ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

