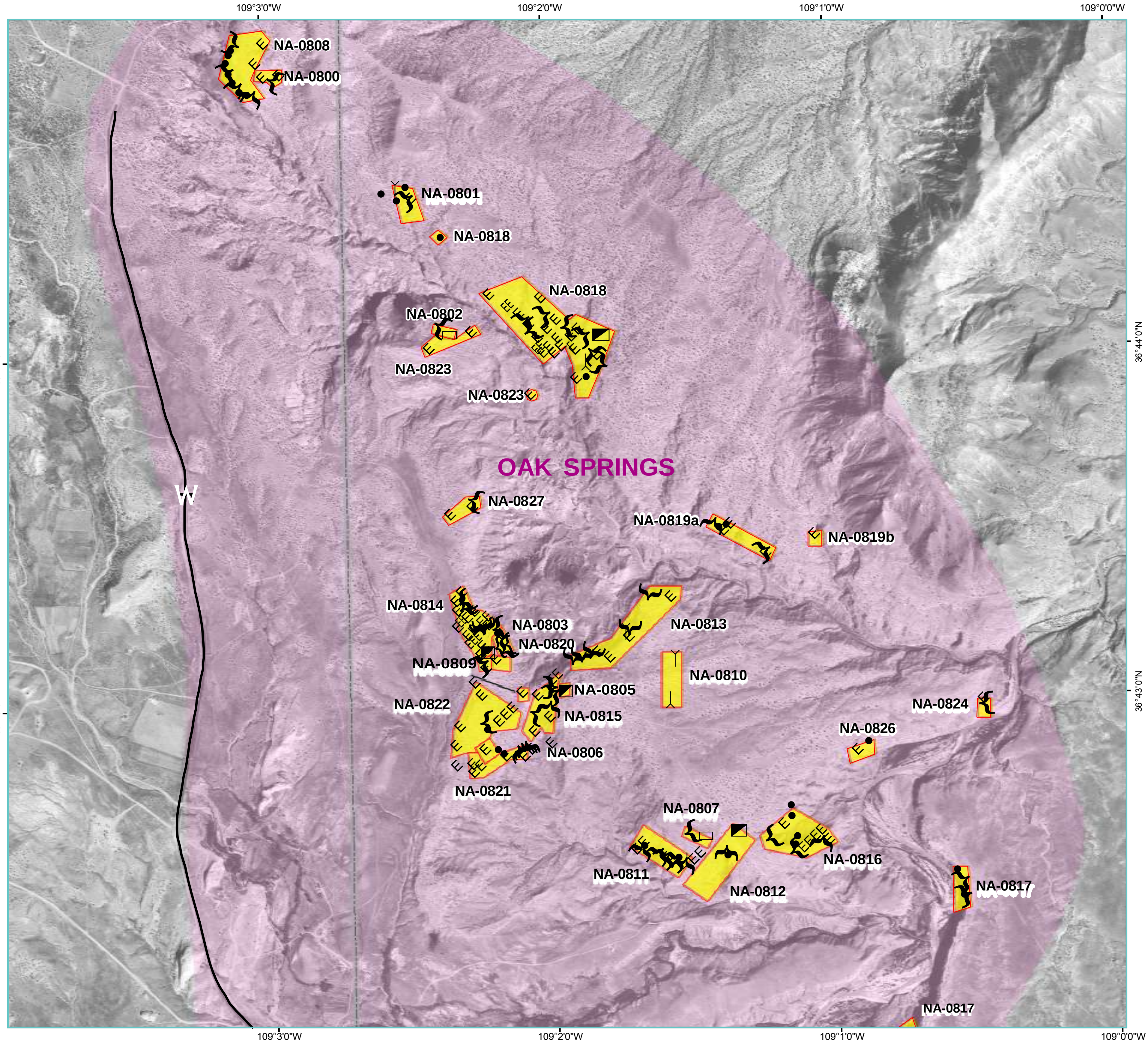
Reclamation projects for all high Priority-1 and Priority-2 AUM projects have been completed. There are 166 identified unreclaimed AUM mine features with environmental problems remaining, as shown in Table 2. The environmental problems are related to uranium mine waste that remains within the AML sites. These sites are located in the high mesas and/or mountainous regions making access to these sites difficult. The NAMLRP has been recognized through OSM's award programs for excellence in reclamation by receiving both National and regional awards (NAMLRP, 2007- S05190702).

Table 2. NAMLRP Reclamation Accomplishments by Problem Area (after NAMLRP, 2007 - S05190702)

AML PROBLEM AREAS	TOTAL # PROJECT SITES (NA-0XXX)	TOTAL # MINE FEATURES	TOTAL # RECLAIMED MINE FEATURES	# PHASES	# UNRECLAIMED MINE FEATURES	COMMENTS
Beclabito	29	90	81	4	18	OSM Award
Bidahochi	2	2	2	1	0	
Black Mesa	17	29	22	3	5	
Cameron	75	103	68	6		
Cove	58	231	202	4	84	OSM Award
Eastern Agency	3	15	14	1	4	
Monument Valley	53	82	67	4	14	OSM Award
Oak Springs	36	238	233	4	9	
Sanostee	8	19	8	1	2	
Sweetwater	27	48	42	2	13	
TseTah	37	179	178	3	17	
TOTALS	344	1036	917		166	

Figure 11 shows an enlarged portion of the Oak Springs Problem Area. The inset map shows locations of the NAMLRP Problem Areas and AUM features across the Navajo Nation. NAMLRP GIS datasets are provided on the GIS Data DVD (DB/AUM) as follows: (NN_AUM_Problem_Areas.shp); (NN_AUM_Project_Sites.shp); and (NN_AUM_Pt_Features.shp).

Figure 12 shows mine features according to reclamation status. Circles represent reclaimed mine features, squares depict unreclaimed mine features, and triangles represent locations of mine features where the reclamation status is not known. Most of these unknown features occur in the Eastern AUM Region. Red symbols indicate that there are unreclaimed waste piles nearby. Green symbols indicate AUMs that were not inventoried for the presence of unreclaimed waste piles. Blue symbols have no unreclaimed waste piles associated with the AUM.



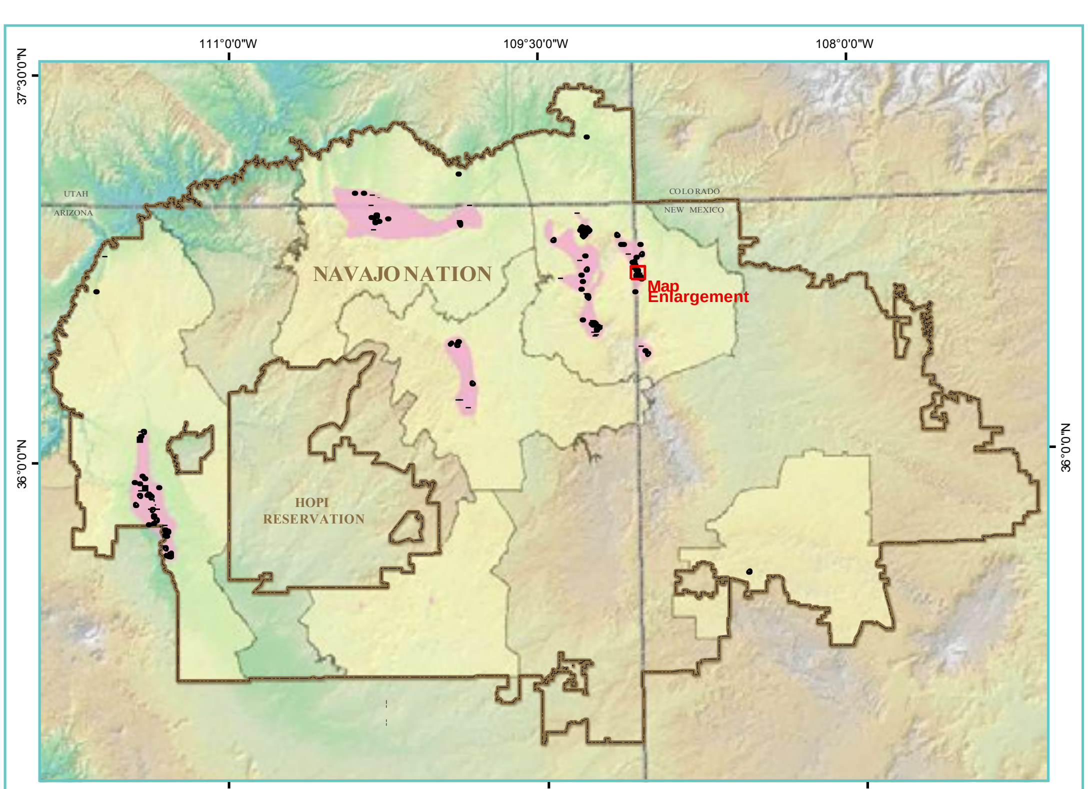
ABANDONED URANIUM MINES AND THE NAVAJO NATION

NAMLRP RECLAMATION PROJECT SITES AND AUM FEATURES IN THE OAK SPRINGS PROBLEM AREA

N W E S

0 1 Miles

Map Scale 1:24,000



Legend

AUM FEATURE

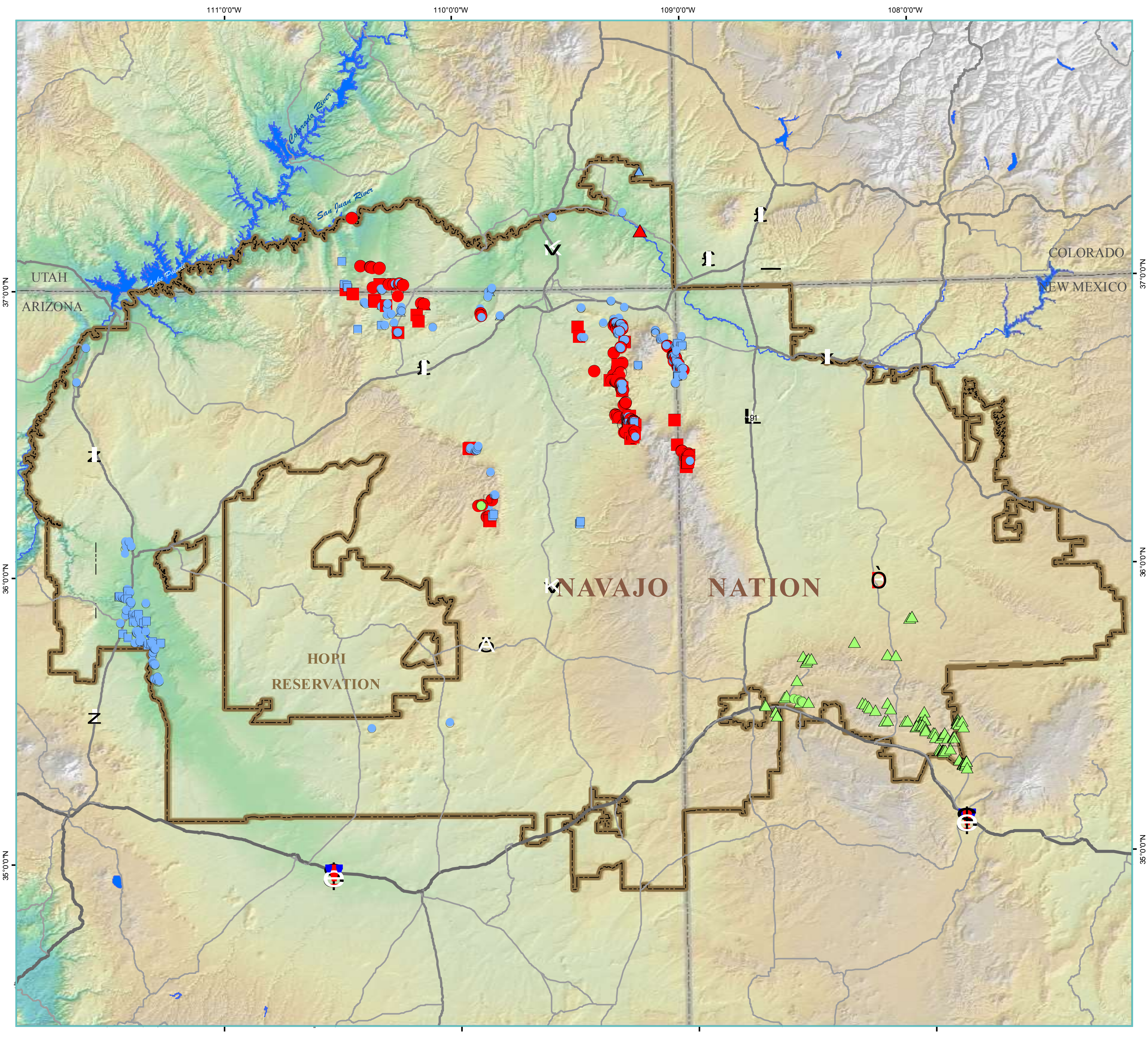
- Portal
- Prospect
- Rimstrip / Pit
- Vertical
- NAMLRP Project Site
- NAMLRP Problem Area

Sources

Reclamation project site boundaries and AUM feature locations are from the Navajo Abandoned Mine Lands Reclamation Program.

Filenames:
DB/AUM/NN_AUM_Problem_Areas.shp
DB/AUM/NN_AUM_Project_Sites.shp and
DB/AUM/NN_AUM_Pt_Features.shp.

Figure 11. NAMLRP Reclamation Project Sites and AUM Features in the Oak Springs Problem Area.



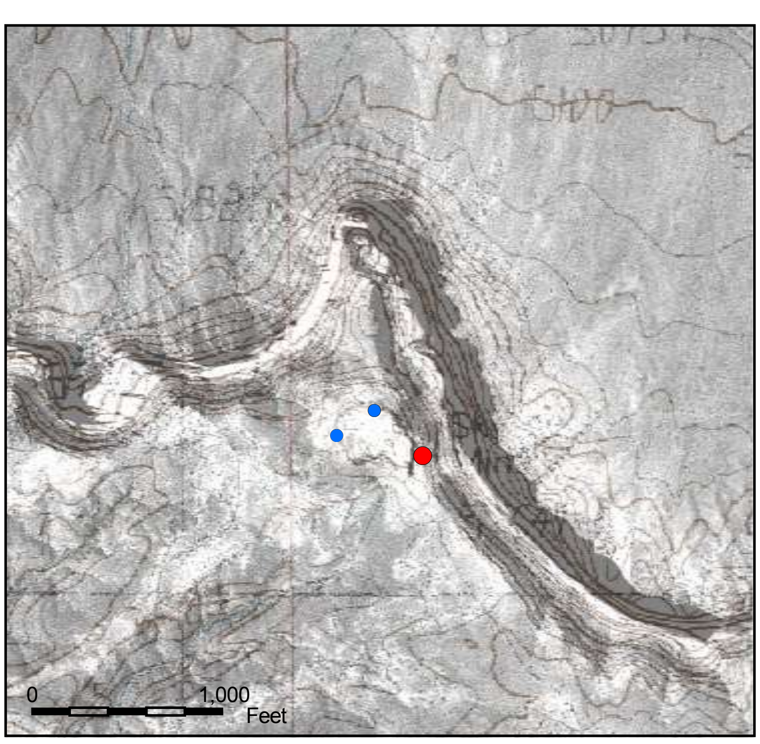
ABANDONED URANIUM MINES AND THE NAVAJO NATION

NAMLRP MINE FEATURE RECLAMATION STATUS AND UNMAPPED ASSOCIATED WASTE PILES

N W E S

0 50 Miles

Map Scale 1:1,750,000



The above inset shows three mine features mapped at the Skyline mine. The reclaimed mine feature (in red) is on the margin of a cliff and has an unmapped associated waste pile. The reclaimed mine features (in blue) on top of the flat mesa do not have unmapped associated waste piles.

Legend

NAMLRP MINE FEATURES

RECLAIMED FEATURE
- Unreclaimed Waste Piles Present
- Presence of Unreclaimed Waste Piles Unknown
- No Unreclaimed Waste Piles

FEATURE RECLAMATION STATUS UNKNOWN
- Unreclaimed Waste Piles Present
- Presence of Unreclaimed Waste Piles Unknown
- No Unreclaimed Waste Piles

UNRECLAIMED FEATURE
- Unreclaimed Waste Piles Present
- Presence of Unreclaimed Waste Piles Unknown
- No Unreclaimed Waste Piles

Sources

Reclaimed mine feature locations and status are from the Navajo Abandoned Mine Lands Reclamation Program. The presence of waste piles was determined by NAMLRP and TerraSpectra Geomatics.

Filenames: DB/AUM/NN_AUM_Pt_Features.shp

Figure 12. NAMLRP AUM Feature Reclamation Status and Presence of Unreclaimed Waste Piles.

Section 3

ENVIRONMENTAL SETTING

ENVIRONMENTAL SETTING

Section 3 contains information about the environmental setting of the Navajo Nation. Maps and associated text and tables are presented that describe administrative boundaries and infrastructure features, climate, topography, physiography and geology, hydrology, soils, and land cover. All of the datasets were prepared using existing data sources, and no field verifications were conducted as part of this project.

The Navajo Nation (Dine'é) is the largest Indian reservation in the United States, covering an area of about 27,000 square miles. The Navajo Nation is comprised of 110 Chapters, including three (3) Navajo satellite reservations: Alamo, Ramah, and Tohajiilee. This area includes a large part of northeastern Arizona, northwestern New Mexico and a small part of southeastern Utah, and is contained within eleven (11) counties (Figure 1). Hopi Reservation tribal lands are located within the Navajo Nation boundaries. On November 4, 2006 the Navajo-Hopi Intergovernmental Compact was signed to lift the 40-year old Bennett Freeze restriction on development, making the area around Moenkopi part of the Hopi Reservation. The eastern portion of the Navajo reservation, located in New Mexico, is commonly referred to as the "Checkerboard" because tribal trust lands are mingled with fee lands (owned by both Navajo and non-Navajo) and federal and state lands under various jurisdictions. The Navajo Nation is generally sparsely populated. The 2000 Census reported a population of 180,462 on the Navajo Nation Reservation and off-reservation trust land.

The Navajo Nation is predominantly located in the Colorado Plateau physiographic province. There is significant topographic relief across the nation, including broad mesas, canyons, dry washes, and mountains. Elevations range from a low of 3,080 feet at the gauging station across from Lee’s Ferry in Marble Canyon to over 10,346 feet at Navajo Mountain. Generally elevations across the Navajo Nation range from about 5,000 feet in the broad valleys to over 8,500 feet in the mountains.

The Colorado Plateau covers 130,000 square miles across northern Arizona, southwestern Utah, western Colorado, and northwestern New Mexico. The Navajo Nation is in the southern half of the Plateau, known as the Navajo Section. The landforms in the region are characterized and affected by alternating resistant and weak rock strata. Flat lying sedimentary rocks occur in an alternating sequence of resistant sandstones and limestones and less resistant shales and siltstones. Resistant beds form ledges, cliffs, mesas, and rock benches that are separated by slopes and valleys carved in the weaker beds. The Plateau was broadly and gently uplifted 10 million years ago generally placing the Navajo Nation over a mile high.

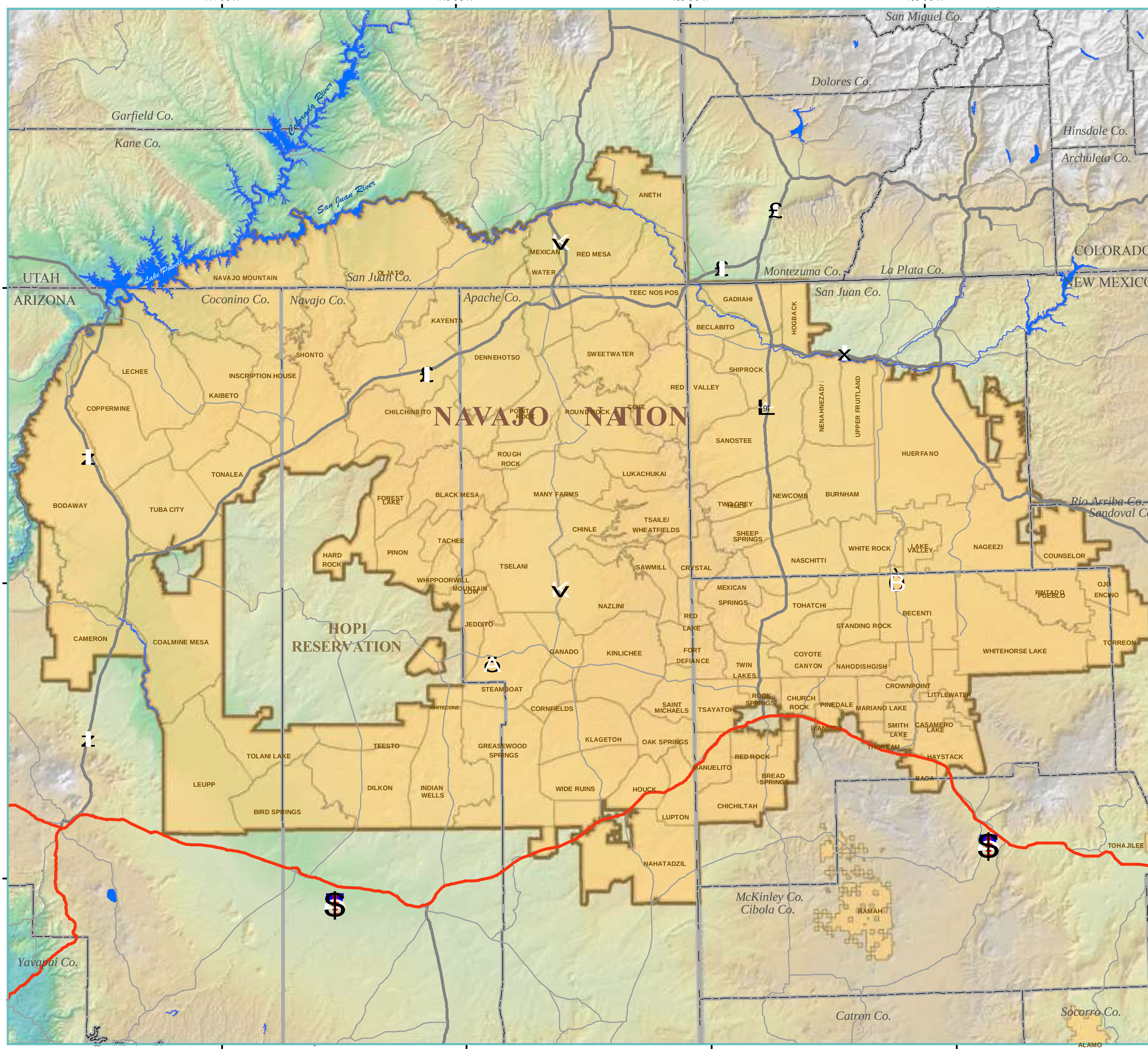
The perennial river valleys on the Navajo Nation include the Puerco, the Little Colorado, the Colorado, and the San Juan. All the other streams are intermittent or ephemeral, except for short reaches downstream from large springs and where the streambed intersects a water table. The underlying bedrock aquifers are composed of beds of sandstone between nearly impermeable layers of siltstone and mudstone. There are also near-surface alluvial aquifers.

The climate of the Navajo Nation varies widely, ranging from semiarid below 4,500 feet to relatively humid above 7,500 feet. Precipitation has a strong and fairly uniform relationship to altitude and the orographic effects of the physiography. The largely semiarid Navajo Nation is shown by the dominance of the 4-12 inch precipitation range. This low precipitation is due to the rain shadow effect of the Sierra Nevada Mountains of California in winter and quasi-permanent subtropical high pressure ridge over the region (Sheppard and others, 1999 - S0728303). Thunderstorms during the summer months account for most of the annual rainfall.

Minimum and maximum annual average temperatures are also directly related to the orographic effect. The higher elevations of the Chuska and Carrizo Mountains, the Defiance Plateau and Black Mesa have summer maximum high temperatures of 66º F or less. The remainder of the Navajo Nation averages more than 66º F. In the lower elevations within the Marble and Little Colorado Canyons, temperatures can average as high as 80º F in the summer. In the winter these same topographically higher areas average below freezing, whereas most of the remainder of the Navajo Nation is above freezing, but in the 30’s. The valleys of the Little Colorado, Colorado, Lake Powell, and the San Juan River up to about Comb Ridge in Utah average about 40º F in the winter (Sheppard and others, 1999 - S0728303).

Except for the months of August and September, strong south winds, with abundant dust and sand, blow almost constantly (Harshbarger, 1946 - S04170306). The prevailing wind direction is from the southwest throughout the region, which is widely displayed in dunes and eroded surfaces (Cooley et al, 1969 - S10290201).

Elevation largely determines what type of biotic communities will exist in a given location, as temperatures generally decrease and precipitation increases as one moves upward (Grahame, 2002 - S06020701). Vegetation in the area ranges from sparse desert scrub/ grassland in the valley to piñon-juniper woodlands at elevations from about 5,000 to 7,000 feet, with coniferous forests at elevations above 7,000 feet. Annual precipitation is typically from 10 to about 15 inches in piñon-juniper woodlands, and tree species in these communities have evolved both drought and cold resistance. Piñons dominate at higher elevations and juniper tends to grow at lower elevations and in more arid areas. Much of the Navajo Nation is sparsely vegetated with sagebrush, tamarisk, and other desert vegetation which is used by local residents for livestock grazing. Small-scale farming of row crops, such as corn and squash, is practiced. In open areas, residents are typically allotted one-acre home site leases. Grazing permits given to residents that own animals can range from 10 to 100 acres.



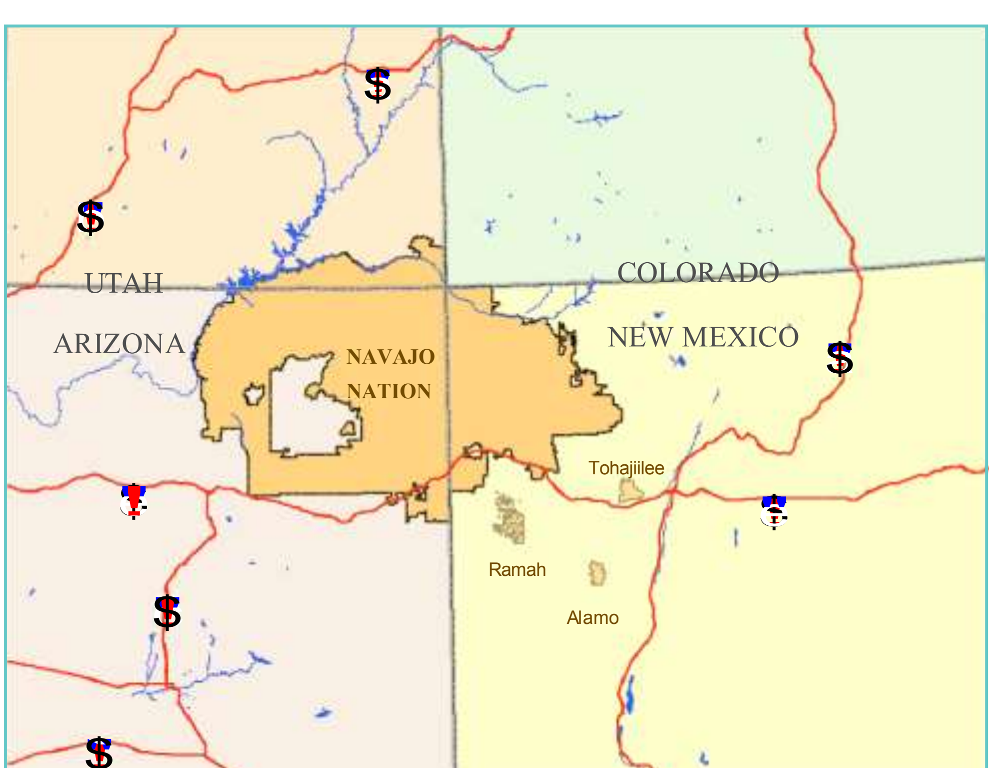
ABANDONED URANIUM MINES AND THE NAVAJO NATION

NAVAJO NATION

N
W E
S

0 50 Miles

Map Scale 1:1,750,000



Legend

Navajo Nation Chapter

State

County

Sources

The Navajo Nation Chapter boundaries are from the Navajo Land Department.
Filename: DB/Boundary/Navajo_Nation.shp

The state boundaries are from the National Transportation Atlas Databases (NTAD) 2002. The dataset has been clipped to the "four corner" states: Arizona, Colorado, New Mexico, and Utah.
Filename: DB/Boundary/NN_State.shp

The county boundaries are from the National Transportation Atlas Databases (NTAD) 2002. The dataset has been clipped to the "four corner" states: Arizona, Colorado, New Mexico, and Utah.
Filename: DB/Boundary/NN_County.shp

Figure 1. Location of the Navajo Nation.

LAND STATUS

The original Navajo Reservation was established by the Treaty of 1868 between the United States of America and the Navajo Tribe of Indians. A reservation of 3,539,500 acres, divided almost equally between Arizona and New Mexico, was defined by the treaty. The Checkerboard area was not part of this original treaty. Additions of lands to the reservation have been made by a series of Executive Orders and Acts of Congress (Cabeen, 1958 - S09210601). During the next 138 years, numerous Executive Orders and Public Land Orders exchanged, bought, assigned and reassigned the land base while additional areas were homesteaded. Figure 2 provides a map with the years of enactments between 1868 and 1934 that led to the creation of the Navajo Nation (Winson, 2002 - S11160601).

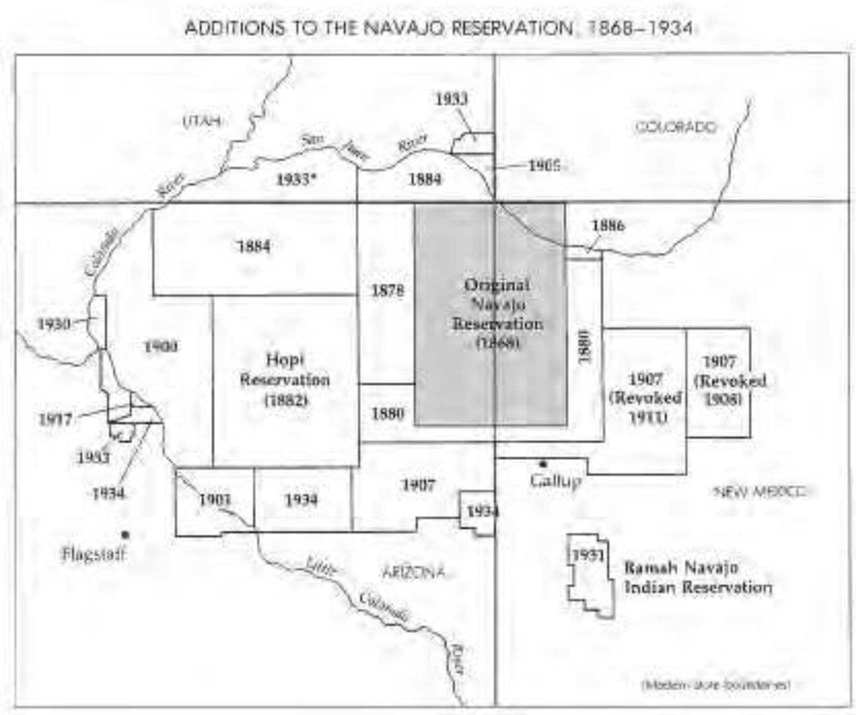


Figure 2. Additions to the Navajo Reservation, 1868 - 1934.

Most of the Navajo Nation consists of Tribal Trust Lands, or areas that are federally recognized and controlled by the tribe. However, as a result of the General Allotment Act of 1887 (commonly referred to as the Dawes Act) that allotted a specified amount of land to each Indian, lands within reservation boundaries may have a variety of types of ownership: tribal, individual Indian, non-Indian, as well as a mix of trust and fee lands (Figure 3). The eastern portion of the Navajo Nation, located in northwestern New Mexico, is such an area, and is referred to as the "Checkerboard area." Within the Checkerboard area there are several land ownership categories, including tribal trust lands, Indian allotments, Navajo tribal fee lands, federal and state lands:

> "Tribal Trust Lands" are land where the title is held in trust by the United States for an individual Indian or a tribe.
> "Indian Allotments" refer to land owned by individual Indians and is either held in trust by the United States or subject to statutory restriction on alienation. Most allotments were originally carved out of tribal lands held in common.
> "Navajo Tribal Fee Land" are alienable by the tribe and taxable by the county.

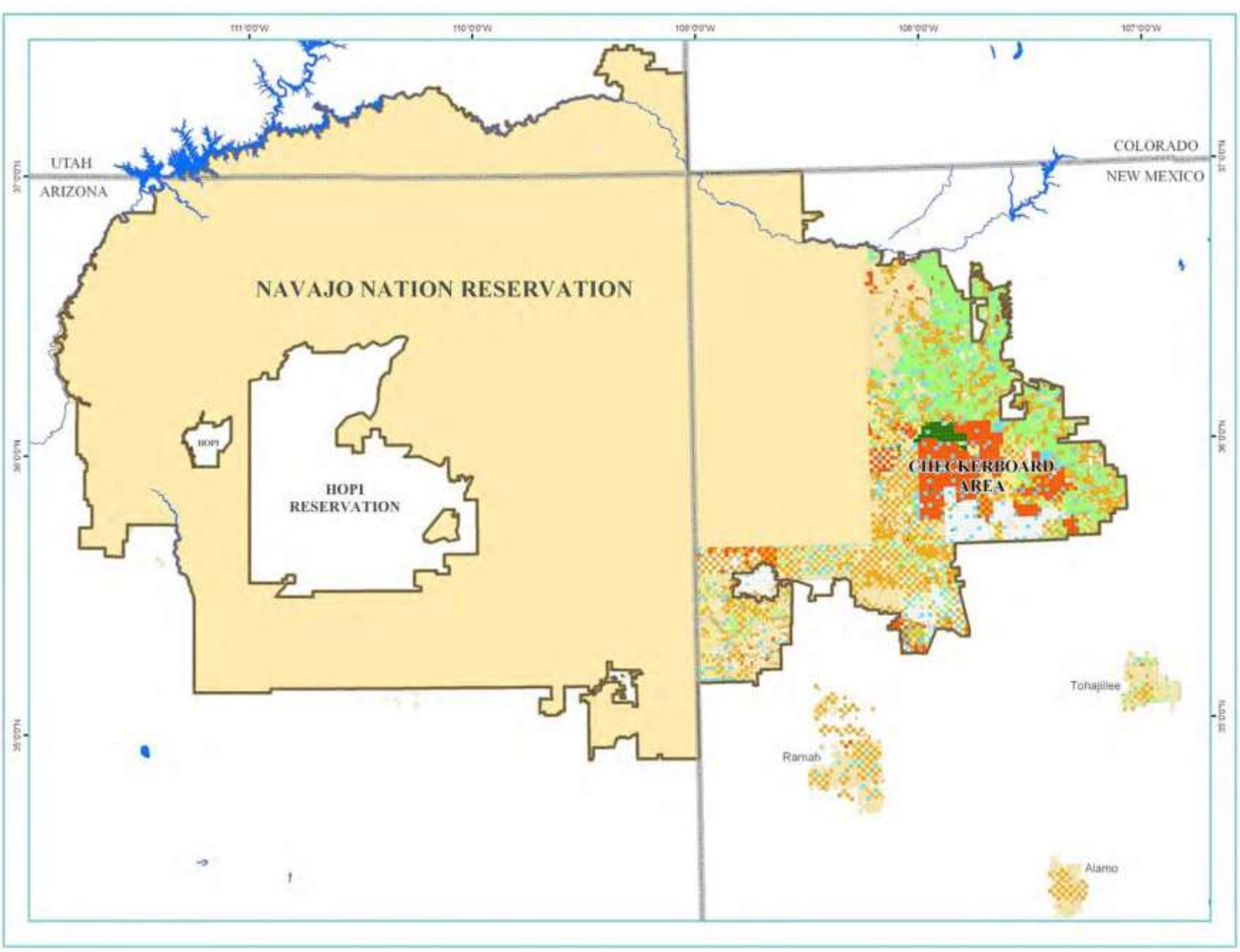
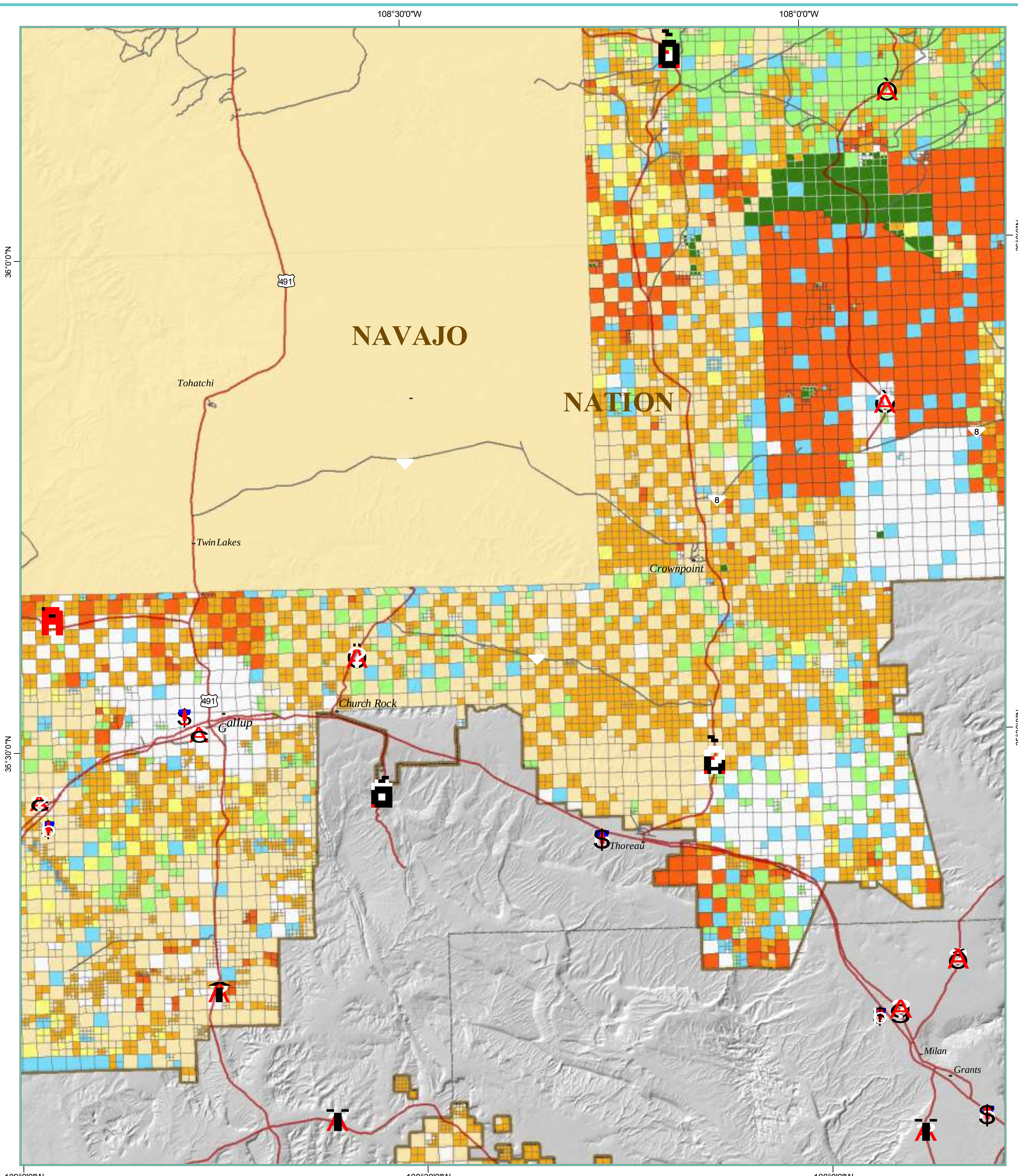


Figure 3. Navajo Nation Land Status.

Figure 4 shows land ownership for the Checkerboard area of the Navajo Nation. This dataset depicts the surface owner or manager of the land parcels. BLM's Master Title Plats are the official land records of the federal government and serve as the primary data source for all federal lands. Information from the State of New Mexico is the primary source for all state lands. The Navajo Land Department (NLD) GIS Section further processed the land ownership dataset and attributed the Indian Lands polygons into Navajo Tribal Trust, Indian Allotment, Navajo Tribal Fee, and Public Land Order numbers. The NLD oversees Navajo Nation land development projects and coordinates projects with the Navajo Nation, Bureau of Indian Affairs, Bureau of Land Management, State, County, private, and other entities involved. This dataset is provided on the GIS Data DVD (DB/Boundary/NN_Land_Status.shp).



ABANDONED URANIUM MINES AND THE NAVAJO NATION

LAND STATUS

0 5 10 Miles

Map Scale 1:450,000

Sources

These data were collected by the U.S. Bureau of Land Management (BLM) in New Mexico at both the New Mexico State Office and at the various field offices. The Navajo Land Department further processed and attributed the Indian Lands polygons into Navajo Tribal Trust, Indian Allotment, Navajo Tribal Fee, and Public Land Order (PLO) by PLO Number.

Filename: DB/Boundary/NN_Land_Status.shp

Legend

NAVAJO NATION SURFACE LAND STATUS

- Navajo Tribal Trust
- Navajo Tribal Fee
- Indian Allotment
- Public Land Order Land
- Bureau of Land Management
- National Park Service
- State
- Private

Figure 4. Land Status in the Eastern Navajo Nation.

NAVAJO NATION ADMINISTRATIVE BOUNDARIES

The Navajo Reservation was established with the Treaty of 1868. Congress ended treaty-making with Indian tribes in 1871 (Bureau of Indian Affairs, 2001 - S05050301). Since then, several Executive Orders and administrative acts have added lands to the original boundaries of the Treaty of 1868 (see Figure 2, page 3-4). The Navajo Reservation is the largest Indian reservation in the United States, and stretches across northwest New Mexico, northeast Arizona, and southeast Utah.

Three Navajo satellite communities are located in New Mexico. These are the Alamo Band of Navajo, located about 30 miles west of Magdalena, the Canoncito Band of Navajo, located in the Tohajiilee Chapter about 25 miles west of Albuquerque, and the Ramah Band of Navajo, which is located about 40 miles south of Gallup. The Navajo Nation also owns four (4) ranches that are outside the boundaries of the Navajo Nation: Big Boquillas Ranch, Crow Mesa Ranch, Espil Ranch, and the Largo Ranch. Neither these satellite communities nor the ranches have been included in the abandoned uranium mine screening assessments.

The sovereign relationship between the governments of the Navajo Nation and the United States was established in the Treaty of 1868. The Navajo Nation is recognized by the United States as a distinct, independent, political community able to exercise powers of self-government (Bayless, 2000 - S05050303). The capital of the Navajo Nation is located in Window Rock, Arizona. The Navajo Nation conducts a government-to-government relationship with the U.S. Government wherein no decisions about their lands and people are made without their consent (BIA, 2001 - S05050301). In 1921, oil was discovered in northwest New Mexico and the first form of the Navajo Tribal Council, a six-member business council, was created for the sole purpose of giving consent to mineral leases. The Navajo Nation did not adopt the Indian Reorganization Act of 1934 and does not operate under a constitution (SW Strategy, 2003 - S05050302). In 1936, the "Rules of the Navajo Tribal Council," were issued, which formed the basis for the Navajo Nation's government. The Navajo Nation Code sets forth the laws of the Navajo Nation.

The Navajo Nation government is a representative form of government with a President, Vice-President, and Council Delegates elected by the Navajo people. It acts by resolution and is separated into three branches: Executive, Legislative, and Judicial. The 88 members of the Council are elected, based on the population of the 110 chapters. The Council is the governing body of the Navajo Nation and its meetings are presided over by the Speaker who is elected by the membership of the Council. The Navajo Nation Council meets four times a year to enact legislation and discuss other issues of importance to the Navajo people. The Executive Branch is headed by a President and Vice-President, who are elected every four years by the Navajo people (SW Strategy, 2003 - S05050302).

NAVAJO CHAPTERS

The Tribal government structure consists of 110 chapters, representing all reservation areas and Navajo communities. The 110 chapters are the local form of government. “Although it would be misleading to consider a chapter as a county, they are more significant than a township or municipality, and are most comparable to counties within a state” (McKenzie, 1999 - S01280302). Each chapter elects a President, Vice-President, Secretary-Treasurer, and Grazing Committee, Farm Board, and/or Land Board member to run the affairs of the local chapter community. Community meetings are held in the chapter houses and the members vote on issues such as home site leases and land use plans. Chapters exercise authority which is delegated by the Navajo Nation government over tribal members, and land/assets within their boundaries (SW Strategy, 2003 - S05050302).

Each of the Navajo Nation Chapters has developed a website, with useful information in their Chapter Profiles and chapter demographics (NNDES, 2006 - S02060604). A Navajo Nation Chapters Directory website is under development at www.navajochapters.org with links to each Chapter’s website.

BUREAU OF INDIAN AFFAIRS (BIA) AGENCIES

There are five (5) BIA agencies within the Navajo Nation: Chinle, Eastern Navajo, Fort Defiance, Shiprock and Western Navajo. The top map in Figure 5 shows the boundaries of the BIA agencies. These agencies are administrative designations created by the BIA primarily for management of reservation land bases. The administrative hierarchy within the BIA divides the United States into different “Area Offices,” which are in turn divided into agencies. In recent years, the agency boundaries have become important to the Navajo Nation for its governmental activities, particularly in planning and service delivery. The agency has become incorporated into the Navajo Nation political system. Each of the agencies have a council which considers issues common to the chapters within that agency. Further, the agency geographical subdivision is used in making reports to the U.S. Department of Interior and the Congress (McKenzie, 1999 - S01280302).

BIA LAND MANAGEMENT DISTRICTS

In 1936, the Commissioner of Indian Affairs established land management districts within the Navajo Indian Reservation. There are 22 BIA Land Management Districts on the Navajo Nation. The bottom map in Figure 5 shows the boundaries of the BIA Districts. District 6 is the Hopi Reservation. District 22 (Alamo) is not shown on the map

STATES AND COUNTIES

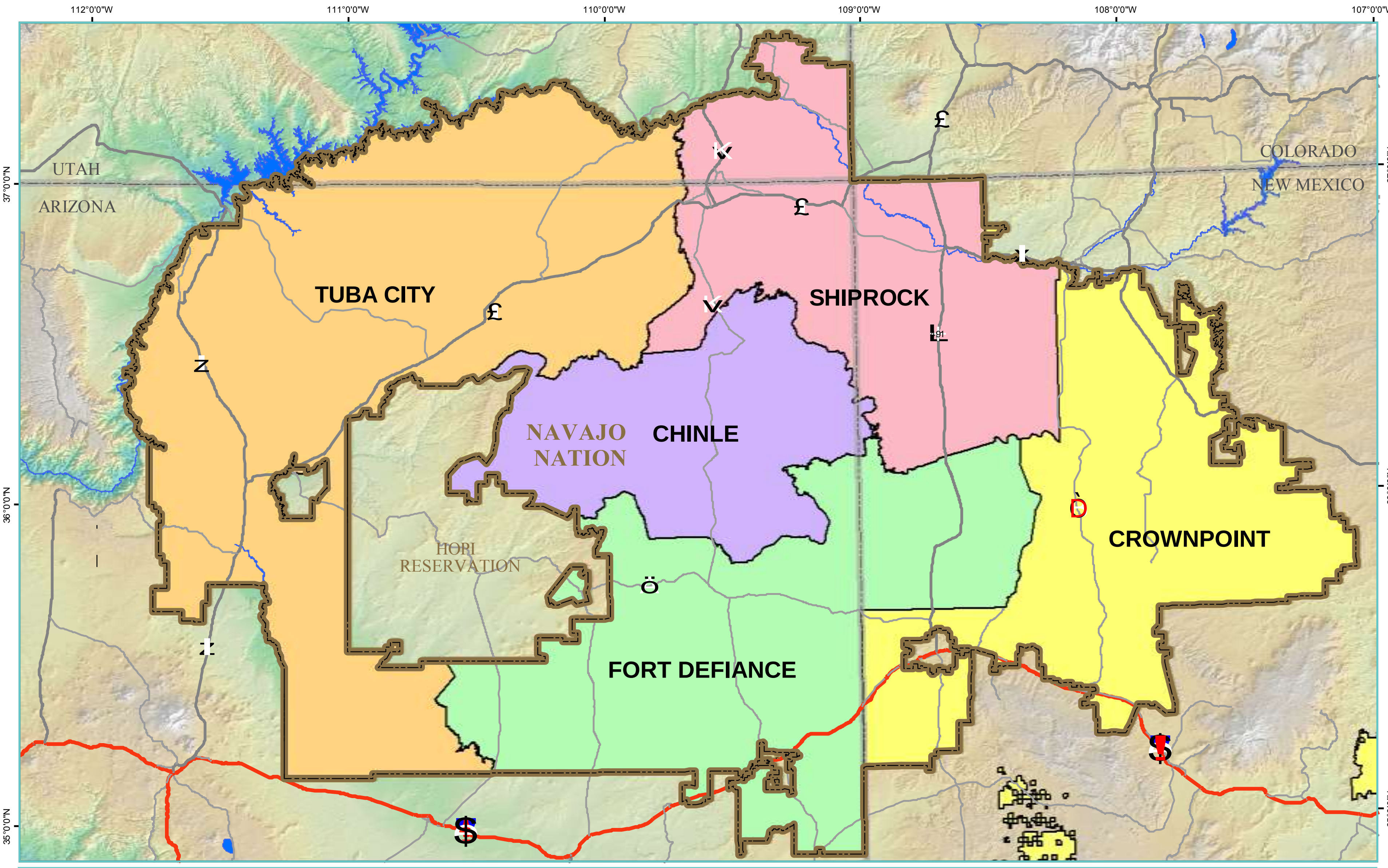
The Navajo Nation is the largest Indian reservation. It spans eleven (11) counties within Arizona, New Mexico, and Utah:

Arizona Counties
    Apache, Navajo, and Coconino

New Mexico Counties
    Bernalillo, Cibola, McKinley, Rio Arriba, San Juan, Sandoval, and Socorro

Utah County
    San Juan

States and counties have limited jurisdiction over the Navajo Nation, and only as provided by Federal law. On the Navajo Nation, only Federal and tribal laws apply to members of the Tribe (BIA, 2001 - S05050301).



NAVAJO NATION AGENCIES

Source
Navajo Nation Agency boundaries are from the Navajo Land Department.

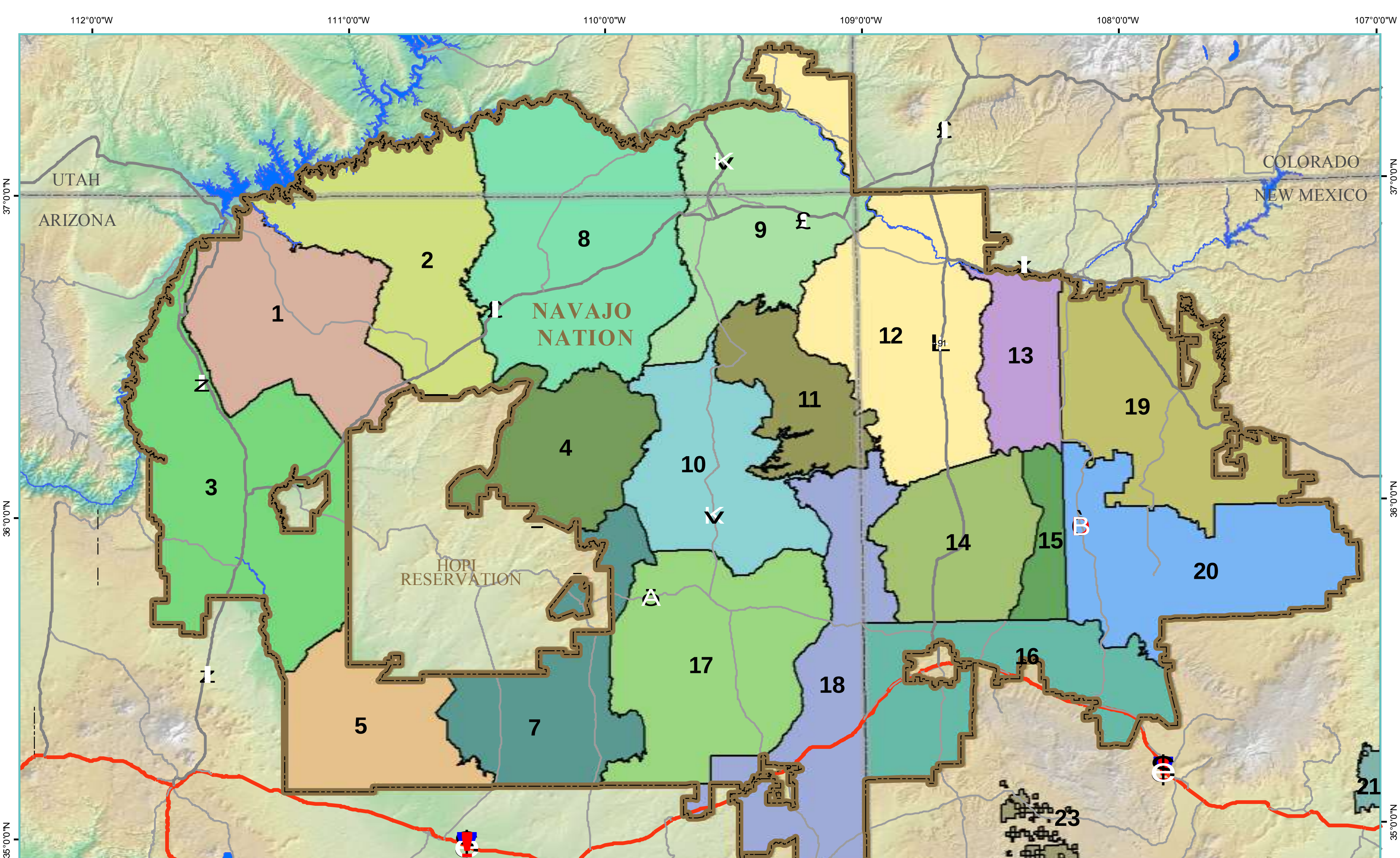
Filename: DB/Boundary/Navajo_Nation.shp

0 50 Miles
Map Scale 1:1,900,000

Legend

AGENCY

- Chinle
- Crownpoint
- Fort Defiance
- Shiprock
- Tuba City



NAVAJO NATION DISTRICTS

Source
Navajo Nation District boundaries are from the Navajo Land Department.

Filename: DB/Boundary/Navajo_Nation.shp

0 50 Miles
Map Scale 1:1,900,000

Legend

16 District

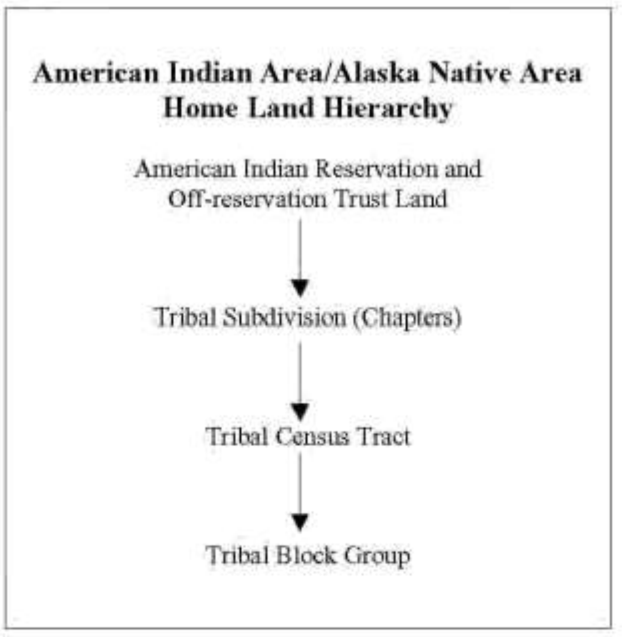
Figure 5. Navajo Nation Agencies and Districts.

NAVAJO NATION DEMOGRAPHICS

Since the first census in 1790, the Federal Government has conducted a census of the U.S. population and its housing units every ten years. However, it was not until 1860 that American Indians were counted in the census as a separate population category. In 1960, the U.S. Census Bureau made many changes in its methods of enumeration in an effort to acquire a more accurate and complete count for American Indians and Alaska Natives (AIANA) (U.S. Census Bureau, 1999 - S05070302). The Census Bureau began to report data systematically for American Indian reservations in conjunction with the 1970 census. The Census Bureau used the reservation boundaries shown on its enumeration maps, which proved in many cases to be inaccurate and incomplete. For the 1980 census, the Census Bureau attempted to improve reservation boundary information and worked with the Bureau of Indian Affairs (BIA) to obtain more accurate maps. In an effort to further improve enumeration for the 1990 census, the Census Bureau increased its collaboration throughout the 1980's with the American Indian and Alaska Native population by creating the Tribal Governments Liaison Program. The Census Bureau and the BIA signed a memorandum of understanding to achieve a more inclusive exchange of boundary information between the two agencies and the tribal authorities. This agreement provided the framework for the Tribal Review Program. The Census Bureau obtained boundary maps from the BIA, which were then provided to the tribal governments for review. A process of reviews and boundary certifications continued until mid-1989. The Census Bureau developed Tribal Review Maps, which were sent to the tribes for approval and final certification by the BIA. The Tribal Review Program improved the accuracy of the reservation and trust land information used for the 1990 census (U.S. Census Bureau, 1994—S05070301). For Census 2000, the Census Bureau relied entirely on Navajo Nation officials to review the legal boundaries already in the Census Bureau's records. The BIA was asked to participate only if the Census Bureau needed additional information (U.S. Census Bureau, 2002 - S05070303).

CENSUS GEOGRAPHIC AREAS FOR AMERICAN INDIAN AND ALASKA NATIVE AREAS (AIANA)

The Census Bureau tabulates and publishes population and housing census data for several geographic areas that cover AIANA areas. The two primary types of AIANA geographic areas on the Navajo Nation are reservation lands and trust lands. In addition, the 1990 Census included programs to allow tabulating AIANA census data by smaller geographic areas. These included: tribal subreservations, census tracts, and block groups.



Reservations and Trust Lands
American Indian reservations are areas with boundaries established by treaty, statute, and/or executive or court order. The Navajo Nation also has trust lands, which are real property held in trust by the Federal Government. Trust lands may be located within a reservation or outside of a reservation. However, the Census Bureau recognizes and tabulates data separately only for the inhabited off-reservation trust lands; on-reservation trust lands are included as part of the Navajo Nation reservation. As with reservations, tribal trust lands may cross state boundaries. The Census Bureau first reported data for tribal trust lands in conjunction with the 1980 census. For the 2000 Census, tribal subreservations were changed to American Indian Tribal Subdivisions, which allow the tabulation and presentation of census data that are more useful to the Navajo Nation.

Tribal Census Tract
Tribal census tracts are small, relatively permanent statistical subdivisions of the Navajo Nation and its off-reservation trust land. The optimum size for a tribal census tract is considered to be about 2,500 people; it must contain a minimum of 1,000 people.

Tribal Block Group
A tribal block group (BG) is a cluster of census blocks that are within a single tribal census tract. The optimum size for a tribal BG is 1,000 people; it must contain a minimum of 300 people.

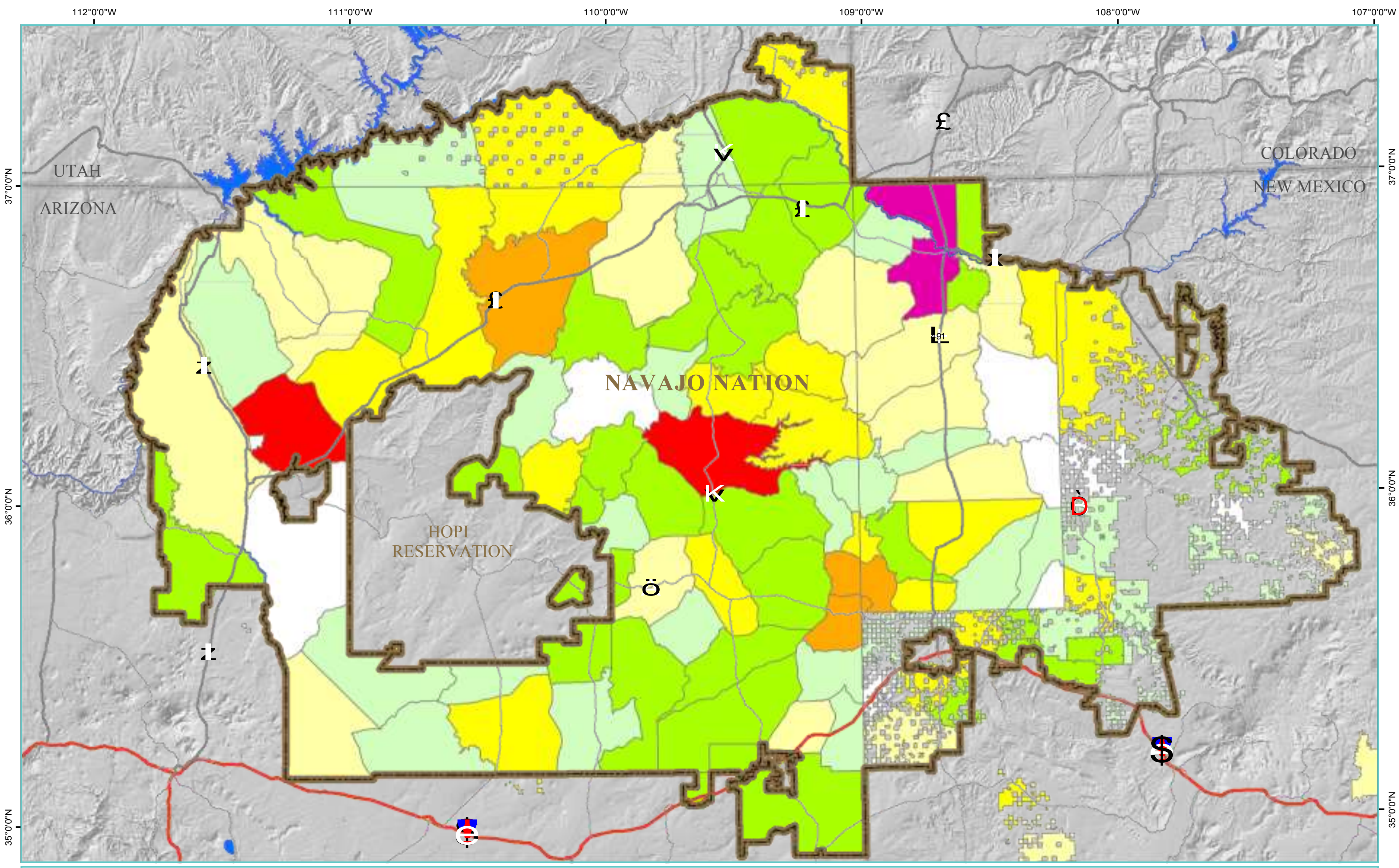
Census Designated Places (CDP)
Census Designated Places, or CDPs, are population concentrations that function as a community, are locally recognized as such, but are not legally incorporated. To recognize the significance of unincorporated communities located on American Indian reservations, the Census Bureau lowered the minimum population size for such CDPs to 250 people for the 1990 census.

Tribal Subdivisions
On May 4, 1999 Taylor McKenzie, the Navajo Nation Vice-President, testified before the U.S. Senate Committee on Indian Affairs in Washington, D.C. regarding the views of the Navajo Nation on the 2000 Census. He stressed the importance that the mapping used by the Census Bureau needed to reflect the political units used by the Navajo Nation - namely, Chapters and Agencies (McKenzie, 1999 - S01280302). Tribal subdivisions were implemented in the 2000 Census. Chapters make up the tribal subdivisions for the Navajo Nation. Users of these data should note that the Tribal Subdivision boundaries used in the 2000 Census are not the same as the Chapter boundaries provided by the Navajo Land Department .

2000 CENSUS DEMOGRAPHICS

The 2000 Census reports the total population on the Navajo Nation Reservation and Off-Reservation Trust Land as 180,462 (U.S. Census Bureau, 2000 - S05070304). Figure 6 shows the total population for the Navajo Nation by Tribal Subdivision from the 2000 Census. There are differences between some of the chapter boundaries and the tribal subdivisions used by the Census Bureau. The tribal subdivisions with the highest populations are Shiprock, Kayenta, Chinle, Tuba City, and Fort Defiance.

Navajo Nation Demographics
Figure 6 provides "DP-1 Profile of General Population and Household Characteristics: 2000 Census" for the Navajo Nation Reservation and Off-Reservation Trust Land, AZ-NM-UT (U.S. Census Bureau, 2000—S05070304). According to the 2000 Census, the total population for the Navajo Nation was 180,462. The median age was 24 years. There were 47,603 occupied households, 21,141 vacant housing units and 11,126 seasonal, recreational, or occasional use on the Navajo Nation. The average size of a household was approximately 3.8 people.



2000 CENSUS - NAVAJO NATION
TOTAL POPULATION BY TRIBAL SUBDIVISION

Population by tribal subdivision data is from
Source
the U.S. Census Bureau - 2000 Census.

Filename: DB/Cultural/nn_tribal_sub_w_pop.shp.

0 50 Miles

Map Scale 1:1,900,000

Legend
TOTAL POPULATION
0 - 500
501 - 1000
1001 - 1500
1501 - 2000
2001 - 4000
4001 - 7500
7501 - 9000
9001 - 10000

SUBJECT	NUMBER	PERCENT
TOTAL POPULATION	**180,462**	**100**
SEX AND AGE		
Male	88,469	49
Female	91,993	51
Under 5 years	17,364	9.6
5 to 9 years	21,373	11.8
10 to 14 years	22,967	12.7
15 to 19 years	18,742	10.4
20 to 24 years	11,912	6.6
25 to 34 years	22,202	12.3
35 to 44 years	24,470	13.6
45 to 54 years	17,316	9.6
55 to 59 years	6,182	3.4
60 to 64 years	5,402	3
65 to 74 years	7,691	4.3
75 to 84 years	3,515	1.9
85 years and over	1,326	0.7
Median age (years)	**24**	**(X)**
18 years and over	106,432	59
Male	50,897	28.2
Female	55,535	30.8
21 years and over	97,395	54
62 years and over	15,707	8.7
65 years and over	12,532	6.9
Male	5,401	3
Female	7,131	4

SUBJECT	NUMBER	PERCENT
HOUSEHOLDS BY TYPE		
Total households	**47,603**	**100**
Family households (families)	37,903	79.6
With own children under 18 years	22,989	48.3
Married-couple family	22,708	47.7
With own children under 18 years	14,614	30.7
Female householder, no husband present	11,759	24.7
With own children under 18 years	6,441	13.5
Nonfamily households	9,700	20.4
Householder living alone	8,841	18.6
Householder 65 years and over	2,697	5.7
Households with individuals under 18 years	28,087	59
Households with individuals 65 years and over	9,924	20.8
Average household size	3.77	(X)
Average family size	4.36	(X)
HOUSING OCCUPANCY		
Total housing units	**68,744**	**100**
Occupied housing units	47,603	69.2
Vacant housing units	21,141	30.8
For seasonal, recreational, or occasional use	11,126	16.2
HOUSING TENURE		
Occupied housing units	**47,603**	**100**
Owner-occupied housing units	36,092	75.8
Renter-occupied housing units	11,511	24.2
Average household size of owner-occupied unit	3.78	(X)
Average household size of renter-occupied unit	3.75	(X)

(X) Not applicable

Source: U.S. Census Bureau, Census 2000 Summary File 1, Matrices P1, P3, P4, P8, P9, P12, P13, P,17, P18, P19, P20, P23, P27, P28, P33, PCT5, PCT8, PCT11, PCT15, H1, H3, H4, H5, H11, and H12.

DP-1 PROFILE OF GENERAL POPULATION AND HOUSEHOLD CHARACTERISTICS: 2000 CENSUS
Navajo Nation Reservation and Off-Reservation Trust Land, AZ-NM-UT

Data from Census 2000 Summary File 1 (SF1) 100-Percent Data
Filename: DB/Demog/NN_2000Census_pop.xls

Figure 6. Navajo Nation Census 2000 Population and Households.

STRUCTURES

For the purposes of this NAUM Project, structures within one (1) mile of an AUM were mapped as an indicator of the target population locations. The target population consists of those people who use target wells or surface water for drinking water, eat food taken from impacted livestock or fisheries, or are regularly present on an AUM site or live within target distance limits.

For the purposes of assessing the potential target population, it is important to know where people live, work, go to school, and routinely gather. The locations of current residences were not readily available for the Navajo Nation. Existing USGS topographic maps include many buildings and other structures of interest. However, a majority of these maps are over 20 years old and require conversion into a suitable GIS format for analysis. More recent USGS Digital Orthophoto Quarter Quadrangles (DOQQs) were available and were used as a basis to map buildings and other structures by photointerpretation. The DOQQs were generated from aerial photography acquired in 1997 and 1998. For a small number of features, the older topographic maps were used as an interpretation aid. The interpretation of structures was limited due to the dates of the DRGs and DOQQs, which ranged in age from 8 to 20 years. Structures that were constructed after the date of the DRG or DOQQ were not present. In some cases, structures that were present at the time the DRGS or DOQQs were generated do not exist today.

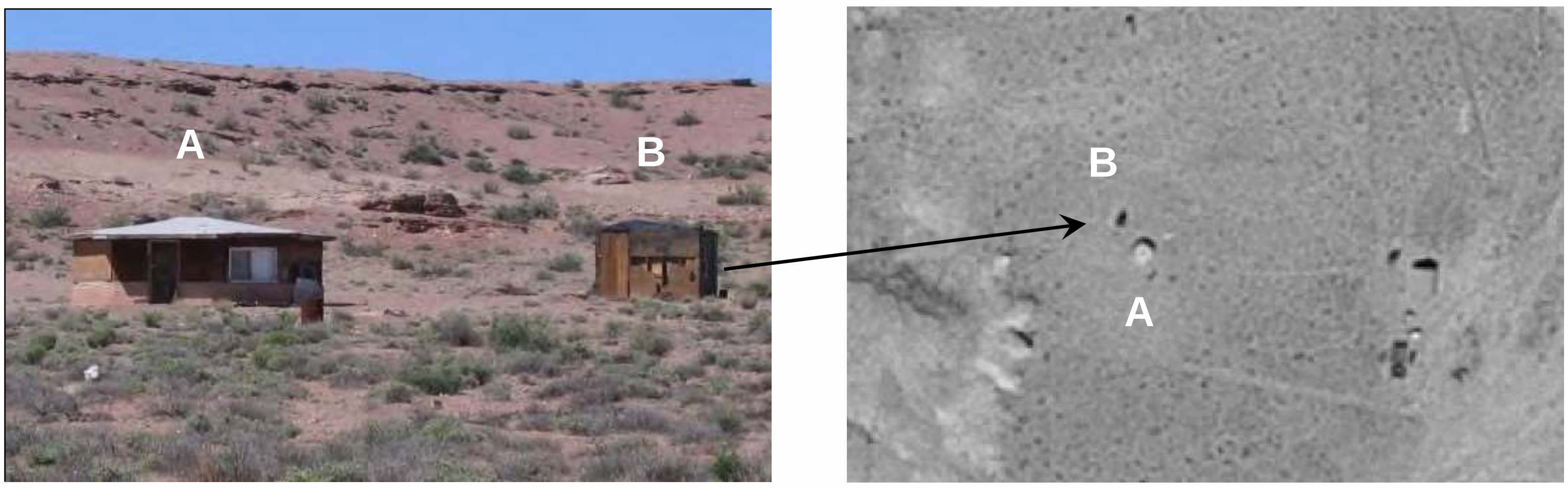


Figure 7. Photo Key Showing Ground Photo and Corresponding DOQQ Image of Structures.

The Navajo Tribal Utility Authority (NTUA) provided point locations for utility meters for the NTUA service areas within five (5) miles of a mapped AUM. The meter locations were collected by NTUA using Global Positioning System (GPS) equipment. It was assumed that where there were water, gas, or electric meters there was probably some type of structure present. The NTUA meter data was very useful in verifying the location of structures that were mapped from the DOQQs. The meter data were also used to include an "assumed structure" category, which designates the locations of structures that may have been constructed after 1997. Use of the NTUA meter location data was limited to this structures mapping effort, and distribution of the data was not permitted. Color DOQQs flown in 2005 were available for New Mexico and were used for structure mapping in the Eastern AUM Region.

More recent aerial photography (2005) was flown by the U.S. Bureau of Indian Affairs (BIA), and DOQQs were generated. These DOQQs were not available for distribution by the BIA for use in this project. However, when they are made available, these color DOQQs should provide a useful source for updating and photo-verifying the structures dataset.

Photo keys were developed to assist with the interpretation of structures and related features (Figures 7 and 8). However, it was not possible to accurately distinguish residences from other types of structures by photointerpreting the DOQQ imagery. Some structures that were mapped may be large sheds or other non-residential structures, and some may be seasonal residences and not occupied full-time. All of these structures, however, are indicative of locations where people might be present. These structures were used as an indicator for the probable location of the target population for the soil pathway and air pathway assessments. A map of structures within one (1) mile of an AUM site is shown on Figure 9. This dataset is provided on the GIS Data DVD (DB/Cultural/NN_Structures_1mi.shp). Also shown on Figure 9 are the locations of Chapter Houses, which was provided by the Navajo Land Department (NLD), and is included on the GIS Data DVD (DB/Cultural/nnchppts.shp). NLD used color and black and white DOQQs, Chapter boundaries, surface roads, and Division of Community Development chapter websites to update the locations of the Chapter Houses.

Another source of information about where people live on the Navajo Nation is the Geographic Names Information System (GNIS), which was developed by the U.S. Geological Survey in cooperation with the U.S. Board on Geographic Names. This point dataset provides the locations and names of populated places for the Navajo Nation and the surrounding region (DB/Cultural/NN_Pop_Places.shp).

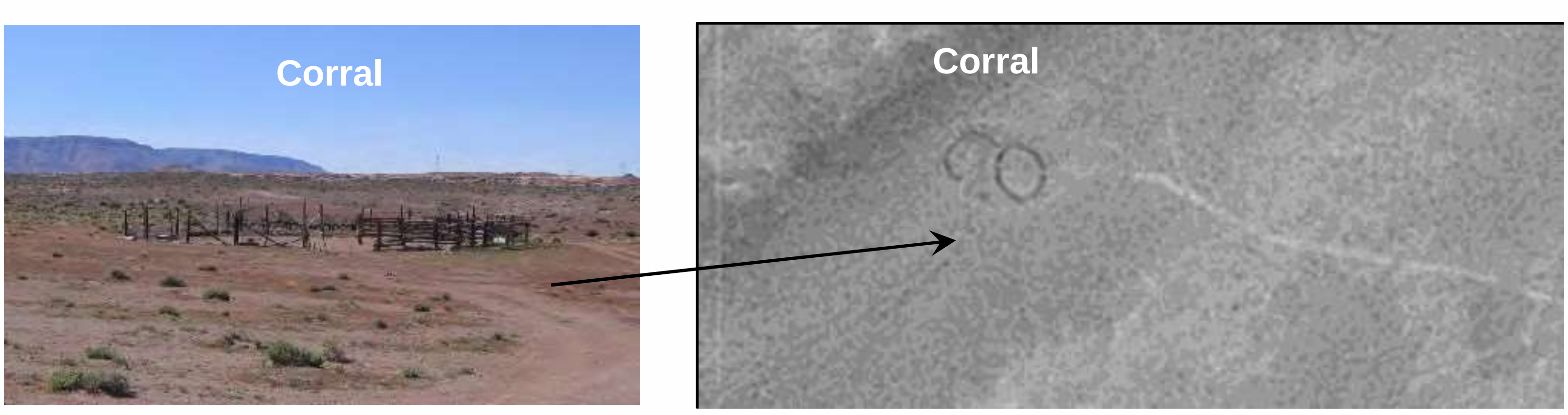
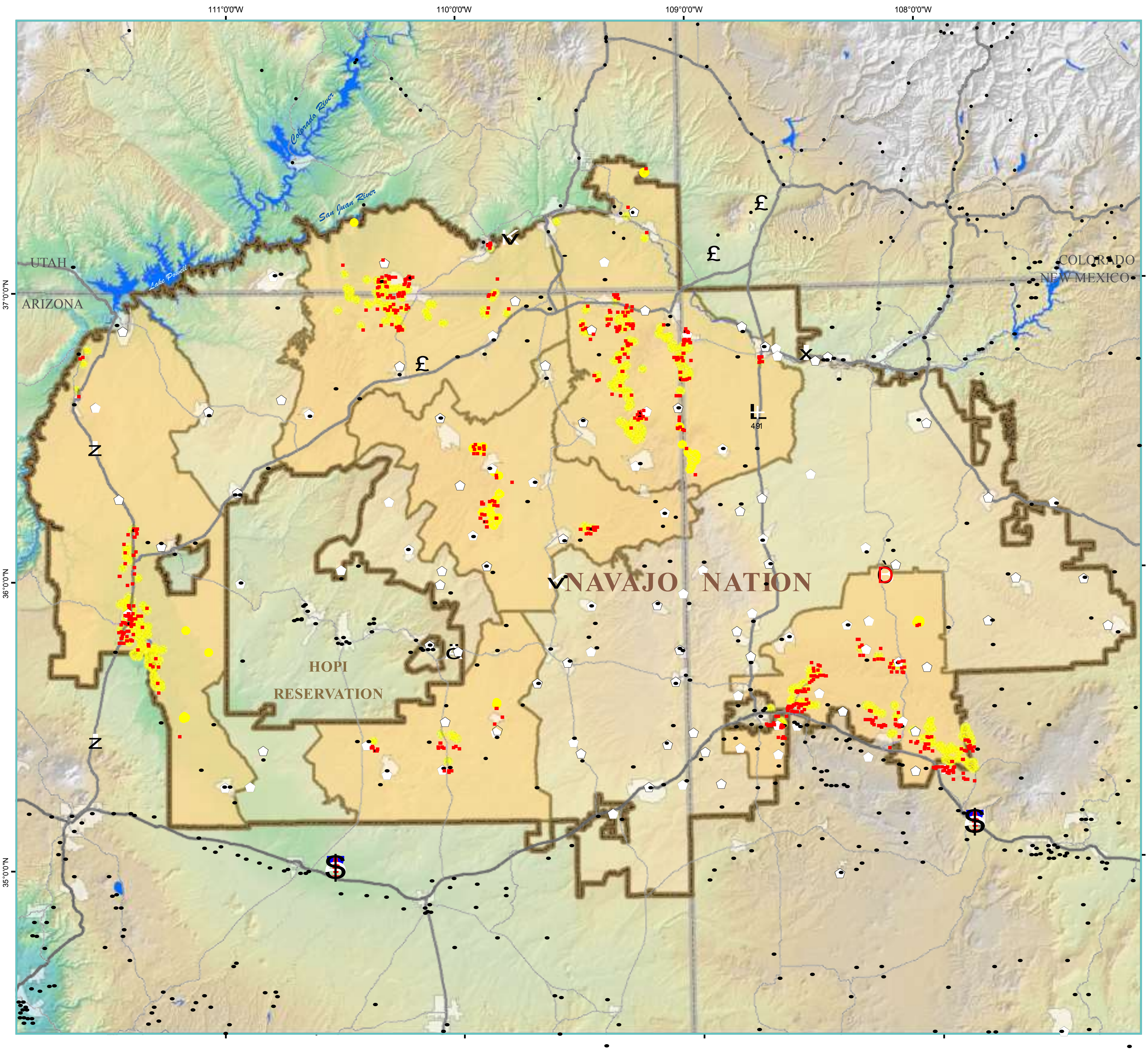


Figure 8. Photo Key Showing Ground Photo and Corresponding DOQQ Image of Corrals.



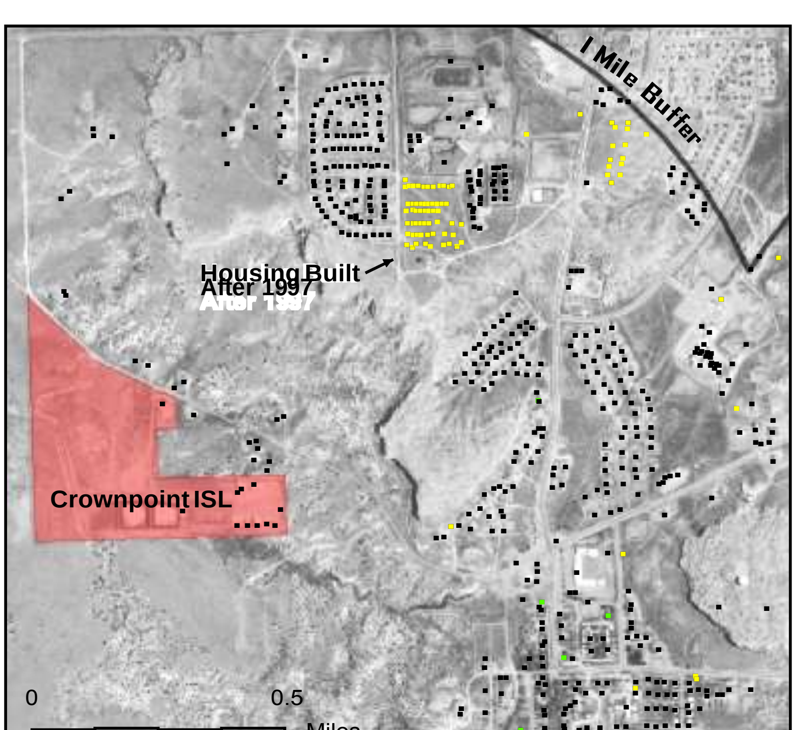
ABANDONED URANIUM MINES AND THE NAVAJO NATION

STRUCTURES WITHIN 1 MILE OF AUMS AND OTHER POPULATED PLACES

N
W E
S

0 50 Miles

Map Scale 1:1,750,000



Community of Crownpoint, which is proximal to the Crownpoint In-Situ Leach facility. Structures were mapped from 1997 orthophotography (shown in black). "Assumed structures" (shown in yellow) were added from utility meter locations provided by the Navajo Tribal Utility Authority (NTUA). These structures are not present on the 1997 orthophotography.

Legend

STRUCTURES AND POPULATED PLACES

- Structures within 1 Mile of an AUM
- Chapter Houses
- GNIS Populated Places
- Designated Census Place
- One Mile Buffer Around an Abandoned Uranium Mine
- Navajo Nation and AUM Region Boundaries

Sources

Structures within one (1) mile of an AUM were photo-interpreted by TerraSpectra Geomatics.
Filename: DB/Cultural/NN_Structures_1mi.shp

Chapter House locations from the Navajo Land Department - GIS Section.
Filename: DB/Cultural/nnchppts.shp

Populated places points were extracted from the Geographic Names Information System (GNIS) database developed by the U.S. Geological Survey.
Filename: DB/Cultural/NN_Pop_Places.shp

Designated Census Place from the U.S. Census Bureau - 2000 Census.
Filename: DB/Demog/nn_censuspl.shp

Figure 9. Structures Within 1 Mile of AUMs and Other Populated Places.

TRANSPORTATION

Federal and state highways that provide access to the Navajo Nation include: U.S. Interstate 40 to the south, U.S. Highway 89 to the west, U.S. Highway 160 to the north, and U.S. Highway 491 to the east. A network of state highways cross the Navajo Nation and are shown in Figure 13. Highway data for the Navajo Nation was extracted from the 2002 National Transportation Atlas Database, (NTAD) and is provided on the GIS Data DVD (DB/Trans/NN_Highways.shp).

Most of the roads on the Navajo Nation are unpaved and are part of the Indian Reservation Roads (IRR) Program. IRR are public roads which provide access to and within Indian reservations, Indian trust land, and restricted Indian land. According to the 2000 BIA Road Inventory Database, the Navajo IRR system consists of 9,826 miles of public roads. Of that, the Navajo Nation maintains 1,451 miles of paved road, and 4,601 miles of gravel and dirt roads. Weather conditions often make many of those roads impassable. In the winter, snow and rain may prohibit access. Because of the prolonged drought, some of these roads have become nearly impassable due to sand dunes, rocky surfaces and deep holes (Navajo Nation, 2002 - S05240717).

The Navajo Nation's roads have been administered by the BIA Navajo Area Branch of Roads (BOR). Figure 13 shows Indian Service Routes on the Navajo Nation. These paved BIA routes are from a GIS dataset of roads obtained from the BIA in 2003. Many of the paved roads were modified by photointerpreting digital orthophotos to adjust or add road features. Figures 10 and 11 show before and after adjustments based on photo interpretation of DOQQs. These modifications were only made to paved roads in Chapters with mapped AUMs. The adjusted dataset is provided on the GIS Data DVD (DB/Trans/NN_Paved.shp).

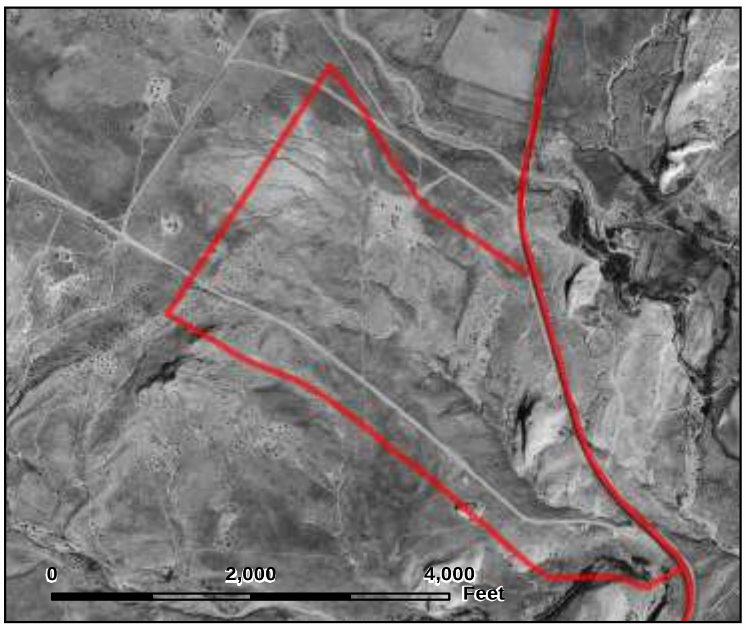


Figure 10. Example of Unadjusted BIA Roads.

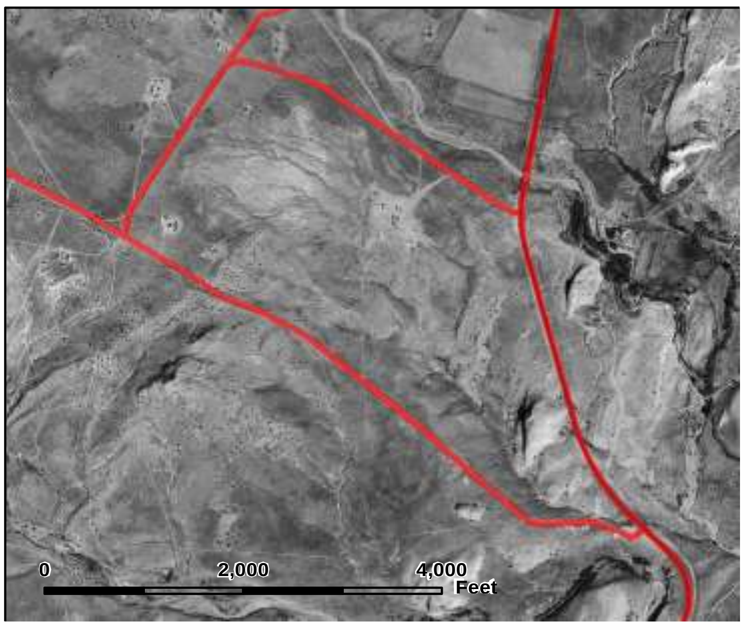


Figure 11. Example of Adjusted BIA Roads.

The Navajo Department of Transportation (NDOT) was created in 1986 by the Navajo Nation Council. NDOT is working to establish the Navajo Nation's road program, which includes development and maintenance of an IRR GIS database. BIA contracted to have aerial photography flown for the Navajo Nation in 2005, and new color orthophotography was generated. The new orthophotography, along with Global Positioning System (GPS) field measurements, will allow development of a more accurate IRR database.

The location of roads has significance to the NAUM Project. The process of locating AUMs was often assisted by following roads on the DOQQs and DRGs. This was particularly true for productive AUMs that required the ore to be hauled by truck. Haulage roads may also have significance as a potential contaminant source. In Figure 12, the Monument No. 2 AUM (outlined in black) is shown with the DOE aerial radiation survey excess Bismuth-214 results. Of note are the elevated excess Bismuth-214 contours that extend beyond the boundary of the AUM and that are coincident with the haulage road.

During the 1950's the U. S. Atomic Energy Commission (AEC) funded a program to construct and/or improve access roads to exploration and mining areas. Five projects in Arizona were on the Navajo Nation in Apache County. These roads provided better access to several uranium mining areas, especially the Lukachukai Mountains, eastern Carrizo Mountains, and the Cane Valley area of Monument Valley (Chenoweth, 1989 - S10100213).

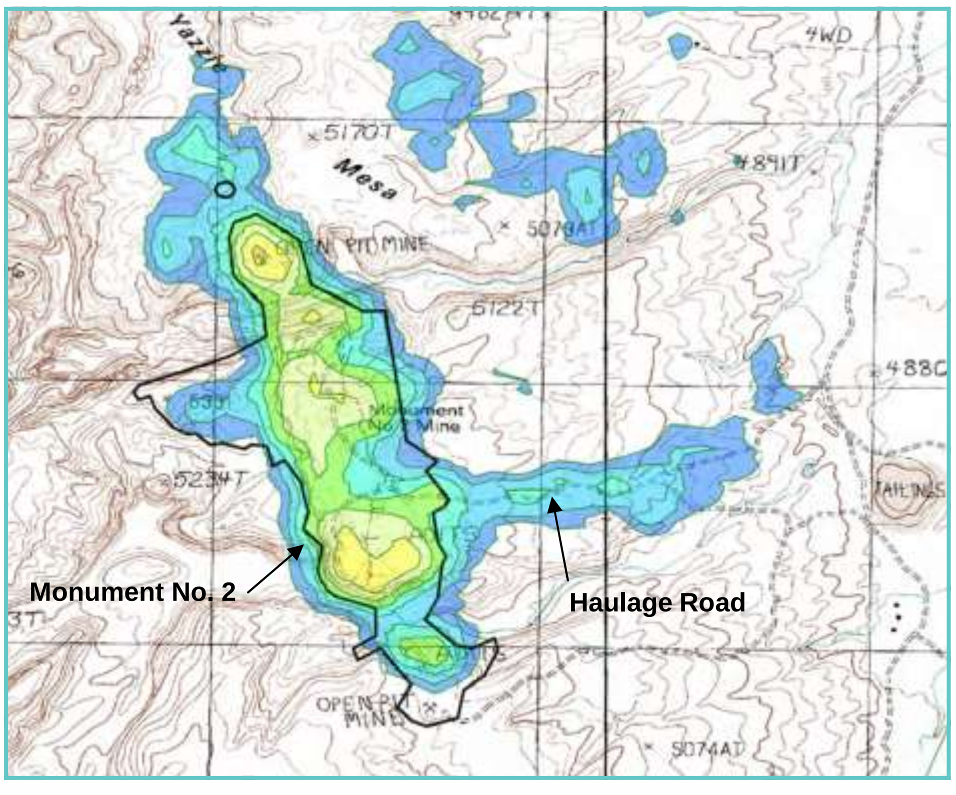
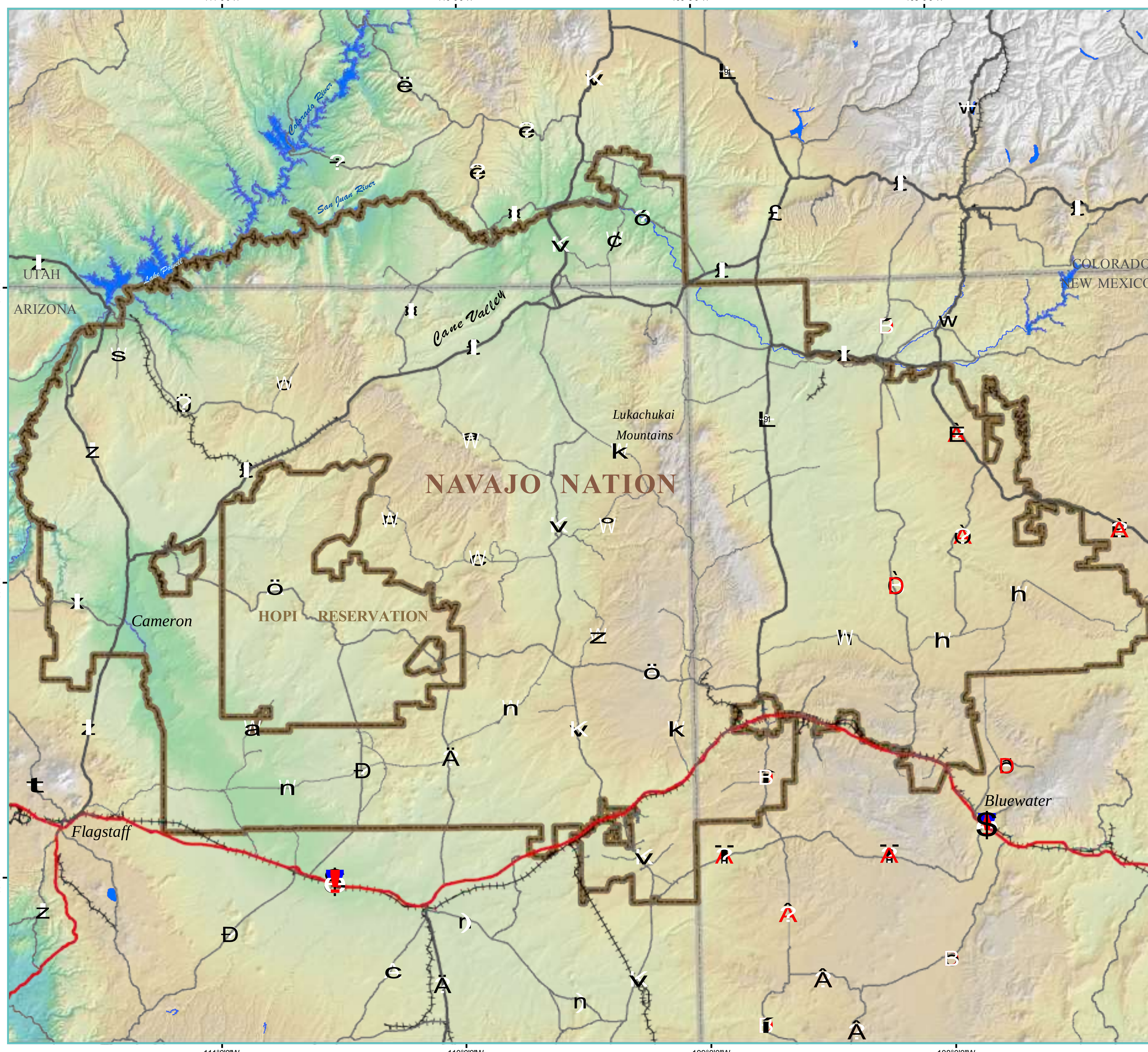


Figure 12. Elevated Excess Bismuth-214 Along Haulage Road.

Railways also played a role in the transport of uranium ore from the Navajo Nation. For example, shipments to the Bluewater ore-buying station were made from some AUMs in the Cameron area. The ore was trucked to Flagstaff and shipped by the Atkinson Topeka and Santa Fe Railway to a siding near Bluewater, where the ore was transferred to trucks for the short haul to the buying station (Chenoweth, 1993 - S10100239). These ore transfer locations may have residual radionuclides, similar to those found at the Cove and Climax Transfer Stations.

Railways that are on or near the Navajo Nation are shown on Figure 13. These data are from the Federal Railroad Administration (FRA) and the Bureau of Transportation Statistics NTAD and are provided on the GIS Data DVD (DB/Trans/NN_rail.shp).



ABANDONED URANIUM MINES AND THE NAVAJO NATION

TRANSPORTATION

N W E S

0 50 Miles

Map Scale 1:1,750,000

Ore trucks, Lukachukai Mountains, Arizona. Photo courtesy of William L. Chenoweth

Legend

- Railroad

ROADS AND ROUTE SHIELDS

- U.S. Interstate Route
- U.S. Route
- Arizona State Route
- New Mexico State Route
- Utah State Route
- Indian Service Route

Sources

Highways for the Navajo Nation were extracted from the National Highway Planning Network, developed by the Federal Highway Administration (FHWA) and the Bureau of Transporation Statistics (BTS) National Transportation Atlas Database, 2002. Filename: DB/Trans/NN_Highways.shp

Paved roads are from the U.S. Bureau of Indian Affairs (BIA) and modified by adjustment or photointerpretation of DOQQs. Changes were only made for Chapters that have AUMs. Filename: DB/Trans/NN_Paved_Roads.shp

Railroads are from the Federal Railroad Administration and BTS. Filename: DB/Trans/NN_rail.shp

Figure 13. Paved Roads and Railroads On and Near the Navajo Nation.

CLIMATE

Temperature, precipitation, and wind conditions that characteristically prevail in a region play an important role in contaminant pathway assessments. These climate factors on the Navajo Nation are discussed in this section.

Other climate impacts are related to the drought conditions the Navajo Nation has been experiencing in recent years. Drought and temperature increases due to climate change affect the amount of vegetation growing on sand dunes. Sand dunes cover approximately one-third of the semi-arid Navajo Nation on the southern Colorado Plateau. Sand supplies here are abundant from both sandstone bedrock and dry river channels. In this area winds capable of moving sand are dominantly from the southwest (Figure 14). The risk of sand dune mobilization within this region is high given: 1) current severe drought conditions; 2) climate variability based on known historic records (such as the drought during the early 20th century); 3) the overall decrease in regional precipitation for this last century; 4) the apparent drying trend on the Navajo Nation, and; 5) the possibility of climate change. Current work indicates that reactivation of stabilized sand is occurring in many areas of the Navajo Nation where the vegetation growing on the dunes, and holding them in place, are dying. Dune mobility is a cause for concern, and is today inundating housing and causing transportation problems. It also may be contributing to a loss of rare and endangered native plants and grazing land, and lower air quality from periodic dust storms (Hiza, 2003 - S05270701). These same climatic variables may have similar effects on vegetation cover that may be stabilizing wind-blown dust from AUM debris or soil cover at AUM reclamation sites. This indicates that the air pathway may take on greater importance as desertification increases.

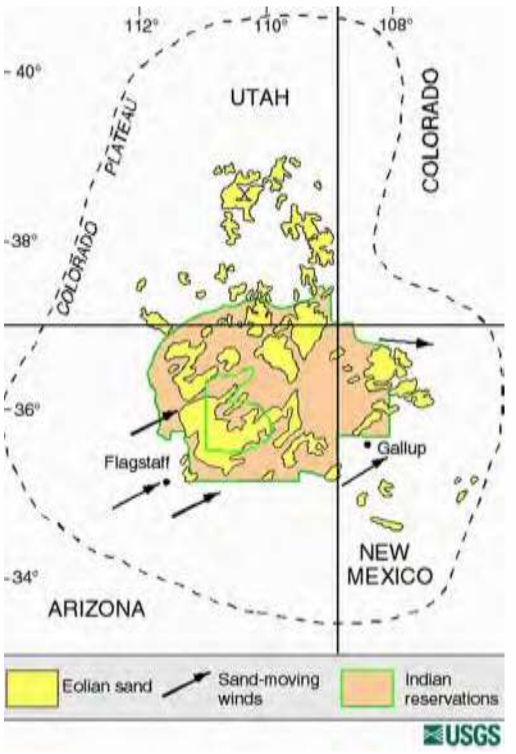


Figure 14. Location of Eolian Sand and Direction of Wind on the Navajo Nation (from Hiza, 2003 - S05270701).

PRECIPITATION

Precipitation is an important parameter to consider when evaluating potential migration pathways. Heavy precipitation provides a driving force to carry hazardous substances through the soil to the ground water, or to carry hazardous substances away from a site through runoff. Data on the intensity, duration, and frequency of storms is needed to calculate the volume of surface water run-on or run-off. If there is flooding potential, the flood characteristics (e.g. stagnant backwater or scour potential due to flow) would be useful information for assessing AUM sites. Conversely, dry conditions can enhance the wind erosion potential for certain soil types, increasing the potential for air transport.

Precipitation throughout Arizona and New Mexico is locally governed to a large extent by elevation and orographic effects and the season of the year. From November through March storm systems from the Pacific Ocean cross the state. These winter storms occur across the Navajo Nation in the higher mountains, where much of the winter precipitation falls as snow. Summer rainfall begins early in July and usually lasts until mid-September. Summer rains fall almost entirely during brief, but frequently intense thunderstorms. The general southeasterly circulation from the Gulf of Mexico brings moisture from these storms into the state. Strong surface heating, combined with orographic lifting as the air moves over higher terrain, causes air currents and condensation. Because precipitation usually is relatively intense, some local runoff and flash flooding result (Cooley et al., 1969 - S10290201).

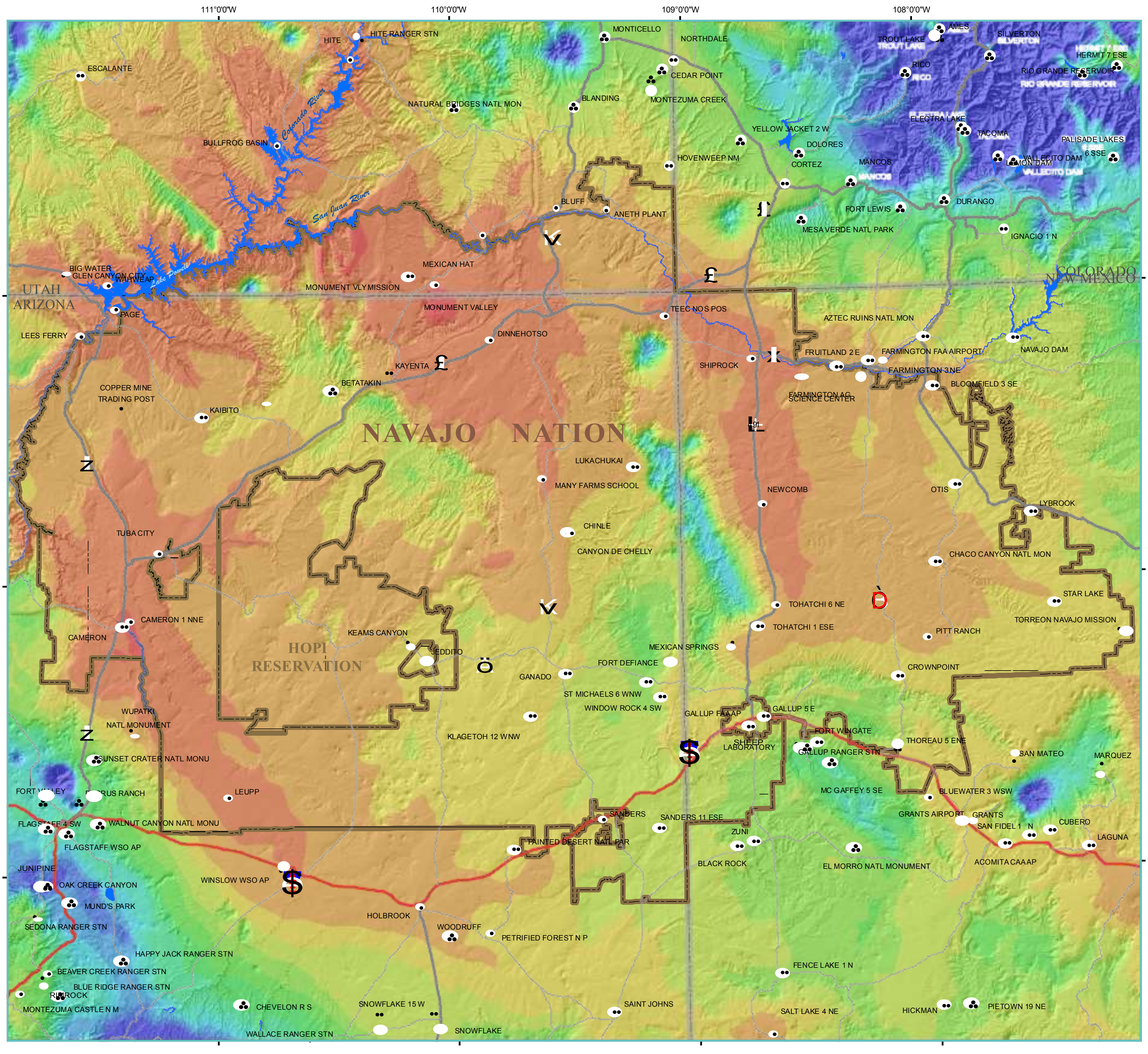
Weather stations are sparsely and unevenly spaced throughout much of Arizona and New Mexico. Factors such as site location, density of distribution, types of equipment, and observer bias all affect the precision, accuracy, and utility of resulting climate data. The National Weather Service (NWS) operates three weather stations in Arizona (Flagstaff, Phoenix, and Tucson), and one station in New Mexico (Albuquerque). Additionally, there is a network of cooperative weather stations that regularly gather and report temperature and precipitation data. The coverage and total number of cooperative weather stations varies over the state. Arizona's tribal lands, which constitute a sizable portion of the total land area of the state, are underrepresented as are high-elevation areas in general (Sheppard et al, 1999 - S07280303).

There are many methods of interpolating climate data from monitoring stations to grid points. Some methods provide estimates of acceptable accuracy in flat terrain, but few have been able to adequately explain the extreme, complex variations in climate that occur in mountainous regions. Significant progress in this area has been achieved through the development of PRISM (Parameter-elevation Regressions on Independent Slopes Model). PRISM is an analytical model that uses point data and an underlying grid such as a digital elevation model (DEM) for a 30 year climatological average (e.g. 1971- 2000 average) to generate gridded estimates of monthly and annual precipitation and temperature (as well as other climatic parameters). PRISM is well suited to regions with mountainous terrain, because it incorporates a conceptual framework that addresses the spatial scale and pattern of orographic processes, where air masses cool as they gain elevation, resulting in precipitation. The PRISM Group at Oregon State University developed a spatially gridded average annual precipitation for the climatological period 1971-2000 that covers the Navajo Nation.

Distribution of the point measurements to a spatial grid was accomplished using the PRISM model. The PRISM Group at OSU used point estimates of precipitation from some or all of the following sources: 1) National Weather Service (NWS) Cooperative (COOP) stations, 2) Natural Resources Conservation Service (NRCS) SNOTEL, 3) United States Forest Service (USFS) and Bureau of Land Management (BLM) RAWS Stations, 4) Bureau of Reclamation (AGRIMET) stations, 5) storage gauges, 6) NRCS Snowcourse stations, 7) other State and local station networks, 8) estimated station data, 9) upper air stations, and 10) NWS/Federal Aviation Administration (FAA) Automated surface observation stations (ASOS). Grids were modeled on a monthly basis and the annual grids of precipitation were produced by averaging the monthly grids, and summing for precipitation. The gridded PRISM average annual precipitation dataset was processed into contours using ESRI's Spatial Analyst software.[1] Polygons were generated and attributed with average annual precipitation range values as shown in Figure 15. This dataset is provided on the GIS Data DVD (DB/Climate/NN_Precipitation.shp).

The largely semi-arid Navajo Nation is shown in Figure 15 by the dominance of 4-12 inches of precipitation. The orographic effect can be seen on the Chuska and Carrizo Mountains and the Defiance Plateau where precipitation rises to 12-28 inches. Black Mesa, with an intermediate elevation, shows this same effect where precipitation rises to 18 inches annually.

[1] Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

NAVAJO NATION AVERAGE ANNUAL PRECIPITATION: 1971 - 2000 AND AVERAGE ANNUAL SNOWFALL

0 50 Miles

Map Scale 1:1,750,000

Aerial photo of flooding after a heavy rain storm along the intermittent Moenkopi Wash near Tuba City, Arizona. Photo courtesy the U.S. Army Corps of Engineers (photo taken October 9, 2002).

Legend

AVERAGE ANNUAL PRECIPITATION (Inches)

- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 24
- 24 - 26
- 26 - 28
- 28 - 30
- >30

AVERAGE ANNUAL SNOWFALL (Inches)

- <10.0
- 10.0- 39.9
- >40

Source

The average annual precipitation on the Navajo Nation for the period 1971 - 2000 is from the PRISM Group at Oregon State University (OSU). PRISM (Parameter-elevation Regressions on Independent Slopes Model) is the analytical model that uses point data and an underlying grid such as a digital elevation model (DEM) for a 30 year climatological average (e.g., 1971- 2000 average) to generate gridded estimates of monthly and annual precipitation. PRISM is well suited to regions with mountainous terrain, because it incorporates a conceptual framework that addresses the spatial scale and pattern of orographic processes. The gridded data was converted to a polygon dataset by TerraSpectra Geomatics.

Filename: DB/Climate/NN_Precipitation.shp

Figure 15. Navajo Nation Average Annual Precipitation: 1971 - 2000.

CLIMATE (continued)

The U.S. Geological Survey (USGS) Navajo Nation Studies program is compiling meteorological information on precipitation type, intensity, and timing on the Navajo Nation. The purpose of these data collection efforts is to examine trends that may contribute to drought intensity. USGS plans to conduct infiltrometer work on alluvial deposits and to use soil moisture probes to evaluate relative effects of precipitation intensities, of both simulated and actual rainfall events, on soil moisture and infiltration (USGS, 2007 - S05220702).

The Navajo Nation Department of Water Resources is developing a database with stream gauge, climate, snow survey, and precipitation data. Inquiries concerning these data can be made to the Navajo Department of Water Resources, Water Management Branch, P.O. Drawer 678, Fort Defiance, Arizona 86504.

SNOWFALL

Snow accumulation can impact the effect of melting snow on soil water recharge, and the potential for contaminant transport at an AUM site. The mean annual snowfall is related to temperature, and more directly to physiography and altitude. However, wind, exposure, and other factors can cause variation in snow accumulation. Figure 16 shows the ranges of annual snowfall recorded at cooperative weather stations in and around the Navajo Nation. These data were acquired from the Western Regional Climate Center in tabular format (Table 1) and were processed into a GIS dataset that is provided on the GIS Data DVD (DB/Climate/NN_Snow.shp).

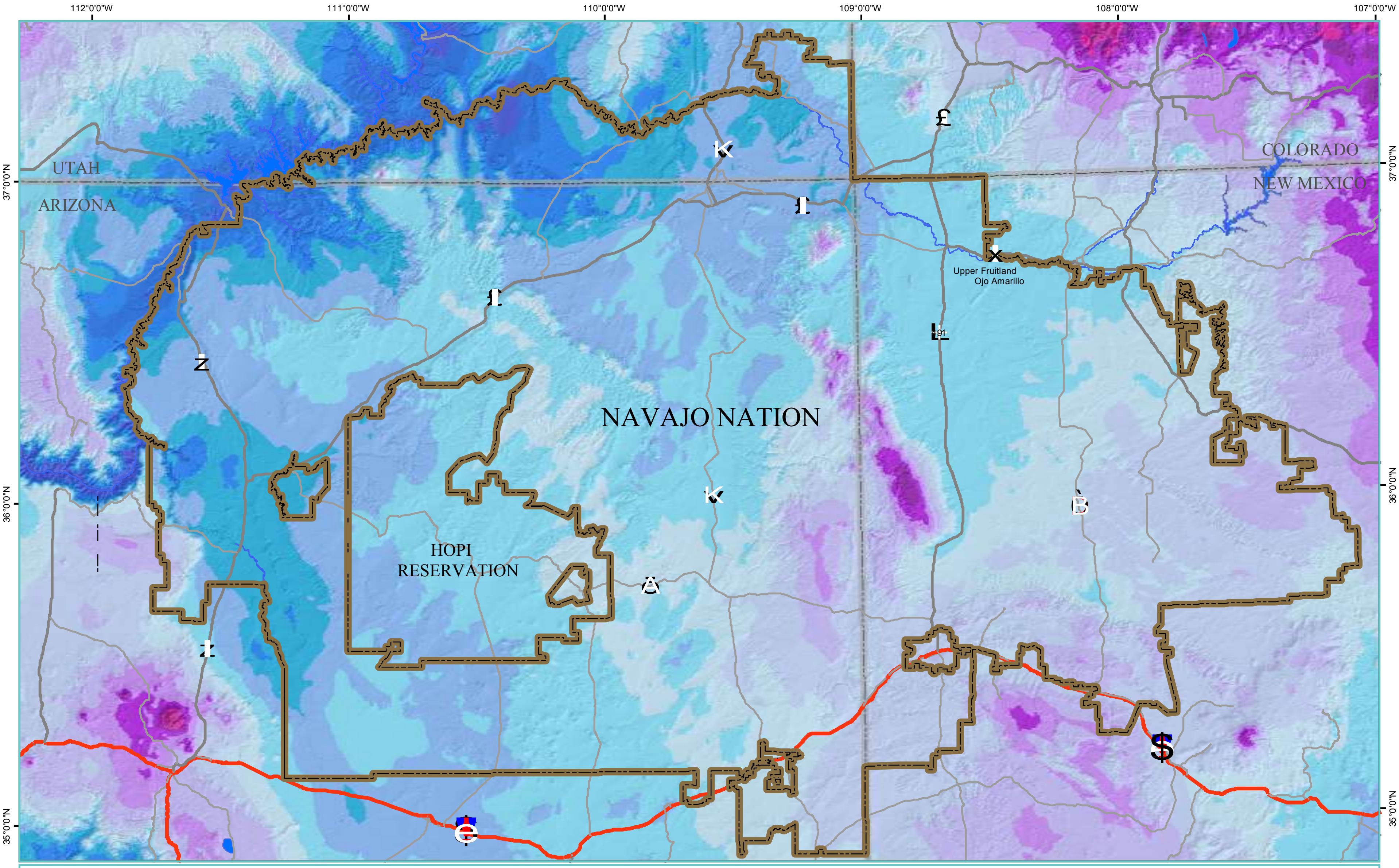
Table 1. Average Annual Snowfall On and Within 1 Mile of the Navajo Nation.

STATION ID	COOPERATIVE STATION NAME	State	Elev_ft	Start_Yr	End_Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
020750-2	BETATAKIN	AZ	7210	1948	2004	10.0	9.3	7.8	3.8	0.6	0.0	0.0	0.0	0.0	1.2	6.4	10.0	50.0
021169-2	CAMERON	AZ	4290	1948	1998	2.2	3.8	1.8	1.0	0.0	0.0	0.0	0.0	0.0	0.3	1.3	3.4	10.0
021169-2	CAMERON 1 NNE	AZ	4160	1962	1992	0.6	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.7
021248-2	CANYON DE CHELLY	AZ	5540	1970	2004	1.8	0.9	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.6	5.5
021634-2	CHINLE	AZ	5540	1908	1970	3.4	2.3	1.5	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.9	3.4	10.0
022099-2	COPPER MINE TRADING POS	AZ	6380	1948	1976	1.5	0.8	1.4	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.6	6.2
022545-2	DINNEHOTSO	AZ	5020	1950	1974	3.8	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.1	6.7
023102-W	FORT DEFIANCE	AZ	6910	1897	1949	8.7	8.2	3.7	1.4	0.8	0.0	0.0	0.0	0.0	0.1	3.4	6.6	30.0
023303-2	GANADO	AZ	6360	1948	2004	4.7	4.1	3.3	0.7	0.0	0.0	0.0	0.0	0.0	0.4	2.2	5.0	20.0
024438-2	JEDDITO	AZ	6710	1948	1955	10.0	4.7	3.6	0.2	0.2	0.0	0.0	0.0	0.0	0.1	2.4	3.8	30.0
024528-2	KAIBITO	AZ	6000	1950	1961	7.8	3.3	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.9	2.5	20.0
024578-2	KAYENTA	AZ	5680	1915	1978	4.1	2.6	1.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.1	10.0
024686-2	KLAGETOH 12 WNW	AZ	6500	1959	1993	2.7	2.5	2.1	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.4	2.3	10.0
024849-2	LEES FERRY	AZ	3140	1916	2004	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	2.1
024872-2	LEUPP	AZ	4700	1948	1981	1.7	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.2	5.1
025129-2	LUKACHUKAI	AZ	6480	1951	2003	3.9	2.7	3.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	1.8	3.3	20.0
025204-2	MANY FARMS SCHOOL	AZ	5320	1951	1975	0.4	0.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.9	4.4
025665-2	MONUMENT VALLEY	AZ	5560	1980	2004	1.1	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.7	5.1
027440-2	ST MICHAELS 6 WNW	AZ	7640	1906	1927	5.6	5.8	3.1	0.8	0.3	0.0	0.0	0.0	0.0	0.8	2.8	7.3	30.0
027488-2	SANDERS	AZ	5930	1949	2004	2.4	1.0	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.1	1.4	6.2
027496-2	SANDERS 11 ESE	AZ	6250	1961	1986	6.2	6.2	3.0	1.7	0.4	0.0	0.0	0.0	0.0	0.5	2.6	7.0	30.0
028468-2	TEEC NOS POS	AZ	5180	1962	2004	2.2	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.1	4.8
028792-2	TUBA CITY	AZ	4940	1900	2004	1.5	0.9	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.7	6.2
029410-2	WINDOW ROCK 4 SW	AZ	6900	1937	1999	6.3	6.1	4.7	1.4	0.1	0.0	0.0	0.0	0.0	0.5	2.5	7.8	30.0
291063-1	BLOOMFIELD 3 SE	NM	5810	1914	2004	3.7	2.2	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.6	3.4	10.0
291647-1	CHACO CANYON NATL MON	NM	6140	1922	2004	3.4	2.9	1.7	0.7	0.0	0.0	0.0	0.0	0.0	0.3	1.7	3.6	10.0
292219-1	CROWNPOINT	NM	6990	1914	1969	3.8	5.7	2.2	0.8	0.1	0.0	0.0	0.0	0.0	0.2	1.7	4.4	20.0
293142-1	FARMINGTON AG SCIENCE C	NM	5630	1978	2004	2.5	3.9	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.5	2.7	10.0
293305-1	FORT WINGATE	NM	7000	1940	1966	6.9	4.0	3.5	0.6	0.0	0.0	0.0	0.1	0.0	0.7	1.8	3.7	20.0
293340-1	FRUITLAND 2 E	NM	5150	1914	2003	3.2	2.3	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.2	1.1	2.7	10.0
293420-1	GALLUP 5 E	NM	6600	1918	1979	4.4	2.3	1.6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	1.1	4.5	10.0
295290-1	LYBROOK	NM	7210	1951	2004	6.1	5.2	3.8	1.4	0.0	0.0	0.0	0.0	0.0	0.8	2.1	6.0	30.0
295685-1	MEXICAN SPRINGS	NM	6440	1944	1972	1.9	1.4	2.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.7	9.4
296098-1	NEWCOMB	NM	5570	1948	1971	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4
296465-1	OTIS	NM	6880	1914	2004	6.3	5.6	4.4	1.3	0.5	0.0	0.0	0.0	0.0	0.8	2.8	5.8	30.0
296900-1	PITT RANCH	NM	6460	1948	1968	1.5	3.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.6	8.9
298284-1	SHIPROCK	NM	4950	1926	2004	1.4	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	3.7
298524-1	STAR LAKE	NM	6640	1922	2004	4.9	3.6	2.7	1.1	0.4	0.0	0.0	0.0	0.0	0.5	1.7	3.9	20.0
298830-4	THOREAU 5 ENE	NM	7100	1930	1992	8.3	5.5	5.3	1.1	0.4	0.0	0.0	0.0	0.0	1.4	3.0	8.1	30.0
298919-1	TOHATCHI 1 ESE	NM	6420	1915	1979	3.1	2.4	1.6	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.7	3.9	10.0
298921-1	TOHATCHI 6 NE	NM	5990	1914	1992	2.2	2.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	2.7	8.6
299031-2	TORREON NAVAJO MISSION	NM	6700	1961	2004	4.9	3.8	2.7	0.9	0.2	0.0	0.0	0.0	0.0	0.7	1.9	4.2	20.0
420157-7	ANETH PLANT	UT	4620	1959	2004	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.2	2.4
420788-7	BLUFF	UT	4320	1928	2004	3.1	1.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.0	8.2
425582-7	MEXICAN HAT	UT	4250	1948	2004	1.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	3.0
425812-7	MONUMENT VALLEY MISSION	UT	5220	1961	1989	3.6	2.5	1.5	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.6	4.2	10.0

TEMPERATURE

In climates that experience freezing temperatures, the amount of surface water run-off expected during winter months increases as percolation through frozen ground is limited. The PRISM Group at Oregon State University developed a spatially gridded average annual minimum temperature and average annual maximum temperature for the climatological period 1971-2000. The PRISM average annual temperature gridded datasets were processed to contours using ESRI's Spatial Analyst software.[1] Polygons were generated and attributed with annual temperature range values as shown in Figure 16. These datasets are provided on the GIS Data DVD (DB/Climate/NN_Temp_Max.shp and DB/Climate/NN_Temp_Min.shp).

[1] Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.



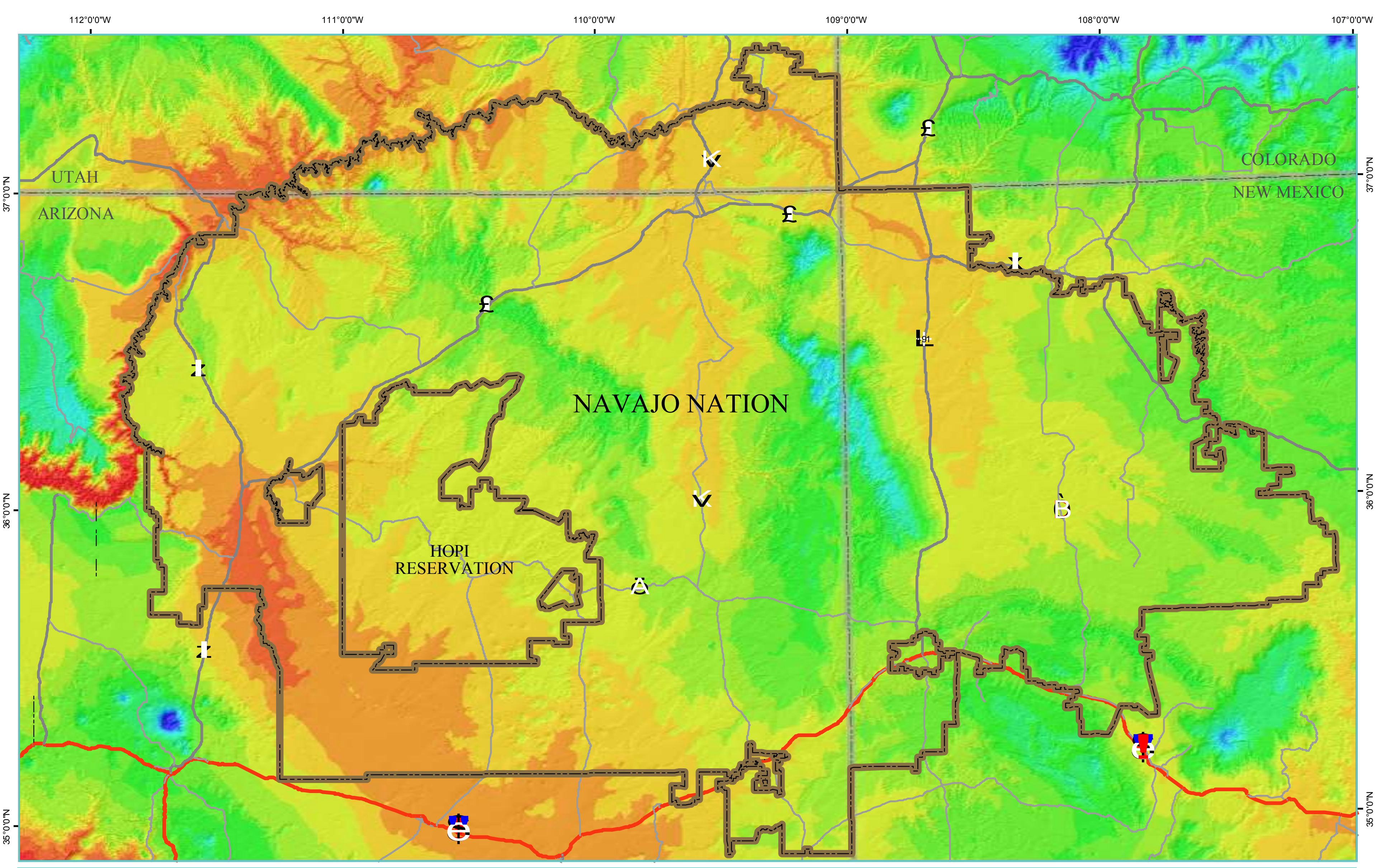
NAVAJO NATION AVERAGE ANNUAL MINIMUM TEMPERATURE: 1971 - 2000

Source
(30 year average) from PRISM Group at Oregon
Gridded average daily minimum temperature
State University, and contoured by TerraSpectra Geomatics.
Filename: DB/Climate/NN_Temp_Min.shp

0 50 Miles
Map Scale 1:1,900,000

Average Annual Minimum Temperature (°F)

<22	30-32	40-42
24-26 / 22-24	34-36 / 32-34	44-46 / 42-44
26-28	36-38	>46
28-30	38-40	



NAVAJO NATION AVERAGE ANNUAL MAXIMUM TEMPERATURE: 1971 - 2000

(30 year average) from PRISM Group at Oregon
Source
Gridded average daily maximum temperature
State University, and contoured by TerraSpectra Geomatics.
Filename: DB/Climate/NN_Temp_Max.shp

0 50 Miles
Map Scale 1:1,900,000

Average Annual Maximum Temperature (°F)

50-52 / <48	60-62 / 56-58	70-72 / 66-68
48-50	58-60	68-70
52-54	62-64	72-74
54-56	64-66	>74

Figure 16. Navajo Nation Average Annual Minimum and Maximum Temperatures: 1971 - 2000.

CLIMATE (continued)

WIND

Wind speeds on the Navajo Nation are usually moderate, although relatively strong winds often accompany frontal activity during late winter and spring months and sometimes occur in advance of thunderstorms. Frontal winds may exceed 30 miles per hour (mph) for several hours and reach peak speeds of more than 50 mph. Spring is generally the windy season. Blowing dust and serious soil erosion of unprotected fields may be a problem during dry periods (DRI, 2003-S08020302; 2003-S08020303; 2007-S05270703).

High Resolution Wind Data
The Department of Energy's Wind Program and the National Renewable Energy Laboratory (NREL) published new wind resource maps for the states of Arizona, Colorado, New Mexico, and Utah. These resource maps show wind speed estimates at 50 meters above the ground and the depict the resource that could be used for utility-scale wind development. Future plans are to provide wind speed estimates at 30 meters, which are useful for identifying small wind turbine opportunities.

As a renewable resource, wind is classified according to wind power classes, which are based on typical wind speeds. These classes range from Class 1 (the lowest) to Class 7 (the highest). In general, at 50 meters, wind power Class 4 or higher can be useful for generating wind power with large turbines. Class 4 and above are considered good resources. Figure 17 indicates that there are areas on the Navajo Nation with wind resources consistent with utility-scale production. This dataset is presented as an indication of potential increased hazard for the air pathway, especially where AUMs are located in higher wind power class areas.

The individual state datasets (Arizona, Colorado, New Mexico, and Utah) were processed into a GIS dataset for the Navajo Nation. The Wind Resources data are provided on the GIS Data DVD (DB/Climate/NN_Wind_Power.shp).

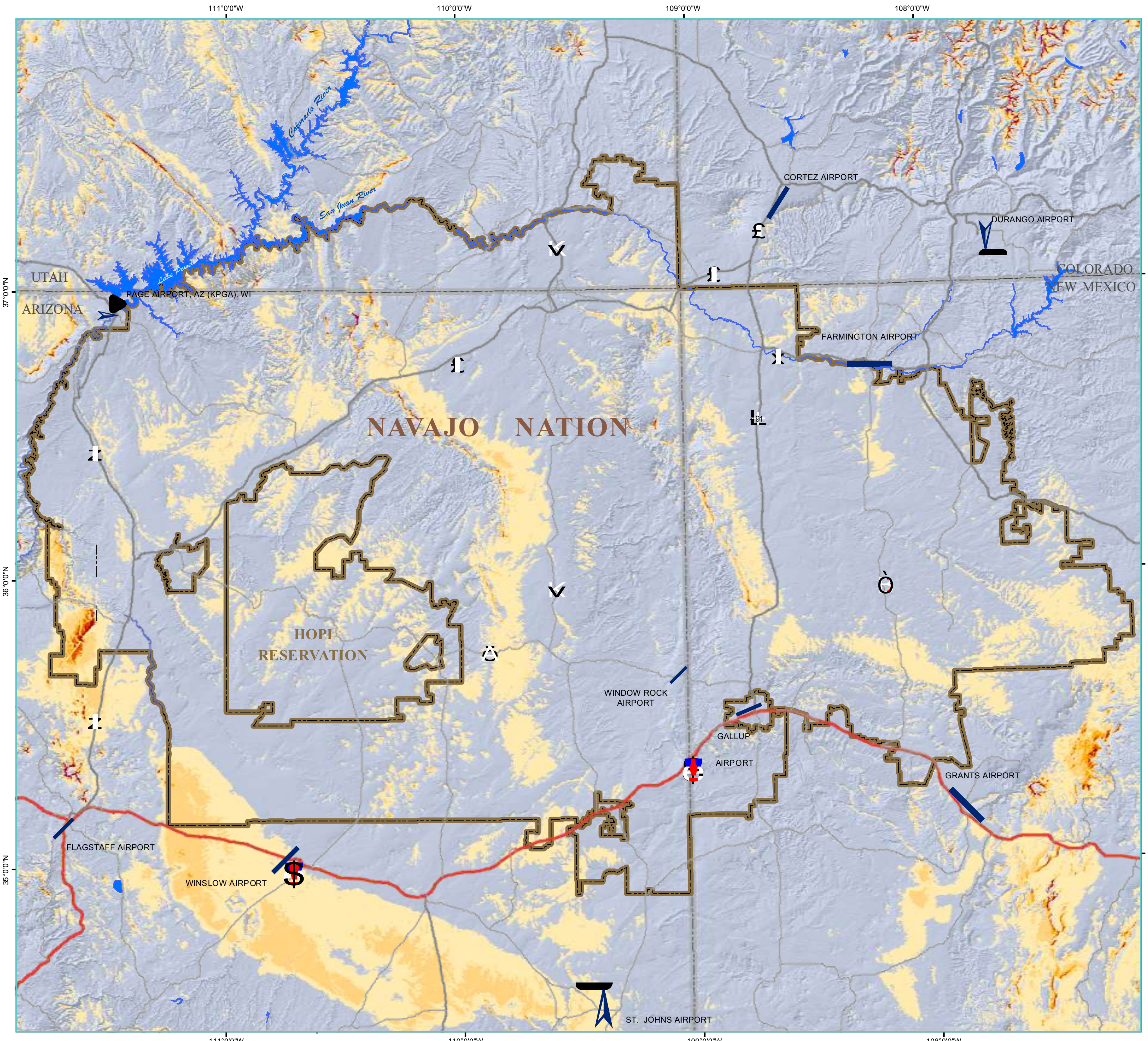
Average Annual Wind Speeds and Average Annual Prevailing Wind Direction
The Western Regional Climate Center (WRCC) is administered by the National Oceanic and Atmospheric Administration and provides monthly average wind speeds. These data are based on hourly observations from all reporting airports in the Western United States, and were collected from 1992-2002. Some stations began operation after 1992. All stations have at least 2 years of hourly data used for the averages. The standard anemometer height for all current stations is 10 meters.

WRCC also provides average annual wind direction. Prevailing wind direction is based on the hourly data from 1992-2002 and is defined as the direction with the highest percent of frequency. Many of these locations have very close secondary maximum which can lead to noticeable differences month to month.

Figure 17 shows the reporting locations, average annual wind speed, and prevailing wind directions for stations located on or near the Navajo Nation. The dataset that is provided on the GIS Data DVD (DB/Climate/NN_Wind.shp) was processed to include only those locations that are located on or proximal to the Navajo Nation. Average monthly wind speed is also tabulated and shown in Table 2. Attribute information in the dataset also provides average wind direction by month and average annual wind direction.

Table 2. Average Wind Speed by Month and Average Annual Wind Speed On and Near the Navajo Nation.

STATION	STATE	ELEV (M)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE ANNUAL
FLAGSTAFF AP, AZ (KFLG). WI	AZ	2137	5.9	6.5	6.2	7.5	7.3	7.1	5.4	4.3	4.7	5.1	5.7	5.9	6.0
GLENDALE-LUKE AFB, AZ (KLUF)	AZ	332	7.1	7.4	7.7	8.8	8.9	8.8	9.1	8.7	7.7	7.3	7.0	7.0	8.0
GRAND CANYON AP, AZ (KGCN).	AZ	2014	5.8	6.9	6.7	7.8	7.9	7.8	6.0	5.1	5.8	5.6	5.7	5.8	6.4
PAGE AIRPORT, AZ (KPGA). WI	AZ	1304	3.4	4.3	5.3	6.5	6.6	6.7	5.9	5.3	4.9	4.2	3.6	3.1	4.9
PHOENIX SKY HARBOR AP, AZ (K	AZ	337	4.9	5.5	6.0	6.8	6.8	6.6	6.7	6.7	5.9	5.3	4.7	4.4	5.8
PHOENIX-DEER VALLEY AP, AZ (	AZ	450	5.5	6.3	6.9	8.6	8.6	8.7	8.5	8.5	7.7	6.8	6.0	5.4	7.3
PRESCOTT AIRPORT, AZ (KPRC).	AZ	1537	6.9	7.7	8.3	9.3	9.2	9.3	8.2	7.2	7.3	7.1	6.6	6.6	7.8
SCOTTSDALE AP, AZ (KSDL). W	AZ	460	4.0	4.9	5.5	6.6	6.9	6.8	6.9	6.6	6.1	5.0	4.1	3.5	5.5
ST. JOHNS AP, AZ (KSJN). WI	AZ	1747	6.4	8.2	8.7	10.9	10.4	9.7	8.0	6.7	6.9	6.5	6.0	5.5	7.7
WINDOW ROCK AP, AZ (KRQE).	AZ	2055	4.6	5.6	6.6	8.6	8.1	7.3	5.4	4.4	4.8	4.5	4.1	4.1	5.6
WINSLOW AIRPORT, AZ (KINW).	AZ	1488	6.6	7.5	8.4	10.0	10.0	9.7	8.5	7.5	7.3	6.6	6.3	6.0	7.9
CORTEZ AP, CO (KCEZ). WIND	CO	1803	6.0	7.0	8.0	9.0	9.0	9.0	7.0	6.0	7.0	7.0	6.0	6.0	7.0
DURANGO AIRPORT, CO (KDRO).	CO	2038	5.0	6.0	7.0	8.0	8.0	7.0	6.0	6.0	6.0	6.0	5.0	5.0	6.0
MONUMENT PASS, CO (KMNH). WI	CO	3365	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
WOLF CREEK PASS, CO (KCPW).	CO	3243	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
ALBUQUERQUE-DOUBLE EAGLE II	NM	1779	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0	-999.0
ALBUQUERQUE INT'L AP, NM (KA	NM	1620	7.1	8.1	8.8	9.8	9.4	9.0	8.0	7.4	7.2	7.5	7.1	6.9	8.0
FARMINGTON AP, NM (KFMN). W	NM	1677	7.9	8.4	9.1	9.9	9.6	9.3	8.7	7.9	7.8	7.9	7.8	7.0	8.5
GALLUP AIRPORT, NM (KGUP).	NM	1972	5.7	6.7	7.5	9.1	8.7	8.1	6.9	5.9	5.9	5.7	5.3	4.9	6.7
GRANTS AIRPORT, NM (KGNT).	NM	1987	7.7	9.2	9.8	11.0	10.3	9.9	8.0	7.3	7.8	8.6	7.7	7.5	8.7
LOS ALAMOS AP, NM (KLAM). W	NM	2179	3.6	5.0	5.7	6.4	6.5	5.9	5.1	4.2	4.8	4.9	3.9	3.4	5.0
SANTA FE AIRPORT, NM (KSAF).	NM	1934	9.6	10.2	10.7	11.7	11.3	11.0	9.8	9.3	9.4	9.7	9.2	8.7	10.0
BRYCE CANYON AP, UT (KBCE).	UT	2312	8.4	8.9	9.1	10.6	10.0	10.1	8.5	8.5	8.7	8.4	8.2	6.9	8.8
CEDAR CITY AP, UT (KCDC).	UT	1714	7.2	7.6	8.4	9.1	9.4	9.3	8.5	8.2	7.5	6.7	6.5	6.6	7.9



ABANDONED URANIUM MINES AND THE NAVAJO NATION

NAVAJO NATION WIND RESOURCES

0 50 Miles

Map Scale 1:1,750,000

Dust storm near Monument Valley.
Photo taken September 30, 2004 by TerraSpectra Geomatics.

Legend

AVERAGE ANNUAL WIND SPEED (MPH) AND PREVAILING WIND DIRECTION

- 4.9
- 5.0 - 5.9
- 6.0 - 6.9
- 7.0 - 7.9
- 8.0 - 8.9
- 9.0 -10.0

WIND POWER CLASS	RESOURCE POTENTIAL	WIND SPEED AT 50 METERS (MPH)
1	Poor	0.0 - 12.5
2	Marginal	12.5 - 14.3
3	Fair	14.3 - 15.7
4	Good	15.7 - 16.8
5	Excellent	16.8 - 17.9
6	Outstanding	17.9 - 19.7
7	Superb	> 19.7

Source

The wind resource data is from the U.S. Department of Energy's National Renewable Energy Laboratory (NERL).
Filename: DB/Climate/NN_Wind_Power.shp

Average annual wind speed and average annual prevailing wind direction is from the Western Regional Climate Center (WRCC).
Filename: DB/Climate/NN_Wind.shp

Figure 17. Navajo Nation Wind Resources.

ELEVATION AND TOPOGRAPHY

Information about the elevation and topography of a region can provide useful insights into many natural systems, such as the climate, soil development, and vegetation. Much of the Navajo Nation is comprised of plateau-like features 4,000 - 7,000 feet above mean sea level. Rising to elevations of more than 8,000 feet are Navajo Mountain, Defiance Plateau, the Carrizo, Chuska, and Zuni Mountains, and the northern part of Black Mesa. Conversely, the deep canyons of the Colorado River (Grand, Marble, and Glen Canyons), the San Juan Canyon, and the canyon of the Little Colorado River are at elevations of less than 3,000 feet. Generally, the valleys of the Little Colorado, Chaco, and San Juan Rivers and the Chinle Wash range from 4,000 to 5,500 feet in elevation. The highest point on the Navajo Nation is Navajo Mountain in southeastern Utah, at about 10,346 feet and the lowest point is the mouth of the Little Colorado River at about 2,800 feet elevation (Cooley et al., 1969 - S10290201)

Topographic data can be used as an important parameter in evaluating the likelihood of potential hazardous material transport to ground water through infiltration or surface water through runoff. This section discusses Digital Elevation Model data and some of the useful derivative products that can be generated.

DIGITAL ELEVATION MODEL DATA

A Digital Elevation Model (DEM) is a numerical representation of the elevation of terrain. DEM data files contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. The data typically is stored in a grid format, with pairs of geographic coordinates (x,y) and corresponding elevation values (z). The intervals between each of the grid points will always be referenced to some geographical coordinate system. This is usually either latitude-longitude or UTM (Universal Transverse Mercator) coordinate systems. The closer together the grid points are located, the more detailed the information will be. The details of the peaks and valleys in the terrain will be better modeled with a small grid spacing than when the grid intervals are very large. Spot elevations, other than at the specific grid point locations, are not contained in the file. As a result, summits and valley points that are not coincident with the grid are not be recorded in the file.

The USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best quality elevation data available across the United States into a seamless raster format. NED is the result of the USGS effort to provide 1:24,000-scale DEM data for the conterminous United States. NED provides data in a consistent projection (Geographic), resolution (1 arc second or approximately 30 meter), and elevation units (meters). The horizontal datum is NAD83 and the vertical datum is NAVD88.

Some areas of the Navajo Nation have more detailed 1/3 arc second (10 meter) DEM data available, but complete 10 meter coverage is not yet available for the entire Navajo Nation.

A shaded-relief representation of the conterminous United States portion of the National Elevation Dataset (NED). Elevation is portrayed as of range of colors, from dark green for low elevations to white for high elevations (USGS, 1999—S05140301)

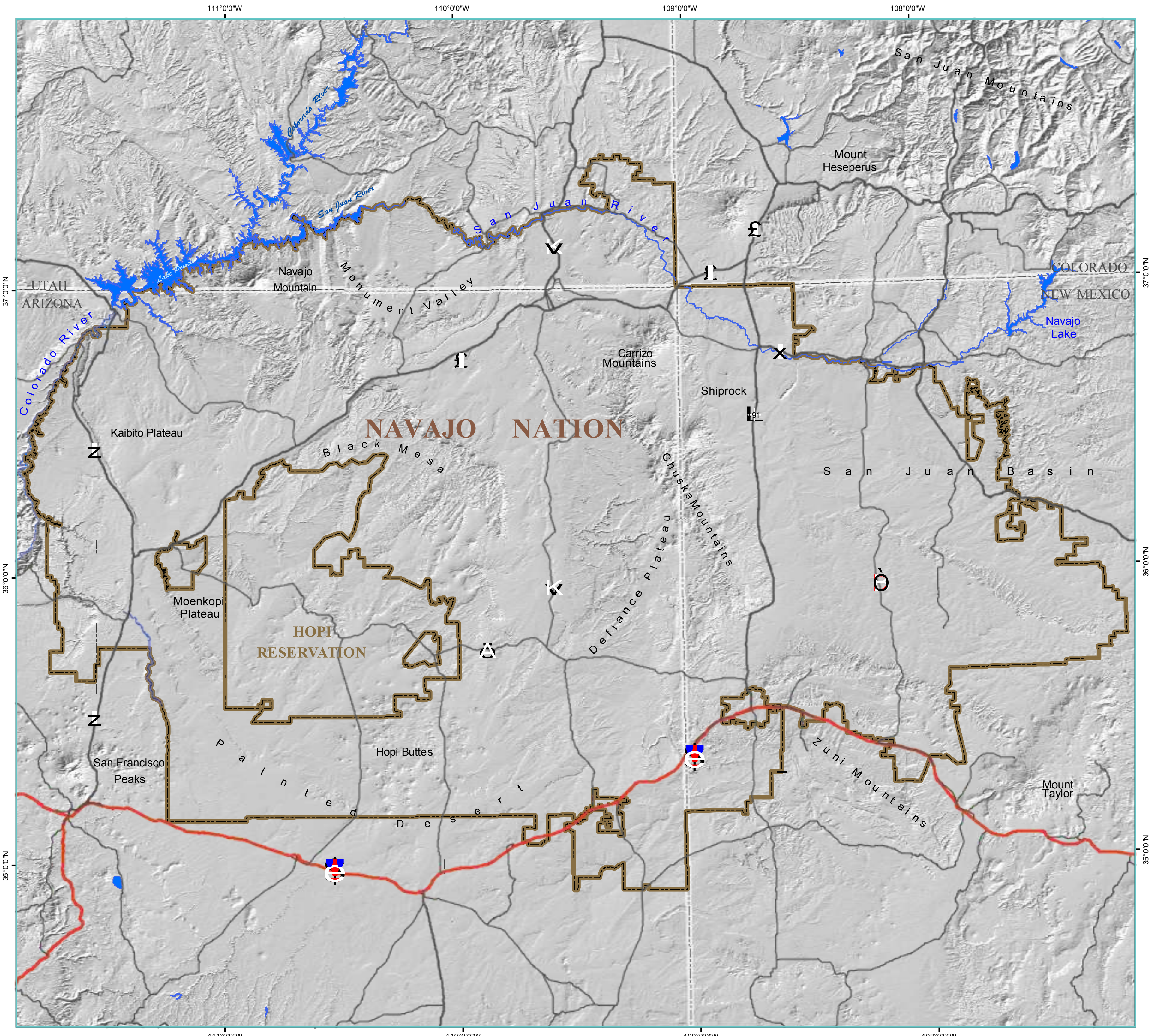
APPLICATIONS OF DEM DATA

A DEM is often an important data layer in a GIS database because elevation data are essential for many earth science applications. Elevation data are critical to many modeling applications such as hydraulic and hydrologic studies, including drainage networks, stream-flow calculations, and watershed delineations. DEMs combined with surface and sub-surface hydrologic data are used for substance transport calculations for environmental hazard analysis. DEMs can be used to create shaded-relief, elevation contours, slope, and aspect maps. The 30 meter resolution DEM for the Navajo Nation is shown as the image in the lower left corner of Figure 18. The DEM has been color-coded to enhance the elevation differences. The DEM raster dataset is provided on the GIS Data DVD (DB/Topo/NN_Elevation.img)

<u>Shaded-Relief Image Maps</u>
There are many practical applications for DEMs. One useful application is to create a shaded-relief map base from DEM data. Relief shading indicates relief by a shadow effect that results in the darkening of one side of terrain features, such as hills and ridges. The darker the shading, the steeper the slope. A shaded relief map helps the user see the topography of an area. The top map on Figure 18 is a shaded relief image of the Navajo Nation that was generated using the NED DEM. Parameters used to create the image were: Solar Azimuth - 125°; Solar Elevation - 45°; Ambient Light - 0.00; DEM scale - 2.0; and Elevation units - meters. Shaded relief maps show features on the surface, such as mountains, valleys, plateaus, and canyons. Areas that are flat or have few features are smooth on the map, whereas areas with steep slopes and mountains appear to have a rough texture. The shaded relief raster dataset is provided on the GIS Data DVD (DB/Topo/NN_Shaded_Relief.img).

<u>Slope</u>
Slope data provides an important parameter for the ground water and surface water pathway assessments. For example, for ground water assessments, the lower the slope the higher the potential for infiltration. Conversely, for surface water pathways, the lower the slope, the lower the potential for runoff. Greater slopes generally result in lower infiltration and higher runoff.

A slope image was generated for the Navajo Nation area using the NED DEM 30-meter DEM data (Figure 19). The DEM data were processed to generate a slope image using percent for the slope value. Areas that have relatively flat terrain are shown as lighter shades of green. As the slope increases, the shades of green darken. These areas correspond with the hilly and mountainous terrain of Navajo Mountain, Black Mesa and the Chuska and Carrizo Mountains. A prominent feature is Shiprock, with very steep, almost vertical slopes on the volcanic neck. The slope raster dataset is provided on the GIS Data DVD (DB/Topo/NN_slope.img).



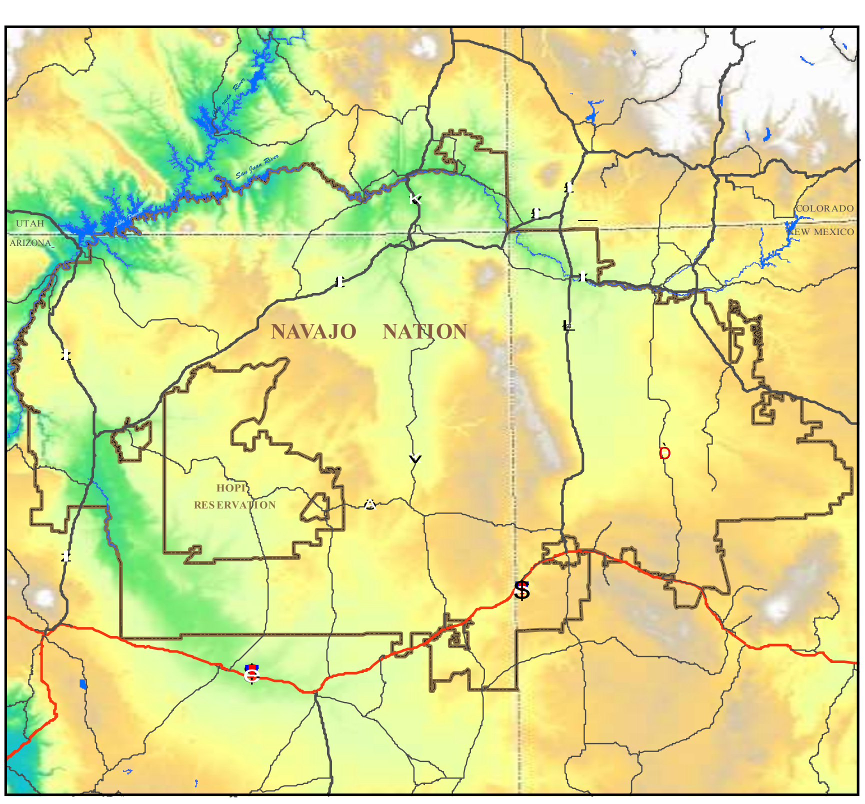
ABANDONED URANIUM MINES AND THE NAVAJO NATION

NAVAJO NATION SHADED RELIEF AND DIGITAL ELEVATION MODEL

N W E S

0 50 Miles

Map Scale 1:1,750,000



Color shaded Digital Elevation Model.

Legend

ELEVATION IN METERS

High : 3023.000000

Low : 1128.000000

Source

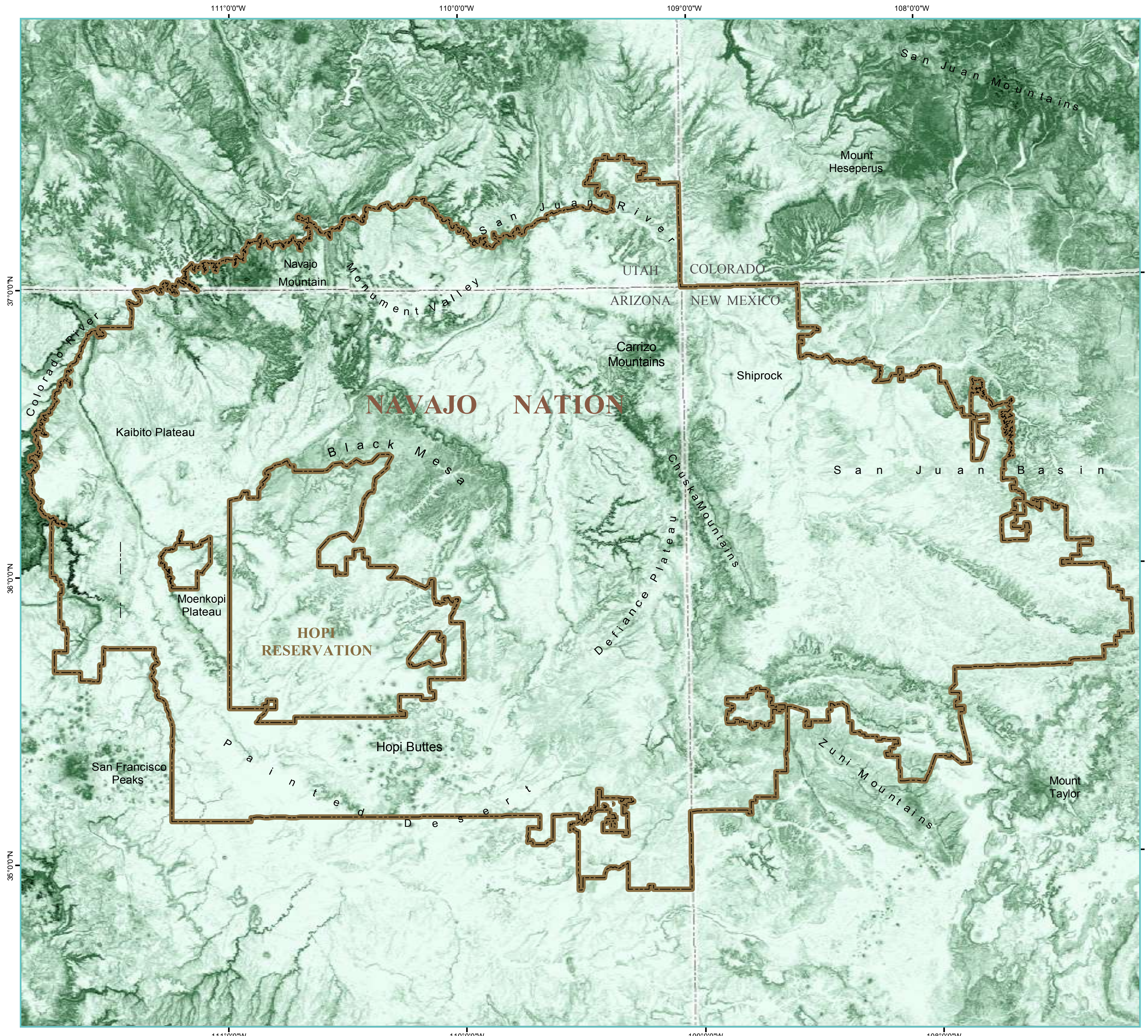
TerraSpectra Geomatics generated the shaded relief image from U.S. Geological Survey (USGS) National Elevation Dataset (NED) 30 meter resolution Digital Elevation Model (DEM) data.

Filename: DB/Topo/NN_Shaded_Relief.img

TerraSpectra Geomatics generated the color shaded DEM from USGS NED 30-meter resolution DEM data.

Filename: DB/Topo/NN_Elevation.img

Figure 18. Navajo Nation Shaded Relief and Digital Elevation Model.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

SLOPE

N
W E
S

0 50 Miles

Map Scale 1:1,750,000

Photo taken in the Lukachukai Mountains at an area with steep slope resulting in erosion.

Legend

SLOPE, IN PERCENT

0 - 2	30.1 - 35.0
2.1 - 5.0	35.1 - 40.0
5.1 - 10.0	40.1 - 45.0
10.1 - 15.0	45.1 - 50.0
15.1 - 20.0	50.1 - 75.0
20.1 - 25.0	75.1 - 100.0
25.1 - 30.0	100.1 - 198.0

Source

TerraSpectra Geomatics generated the slope image from U.S. Geological Survey (USGS) National Elevation Dataset (NED) 30 meter resolution Digital Elevation Model (DEM) data.
Filename: DB/Topo/NN_Slope.img

Note: In ERDAS IMAGINE, the relationship between percentage and degree expressions of slope is as follows:

A 45 degree angle is considered a 100% slope
A 90 degree angle is considered a 200% slope

Slopes less than 45 degrees fall within the 1 - 100% range
Slopes between 45 degrees and 90 degrees are expressed as 100 - 200% slopes

Figure 19. Slope (in percent) On the Navajo Nation.

PHYSIOGRAPHY

The word physiography is derived from the Greek word "*Physike*" meaning the science of nature. Physiography is the study of the earth's physical features and the processes that have shaped the landscape. A seminal classification system was developed by Nevin Fenneman in order to help understand and describe regional landscape characteristics. A map resulting from his work was compiled in 1946 for the entire United States at a scale of 1:7,000,000 and titled "Physical Divisions of the United States" (Fenneman, 1946 - S04180301). The United States was divided into eight major divisions, 25 provinces, and 86 sections representing distinctive areas having common topography, rock types and structure, as well as geologic and geomorphic history. The entire Navajo Nation is contained within the Intermontaine Plateaus division and Colorado Plateau province.

The Colorado Plateau province is further separated into physiographic sections on the basis of the distribution of canyons, rock benches, mesas, and plains. Fenneman divided the Colorado Plateau province into the following six sections: Grand Canyon, High Plateaus of Utah (rock terraces of southern Utah), Uinta Basin, Canyon Lands of Utah, Navajo section, and Datil section (Cooley et al., 1969 - S10290201). Figure 20 shows the boundaries of the sections within Fenneman's Colorado Plateau province that cover the Navajo Nation.

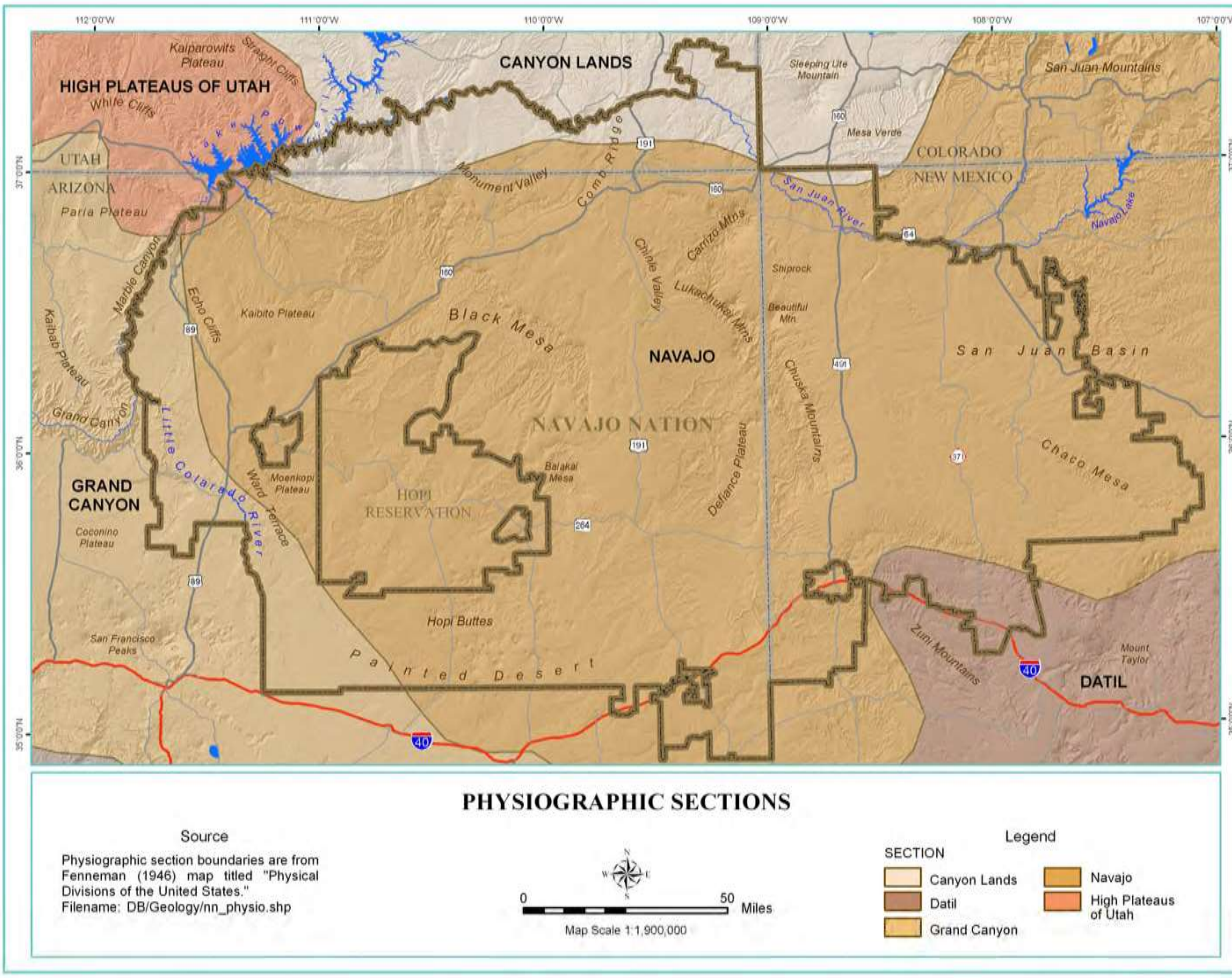


Figure 20. Physiographic Sections On the Navajo Nation.

The Defiance Plateau, Chuska, Lukachukai, and Carrizo Mountains form the area of the Defiance Uplift that splits the Navajo Nation physiographically and geologically. On the east side is the structurally low San Juan Basin, and on the west side is the structurally low Black Mesa Basin where Black Mesa is at the center. The Zuni Uplift at the location of the Zuni Mountains in New Mexico is another structural uplift at the southeastern margin of the Navajo Nation. The dramatic mesas of Monument Valley are the result of another broad uplift called the Monument Uplift.

These broad gentle upwarps are characteristic of the Colorado Plateau. The southern and eastern flanks of the Monument Upwarp in Arizona and Utah are where the Shinarump hosted uranium deposits are located, while the Defiance Uplift is the location of Morrison hosted uranium in Arizona and New Mexico.

This dataset is provided on the GIS Data DVD (DB/Geology/nn_physio.shp). Attributes include Fenneman division, province, and section codes and names.

GEOLOGY

URANIUM BEARING FORMATIONS ON THE NAVAJO NATION

The Navajo Nation occurs within the Colorado Plateau that is characterized by a relatively complete and continuous sequence of flat-lying Paleozoic and Mesozoic sediments (Figure 22) that are gently deformed by a series of folds and monoclines (Scarborough, 1981 – S09240202). These Mesozoic sediments are the dominant host of uranium and vanadium. Table 3 shows the amount of uranium production by host rock on or within one mile of the Navajo Nation.

Table 3. Uranium Production On or Within One (1) Mile of the Navajo Nation.

URANIUM BEARING HOST ROCKS	Pounds U_3O_8 Produced
Tertiary Bidahochi Formation	580
Cretaceous Dakota Sandstone	458,306
Cretaceous Toreva Formation	55,739
Jurassic Kayenta Formation	547
Jurassic Morrison Formation	98,662,464
Jurassic Navajo Sandstone	229
Jurassic Todilto Limestone	3,116,806
Triassic Chinle Formation	10,033,780
Total Navajo Nation (+ 1 Mile)	**112,328,451**

An understanding of uranium and where it is located on the Navajo Nation requires an understanding of the geology. The original sources of uranium are igneous rocks, but the ore deposits occur in sedimentary rocks. Broad, gentle upwarps are characteristic of the Colorado Plateau, and play a role in the location of uranium mines. The southern and eastern margins of the Monument Uplift in Arizona and Utah are the location of the uranium-mineralized Shinarump Member of the Upper Triassic Chinle Formation. At the center of the uplift the Chinle is eroded away. Likewise, the margins of the northern end of the Defiance Uplift and the northern flank of the Zuni Uplift are the locations of the uranium-mineralized Upper Jurassic Morrison Formation. Cameron, Arizona is the location of another outcropping of the Chinle Formation, where the uranium-mineralized Shinarump and Painted Forest Members are exposed. These rocks, being older, are exposed farther southwest from the very broad Black Mesa Basin. The uranium-mineralized upper sandstone member of the younger upper Cretaceous Toreva Formation is located near the center of the basin.

These areas characterize the southern part of the Colorado Plateau Uranium Province (Finch, 1996 - S05310701). These formations are fluvial or stream and alluvial plain deposited rocks, where more permeable channels of sand formed pathways for uranium-mineralized fluid that were surrounded by less permeable silts and clays. These ores are characterized by tabular sandstone deposits in this region. One likely source of the uranium in these deposits are thick volcanic and related sedimentary beds that overly these host formations. Volcanic arcs that were to the west and south of the province deposited thick fine-grained ash over the host formations. Uranium was later leached from the ash and perhaps precipitated by reduction in the lower host fluvial sandstones (Finch, 1996 - S05310701). However, the source and process of precipitation is still unsettled (McLemore and Chenoweth, 2003 - S08020606). The following is a discussion of the major uranium host sedimentary rocks as well as a brief discussion of the minor host rocks. Also presented are production figures for each of the formations in each of the areas of mineralization across the Navajo Nation.

<u>Triassic Chinle Formation</u>

The Chinle Formation is mineralized in the Cameron, Arizona and the Monument Valley, Arizona and Utah areas (Chenoweth and Malan, 1973 - S10280204). In the Cameron area, the uranium ore deposits are mined mostly from open pits from the fluvial sandstones of the Shinarump and Petrified Forest Members of the Chinle (Chenoweth, 1993 - S10100239). The ore deposits in the Petrified Forest Member were in sandstone lenses up to six feet thick and one mile in length that filled paleostream channels. The Shinarump deposits were similar but smaller. The Petrified Forest Member contained most of the uranium mines and produced about 1,150,000 pounds of uranium oxide; whereas the mines in the Shinarump produced about 55,700 pounds of uranium oxide. In the Bitter Springs area, mines in the Petrified Forest Member produced 718 pounds of uranium oxide.

In the Monument Valley area, uranium was only produced from the Shinarump Member of the Chinle (Gregg and Evensen, 1989- S10020208; and Chenoweth, 1991 - S03100502). In this region the Shinarump forms the many vertical walled mesas of the landscape as erosional remnants of a great fluvial system. Figure 21 shows the uneroded remnant Shinarump paleochannels in red (Young and Malan, 1964 - S06120601). Interpreted locations for eroded Shinarump paleochannels are shown in yellow. The locations of mapped AUMs are shown in black and illustrate the strong correlation with the remnant paleochannels.

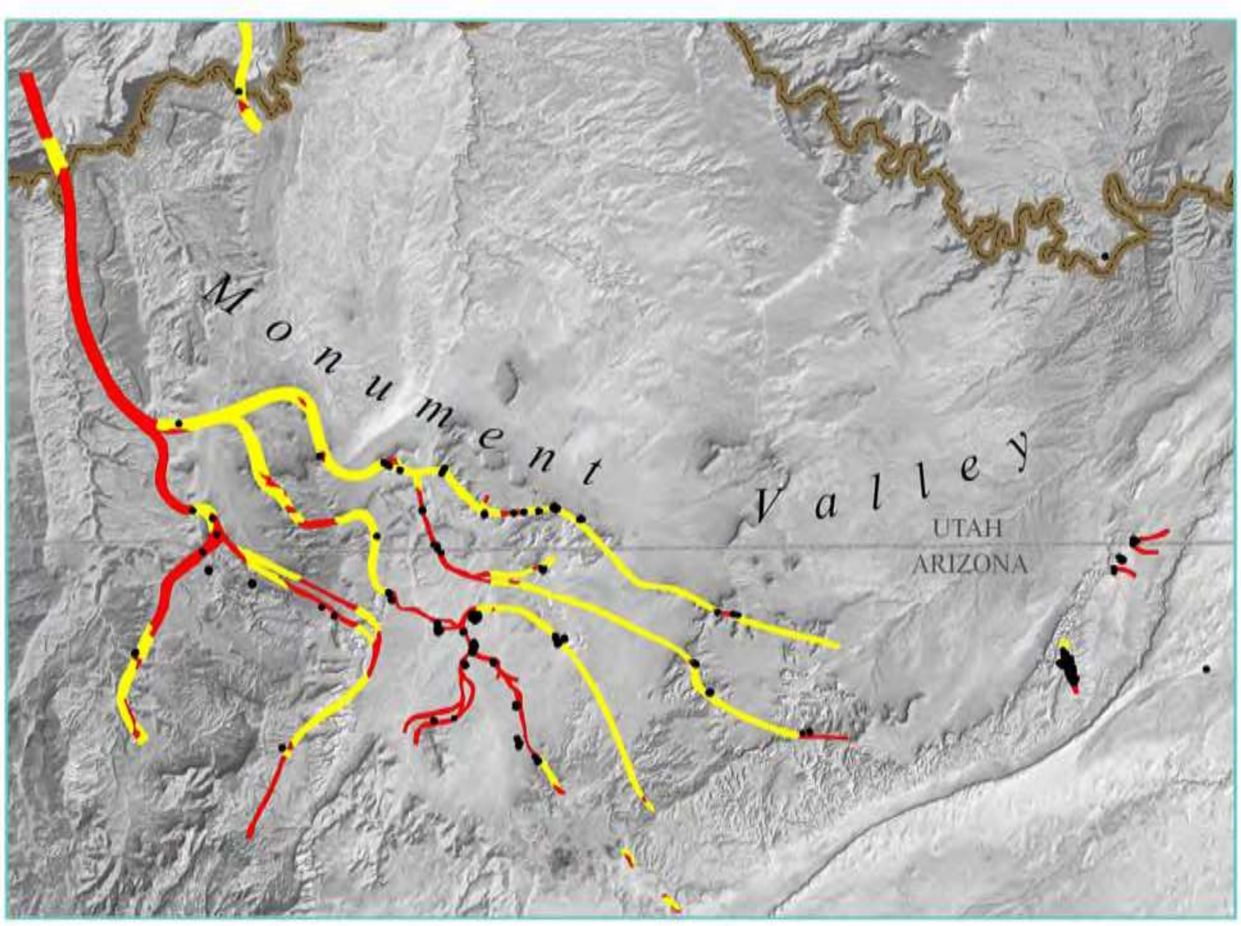
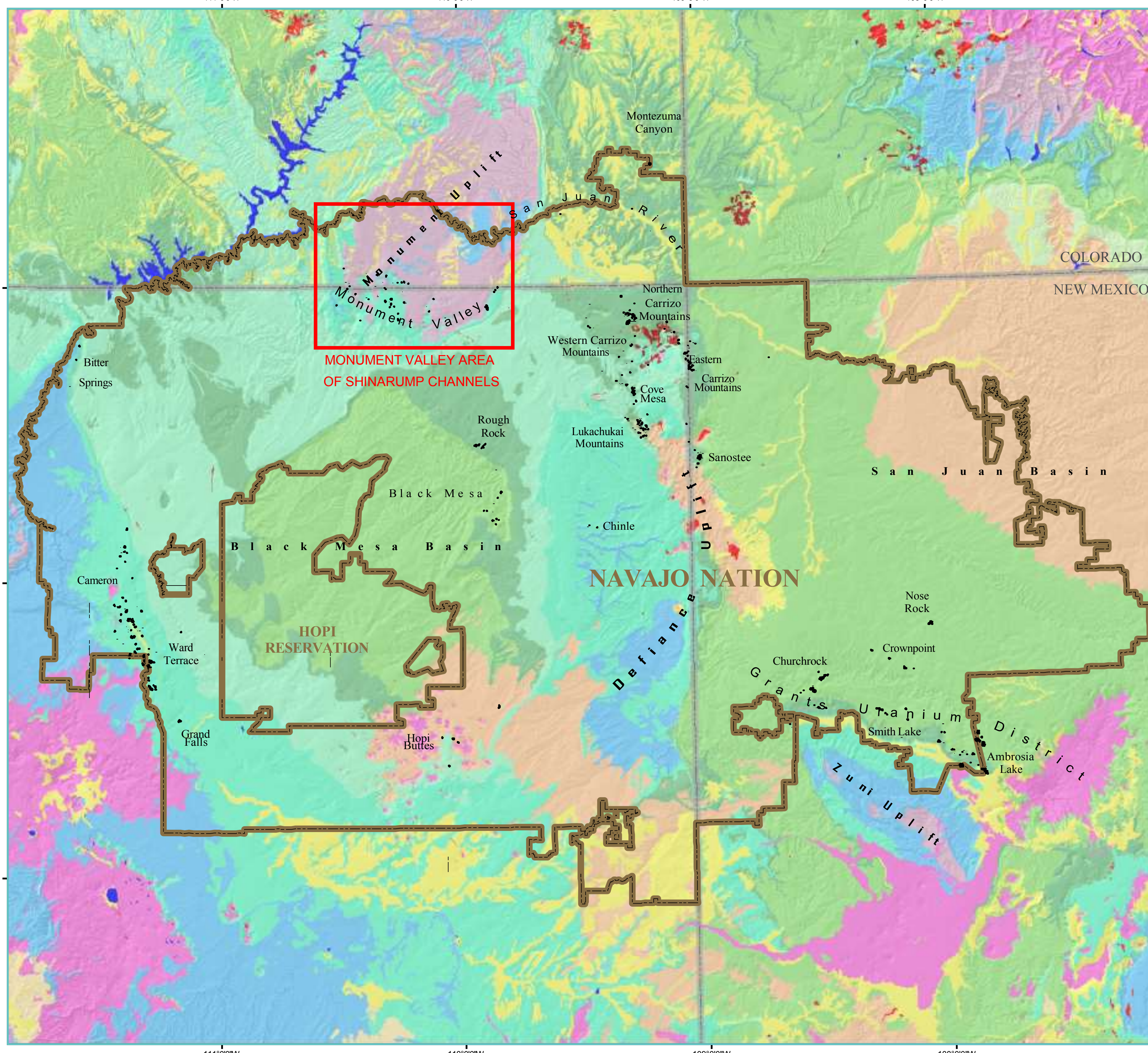


Figure 21. Shinarump Channels in the Monument Valley Area. Uranium-bearing channels of the Shinarump Member of the Triassic Chinle Formation (Young and Malan, 1964 - S06120601). Red represents the uneroded channels and yellow the estimated eroded channels. AUM locations are shown in black.

The ore deposits occurred in these channels and were up to 200 feet deep and 2,000 feet wide. The ore existed in lenses up to 8 feet thick and a few hundred feet long, with a length to width ratio up to 10 to 1. The Monument No. 2 mine, the largest producer in the region, was found in an inner scour channel that was two miles long, 700 feet wide, and 80 feet deep within an even larger Shinarump paleochannel. In the entire Monument Valley area, about 8.8 million pounds of uranium oxide were produced from the Shinarump Member.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

GEOLOGY

N
W E
S

0 50 Miles

Map Scale 1:1,750,000

View to the east across Red Wash from the Red Wash Point Mine site in the the Red Valley Chapter. The cliff on the left is the southern margin of King Tutt Mesa, showing an exposure of the Salt Wash Member of the Morrison Formation. On the right side across Red Wash is a full exposure of the Morrison from the Salt Wash Member in the wash wall to the Brushy Basin Member supporting the linear hill cutting across the photo in the background. Photo courtesy of TerraSpectra Geomatics.

Legend

List of Map Units

SEDIMENTARY ROCKS	IGNEOUS ROCKS
Quaternary	Cenozoic Intrusives
Quaternary-Tertiary	Cenozoic Volcanics
Tertiary	Tertiary-Cretaceous Intrusives
Tertiary-Cretaceous	Cretaceous Volcanics
Cretaceous	PRE-CAMBRIAN ROCKS
Jurassic	Pre-Cambrian Rocks
Jurassic-Triassic	OTHER
Triassic	Water
Paleozoic	Abandoned Uranium Mines

Source

The geologic map is from the RS/GIS Laboratory, College of Natural Resources, Utah State University (2004).

Filename: DB/Geology/NN_Geology.shp

Figure 22. Geologic Map of the Navajo Nation.

GEOLOGY (continued)

Jurassic Todilto Limestone

The Grants Uranium District is one of a few areas in the United States to produce uranium from limestone beds (Chenoweth, 1985 - S08020601). The Jurassic Todilto Limestone is found along the north side of Interstate 40 and below the Morrison rim to the north. It averages about 15 feet thick in this area (Hilpert, 1963 - S08250701). These limestone-hosted ore deposits were mostly mined in open pits. One Todilto Limestone deposit also occurs in the Sanostee area (Chenoweth, 1985 - S08250504).

Jurassic Navajo Sandstone

The Bluestone No. 1 mine, in the eastern part of Monument Valley, is the one known ore deposit on the Navajo Nation that is found in the Navajo Sandstone Formation (Chenoweth, 1991 - S10020202).

Jurassic Morrison Formation

The uranium-mineralized Morrison Formation is found in and around the Carrizo Mountains in Arizona and New Mexico, in the Rough Rock area west of Chinle, Arizona, and in the Sanostee area and along the northern flank of the Zuni Uplift in New Mexico. Chenoweth and Malan (1973 - S10280204) provide an overview of the Morrison Formation in northeastern Arizona, in which they report that the Morrison Formation is comprised of four members in ascending order: the Salt Wash, Recapture, Westwater Canyon, and Brushy Basin. In the Carrizo Mountain and Rough Rock areas it is the Westwater Canyon Member sandstones that are host to the uranium-vanadium ores. It ranges in thickness from 0 to 220 feet thick and is usually at least 180 feet thick where mineralized. Ore bodies are found in paleostream channels within lens shaped ore bodies that range up to 1,100 feet long, up to 400 feet wide and up to 22 feet thick. The ore bodies of the Lukachukai Mountains are the largest and contain less vanadium than other areas. On the northwest, north, and east flanks of the Carrizo Mountains ore bodies occur in clusters, while in the southern Carrizo's they are isolated deposits. In the Rough Rock area, ore bodies are few and small. In the Sanostee area the Salt Wash Member deposits are few and very small, whereas the Recapture Member is the largest producer (Chenoweth, 1985 - S08250504). The Enos Johnson 3 was the largest producing mine (134,438 pounds of uranium) in the Recapture and was the only mine outside the Grants Uranium District that produced during the post-AEC period (after 1970). The Morrison produced about 4.7 million pounds of uranium in Arizona and in the East Carrizo's and Sanostee areas of New Mexico.

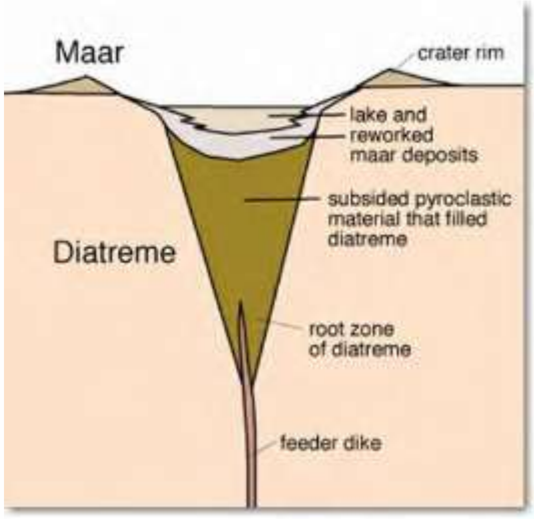
The Morrison in the Grants Uranium District dips gently northward from the Zuni Uplift into the San Juan Basin to the north, such that Morrison ore deposits are found at the surface along the rim north of Interstate 40 and at increasing depths northward (Hilpert, 1963 - S08250701). In this region, the Salt Wash Member is absent, leaving only the Recapture, Westwater Canyon, and Brushy Basin Members. Thickness ranges from 0 to 600 feet thick, averaging 450 feet. The Poison Canyon Mine, which was an economic producer, is a sandstone bed that is an intertongue of the Westwater Canyon within the Brushy Basin. The Westwater Canyon Member contains the largest number and size of ore deposits. In total, all members of the Morrison in this region produced about 94 million pounds of uranium.

Jurassic Kayenta Formation, Cretaceous Dakota Sandstone, Cretaceous Toreva Formation, and Tertiary Bidahochi Formation

Only two ore deposits (Hosteen Nez and Yellow Jeep No. 7A and 7B) are found in the Jurassic Kayenta Formation in the Ward Terrace area near Cameron, Arizona (Chenoweth, 1993 - S10100239). Several ore deposits are found in the 70 to 180 foot thick Cretaceous Dakota Sandstone in the Church Rock area. The Church Rock Mine is the most notable deposit as it is the only one to have produced from the Morrison and the Dakota (188,686 pounds of uranium).

Uranium ore deposits are found in the fluvial upper member of the Cretaceous Toreva Formation on the eastern side of Black Mesa (Chenoweth, 1990 - S10100236).

The Tertiary Bidahochi Formation is host to one productive uranium mine, the Morale Mine, found in the Hopi Buttes area of the Southern AUM Region. It is found in lake deposits of a volcanic crater (maar), likely above a buried volcanic neck (diatreme). Hopi Buttes is the largest such area in the world, containing more than 300 diatremes (Chenoweth, 1990 - S10020205)



Model of a Maar - Diatreme Volcano. Maars are low-relief volcanic craters formed by shallow phreatic explosions. The diatremes are subsurface pipes that fed the maars and were filled by volcanic material at the time of the eruption. They are now exposed because of lowering of the land surface by erosion. *From http://volcano.und.nodak.edu/vwdocs/*

GEOLOGIC MAPPING ON THE NAVAJO NATION

The geologic map (Figure 22) was produced from four state geologic maps for the Southwest Regional Gap Analysis Project. These maps were compiled at a map scale that is appropriate for regional applications. This geologic dataset is provided on the GIS Data DVD (DB/Geology/NN_Geology.shp)

In 1969, USGS published a Geological Survey Professional Paper 521-A that included a "Geologic Map of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah" at a scale of 1:125,000 (Cooley et al., 1969 - S10290201). Small portions of the map have been automated (e.g., Red Valley and Cove Chapters), but the entire map is not available in digital format. The USGS Navajo Nation Studies Program in Flagstaff, Arizona has begun a new geologic mapping project to remap the Navajo Nation. The Cameron, Arizona quadrangle is the first in a series of 30 x 60 minute quadrangles (1:100,000 scale) to be mapped, and is in a review draft stage. These maps will be made available by the USGS in GIS format.

GEOLOGY (continued)

KARST

Karst is a term used to describe a topography characterized by caves, sinkholes, and underground drainage. What distinguishes a karst landscape from other landscapes is the dominance of solution features in soluble sedimentary rocks, such as limestone and gypsum (Hill, 2003 - S06150302).

An important parameter in the evaluation of potential ground water pathways is whether an AUM site is located in an area of karst terrain. In karst formations, ground water moves rapidly through solution channels caused by dissolution of the rock materials. Therefore, hazardous substances associated with an AUM located in karst terrain would be more likely to reach the ground water (EPA, 1991 - S01230301).

Figure 23 shows areas of karst on and near the Navajo Nation. These data are from a digital version of the U.S. Geological Survey Open File Report 2004-1352, “Engineering Aspects of Karst.” The open-file report is a map with accompanying explanatory text. The map shows areas containing distinctive surficial and subterranean features that have been developed by solution of carbonate and other rocks and are characterized by closed depressions, sinking streams, and cavern openings. These areas are commonly referred to as karst. Included on the map are areas of features analogous to karst, also called pseudokarst, which is karst-like terrain produced by processes other than the dissolution of rocks.

According to this regional karst dataset, there are some areas of karst carbonate rocks on the western and southernmost edges of the Western AUM Region, on the north central edge of the North Central AUM Region, and on the southern edge of the Eastern AUM Region. Volcanic pseudokarst also is present in the southernmost area of the Western AUM Region. Unconsolidated pseudokarst is shown extending north from the south central edge of the Northern AUM Region. This is the only area on the Navajo Nation that appears to have AUMs within karst or karst-like terrain.

This dataset is provided on the GIS Data DVD (DB/Geology/NN_Karst.shp). These data are intended for geographic display and analysis at the national level, and for large regional areas. The data should be displayed and analyzed at scales appropriate for 1:7,500,000-scale data. These map layers are intended to provide users with a national scale karst data coverage to use for graphic and demonstration purposes. These data are not intended for, and should not be used for, site-specific research.

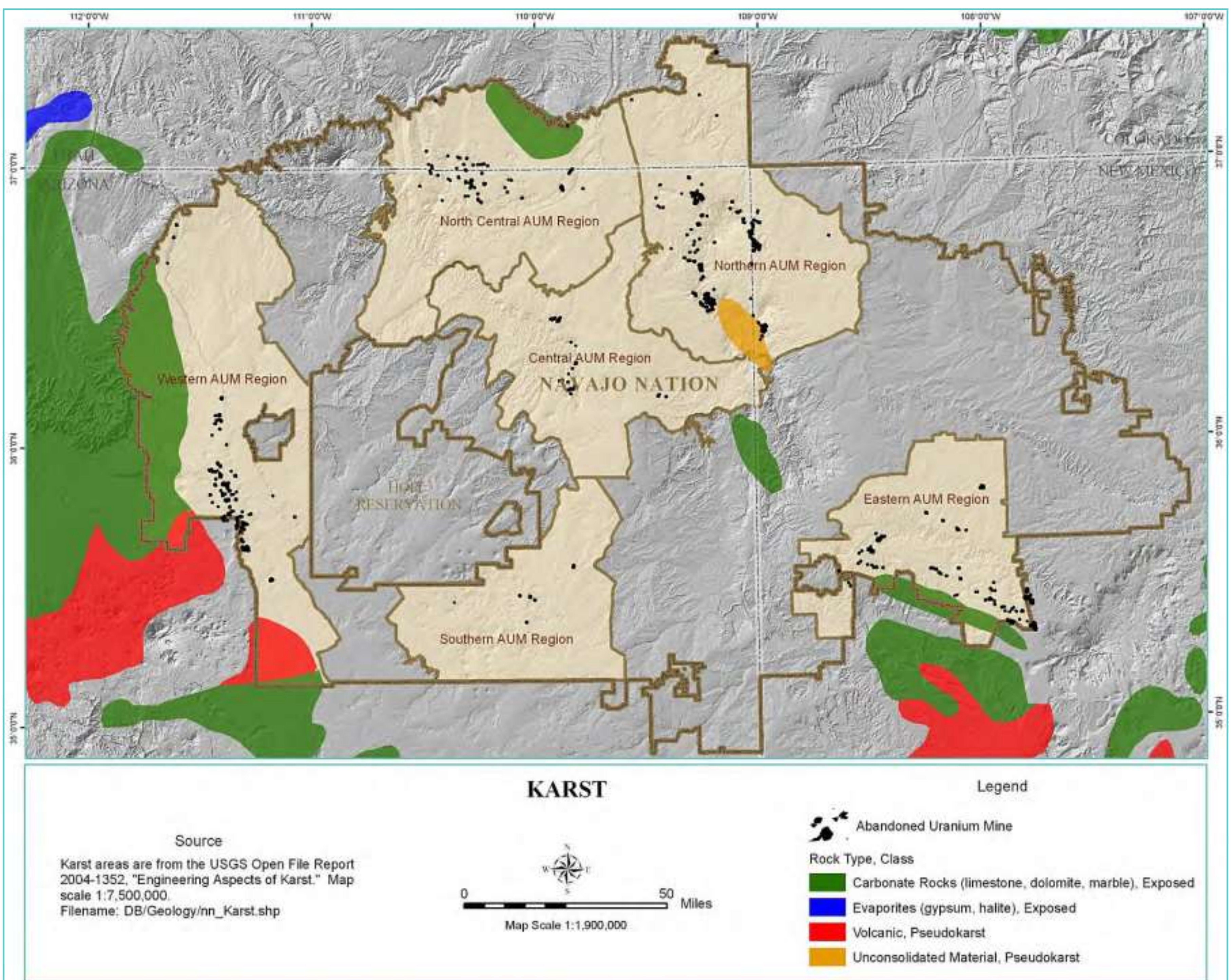


Figure 23. Karst Terrain On and Near the Navajo Nation.

GROUND WATER RESOURCES

Ground water is a potential pathway for the transport of hazardous substances. The ground water pathway is important when assessing the threat posed to drinking water and to populations relying on ground water as their source of drinking water. Evaluation of the ground water pathway requires a general understanding of the local geology and subsurface conditions. Of particular interest is descriptive information relating to the subsurface stratigraphy, permeability of the underlying strata, aquifers, and ground water use. There are two additional key considerations in the evaluation of ground water pathways: depth to aquifer and the presence of karst terrain.

COLORADO PLATEAU REGIONAL AQUIFERS

The Navajo Nation falls within the Colorado Plateau and Wyoming basin (referred to hereafter as Colorado Plateau) consolidated rock aquifer system, which covers northern Arizona, western Colorado, northwestern New Mexico, and eastern Utah (Figure 24). This area is approximately coincident with the Colorado Plateau physiographic province. The distribution of aquifers in the Colorado Plateau is controlled in part by the structural deformation and erosion that has occurred since deposition of the sediments that compose the aquifers. The principal aquifers in younger rocks are present only in basins, such as the San Juan basin. In uplifted areas, such as the Defiance Uplift, younger rocks have been eroded away, and aquifers are present in older rocks that underline more extensive parts of the Colorado Plateau area (Robson and Banta, 1995 - S06150301).

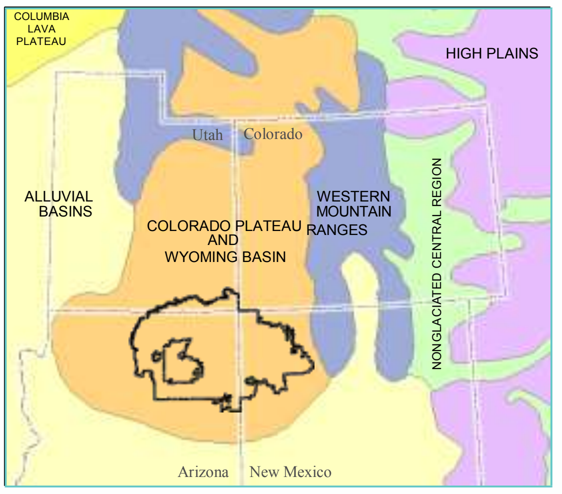


Figure 24. Ground Water Regions (from Robson and Banta, 1995 - S06150301).

For municipal water on the Navajo Nation there are several aquifers: Coconino (C), Navajo (N), Dakota (D), Morrison (M), Mesaverde, and numerous alluvial aquifers. The three primary water-bearing aquifers for the Navajo Nation are the D-, N-, and C-aquifers (Navajo Department of Water Resources [NDWR], 2000 - S12130214). Figure 25 shows the areas of aquifer recharge on the Navajo Nation and Figure 26 depicts water level contours and general direction of water movement on the Navajo Nation. These datasets are provided on the GIS Data DVD (DB/Water/NN_Aquifers.shp and NN_Water_Level_and_Direction.shp)

D-Aquifer: The Dakota, Cow Springs, Westwater Canyon Member of the Morrison Formation, and Entrada Sandstones form the D-multiple aquifer system. Recharge to the D-aquifer is from local precipitation and runoff from the Defiance Uplift to the east. Ground water flows to the west, and south from the areas of recharge (Figure 26). Some water is lost from the aquifer by downward leakage into the underlying aquifer. Water in the D-aquifer is of marginal to unsuitable chemical quality for domestic use (Arizona Department of Water Resources [ADWR], 2003 - S08030302).

N-Aquifer: The Navajo Sandstone and Wingate Sandstone are the main water-bearing units in the N-aquifer. The aquifer generally is under water-table conditions (unconfined). Precipitation falling on the exposed aquifer units is the main source of recharge for the N-aquifer. Groundwater in the N-aquifer moves southward and southeastward under Black Mesa. The flow divides under the mesa, moving westward and eastward. Water in the N-aquifer is of good quality and suitable for most uses (Cooley et al., 1969; ADWR, 2003; and NDWR, 2000).

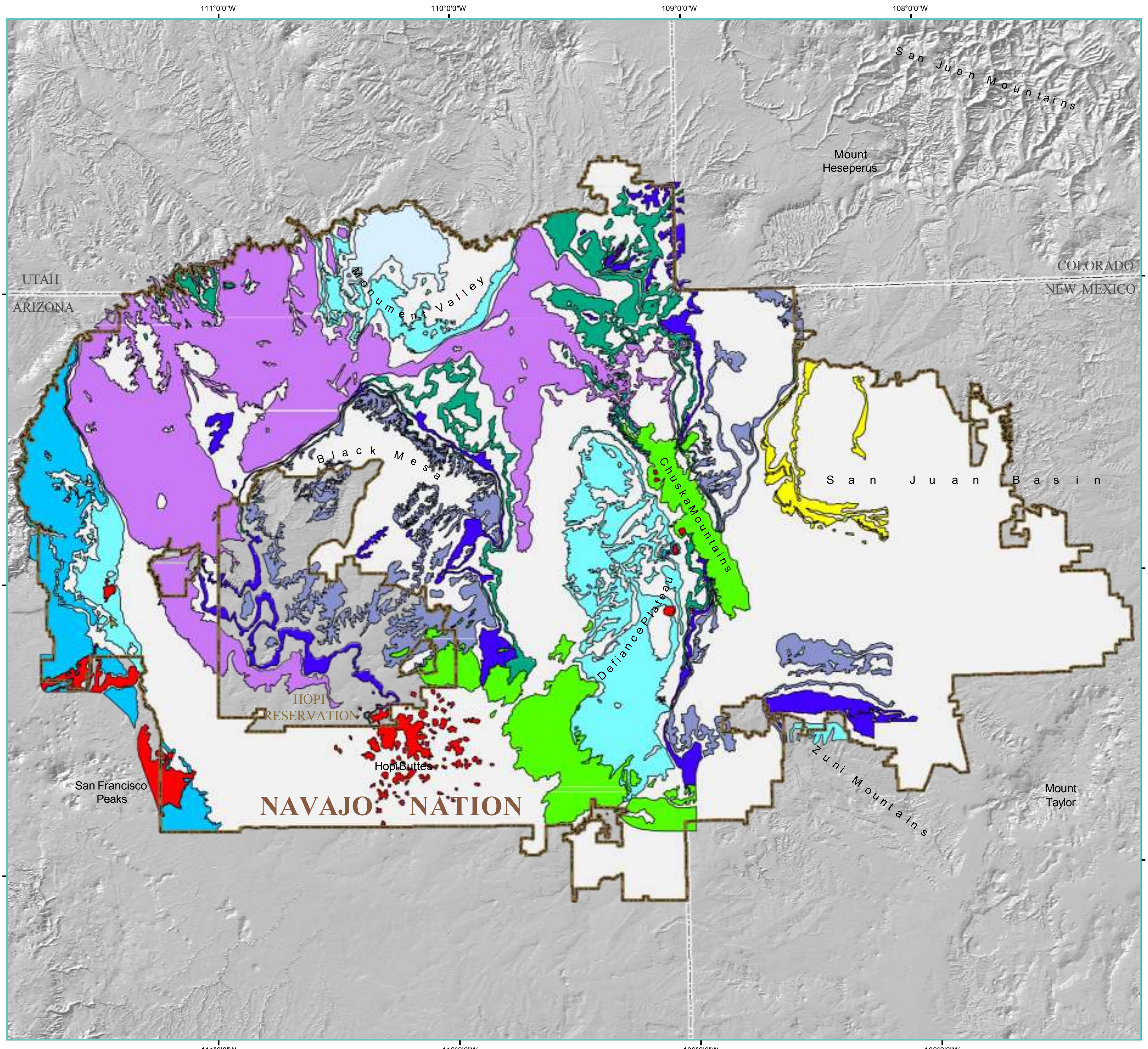
C-Aquifer: The Coconino Sandstone and its lateral equivalents, the De Chelly and Glorieta Sandstones, are the chief water-bearing units in the southern part of the Colorado Plateau. These units are interconnected hydraulically, and with the upper part of the Supai Formation, the Yeso Formation, and the San Andres Limestone, form the C-aquifer system (Cooley et al., 1969; NDWR, 2000). The C-aquifer is recharged by rainfall and by runoff from the Defiance Uplift. Ground water in the C-aquifer moves to the northwest from the large areas of inflow on the south and east (Cooley et al., 1969; ADWR, 2003, NDWR, 2000).

Local Aquifers: Water-yielding units excluded from the principal aquifers can form aquifers of local importance, but these units either are not extensive enough or are not productive enough to be considered as principal aquifers. In general, these rocks are considered to be confining units containing minor water-yielding units (Robson and Banta, 1995). Local aquifers are of importance for domestic water supplies where the three regional aquifers, the D-, N-, and C-aquifers are too deep or have unsuitable water quality (ADWR, 2003). Unconsolidated sediments and alluvial deposits, mainly of Quaternary age, have hydrologic importance (Cooley et al., 1969). The local aquifers include alluvial deposits, which occur in washes and stream channels throughout the basin and various sandstones. Water enters the alluvium as discharge from the D-, N- and C-aquifers, as streamflow infiltration, or as direct rainfall. In thicker sections the alluvium is a steady source of water, but smaller washes can go dry because of overuse or drought conditions (ADWR, 2003). The Quaternary deposits mostly are less than 30 feet thick, but are as thick as 225 feet in a few places. They form a discontinuous, rather permeable mantle. The alluvium is the chief source of water in dug wells; it is also the source of water in some springs and drilled wells. Depth to water in wells drilled in the alluvium is shallow, from a few feet to about 100 feet below the land surface (Cooley et al., 1969).

WATER SOURCES

Identifying the location of drinking water wells, the depth of the aquifer for the well, and if possible, the populations associated with a drinking water well are especially important information for contaminant pathway assessments. Depth to shallowest aquifer is an important measurement when evaluating potential contamination of ground water. An aquifer is defined by the EPA as a "saturated subsurface zone from which drinking water is drawn." The shallower a source of water, the higher the threat of contamination by hazardous substances (EPA, 1991 - S01230301).

The NDWR Water Management Branch maintains an extensive database of ground water well information, which is the primary data resource for ground water information on the Navajo Nation. For this NAUM Project, the NDWR wells dataset was augmented with data from the ADWR, New Mexico Office of the State Engineer, Utah Division of Water Rights, USACE water sample locations, USGS NHD, Geographic Names Information System, USGS Ground Water Site Investigations Database, DRGs, DOQQs, and the Church Rock Uranium Monitoring Project (CRUMP) sampled water sources. The database includes available information for: Well Identifiers (NDWR, alias names, PWSID, and USGS-ID), source of the well location, operator, type of well (artesian, mineral, observation, water or well; developed or natural spring; and unknown), use (agriculture, domestic, industry, livestock, municipal, other and unknown), well depth, and aquifer. Wells within four miles of an AUM were used as a target parameter in the HRS-derived model. Figure 27 shows the locations of water sources (symbolized by well type) within four miles of an AUM. The inset map provides an enlarged view to show better detail of the well type data and symbols. All well types were included in the analysis (only oil wells and possible oil wells were excluded). Wells outside the four mile buffers are also shown with a single point symbol. These datasets are provided on the GIS Data DVD (DB/Water/NN_Wells.shp and NN_Wells_4mi.shp).



ABANDONED URANIUM MINES AND THE NAVAJO NATION

AREAS OF AQUIFER RECHARGE ON THE NAVAJO NATION

N W E S

0 50 Miles

Map Scale 1:1,750,000

Legend

RECHARGE UNIT DESCRIPTION

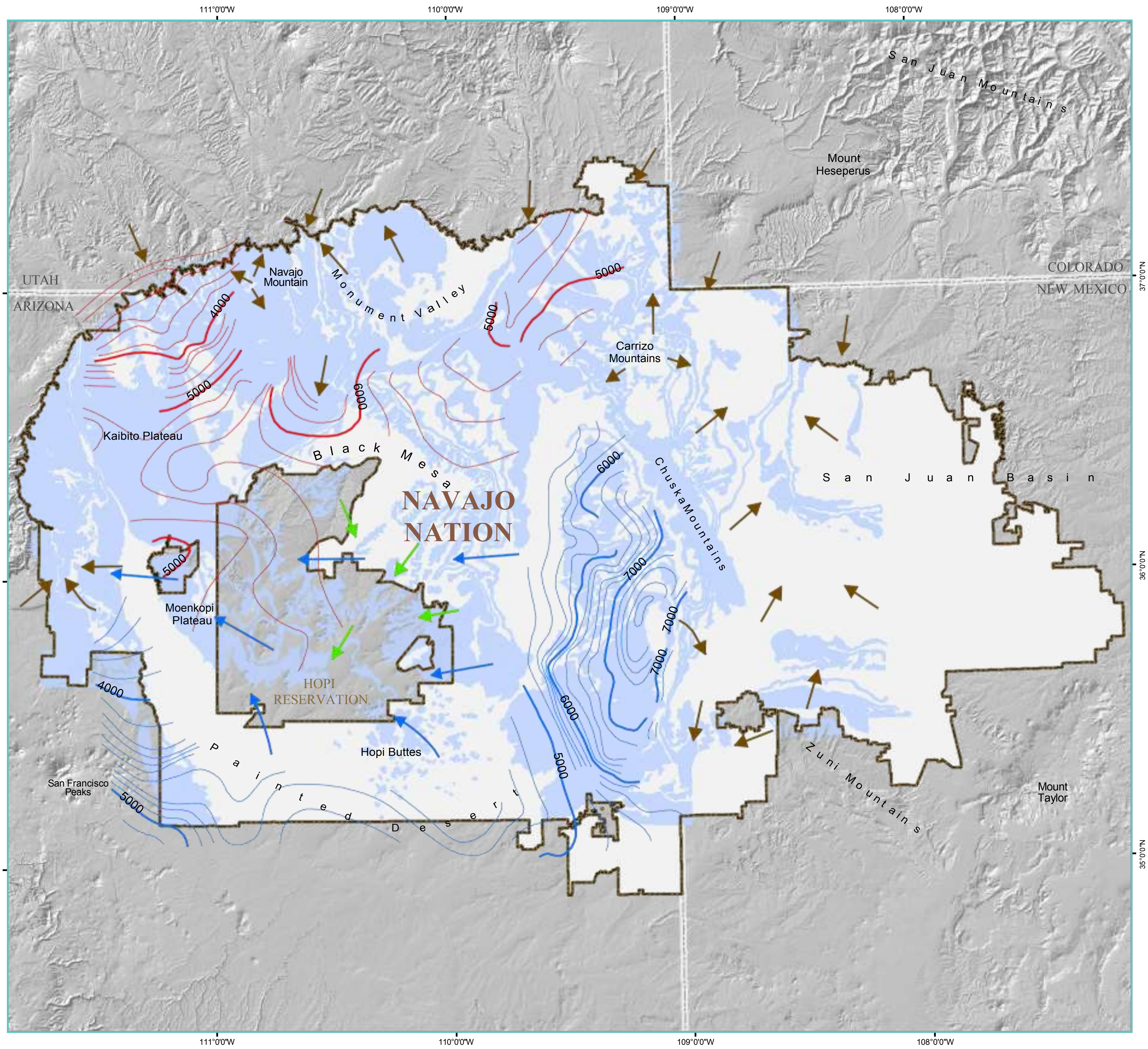
- Rocks receiving little or no recharge.
- Cedar Mesa Sandstone Member of the Cutler Formation
- Shinarump Member of the Chinle Formation, Moenkopi Formation and De Chelly Sandstone Member of the Cutler Formation in Monument Valley; Sonsela Sandstone Bed of the Petrified Foest Member and Shinarump Member of the Chinle Formation, Moenkopi Formation, and De Chelly Sandstone on the Defiance Plateau; Shinarump Member and Sonsela Sandstone Bed of the Petrified Forest Member of the Chinle Formation in the Zuni Mountains; Shinarump Member in the western part of the Navajo Nation.
- Chuska Sandstone and upper member of the Bidahochi Formation
- Rocks of the D multiple-aquifer system. Dakota Sandstone, Cow Springs Sandstone and Westwater Canyon Member of the Morrison Formation; and the Entrada Sandstone in the southern and central parts of the Navajo Nation.
- Kaibab Limestone, Toroweap Formation, and Coconino Sandstone
- Mesaverde Group. Toreva Formation and Yale Point Sandstone in Black Mesa; Gallup Sandstone and Point Lookout Sandstone in San Juan Basin.
- Salt Wash and Westwater Canyon Members of the Morrison Formation, Summerville Formation, and Bluff Sandstone in the northeastern part of the Navajo Nation; Salt Wash Member of the Morrison Formation, Summerville Formation, Bluff Sandstone, and Entrada Sandstone in the northwestern and central parts of the Navajo Nation.
- Rocks of the N multiple-aquifer system. Navajo Sandstone, sandy facies of the Kayenta Formation, and Lukachukai member of the Wingate Sandstone.
- Ojo Alamo Sandstone, Pictured Cliffs Sandstone, and Cliff House Sandstone
- Volcanic Rocks

Source

Areas of recharge and discharge of aquifers on the Navajo Nation is from Plate 5 "Map Showing Water-Level Contours, Direction of Water Movement, and Areas of Recharge and Discharge of Aquifers in the Navajo and Hopi Indian Reservations" in U.S. Geological Survey Professional Paper 521-A "Regional Hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah", by M.E. Cooley and others, 1969.

Filename: DB/Water/NN_Aquifers.shp

Figure 25. Areas of Aquifer Recharge On the Navajo Nation.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

WATER LEVEL CONTOURS, DIRECTION OF WATER MOVEMENT, AND AREAS OF RECHARGE OF AQUIFERS ON THE NAVAJO NATION

0 50 Miles

Map Scale 1:1,750,000

Source

Water level contours, direction of water movement, and areas of recharge of aquifers on the Navajo Nation are from Plate 5 "Map Showing Water-Level Contours, Direction of Water Movement, and Areas of Recharge and Discharge of Aquifers in the Navajo and Hopi Indian Reservations" in U.S. Geological Survey Professional Paper 521-A "Regional Hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah", by M.E. Cooley and others, 1969.

Filenames:

DB/Water/ NN_Water_Level_and_Direction.shp
DB/Water/NN_Aquifers.shp

Legend

WATER LEVEL CONTOURS

7000 C Aquifer Water-level Contour (contour interval 100 and 200 feet)

4000 N Aquifer Water-level Contour (contour interval 200 feet)

DIRECTION OF WATER MOVEMENT

C Aquifer Direction of Ground Water Movement

Near Surface Direction of Ground Water Movement; Near Surface Direction

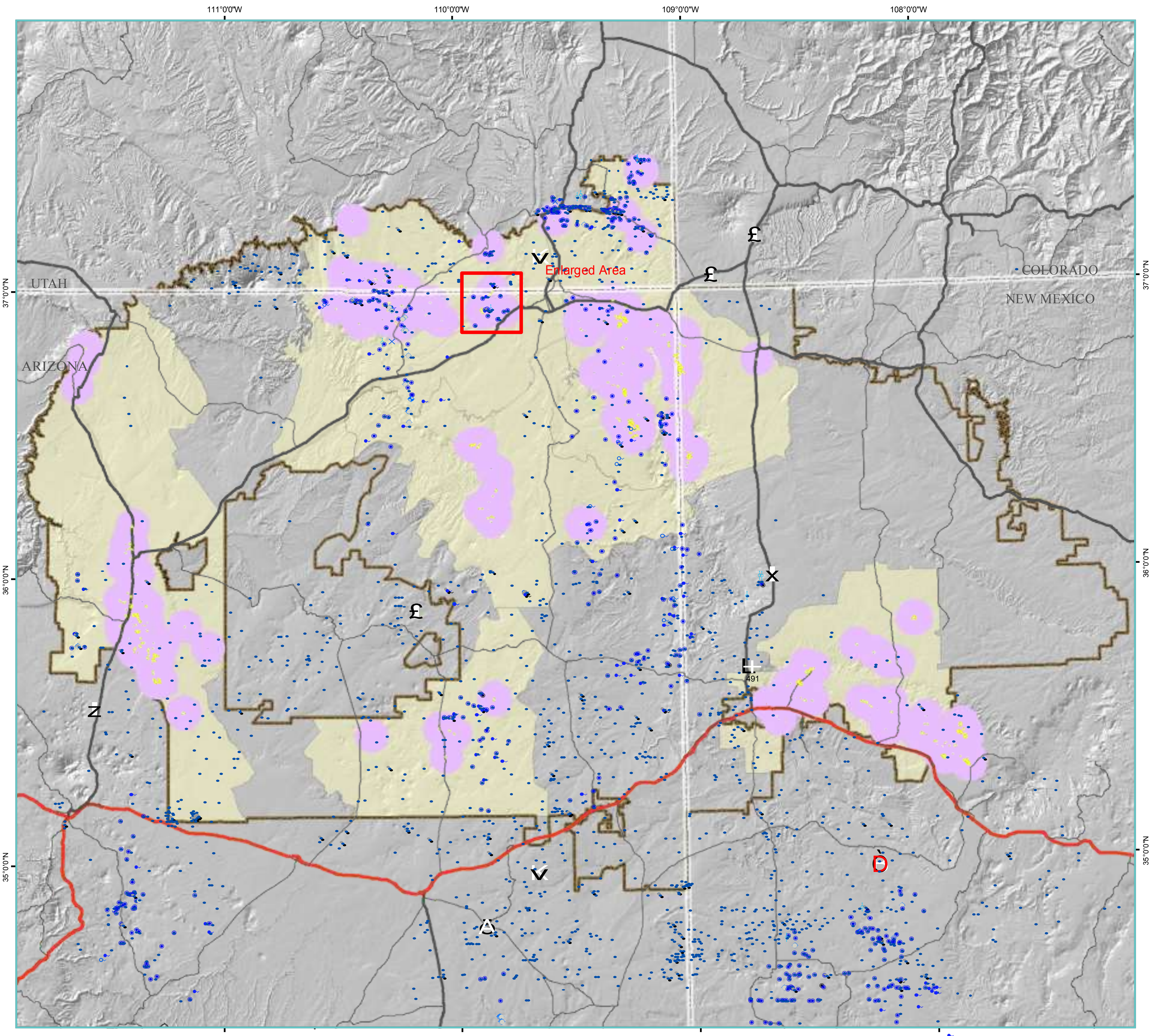
D Aquifer Direction of Ground Water Movement

RECHARGE

Rocks Receiving Recharge

Rocks Receiving Little or No Recharge

Figure 26. Water Level Contours, Direction of Water Movement, and Areas of Recharge of Aquifers On the Navajo Nation.



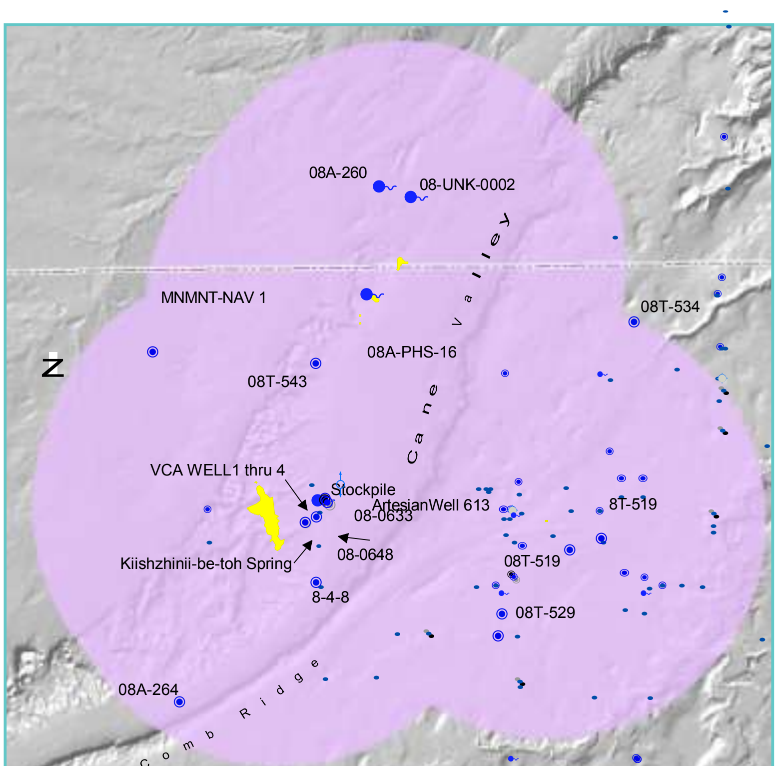
ABANDONED URANIUM MINES AND THE NAVAJO NATION

WATER SOURCES WITHIN FOUR MILES OF AN ABANDONED URANIUM MINE AND ACROSS THE NAVAJO NATION

N
W E
S

0 50 Miles

Map Scale 1:1,750,000



Enlarged view of water sources within four miles of AUMs symbolized by "well type" in the Cane Valley, Arizona and Utah area.

Legend

TYPE OF WELL WITHIN 4 MILES OF AUM

- Artesian Well
- Developed Spring
- Natural Spring
- Unknown
- Water Well
- Well

WELLS OUTSIDE THE 4 MILE BUFFER

- All Wells

- Abandoned Uranium Mine (AUM)
- 4 Mile Buffer Around AUM

Sources

Water sources are primarily from the Navajo Department of Water Resources and augmented using data from the Arizona Department of Water Resources, New Mexico Office of the State Engineer, Utah Division of Water Rights, U.S. Army Corps of Engineers water sample locations, USGS/EPA National Hydrography Dataset, USGS Geographic Names Information System, USGS Ground Water Site Investigations Database, USGS topographic quadrangles, and USGS digital orthophotography.

Filenames: DB/Water/ NN_Wells_4mi.shp and DB/Water/NN_Wells.shp

AQUIFER SENSITIVITY

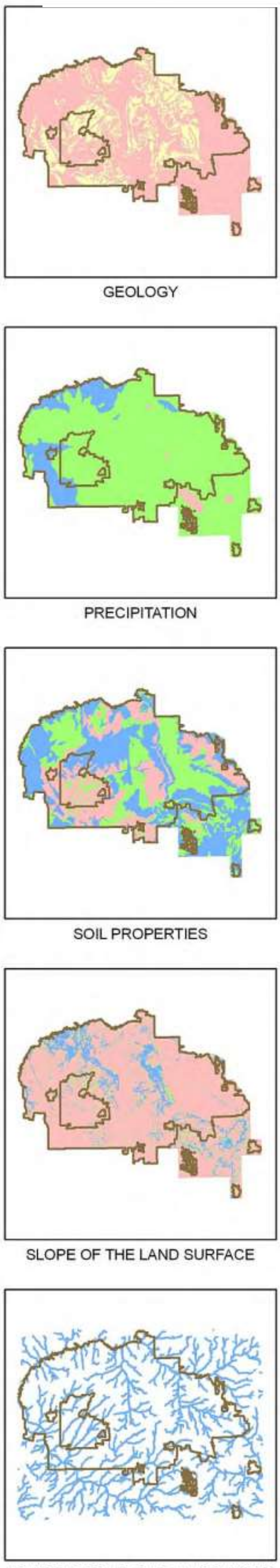


Figure 28. Inputs to Aquifer Sensitivity

Blanchard (2002 - S01200301) cites the definition of aquifer sensitivity as "the relative ease with which a contaminant applied on or near a land surface can migrate to the aquifer of interest. Aquifer sensitivity is a function of the intrinsic characteristics of the geological materials, and the overlying unsaturated zone." Blanchard developed a model of aquifer sensitivity for the Navajo Nation using broad physical characteristics to describe aquifer sensitivity to surface and near surface contaminants.

The factors used in the Blanchard model include geology, precipitation, soil properties, slope of the land surface, and stream courses. Each of these factors is shown to the left in Figure 28. Blanchard stated that the largest limitation to this method was inadequate information on depth to the uppermost aquifer. The following describes the inputs used in Blanchard's (2002) assessment.

The geology was developed from Cooley et al. (1969 - S10290201). It identifies where consolidated rocks are recharged and unconsolidated deposits are at the surface and facilitate aquifer contamination (pink on the geology map in Figure 28). Geology acts as a surrogate for impact of the vadose or unsaturated zone. Yellow identifies areas that do not contribute to recharge. The eastern portion of the Eastern AUM Region was not included in the Cooley map; in order to not underestimate the contamination potential of this part of the study area, Blanchard assigned it to the "significant potential" category.

Water provides the solvent in which contaminants are transported from the land surface to the aquifers. Precipitation is the surrogate for recharge where greater precipitation results in greater potential for contaminants to infiltrate the land surface. In the precipitation map in Figure 28, pink indicates high precipitation, green indicates relatively uniform intermediate precipitation, and blue indicates the least precipitation and potential to facilitate aquifer contamination.

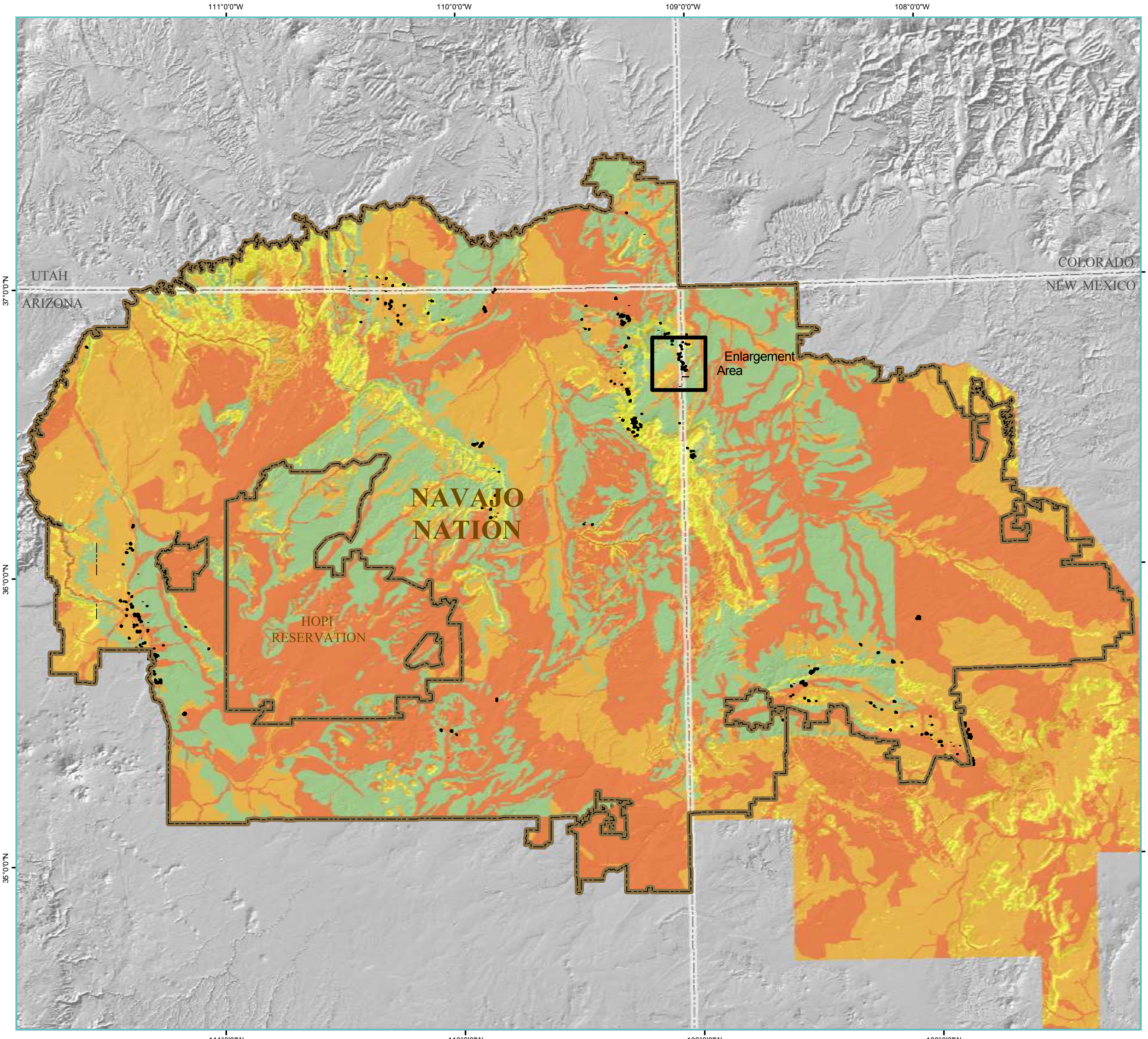
Several soil properties contribute to the potential to facilitate aquifer contamination, including: texture, infiltration rate, drainage, and organic content. These properties were developed from a modified version of the STATSGO, or State Soil Geographic database created by the U.S. Department of Agriculture, National Resources Conservation Service (Schwarz and Alexander, 1995 - S08030303). Blanchard further explains that finely textured soil reduces the rate at which water and contaminants move through the soil (low hydraulic conductivity). High infiltration rates indicate a soil that permits a high volume of water to enter from the land surface. Lower drainage rates indicate a higher resident time. Soil organic content affects microbial activity and sorption. Blanchard found that soils on the Navajo Nation had an organic content of less than 2 percent, indicating minimal microbial activity and sorption. With no relative difference across the Navajo Nation, organic content was not used. In the soil properties map (shown in Figure 28) blue indicates areas with the least potential, where the soil is fine-grained, has a low infiltration rate, is poorly drained, and has a high organic content. Green indicates areas with intermediate potential, and pink indicates areas with the most potential.

Land surface slope affects the ability of precipitation to infiltrate soil. Slopes less than 6 degrees (pink in the slope map in Figure 28) permit precipitation to stay in contact longer with the soil, thereby increasing infiltration of water into the land surface. Conversely, slopes of 6 to 12 degrees (intermediate slopes shown in green) and steep slopes greater than 12 degrees (blue in the slope map at left) minimize infiltration because water runs off quickly.

Blanchard developed buffered fourth-order and higher stream courses from USGS DEM's (shown in Figure 28). Stream courses, wherever they occurred, were assigned the greatest potential to facilitate contamination because they concentrate runoff and have flat slopes. Floodplain and terrace soils are also composed of materials that facilitate contamination.

Blanchard summed the assigned numeric scores for each of the precipitation, soil properties, and slope layers and multiplied by the geology score (1 for facilitates contamination and 0 for does not facilitate contamination). A final aquifer sensitivity map was developed from these scores and is shown on Figure 29. The highest scores represent the most potential for contamination, low scores have the least potential, and intermediate scores produce intermediate potential. The insignificant category represents areas where the geology score was zero, or were not areas of recharge to bedrock aquifers, and/or were not areas of unconsolidated deposits (stream alluvial deposits).

This dataset is provided on the GIS Data DVD (DB/Water/NN_Aquifer_Sensivitiy.shp).

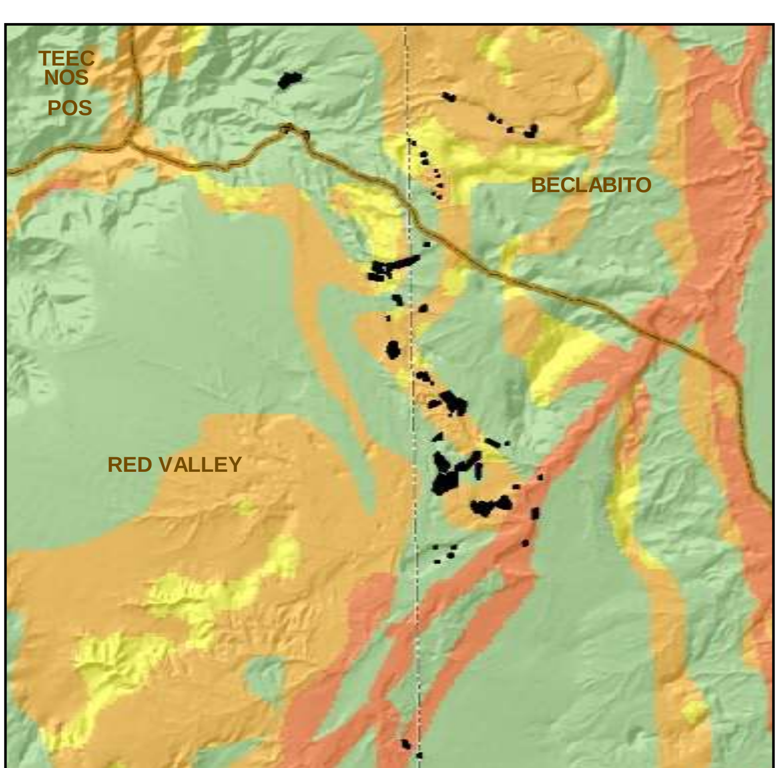


ABANDONED URANIUM MINES AND THE NAVAJO NATION

AQUIFER SENSITIVITY

0 50 Miles

Map Scale 1:1,750,000



Enlarged view of AUMs and aquifer sensitivity in the northeast portion of the Red Valley Chapter area.

Legend

Abandoned Uranium Mines

Aquifer Sensitivity Class

- 0 - Insignificant Potential
- 1 - Least Potential
- 2 - Intermediate Potential
- 3 - Most Potential

Sources

Aquifer sensitivity was developed and provided by Paul Blanchard (2002), U. S. Geological Survey, Water Resources Division in Albuquerque, New Mexico. The data are from the Water-Resources Investigations Report 02-4051 titled "Assessments of Aquifer Sensitivity on Navajo Nation and Adjacent Lands and Ground-Water Vulnerability to Pesticide Contamination on the Navajo Indian Irrigation Project, Arizona, New Mexico, and Utah."

Aquifer sensitivity, which is shown above on a shaded relief image, refers to the potential to contaminate the ground water - ranging from "insignficant" to the "most" potential. This was determined by an investigation of the geology, precipitation, soils, slope, and stream courses of the area.

Filename: DB/Water/NN_Aquifer_Sensitivity.shp

Figure 29. Aquifer Sensitivity on the Navajo Nation.

SURFACE WATER RESOURCES

Evaluation of the surface water pathway requires an understanding of where surface water occurs proximal to the AUM sites, as well as the flood potential of a site. Proximity is directly related to the ease with which hazardous substances can migrate to surface water. Surface waters include streams, rivers, and lakes. On the Navajo Nation, where the mean annual precipitation is less than 20 inches, intermittently-flowing waters and ditches also qualify as surface water. Release of a hazardous substance from an AUM to surface water could threaten drinking water supplies, human food chain organisms, and sensitive environments. The distance from an AUM site to surface water can be used as an indicator of the likelihood of release of hazardous substances to surface water. The location of an AUM site with respect to surface water floodplains is another important indicator of the likelihood of release of a hazardous substance, and is also directly related to distance from surface water (EPA, 1991 - S01230301). No floodplain maps for the Navajo Nation were found to be available from either the Federal Emergency Management Agency or the U.S. Army Corps of Engineers.

WATERSHEDS

A watershed is the area of land draining into a river or stream at a given location. The United States is divided and subdivided into successively smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units (also referred to as watersheds). The hydrologic units are arranged hierarchically, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system (USGS, 2003 - S07290302).

Figure 30 shows the three HUC regions covering the Navajo Nation: Rio Grand (HUC 13), Upper Colorado (HUC 14), and the Lower Colorado (HUC 15). The Navajo Nation is within 5 HUC sub-regions, which are shown in Figure 31. HUCs for the watersheds are listed in the legend of Figure 31. This dataset is provided on the GIS Data DVD (DB/Water/NN_Subbasins.shp).

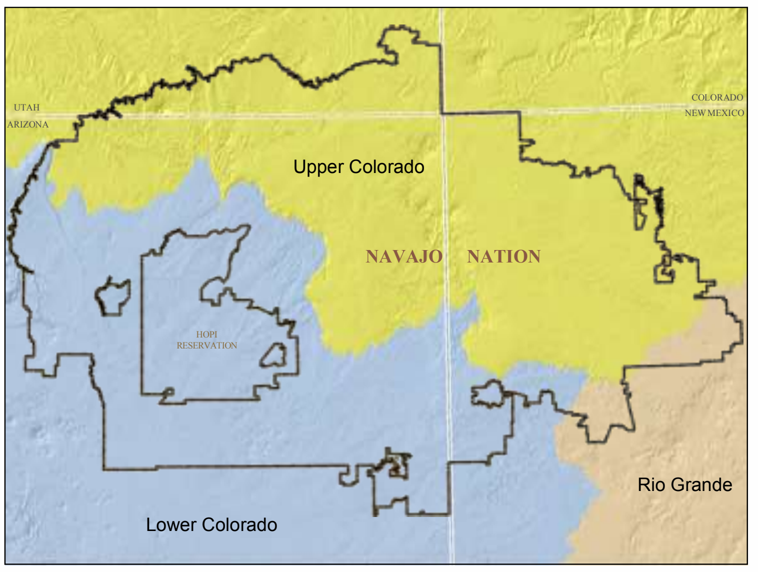


Figure 30. Hydrologic Unit Code Regions (USGS, 2003 - S07290302).

DRAINAGES

Drainages are important to surface water pathway screening assessments. This factor involves assessing whether potential drainage pathways exist for the transport of hazardous substances via surface water, and if so, whether any targets (e.g., intakes supplying drinking water, fisheries, or sensitive environments) are likely to be exposed to contaminants.

Erosion is a concern for AUM sites because of the mine wastes. Major sources of erosion/sediment loadings at mining sites include waste rock and overburden piles, haul and access roads, exploration areas, and reclamation areas. The main factors influencing erosion include rainfall/snowmelt runoff, soil infiltration rate, soil texture and structure, vegetative cover, slope length, and erosion control practices. Erosion may cause loading of sediments to nearby drainages, especially during severe storm events and high snowmelt periods.

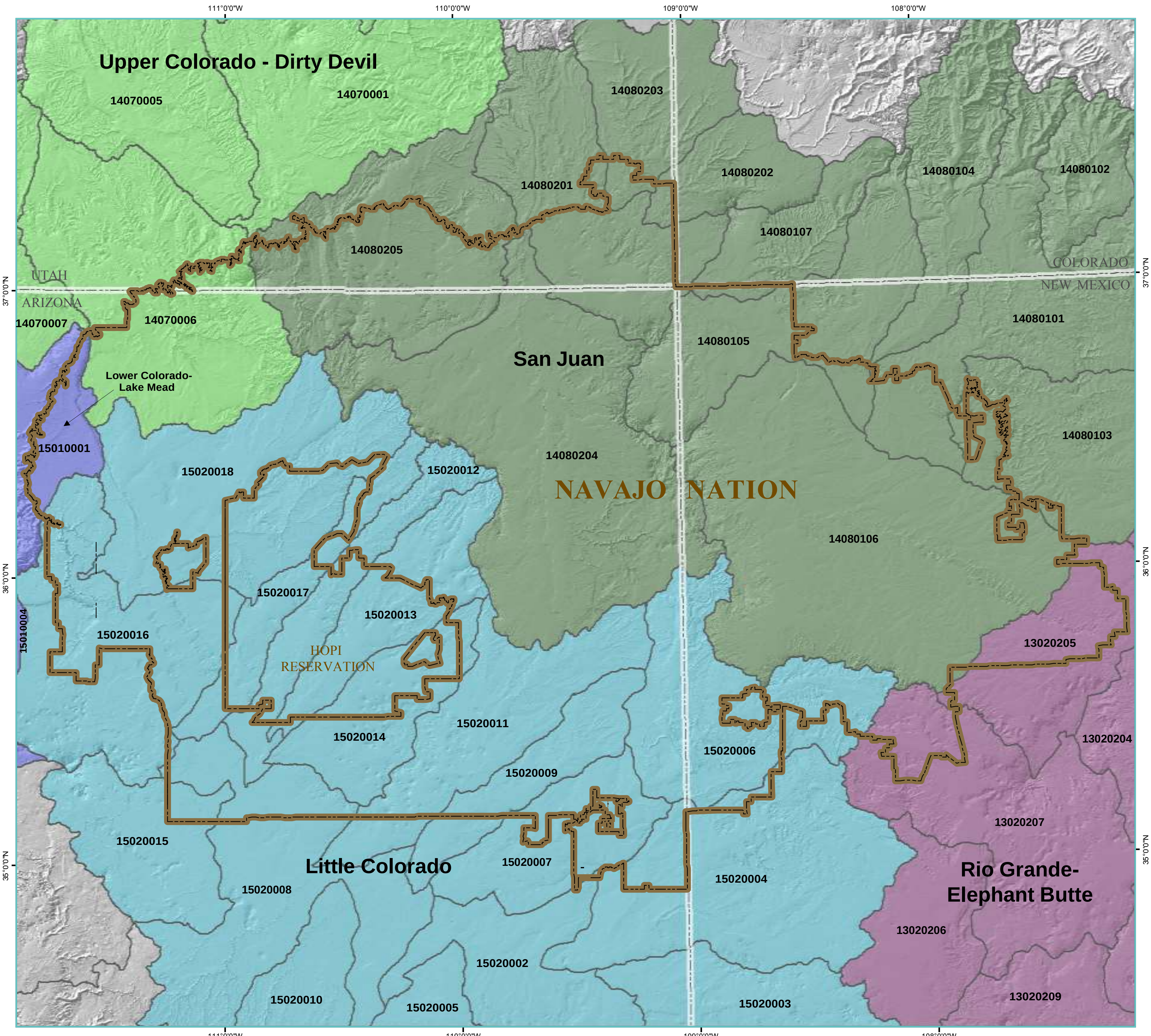
The majority of surface waters flowing within, or originating from, the Navajo Nation are either intermittent or ephemeral. Intermittent streams flow water part of the time in most years and have a defined stream channel. Ephemeral streams flow water in response to heavy rainfall events and do not have a defined stream channel. Stream flow in the intermittent channels is also dependent on storm events. Differences in rainfall patterns cause stream flow to be extremely variable. Perennial streams have visible water flowing above the streambed year-round.

The type of soil and the amount and type of vegetation have a significant effect on the amount of precipitation that becomes surface runoff. Vegetation on the Navajo Nation generally consists of sparse grasses and desert shrubs at lower altitudes, and piñon-juniper forests at higher altitudes. Approximately one-half of the annual precipitation occurs from July through October, generally in the form of localized, short-duration, high-intensity thunderstorms. Due to the torrential character of the much of the rainfall, and the abundance of bare rock surfaces, the consequent runoff means that thunderstorms anywhere in the basin of a drainage may create large flows, which are commonly of limited duration and extent (Cooley et al., 1969 - S10290201).

Hazardous constituents (e.g., radionuclides and heavy metals) associated with discharges from uranium mining operations may be found at elevated levels in sediments (EPA, 2000 - S02200302). For example, radioactive elements were released to the Puerco River through mine-water discharge, and by a catastrophic spill of uranium mine tailings and mine water. Several large uranium mines and a processing mill released contaminated mine water to a small tributary of the Puerco River, know as Pipeline Arroyo. Because the ore deposits lie beneath the water table, water draining to mine tunnels was pumped and released to Pipeline Arroyo. Mine dewatering released an estimated total of 510 tons of uranium and 260 trillion pico curies of gross-alpha radioactivity to the Puerco River over a 22 year period. On July 16, 1979, the failure of an earthen dam, holding uranium-mining and milling wastewater and sediment, released about 94 million gallons of highly acidic liquid and 1,100 tons of uranium-mine tailings to the Puerco River through Pipeline Arroyo. However, despite the large size of the spill, more radioactive elements were released gradually by mining over a period of more than two decades. At least 300 times more uranium and six times more total gross-alpha activity were released by day-to-day pumping from the underground mines than was released by the spill (Wirt, 1994 - S03030609).

Surface water features on and near the Navajo Nation were acquired from the USGS National Hydrography Dataset high resolution (NHDH) database (shown on Figure 32). These datasets are available on the GIS Data DVD (DB/Water/NN_WaterBody_NHDH.shp; DB/Water/NN_Points_NHDH.shp; DB/Water/NN_Flowline_NHDH.shp; and DB/Water/NN_Areas_NHDH.shp).

Figure 33 shows drainages that were interpreted as potential downstream surface water pathways on the Navajo Nation. The drainage dataset documents streams within one mile overland and downslope of AUMs for a distance of at least fifteen miles. The primary source for these stream courses was the NHDH, but it was augmented by the addition of streams that were automated from DRGs and DOQQs. These drainage datasets are provided on the GIS Data DVD (DB/Water/NN_Drainage_HR_AUM.shp and DB/Water/NN_Drainage_Poly_HR_AUM.shp).



ABANDONED URANIUM MINES AND THE NAVAJO NATION

WATERSHEDS BY SUB-REGION

N W E S

0 50 Miles

Map Scale 1:1,750,000

Legend

WATERSHED HUCS AND NAMES BY SUB-REGION

1302 - RIO GRANDE - ELEPHANT BUTTE
- 13020204, Rio Puerco
- 13020205, Arroyo Chico
- 13020206, North Plains
- 13020207, Rio San Jose
- 13020209, Rio Saldo

1407 - UPPER COLORADO - DIRTY DEVIL
- 14070001, Upper Lake Powell
- 14070005, Escalante
- 14070006, Lower Lake Powell
- 14070007, Paria

1408 - SAN JUAN
- 14080101, Upper San Juan
- 14080102, Piedra
- 14080103, Blanco Canyon
- 14080104, Animas
- 14080105, Middle San Juan
- 14080106, Chaco
- 14080107, Mancos
- 14080201, Lower San Juan-Four Corners
- 14080202, Mcelmo
- 14080203, Montezuma
- 14080204, Chinle
- 14080205, Lower San Juan

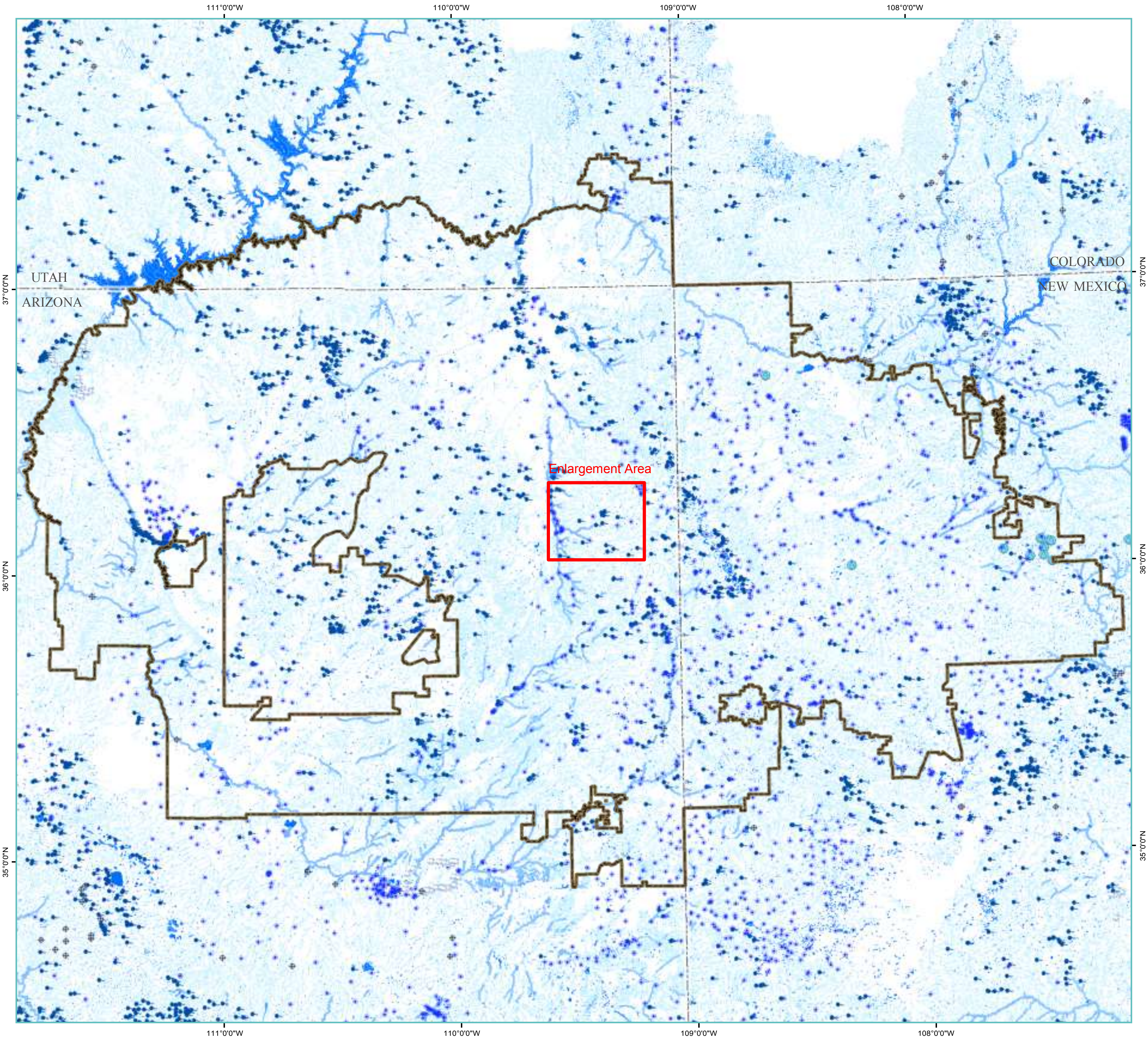
1501 - LOWER COLORADO - LAKE MEAD
- 15010001, Lower Colorado-Marble Canyon
- 15010004, Havasu Canyon

1502 - LITTLE COLORADO
- 15020011, Cottonwood Wash
- 15020012, Corn-Oraibi
- 15020013, Polacca Wash
- 15020014, Jadito Wash
- 15020015, Canyon Diablo
- 15020016, Lower Little Colorado
- 15020017, Dinnebito Wash
- 15020018, Moenkopi Wash
- 15020002, Upper Little Colorado
- 15020003, Carrizo Wash
- 15020004, Zuni. Arizona
- 15020005, Silver
- 15020006, Upper Puerco
- 15020007, Lower Puerco
- 15020008, Middle Little Colorado
- 15020009, Leroux Wash
- 15020010, Chevelon Canyon

Source

Watershed boundaries are from the U.S. Geological Survey (USGS) National Hydrography Dataset high resolution (NHDH). Filename: DB/Water/NN_Subbasins.shp

Figure 31. Watersheds On and Near the Navajo Nation.



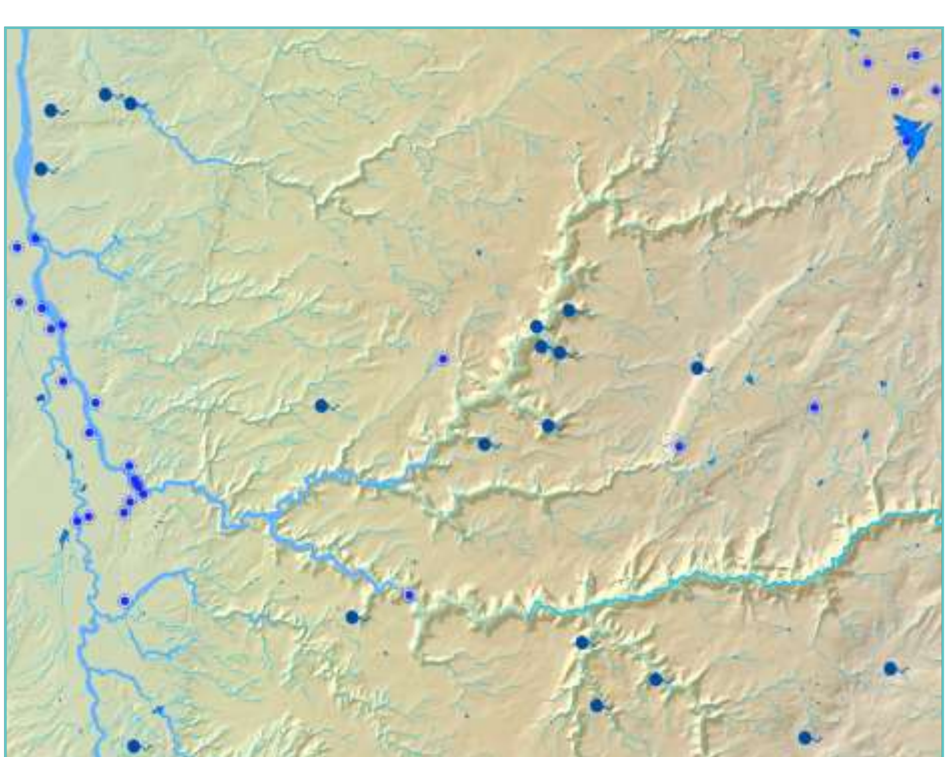
ABANDONED URANIUM MINES AND THE NAVAJO NATION

SURFACE WATER FEATURES

N
W E
S

0 50 Miles

Map Scale 1:1,750,000



Enlargement of National Hydrography Dataset high-resolution data.

Legend

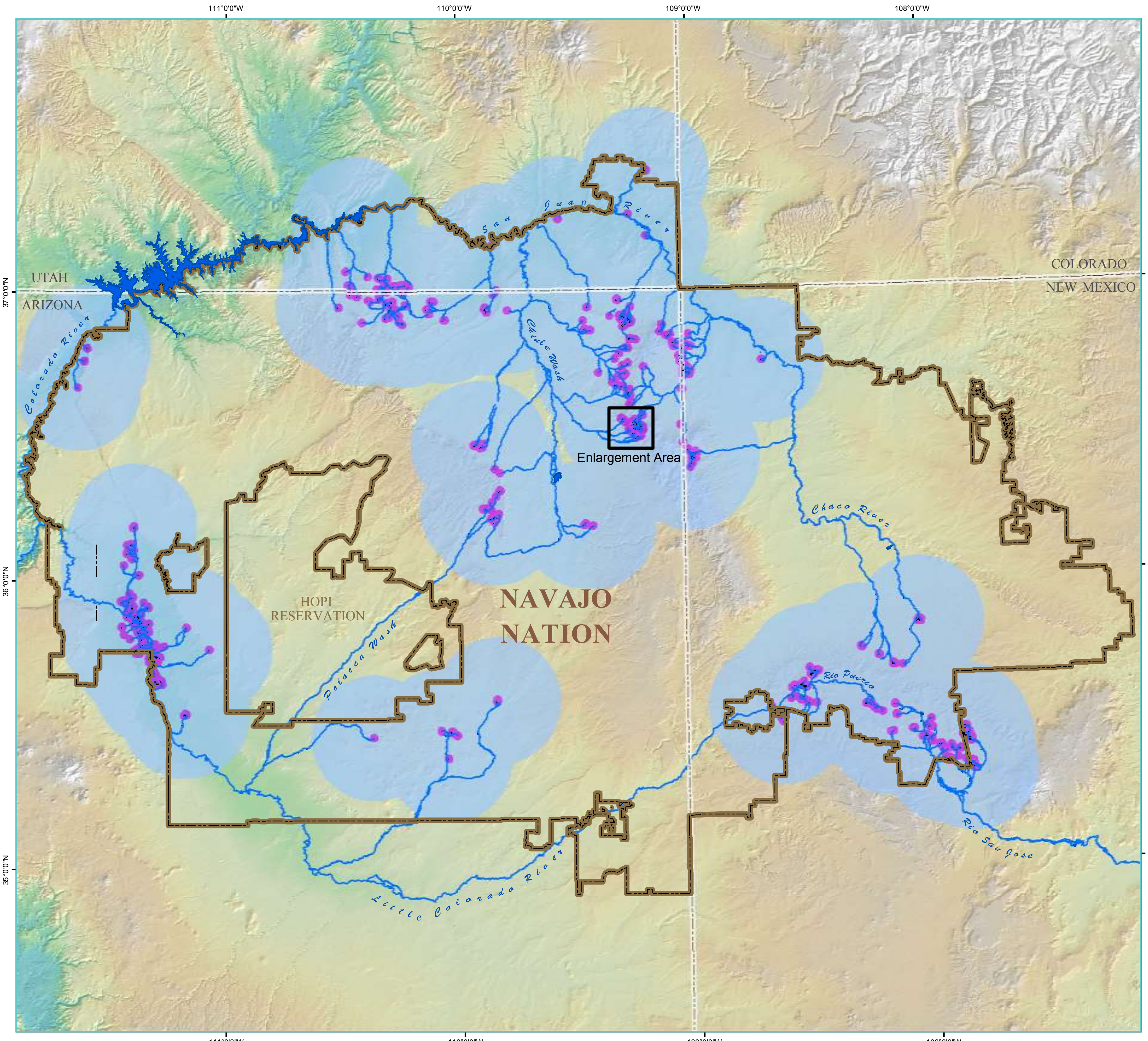
- Gaging Station
- Gate
- Reservoir
- Sink/Rise
- Spring/Seep
- Water Intake/Outflow
- Waterfall
- Well
- Artificial Path
- Stream/River, Intermittent
- Stream/River, Perennial
- Waterbody
- Areas: Complex Channels, Canal/Ditch, Dam/Weirs, Inundation Areas, Rapids, Streams/Rivers, and Washes

Sources

Surface water features are from the U.S. Geological Survey (USGS) National Hydrography Dataset high resolution (NHDH) 1:24,000 scale database.

Filenames:
DB/Water/NN_WaterBody_NHDH.shp
DB/Water/NN_Points_NHDH.shp
DB/Water/NN_Flowline_NHDH.shp
DB/Water/NN_Areas_NHDH.shp

Figure 32. Surface Water Features On and Near the Navajo Nation.



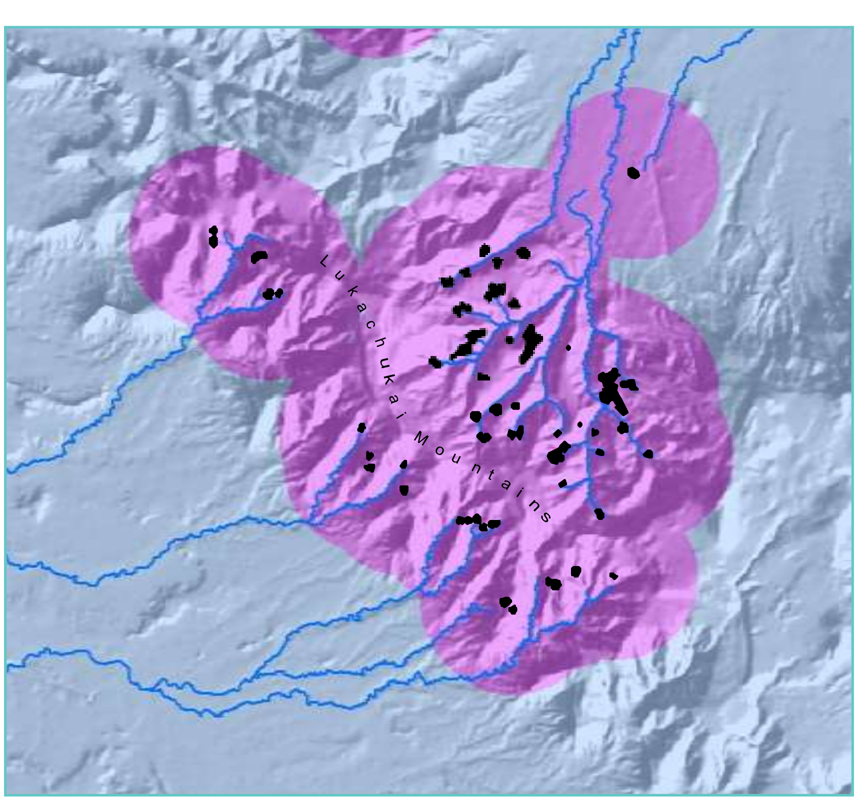
ABANDONED URANIUM MINES AND THE NAVAJO NATION

DOWNSTREAM DRAINAGES WITHIN ONE MILE OF AN AUM

N
W E
S

0 50 Miles

Map Scale 1:1,750,000



Enlargement of AUMs with a One Mile Buffer and Drainages Extending Downstream.

Legend

Abandoned Uranium Mine (AUM)

DRAINAGE FEATURES

Downstream Water Pathway

Downstream Waterbodies

ABANDONED URANIUM MINE BUFFERS

1 Mile

15 Miles

Sources

Drainages downstream and within one (1) mile of an AUM were mapped using the U.S. Geological Survey (USGS) National Hydrography Dataset high resolution (NHDH) 1:24,000 scale database and interpreted using USGS digital orthophotography.

Filenames:
DB/Water/NN_Drainage_HR_AUM.shp
DB/Water/NN_Drainage_Poly_HR_AUM.shp

Figure 33. Downstream Drainages Within One Mile of an AUM.

SOILS

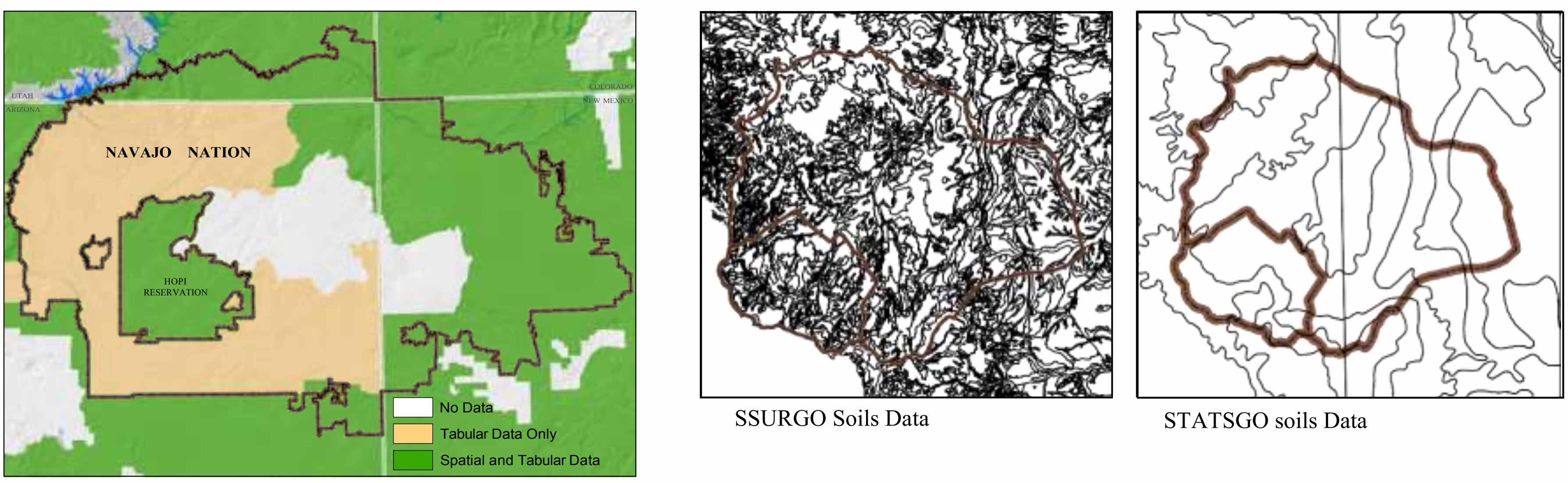
Soils properties, such as infiltration rate, drainage, and texture, can have significant impact on the likelihood of hazardous substances reaching ground water. Course textured, well drained soils with high infiltration rates have a higher potential for movement of water through the soil media to the underlying geologic material than fine textured, poorly drained soils with low infiltration rates. Soil erodibility characteristics are important to assess the soil runoff potential. Soil erodibility is also important when assessing windblown transport potential (EPA, 1991 - S01230301).

SOIL GEOGRAPHIC DATABASES

The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) is responsible for collecting, storing, maintaining, and distributing soil survey information for privately owned lands in the United States. NRCS has established two primary soil geographic databases: the Soil Survey Geographic (SSURGO) database and the State Soil Geographic (STATSGO) database.

SSURGO

The SSURGO database provides the most detailed level of information and was designed primarily for farm and ranch, landowner/user, township or county natural resource planning and management. Maps are made at scales ranging from 1:12,000 to 1:63,360. Data for SSURGO are collected and archived in 7.5-minute topographic quadrangle units. SSURGO data are not yet available for the entire Navajo Nation (see Figure 34.). Soil surveys are being conducted over most of the Navajo Nation, with the exception of the central area.



SSURGO Soils Data

STATSGO soils Data

Figure 34. Status of SSURGO Processing as of May 30, 2007 and Comparison of SSURGO and STATSGO data.

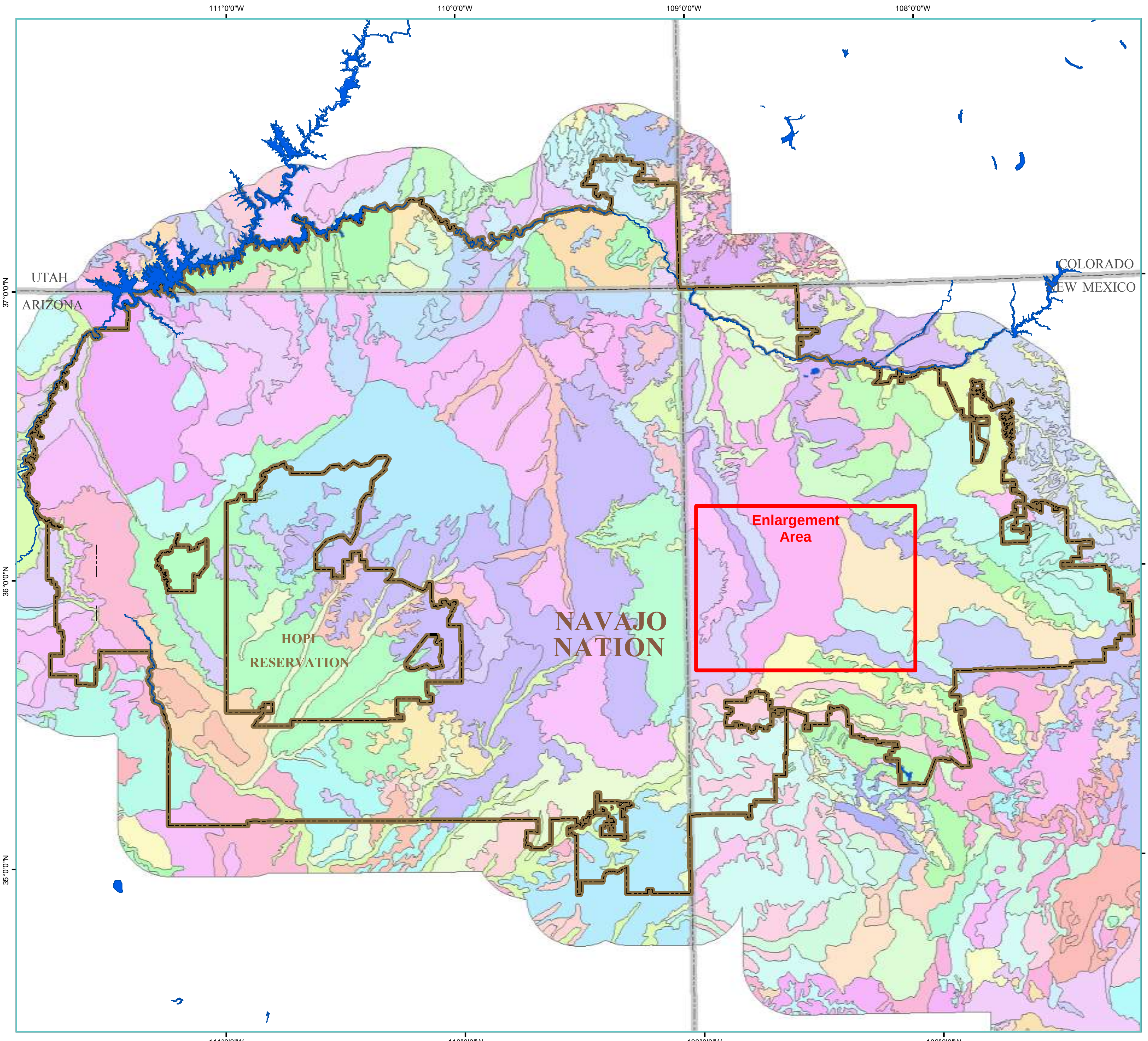
STATSGO

STATSGO was developed by the National Cooperative Soil Survey and was published in 1994. This dataset contains general soil association polygon units and has been compiled over the entire Navajo Nation. It consists of a broad based inventory of soils and non-soil areas that occur in a repeatable pattern on the landscape. These data are intended for geographic display and analysis at the state, regional, and national level. The data should be displayed and analyzed at scales appropriate for 1:250,000-scale data. Figure 34 illustrates the difference in mapping detail between the SSURGO and STATSGO databases.

The soil map units in the STATSGO dataset are linked to attributes in the National Soil Information System database, which gives the proportionate extent of the component soils and their properties. These raw STATSGO spatial data were subsequently clipped to an area that included and extended 20 kilometers beyond the Navajo Nation boundary. Key parameters were extracted: soil map unit, hydrologic group, permeability, K factor erodibility, and wind erodibility index (Table 4). Results for these parameters are presented in Figures 35 thru Figure 39, respectively. Datasets used for these maps are provided on the GIS Data DVD (DB/Soils/NN_STATSGO.shp and DB/Soils/nnstsgob_all).

Field	Type	Description
HYDGRP	Hydrologic Group	A code identifying the hydrologic characteristics of the soil. The coding transformations are: A = 1 (high infiltration, deep soils, well drained to excessively drained sands and gravels), B = 2 (moderate infiltration rates, deep and moderately deep, moderately well and well drained soils with moderately coarse textures), C = 3 (slow infiltration rates, soils with layers impeding downward movement of water, or soils with moderately fine or fine textures), D = 4 (very slow infiltration rates, soils are clayey, have a high water table, or are shallow to an impervious layer).
WEI	Wind Erodibility Index (in tons/acre/year)	A code for Wind Erodibility Index (WEI in tons/acre/year), developed from the STATSGO layer file two character code for WEG (Wind Erodibility Group) converted to numeric codes. The coding transformations are:WEG 1 = 310, WEG 2 = 134, WEG 3 = 86, WEG 4 = 86, WEG 4L = 86, WEG 5 = 56, WEG 6 = 48, WEG 7 = 38, WEG 8 = 0. WEG 1, Surface texture - VFS,FS,S,COS, percent aggregates = 1, WEI = 310 t/a/y. WEG 2, Surface texture - LVFS,LFS,LCOS,Sapric material, percent aggregates = 10, WEI = 134 t/a/y. WEG 3, Surface texture - VFSL,FSL,SL,COSL, percent aggregates = 25, WEI = 86 t/a/y. WEG 4, Surface Texture - C,SIC,noncalcareous CL,SICL(>35% clay), percent aggregates = 25, WEI = 86 t/a/y. WEG 4L, Surface texture - calcareous L/SIL/CL,SICL, percent aggregates = 25, WEI = 86 t/a/y. WEG 5, Surface textue - noncalcareous L/SIL(<20% clay),SCL,SC, percent aggregates = 40, WEI = 56 t/a/y. WEG 6, Surface texture - noncalcareous L/SIL(>20% clay),CL(<35% clay), percent aggregates = 45, WEI = 48 t/a/y. WEG 7, Surface texture - SI, noncalcareous SICL(<35% clay), percent aggregates = 50, WEI = 38 t/a/y. WEG 8, Erosion not a problem - 0 t/a/y.
KFACT	Soil Erodibility Factor	An erodibility factor which quantifies the susceptibility of soil particles to detachment and movement by water. Actual k factor used in the Revised Universal Soil Loss Equation adjusted for rock fragments to calculate soil loss by water. Computed as a layer thickness weighted average, across soil layers, of the variable kfact contained in the STATSGO layer file. Missing value indicator = -1.0.
PERM	Permeability of the soil (in inches per hour)	Permeability of the soil (in inches per hour). Computed as a layer thickness weighted average, across soil layers, of a simple average of permh and perml contained in the STATSGO layer file.

Table 4. STATSGO Codes Used for Key Parameters.



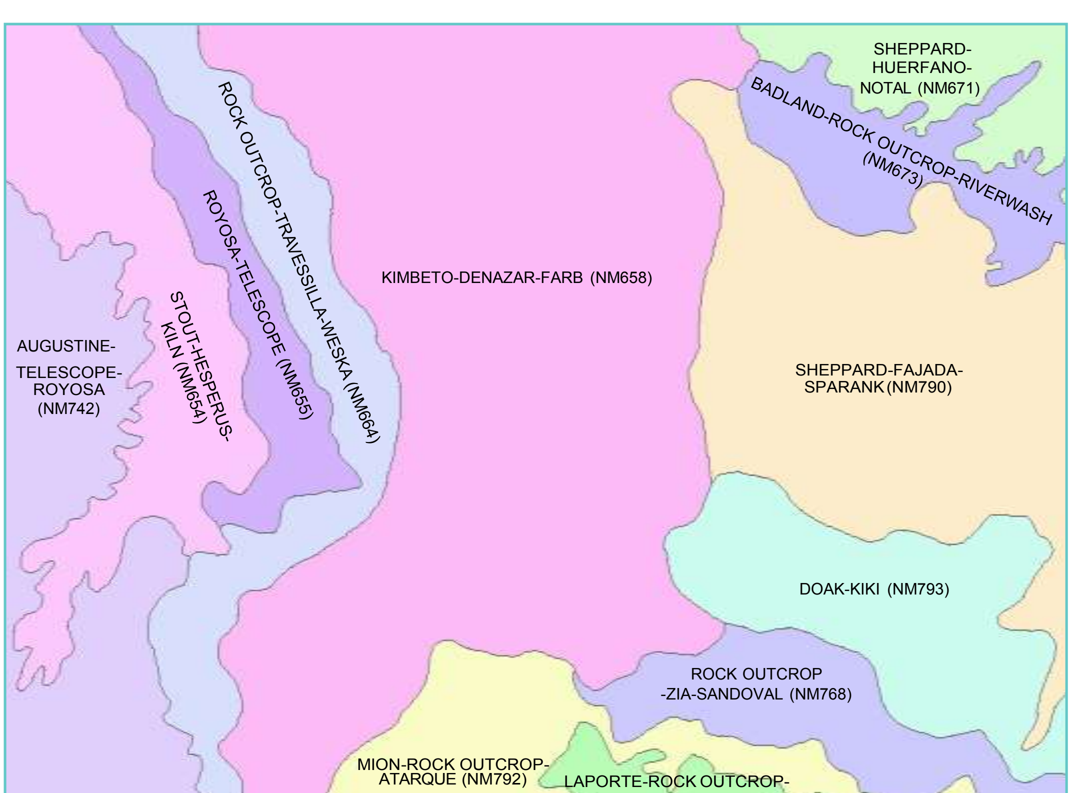
ABANDONED URANIUM MINES AND THE NAVAJO NATION

SOIL MAP UNITS

N W E S

0 50 Miles

Map Scale 1:1,750,000



Enlarged view showing STATSGO mapunit soil names and mapunit ID (MUID).

Sources

Data used to develop this map were derived from the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) Cooperative Soil Survey known as the State Soil Geographic (STATSGO) data set, published in 1994.

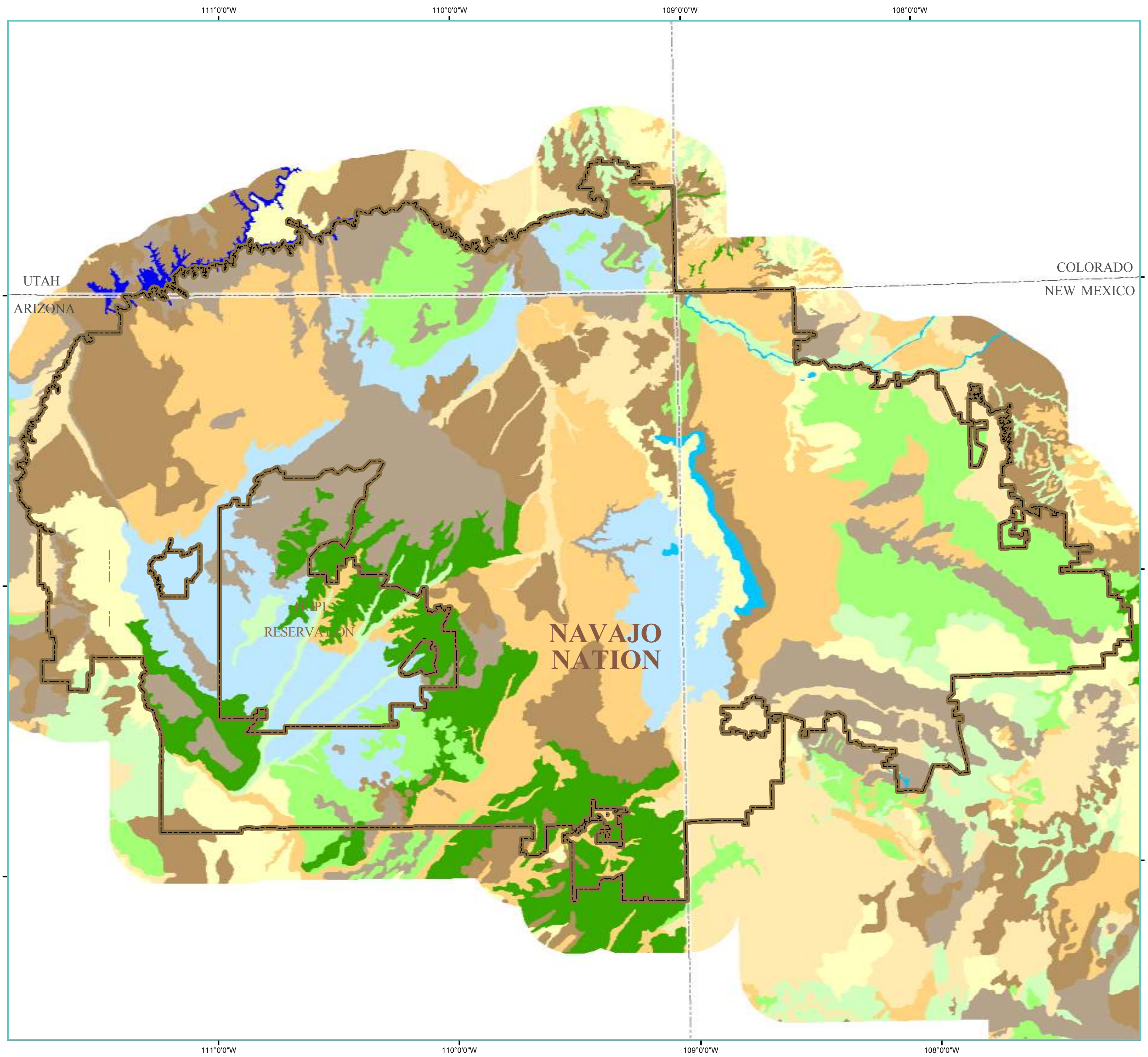
These data provide information about soil features on or near the surface of the Earth. Data were collected as part of the National Cooperative Soil Survey. There are over 100 different soil mapunits across the Navajo Nation, each having distinctive patterns of soils, topography and drainage.

Each STATSGO mapunit is identified by an alphanumeric mapunit ID (MUID) consisting of the two-letter postal abbreviation for the state, followed by a three-digit number (e.g., AZ001 is the first mapunit for Arizona). There are names for the dominant soil in the unit. In the enlarged view, soil mapunts are shown for a small portion of the eastern Navajo Nation, in northwest New Mexico. The map-unit polygons are labelled using data in the "MUNAME" field of the GIS dataset. This field includes the dominant soil names and MUID.

These data are intended for geographic display and analysis at the state, regional, and national level. The data should be displayed and analyzed at scales appropriate for 1:250,000-scale data.

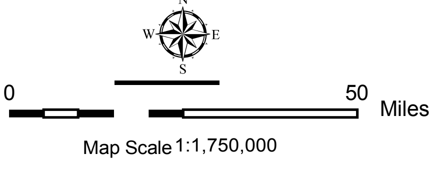
Filename: DB/Water/NN_STATSGO.shp (MUID)

Figure 35. Soil Map Units.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

HYDROLOGIC GROUP



Sources

Data are from the Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) data set. A code identifying the hydrologic characteristics of the soil was extracted from the STATSGO data. The character codes defined in the STATSGO component file are converted into numeric codes according to Schwartz and Alexander, 1995. The coding transformations are:

A = 1 (high infiltration, deep soils, well drained to excessively drained sands and gravels),

B = 2 (moderate infiltration rates, deep and moderately deep, moderately well and well drained soils with moderately coarse textures),

C = 3 (slow infiltration rates, soils with layers impeding downward movement of water, or soils with moderately fine or fine textures),

D = 4 (very slow infiltration rates, soils are clayey, have a high water table, or are shallow to an impervious layer).

The transformed data are averaged across components using the component percentage as the area-weighting factor, then reapportioned into hydrologic group intergrades.

Hydrologic groups are based on the relationship between soil properties and hydrologic properties. These properties include depth to a seasonally high water table, intake rate and permeability after prolonged wetting, depth to a very slowly permeable layer, and wetness characteristics.

Filename: DB/Water/NN_STATSGO.shp (HYDGRPWTAV)

Legend

Water

HYDROLOGIC GROUP INTERGRADES, Weighted Average

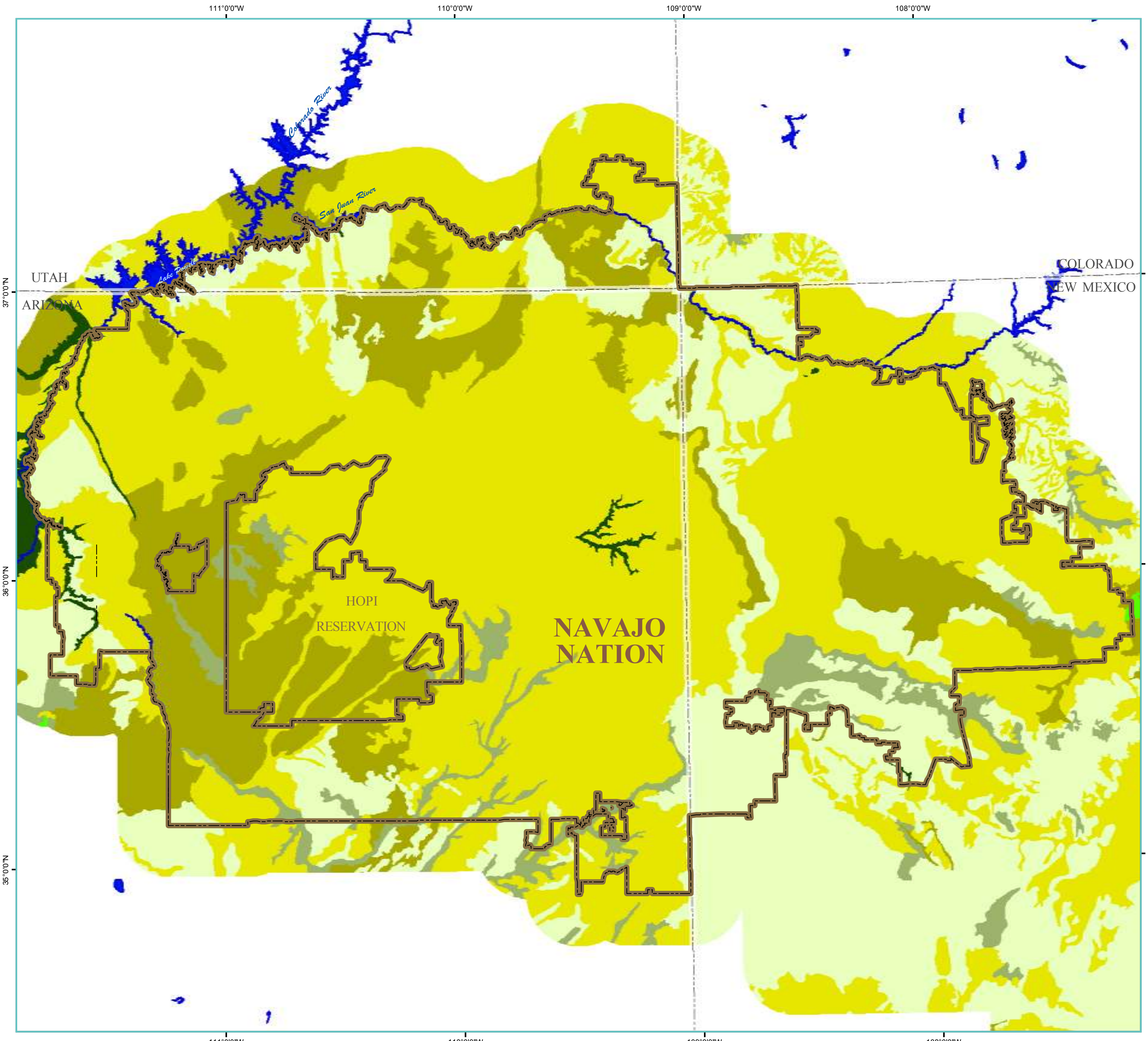
A, A- — High infiltration, deep soils, well drained to excessively drained sands and gravels

B+, B, B- — Moderate infiltration rates, deep and moderately deep, moderately well and well drained soils with moderately coarse textures

C+, C, C- — Slow infiltration rates, soils with layers impeding downward movement of water, or soils with moderately fine or fine textures

D+, D — Very slow infiltration rates, soils are clayey, have a high water table, or are shallow to an impervious layer.

Figure 36. Hydrologic Group.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

PERMEABILITY

N
W E
S

0 50 Miles

Map Scale 1:1,750,000

Sources

Data from the Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) data set.

Soil permeability is the quality of the soil that enables water or air to move through it. STATSGO weighted average soil permeability rate is expressed as inches per hour.

The STATSGO layer file "permh" and "perml" values were averaged across layers (by layer thickness) and components (by component percentage) as the depth- and area-weighting factors.

Filename: DB/Water/NN_STATSGO.shp (PERMWTAVG)

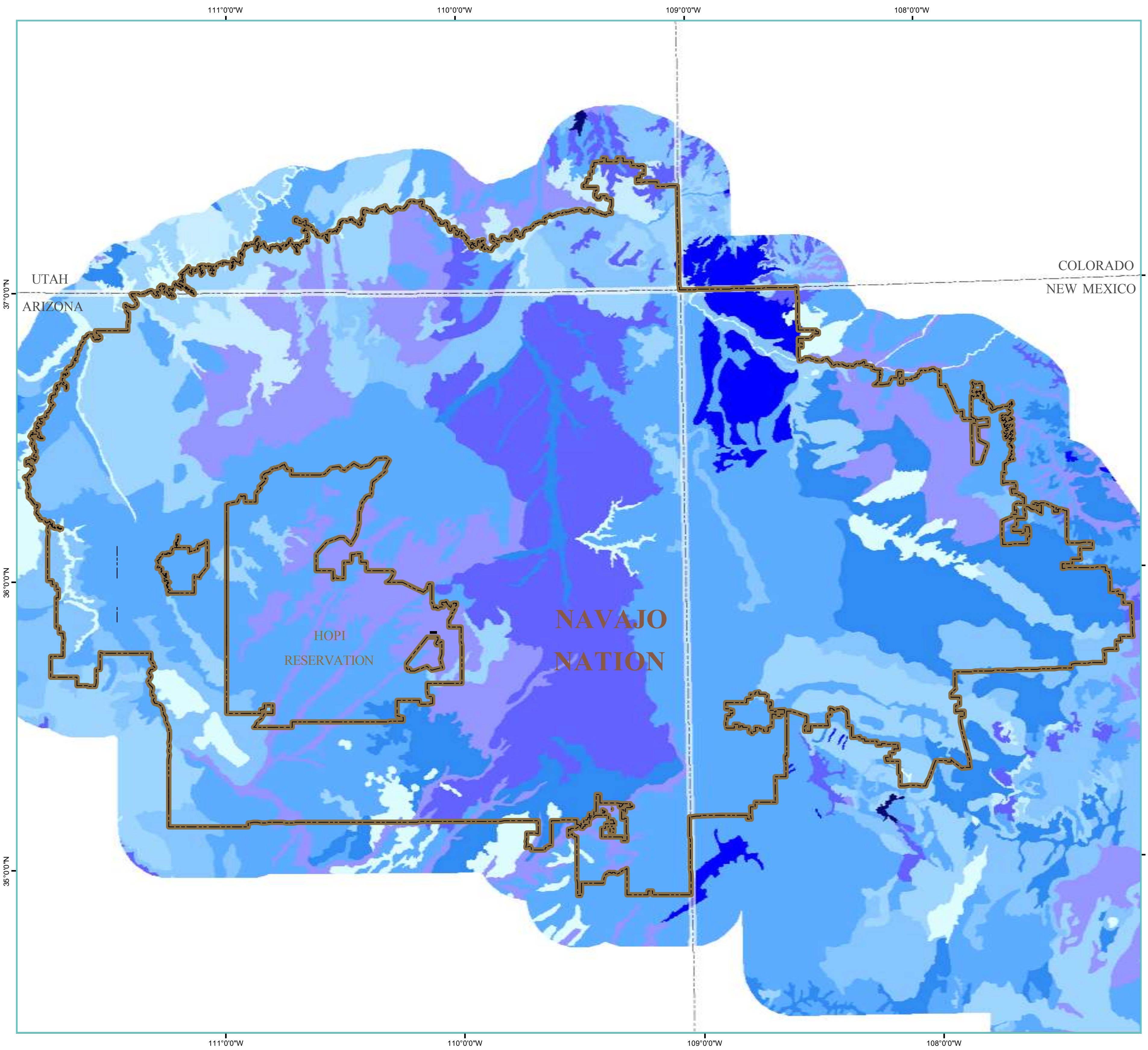
Legend

Major Waters

PERMEABILITY RATE (Inches/Hour)

- 6.01 - 16.53; Rapid
- 2.01 - 6.00; Moderately Rapid
- 0.61 - 2.00; Moderate
- 0.21 - 0.60; Moderately Slow
- 0.07 - 0.20; Slow
- 0.01 - 0.06; Very Slow
- 0.00; Impermeable

Figure 37. Soil Permeability.



ABANDONED URANIUM MINES AND THE NAVAJO NATION

SOIL ERODIBILITY BY WATER (K-FACTOR)

N W E S

0 50 Miles

Map Scale 1:1,750,000

Sources

Data are from the Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) data set.

K-Factor is an erodibility factor that quantifies the susceptibility of soil particles to detachment and movement by water. K-Factor is often used in the Revised Universal Soil Loss Equation to estimate soil loss by water in soils with high quantities of rock fragments. The STATSGO layer file "kfact" value for the surface layer was averaged across components using the component percentage as the area-weighting factor.

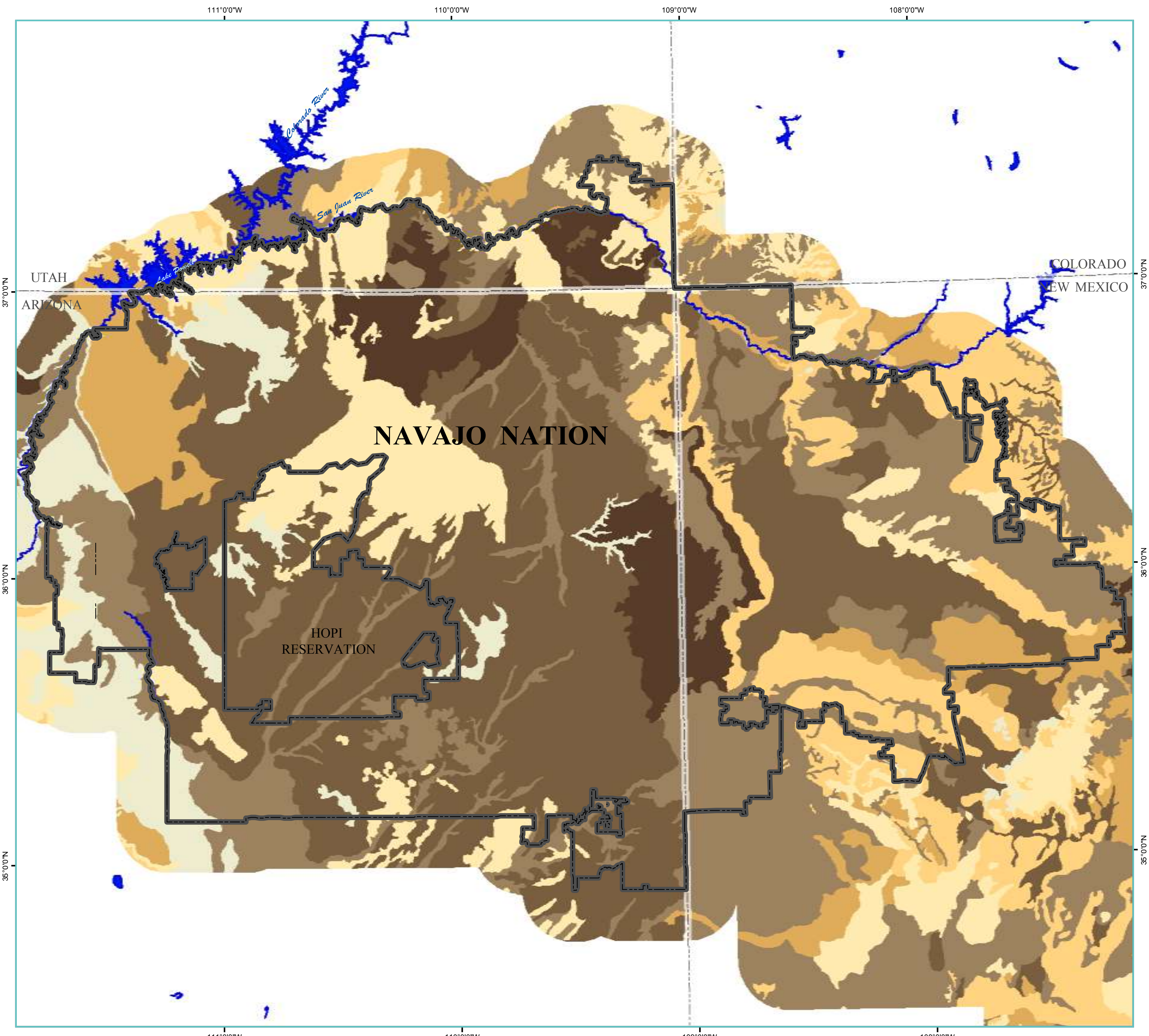
Filename: DB/Water/NN_STATSGO.shp (KFAC1WTAVG)

Legend

SOIL ERODIBILITY FACTOR

- 0.00 - 0.05; Less susceptible to soil loss by water
- 0.06 - 0.10
- 0.11 - 0.14
- 0.15 - 0.19
- 0.20 - 0.24
- 0.25 - 0.29
- 0.30 - 0.34
- 0.35 - 0.38
- 0.39 - 0.43
- 0.44 - 0.48; More susceptible to soil loss by water

Figure 38. Soil Erodibility by Water (K-Factor).



ABANDONED URANIUM MINES AND THE NAVAJO NATION

SOIL ERODIBILITY BY WIND

0 50 Miles

Map Scale 1:1,750,000

Sources

Data are from the Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) data set.

STATSGO weighted-average soil surface wind erodibility index is expressed in tons per acre per year, developed from the STATSGO layer file 2-character code for WEG (wind erodibility group) converted to numeric codes. The coding transformations were WEG 1 = 310, WEG 2 = 134, WEG 3 = 86, WEG 4 = 86, WEG 4L = 86, WEG 5 = 56, WEG 6 = 48, WEG 7 = 38, WEG 8 = 0. The transformed data were then averaged across components using the component percentage as the area-weighting factor.

WEG 1, Surface texture - VFS,FS,S,COS,percent aggregates = 1, WEI = 310 t/a/y;
WEG 2, Surface texture - LVFS,LFS,LCOS,Sapric material, percent aggregates = 10, WEI = 134 t/a/y;
WEG 3, Surface texture - VFSL,FSL,SL,COSL, percent aggregates = 25, WEI = 86 t/a/y;
WEG 4, Surface Texture - C, SIC, noncalcareous CL,SICL (>35% clay), percent aggregates = 25, WEI = 86 t/a/y;
WEG 4L, Surface texture - calcareous L/SIL/CL,SICL, percent aggregates = 25, WEI = 86 t/a/y;
WEG 5, Surface textue - noncalcareous L/SIL(<20% clay), SCL,SC, percent aggregates = 40, WEI = 56 t/a/y;
WEG 6, Surface texture - noncalcareous L/SIL(>20% clay),CL(<35% clay), percent aggregates = 45, WEI = 48 t/a/y;
WEG 7, Surface texture - SI, noncalcareous SICL (<35% clay), percent aggregates = 50, WEI = 38 t/a/y;
WEG 8, Erosion not a problem - 0 t/a/y

Filename: DB/Water/NN_STATSGO.shp (WEI1WTAVG)

Legend

Major Waters

WIND ERODIBILITY INDEX (Tons/Acre/Year)

- WEI 8 - (0 t/a/y)
- WEI 7 - (38 t/a/y)
- WEI 6 - (48 t/a/y)
- WEI 5 - (56 t/a/y)
- WEI 4, WEI 4L and WEI 3 - (86 t/a/y)
- WEI 2 - (134 a/t/y)
- WEI 1 - (310 a/t/y)

Figure 39. Soil Erodibility by Wind (WEI).

SENSITIVE ENVIRONMENTS

Sensitive environments are terrestrial or aquatic resources, fragile natural settings, or other areas with unique or highly-valued environmental or cultural features. Typically, areas that fall within the definition of sensitive environments are established and/or protected by State or Federal Law, and include National Parks, National Monuments, habitats of species of concern, and wildlife refuges (EPA, 1991 - S01230301).

FISHERIES

Fisheries are an area of a surface water body from which food chain organisms are taken or could be taken for human consumption on a subsistence, sporting, or commercial basis. Food chain species include fish, shellfish, crustaceans, amphibians, and amphibious reptiles. Fisheries on the Navajo Nation are shown in Figure 40 (Navajo Nation Fish and Wildlife, 2007 - S05310702).

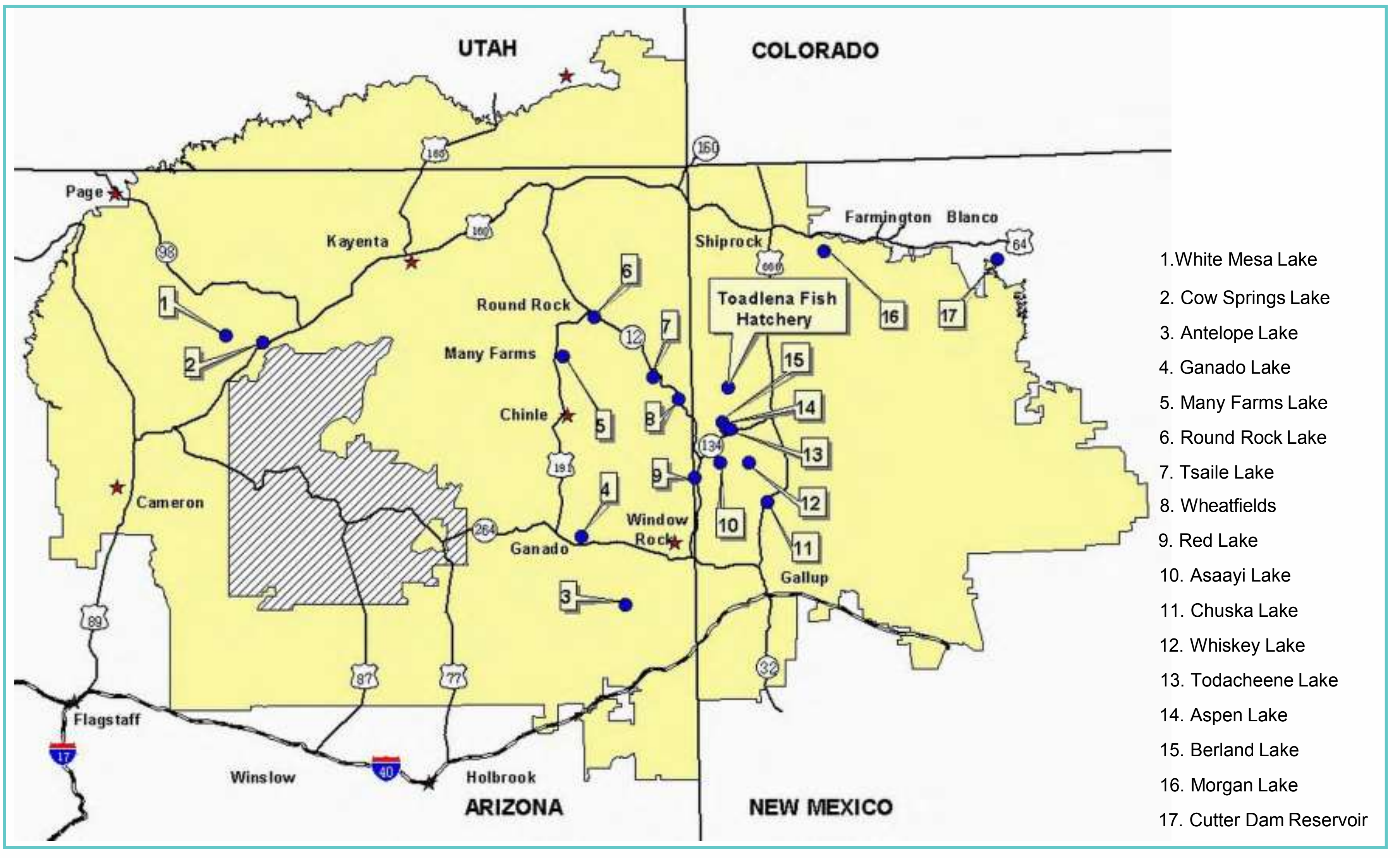


Figure 40. Fisheries on the Navajo Nation.

PROTECTED AREAS

Table 5 lists the protected federal lands that are on or adjacent to the Navajo Nation:

(1) National Historic Park
(1) National Historic Site
(4) National Monuments
(2) National Parks
(1) National Recreation Area
(2) Wilderness Areas
(1) Wilderness Study Area

These protected federal land areas are shown on Figure 41. The locations for these protected areas are provided on the GIS Data DVD (DB/SEN_Env/NN_NPS.shp and DB/Env_Sens/NN_Wilderness.shp).

Table 5. Protected Federal Lands on and Near the Navajo Nation.

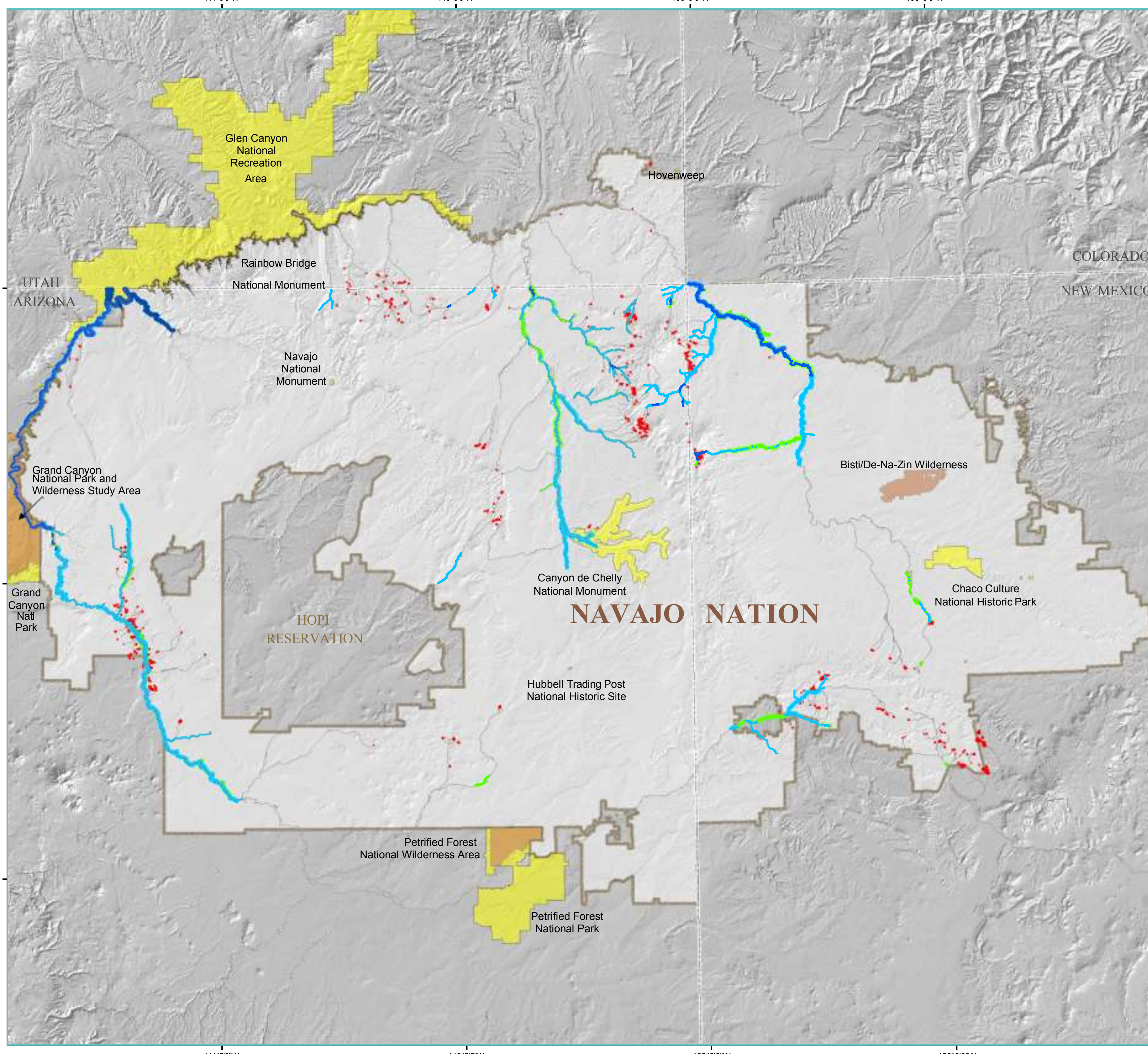
NAME	TYPE
Chaco Culture	National Historic Park
Hubbell Trading Post	National Historic Site
Canyon de Chelly	National Monument
Hovenweep	National Monument
Navajo	National Monument
Rainbow Bridge	National Monument
Grand Canyon	National Park
Petrified Forest	National Park
Glen Canyon	National Recreation Area
Bisti/De-Na-Zin Wilderness	Wilderness BLM
Petrified Forest National Wilderness Area	Wilderness NPS
Grand Canyon National Park Wilderness Study Area	Wilderness Study Area NPS

WETLANDS

Perhaps the most common type of sensitive environment is wetland areas. Federal Regulation 40 CFR 230.3(t) provides the EPA wetland definition as: "an area that is sufficiently inundated or saturated by surface or ground water to support vegetation adapted for life in saturated soil conditions." Wetland and riparian vegetation serves as important wildlife habitat. A large percentage of wildlife species depend on these areas for foraging, nesting, or cover during some portion of their life-cycle.

The U.S. Fish and Wildlife Service (USFWS), through the National Wetlands Inventory (NWI), is required to identify, classify, and digitize all wetlands and deepwater habitats in the United States. Figure 41 presents the wetlands data digitized from the 1:100,000-scale maps NWI published in 1983. The NWI wetlands data are not available for the Utah portion of the Navajo Nation.

The USFWS wetland classifications are from 1:120,000-scale black and white aerial photographs taken in 1972 and 1973. The basemaps used are 1:100,000 scale topographic quadrangles or photographic enlargements of 1:250,000-scale topographic quadrangles. The interpretations were prepared primarily by stereoscopic analysis of high-altitude aerial photographs. Wetlands were identified on the photographs based on vegetation, visible hydrology, and geography. The aerial photographs typically reflect conditions during the specific year and season when they were taken. These environments can change significantly from year to year depending upon the



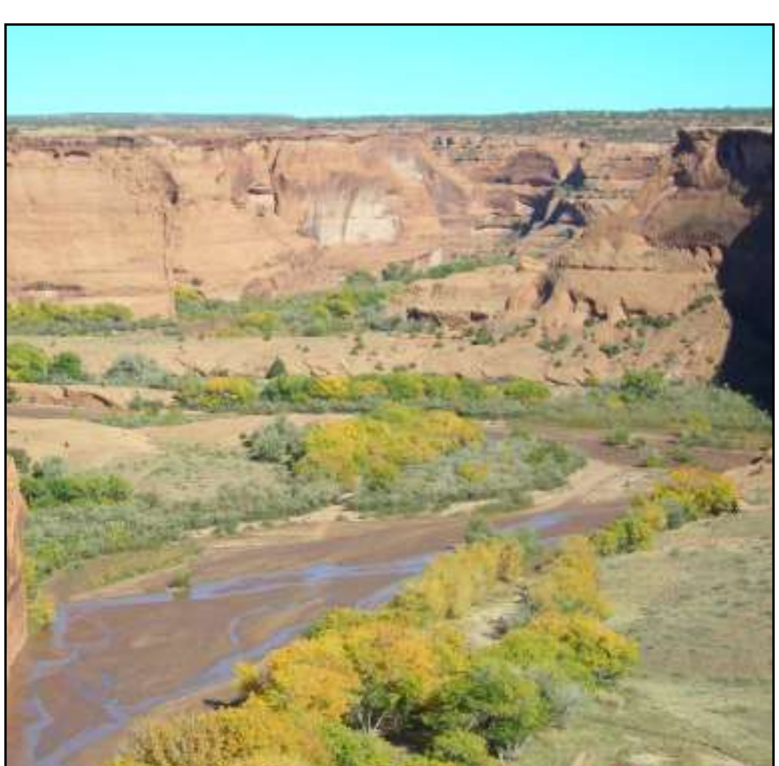
ABANDONED URANIUM MINES AND THE NAVAJO NATION

WETLANDS DOWNSTREAM FROM AUMS AND PROTECTED AREAS

N W E S

0 50 Miles

Map Scale 1:1,750,000



View of Canyon de Chelly from Tseyi Overlook Showing Riparian Vegetation.
Photo courtesy NPS (www.nps.gov/cach/photosmultimedia/index.htm)

Legend

WETLANDS ALONG DOWNSTREAM DRAINAGES
- Palustrine
- Riverine, Intermittent
- Riverine, Perennial
- Lacustrine
- Palustrine
- Riverine, Intermittent
- Riverine, Perennial

PROTECTED AREAS
- Wilderness and Wilderness Study Areas
- National Park Service

AUM RELATED
- Drainage Downstream From AUM - No Mapped Wetlands
- Abandoned Uranium Mine

Sources

Wetlands are from the U. S. Fish and Wildlife Service National Wetlands Inventory (NWI) 1:100,000-scale maps compiled in 1983 from black and white 1:120,000-scale aerial photography taken in 1972 and 1973.

The 2005 version of the Wilderness and Wilderness Study Areas are from the 1:2,000,000-Scale National Atlas of the United States.

The 2007 verision of Administrative Boundaries of National Park System Units are from the National Park Service.

Filenames:
DB/Sens_Env/NN_Wetlands_Lines.shp
DB/Sens_Env/NN_Wetlands_Polys.shp
DB/Sens_Env/NN_Wilderness.shp
DB/Sens_Env/NN_NPS.shp

Figure 41. Wetlands Downstream from AUMs and Protected Areas On and Near the Navajo Nation.

SENSITIVE ENVIRONMENTS (continued)

weather conditions. Reliable wetlands mapping usually requires multiple dates of imagery and field verifications. In recognition of the importance of riparian areas in the western states, the USFWS has adopted a standardized riparian definition and developed conventions to guide the mapping of riparian areas (USFWS, 1997 - S08030304).

ENDANGERED AND SENSITIVE SPECIES

The Navajo Natural Heritage Program (NNHP) is the Navajo Nation's rare, threatened and endangered species office. NNHP collects, manages and disseminates biological and ecological information for land-use planning to promote the conservation of biological diversity on the Navajo Nation. The NNHP maintains a comprehensive database of information on rare and protected plant and animal species and biological communities on the Navajo Nation.

NNHP reviews and updates the Navajo Endangered Species List every two years, pursuant to the Navajo Tribal Code. Information on rare and protected plant and animal species and biological communities on the Navajo Nation is stored in a data system composed of a computerized database, manual files, maps and a library. Information in the NNHP Database include:

- Biological descriptions of plants and animals occurring on the Navajo Nation. Descriptions include details on taxonomic status, identification, habitat preferences, reproductive biology, phrenology, etc.
- Information on the status of plants and animals that are rare or protected at the Navajo Nation or federal level.
- Information about specific geographic locations for rare or protected plants and animals on the Navajo Nation.
- Annotated bibliography of publications (reports, articles, books, etc.) relating to biology, ecology and conservation issues, with primary geographic emphasis on the Navajo Nation and Colorado Plateau area.
- A list of species of concern potentially occurring on each U.S. Geological Survey 7.5-minute quadrangle covering the Navajo Nation. "Species of concern" include protected, rare, and certain native species, as well as species of economic or cultural significance.
- Cultural information about plants and animals occurring on the Navajo Nation (e.g., traditional uses and Navajo names). This information is currently limited.

The Endangered Species List for the Navajo Nation adopted under the Navajo Resources Committee Resolution No. RCAU-103-05 on August 9, 2005 are listed below. Sensitive species lists for the Navajo Nation can be found at http://nnhp.navajofishandwildlife.org. There are four types of sensitive species, arranged by Group:

GROUP 1: Those species or subspecies that no longer occur on the Navajo Nation.

GROUP 2 (G2) & GROUP 3 (G3): "Endangered" -- Any species or subspecies whose prospects of survival or recruitment within the Navajo Nation are in jeopardy or are likely within the foreseeable future to become so.

G2: A species or subspecies whose prospects of survival or recruitment are in jeopardy.
G3: A species or subspecies whose prospects of survival or recruitment are likely to be in jeopardy in the foreseeable future.

GROUP 4: Any species or subspecies for which the Navajo Nation Department of Fish and Wildlife (NNDFWL) does not currently have sufficient information to support their being listed in G2 or G3 but has reason to consider them. The NNDFWL will actively seek information on these species to determine if they warrant inclusion in a different group or removal from the list.

NAVAJO ENDANGERED SPECIES LIST – August 2005
Scientific name (Common name)

GROUP 1:

MAMMALS	*Canis lupus* (Gray Wolf)
	Lontra canadensis (Northern River Otter)
	Ursus arctos (Grizzly or Brown Bear)
FISHES	*Gila elegans* (Bonytail)

GROUP 2:

MAMMALS	*Mustela nigripes* (Black-footed Ferret)
BIRDS	*Coccyzus americanus* (Yellow-billed Cuckoo)
	Empidonax traillii extimus (Southwestern Willow Flycatcher)
AMPHIBIANS	*Rana pipiens* (Northern Leopard Frog)
FISHES	*Gila cypha* (Humpback Chub)
	Gila robusta (Roundtail Chub)
	Ptychocheilus lucius (Colorado Pikeminnow)
	Xyrauchen texanus (Razorback Sucker)
PLANTS	*Astragalus cutleri* (Cutler's Milk-vetch)
	Astragalus humillimus (Mancos Milk-vetch)
	Erigeron rhizomatus (Rhizome Fleabane)
	Pediocactus bradyi (Brady Pincushion Cactus)
	Sclerocactus mesae-verdae (Mesa Verde Cactus)

SENSITIVE ENVIRONMENTS (continued)

GROUP 3:

MAMMALS	*Antilocapra americana* (Pronghorn)[1] *Ovis canadensis* (Bighorn Sheep)[2]
BIRDS	*Aquila chrysaetos* (Golden Eagle) *Buteo regalis* (Ferruginous Hawk) *Cinclus mexicanus* (American Dipper) *Strix occidentalis lucida* (Mexican Spotted Owl)
INVERTEBRATES	*Speyeria nokomis* (Western Seep Fritillary)
PLANTS	Allium gooddingii (Gooding's Onion) Asclepias welshii (Welsh's Milkweed) Astragulus cremnophylax var. hevroni (Marble Canyon Milk-vetch) Carex specuicola (Navajo Sedge) Erigeron acomanus (Acoma Fleabane) Pediocactus peeblesianus var. fickeiseniae (Fickeisen Plains Cactus) Penstemon navajoa (Navajo Penstemon) Platanthera zothecina (Alcove Bog-orchid)

[1] G3 designation excludes NNDFWL Management Unit 16 ('New Lands'), the boundaries of which are: From Sanders, AZ east along Unit 4 boundary to the Zuni boundary; south along the boundary past AZ Hwy 61 to the Navajo Nation/state boundary; west along the boundary past US Hwy 491 to the Navajo Nation/state boundary; north along Rd 2007 to Navajo, AZ; west (to the north and south of Interstate 40) to the state/Petrified Forest National Park boundary; north along the boundary to the Unit 8 boundary; east along the boundary to US Hwy 191; south to Chambers and east to Sanders. For a Unit 16 map, contact NNDFWL, P.O. Box 1480, Window Rock, AZ, 86515, (520) 871-6451.

[2] Special hunts of Ovis canadensis may be conducted in Management Unit 11 for management purposes.

CHAPTER LAND USE PLANNING - WILDLIFE AREAS MAP

The Resources Committee of the Navajo Nation Council passed a Resolution RCMA-34-03 on March 13, 2003 titled "Approving Biological Resource Land Use Clearance Policies and Procedures to Assist the Navajo Nation Government and Chapters Ensure Compliance with Federal and Navajo Laws which Protect Fish, Wildlife, Plant Species and Their Habitat, and Expedite Land Use Approval." To assist the 110 Navajo Nation Chapters in developing Land-Use Plans under the Local Governance Act (LGA), the Navajo Department of Fish and Wildlife identified areas that are sensitive to wildlife across the Navajo Nation. They delineated six types of wildlife areas, covering the entire Navajo Nation, on 1:100,000 scale quadrangle maps. Maps generated from a GIS dataset are posted on the Internet at URL *http://www.navajofishandwildlife.org/clup.htm*.

The six categories of wildlife areas are described as follows:

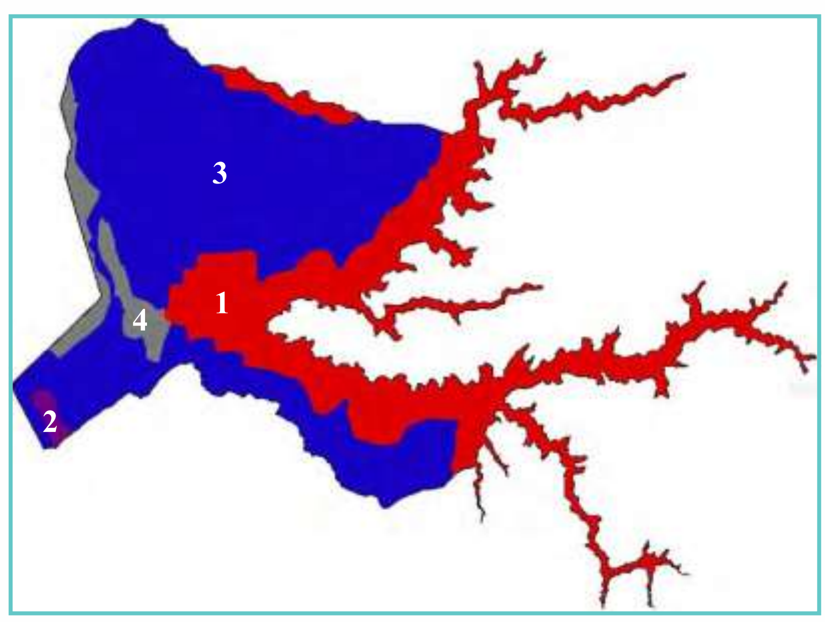


Figure 42. Example Wildlife Areas Map for the Chinle Chapter (from Navajo Department of Fish and Wildlife.

AREA 1: HIGHLY SENSITIVE WILDLIFE RESOURCES (RED)
This area contains the best habitat for endangered and rare plant, animal and game species, and the highest concentration of these species on the Navajo Nation. The purpose of this area is to protect these valuable and sensitive biological resources to the maximum extent practical.

AREA 2: MODERATELY SENSITIVE WILDLIFE RESOURCES (PURPLE)
This area has a high concentration of rare, endangered, sensitive and game species occurrences or has a high potential for these species to occur throughout the landscape. The purpose of this area is to minimize impacts on these species and their habitats within Area 2, and to ensure the habitats in Area 1 do not become fragmented.

AREA 3: LOW SENSITIVITY WILDLIFE RESOURCES (BLUE)
This area has a low, fragmented concentration of species of concern. Species in this area may be locally abundant on 'islands' of habitat, but islands are relatively small, limited in number and well spaced across the landscape.

AREA 4: COMMUNITY DEVELOPMENT (GRAY)
The Department has determined that areas around certain communities do not support the habitat for species of concern and, therefore, development can proceed without further biological evaluation.

AREA 5: BIOLOGICAL PRESERVE (GREEN)
These areas contain excellent, or potentially excellent, wildlife habitat and are recommended by the Department for protection from most human-related activities, and in some cases are recommended for enhancement.

AREA 6: RECREATIONAL (BROWN)
These areas are used for recreation that involves wildlife, or have potential for development for this purpose. Recreation can involve consumptive and/or non-consumptive uses of wildlife resources, and is often a part of a broader outdoor experience. Examples include fishing lakes, camping and picnic areas and hiking trails.

PUBLIC LAND SURVEY SYSTEM (PLSS)

The U.S. Bureau of Land Management (BLM) cadastral survey program is responsible for the official boundary surveys for all federal agencies in the United States. The Public Land Survey System (PLSS), also called the Rectangular Survey System, is the foundation for many survey-based land information systems. In 1785, the Continental Congress enacted the Land Ordinance which set in motion a rectangular survey system to lay out one mile square parcels over all of the federal lands outside the 13 colonies and their western territories. Our present system of public land survey still retains the basic elements set forth in the Land Ordinance of 1785 (BLM, 2003 - S05140305).

Under the cadastral system, the public domain is plotted from a principal meridian (running north and south) and base line (running east and west) into a grid of squares approximately 6 miles to the side, called "townships." The township is further divided into sections of one-mile squares containing 640 acres. Sections are numbered 1-36 from the upper right hand corner. The sections can be further subdivided into quarter sections of 160 acres. The quarters can be divided into half-quarters of 80 acres or into quarter-quarter sections of 40 acres, etc. Many of the references to locations of AUMs or leases/permits are described in terms of the PLSS. Often, the location is described by Township, Range, and Section, or somewhere within a square mile.

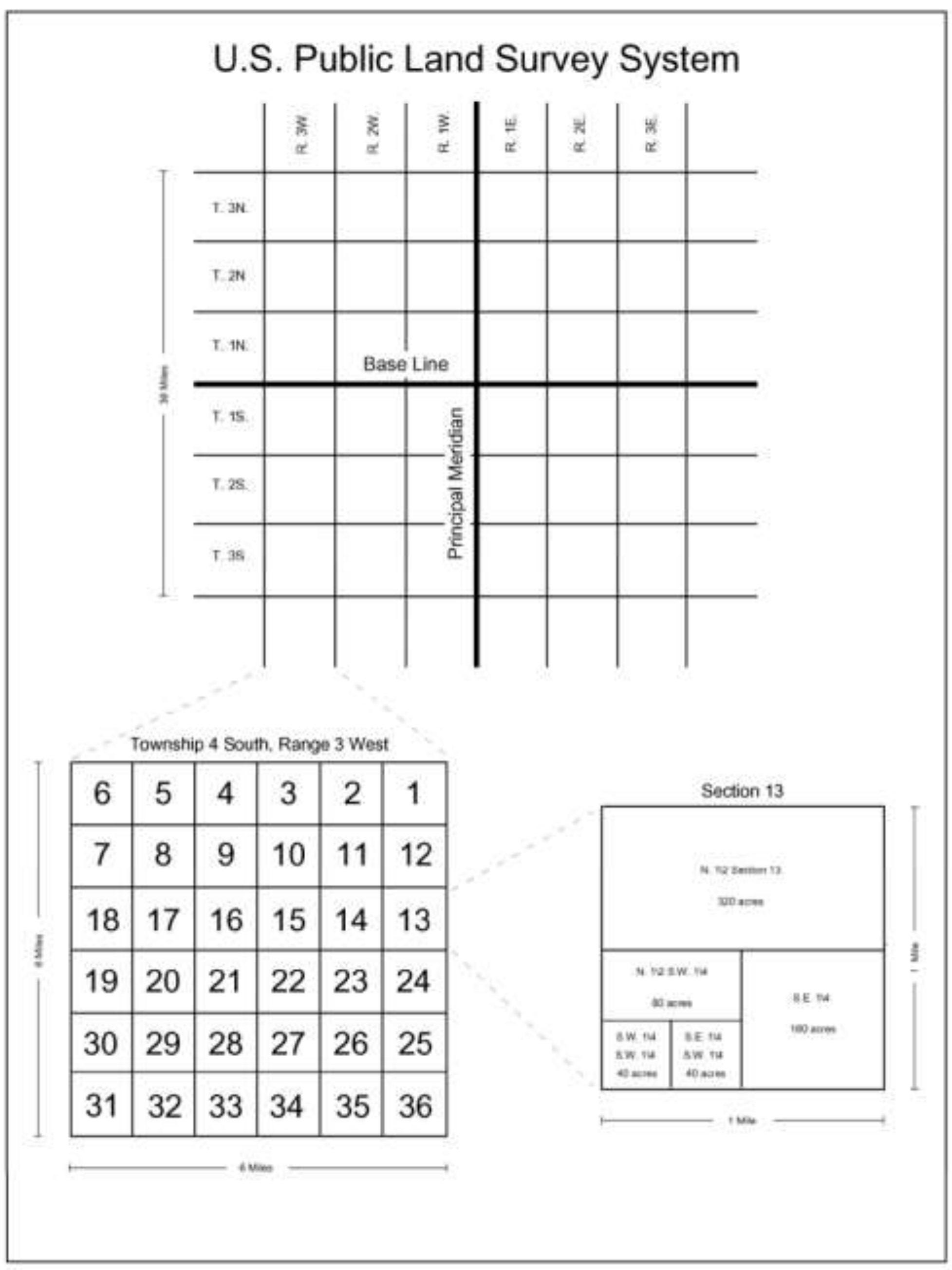
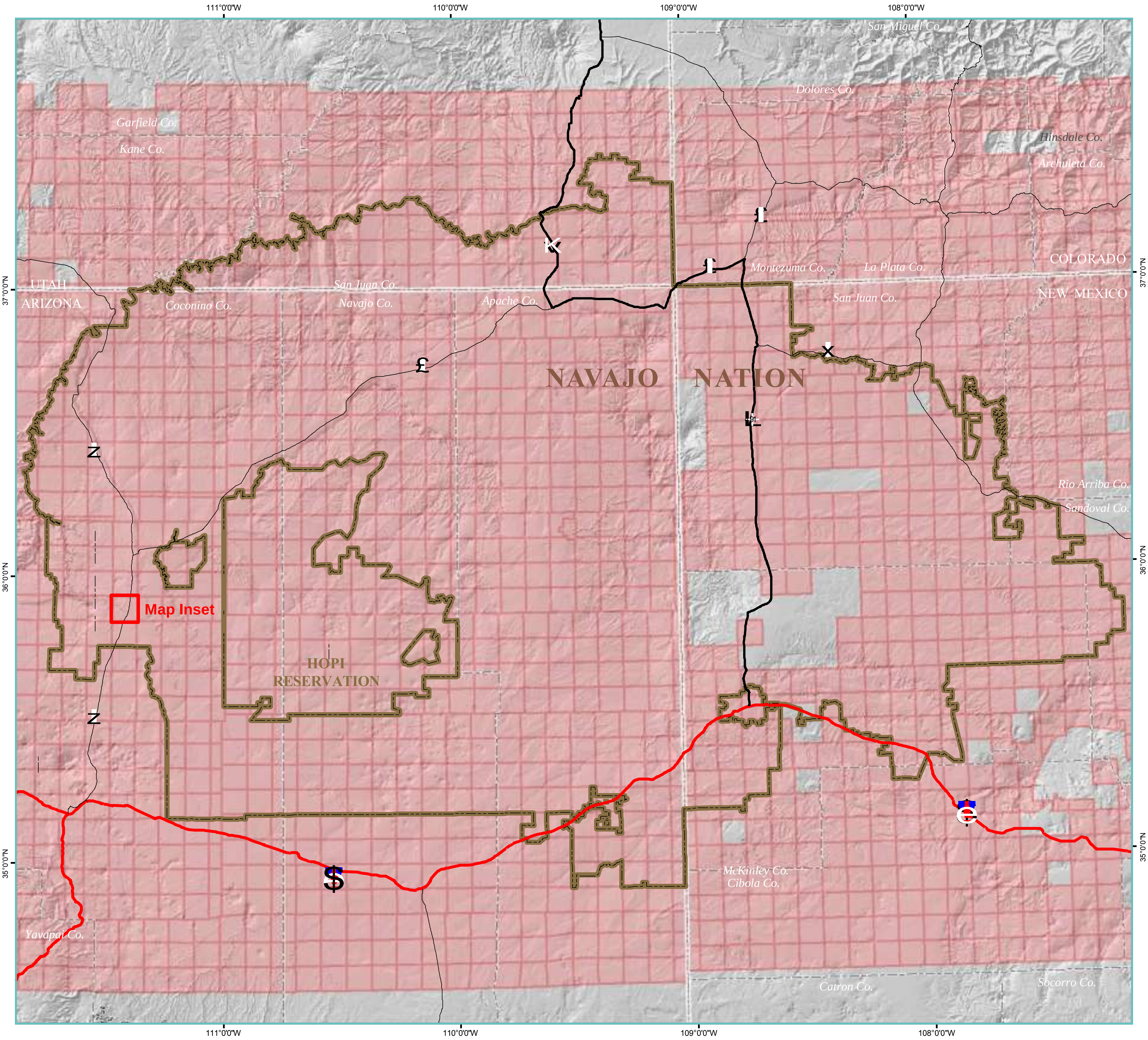


Figure 43. Diagram Showing the Relationship Between PLSS Township, Range and Sections.

The BLM Geographic Coordinate Data Base (GCDB) is a collection of coordinate values and other descriptive information for corner positions and monuments recorded in the PLSS (BLM, 2003 - S05140306). The collection, analysis, and management of the data is the responsibility of the BLM, Branch of Cadastral Survey. The GCDB grid is computed from BLM survey records (official plats and field notes), local survey records, and geodetic control information. BLM collects the GCDB data on a township basis. The survey boundaries are delineated by computing the geographic positions of township, section, aliquot part, government lot, and special survey corners. Next, official land descriptions are assigned to each land unit in the grid. The records are then reformatted so Geographic Information System (GIS) software can be used to spatially view the PLSS information.

The BLM began collection of the geographic coordinate information in 1989 and the data collection effort continues today. GCDB data has been collected for approximately three quarters of the townships in the Western United States. However, as shown on Figure 44, PLSS and GCDB data are not complete for the New Mexico part of the Navajo Nation. Pink grid cells are where Townships are mapped. The enlargement map on Figure 44 shows an example of the PLSS in the area of the Cameron Trading Post, which is located in the southwest quarter of the southeast quarter of Section 21, Township 29 North, Range 9 East. The Township is shown with thick red lines. Sections are shown by thinner red lines, and quarter and quarter-quarter sections are shown with thin pink lines.

These PLSS GIS datasets are provided on the GIS Data DVD under the DB/PLSS directory (NN_GCDB_Twnship.shp; NN_GCDB_Sections.shp; and NN_GCDB_QSections.shp).

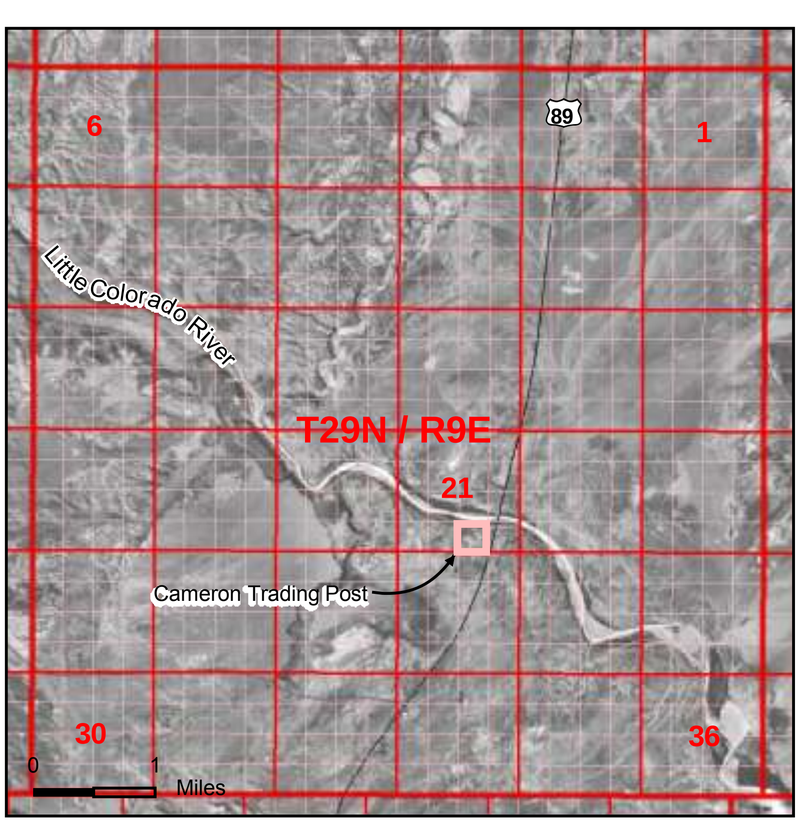


ABANDONED URANIUM MINES AND THE NAVAJO NATION

PUBLIC LAND SURVEY SYSTEM (PLSS)

0 50 Miles

Map Scale 1:1,750,000



Township 29 North (T29N), Range 9 East (R9E). The Cameron Trading Post, Arizona is located in the SW Quarter of the SE Quarter of Section 21.

Legend

- Township
- Sections
- Quarter Sections

Sources

The Township, Section, and Quarter Section datasets were developed by the U.S. Bureau of Land Management.

Filenames:
NN_GCDB_Twnshp.shp
NN_GCDB_Sections.shp
NN_GCDB_QSections.shp

Figure 44. Public Land Survey System (PLSS) of the Navajo Nation.

DIGITAL RASTER GRAPHIC (DRG), ORTHOPHOTO, AND SATELLITE IMAGES

DIGITAL RASTER GRAPHIC (DRG) IMAGES

Topographic maps are the base map series of the U.S. Geological Survey (USGS). USGS topographic maps are available as paper maps and scanned raster files. A Digital Raster Graphic (DRG) is a georeferenced image of a scanned USGS topographic map. The maps were scanned at a resolution of 250 dots per inch. The horizontal and vertical accuracy of the DRG matches the accuracy of the published source map. A DRG may be used as a source or background layer in a Geographic Information System (GIS) to collect, review, and revise other digital data. When the DRG is combined with other digital products, such as a Digital Orthophoto Quarter Quad (DOQQ) or a Digital Elevation Model (DEM), the resulting image provides additional visual information for the extraction and revision of base cartographic information. DRGs can be used to help identify the surface water migration route, nearby wetlands, and sensitive environments (EPA, 1991 - S01230301). DRGs were used to help assess the completeness of digital data that were acquired from various sources for the Navajo Nation GIS Database. DRGs for the Navajo Nation were generated from 1963 to 1997. See the index shapefile for DRG dates on the GIS Data DVD (DB/Index/ NN_Topo24K.shp).

DIGITAL ORTHOPHOTO QUARTER QUADRANGLE (DOQQ) IMAGES

DOQQs are computer-generated images of an aerial photograph in which image displacements caused by terrain relief, camera tilt and lens distortions have been removed. The aerial photographs are scanned and processed to create a georeferenced and planimetrically accurate digital image. The resulting DOQQ combines the image characteristics of a photograph with the geometric qualities of a map. A DOQQ can be used in most any GIS that can manipulate raster images. DOQQs can be used as a cartographic base for displaying other digital spatial data. The accuracy and detail provided by a DOQQ allow users to evaluate their data for accuracy and completeness, make modifications to data, and even generate new thematic layers. DOQQs were used extensively in the review and correction of several spatial datasets prepared for this NAUM Project. The USGS generated DOQQs from black and white aerial photography acquired during the 1990s for the Navajo Nation. Any recent construction after this period, such as new roads or housing developments, will not be evident on the DOQQs. The accuracy and quality of USGS DOQQs meet National Map Accuracy Standards at 1:12,000 scale, and have a 1-meter ground resolution, and accuracy of +/- 33 feet. The U.S. Bureau of Indian Affairs had new digital orthophotos generated for the Navajo Nation using 2005 aerial photography.

County Mosaics

Due to the large number of images (i.e., 515 DRGs and 2,060 DOQQs) and large file sizes (29 megabytes per DRG and 50 megabytes per DOQQ), required to cover the Navajo Nation, it was necessary to acquire county DRG and DOQQ mosaics in compressed format. The county DRG and DOQQ mosaics were developed by the U.S. Natural Resource Conservation Service (NRCS) using LizardTech's MrSID compression software to produce dramatically smaller image sizes (4.4 GB total for the DRG mosaics and 10.7 GB total for the DOQQ mosaics) with little loss in quality. The county DRG and DOQQ mosaics for the Navajo Nation are referenced to the North American Datum of 1983 (NAD83) and use the Universal Transverse Mercator (UTM) projection, Zone 12 for all except the Sandoval County DRG and DOQQ mosaics, which use Zone 13. Table 6 identifies the DVD Name and filenames for the DRG and DOQQ county mosaics that are provided and cover the Navajo Nation.

Table 6. DRG and DOQQ County Mosaics with Corresponding DVD Name, Filenames, and UTM Zone.

County, State	DRG Filename	DVD Name	DOQQ Filename	DVD Name	UTM Zone
Apache, Arizona	Apache_AZ_DRG.sid	DVD_DRG	Apache_AZ_DOQQ.sid	DVD_DOQQ_1	12
Coconino, Arizona	Coconino_AZ_DRG.sid	DVD_DRG	Coconino_N_AZ_DOQQ.sid Coconino_S_AZ_DOQQ.sid	DVD_DOQQ_1	12
McKinley, New Mexico	McKinley_NM_DRG.sid	DVD_DRG	McKinley_NM_DOQQ.sid	DVD_DOQQ_2	12
Navajo, Arizona	Navajo_AZ_DRG.sid	DVD_DRG	Navajo_N_AZ_DOQQ.sid Navajo_S_AZ_DOQQ.sid	DVD_DOQQ_2	12
Sandoval, New Mexico	Sandoval_NM_DRG.sid	DVD_DRG	Sandoval_NM_DOQQ.sid	DVD_DOQQ_3	13
San Juan, New Mexico	San_Juan_NM_DRG.sid	DVD_DRG	San_Juan_NM_DOQQ.sid	DVD_DOQQ_3	12
San Juan, Utah	San_Juan_UT_DRG.sid	DVD_DRG	San_Juan_SW_UT_DOQQ.sid San_Juan_SE_UT_DOQQ.sid	DVD_DOQQ_3	12

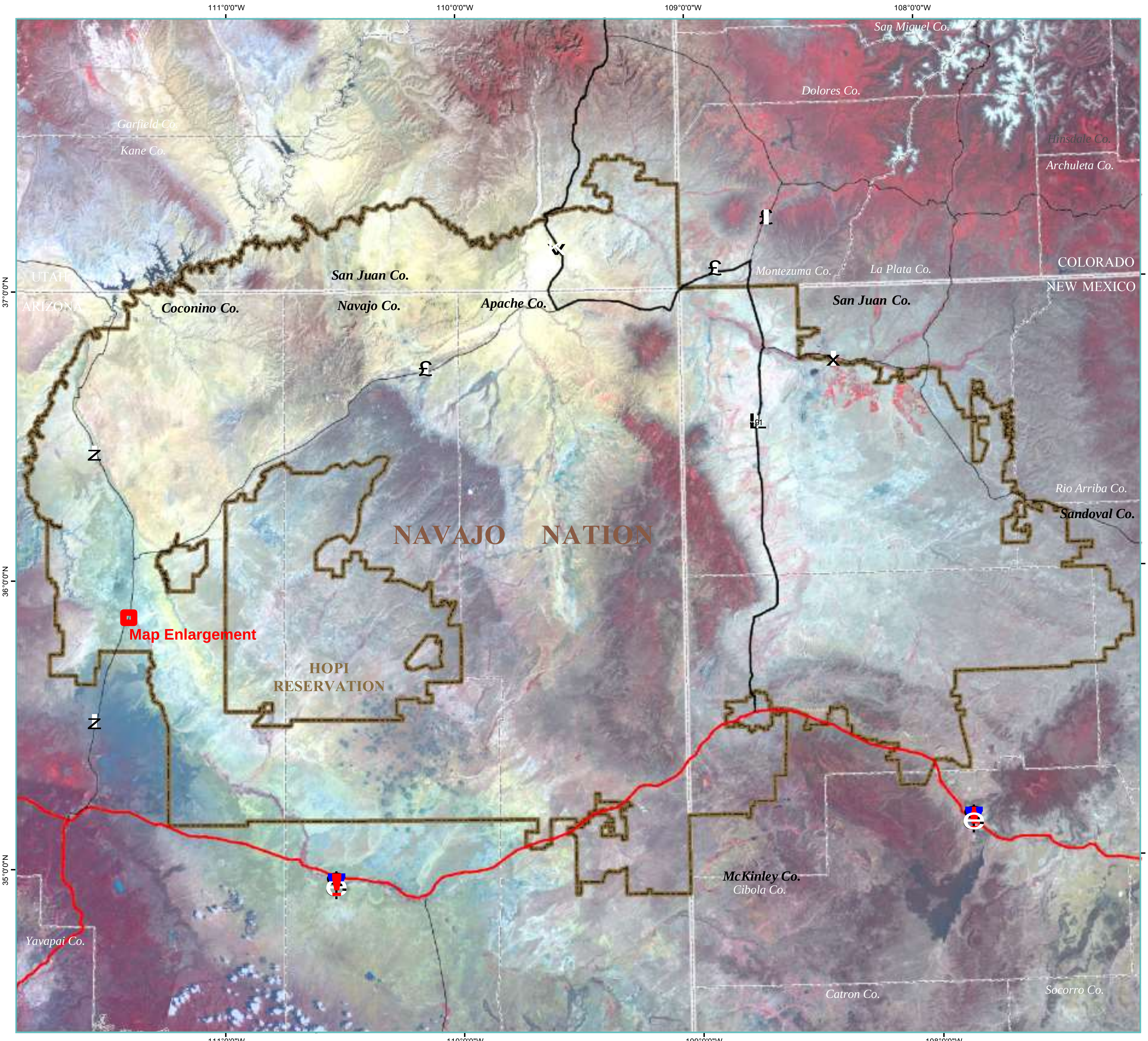
SATELLITE IMAGES

The Landsat satellites are earth observing instruments that were designed to provide consistently calibrated Earth imagery to support monitoring of changes in the Earth's land surface and associated environment. They detect spectrally-filtered radiation at visible, near-infrared, short-wave, and thermal infrared frequency bands from the sun-lit Earth. The imagery can be used in a variety of applications, including land and water management, global change research, oil and mineral exploration, agricultural forecasting, pollution monitoring, change detection, and cartographic mapping.

Figure 45 shows a Landsat MultiSpectral Scanner (MSS) image mosaic. It was developed from North American Landscape Characterization (NALC) Triplicate Data that uses precision (i.e. ground control points) and terrain corrected Landsat 4 and 5 MSS images. The four images that comprise the mosaic were acquired by Landsat between June 18, 1992 and September 5, 1992. The MSS bands 4 (Near-Infrared wave-length), 3 (Red wavelength), and 2 (Green wavelength) are displayed with red, green, and blue, respectively, producing a False Color Infrared composite image, wherein vegetation is red.

Landsat 7 is a later generation earth observing satellite that uses the Enhanced Thematic Mapper Plus (ETM+). It produces enhanced spectral and spatial resolution satellite imagery. Its panchromatic band 8 provides black and white imagery with a spatial resolution of 15 meters. Thirteen Landsat 7 ETM+ panchromatic band 8 (visible light) images were acquired from the Global Land Cover Facility (GLCF). Dates of the imagery range between June 6, 2000 and August 26, 2002. These orthorectified images were mosaiced together to provide a single 15 meter resolution black and white image of the entire Navajo Nation.

The two (2) satellite images are provided on the DVD named "DVD_DOQQ_3" (Satellite/NN_Landsat_ETM_Pan.img and Satellite/ Nav_MSS.img).



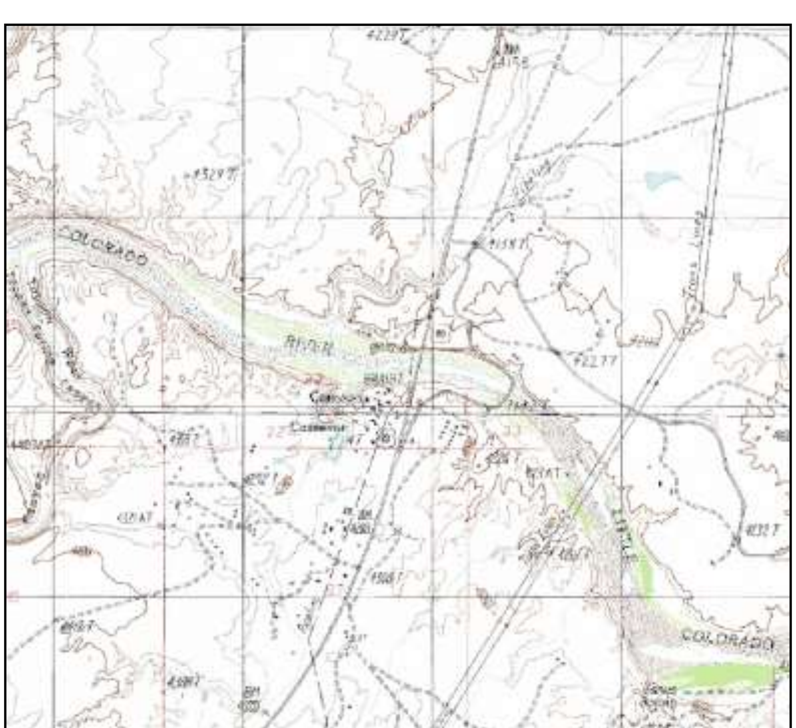
ABANDONED URANIUM MINES AND THE NAVAJO NATION

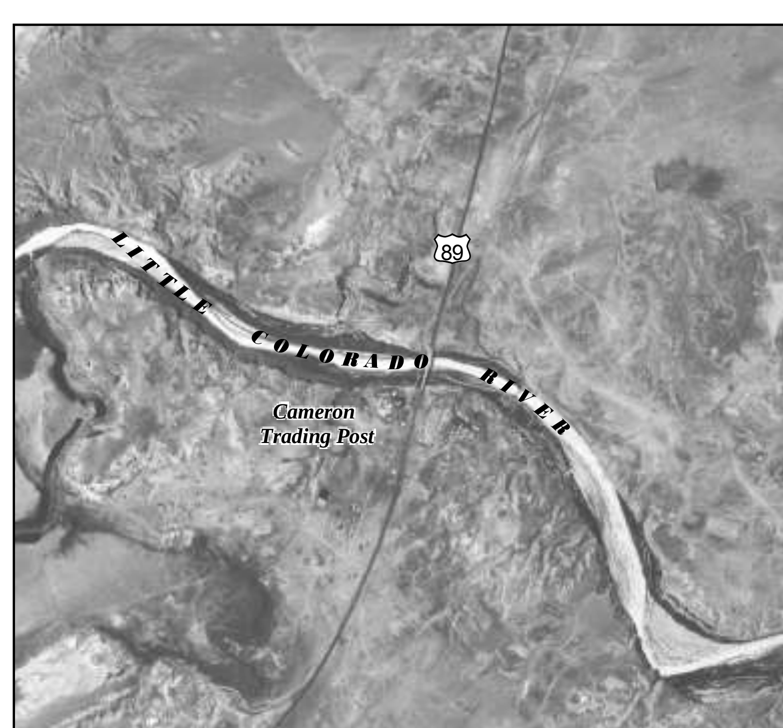
LANDSAT, DIGITAL RASTER GRAPHIC (DRG), AND DIGITAL ORTHOPHOTO QUARTER QUADRANGLE (DOQQ) IMAGERY

N W E S

0 50 Miles

Map Scale 1:1,750,000





The map enlargements above show portions of a County DRG mosaic (left) and County DOQQ mosaic (right) of the Cameron Trading Post and Little Colorado River area. The County mosaics were acquired from the Natural Resources Conservation Service.

The Landsat MultiSpectral Scanner (MSS) image mosaic in the top map was developed from four EROS Data Center 1992 North American Landscape Characterization (NALC) Triplicate images. The counties named with black text identify the DRG and DOQQ County Mosaics that are provided on DVDs with this document.

Figure 45. Landsat, Digital Raster Graphic, and Digital Orthophoto Quarter Quadrangle Imagery of the Navajo Nation.

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Dumping muck, Frank No. 1 mine.
Photo courtesy of William L. Chenoweth.

Portals at the Mesa 1 mine, Lukachukai Mountains, Arizona.
Photo courtesy of William L. Chenoweth.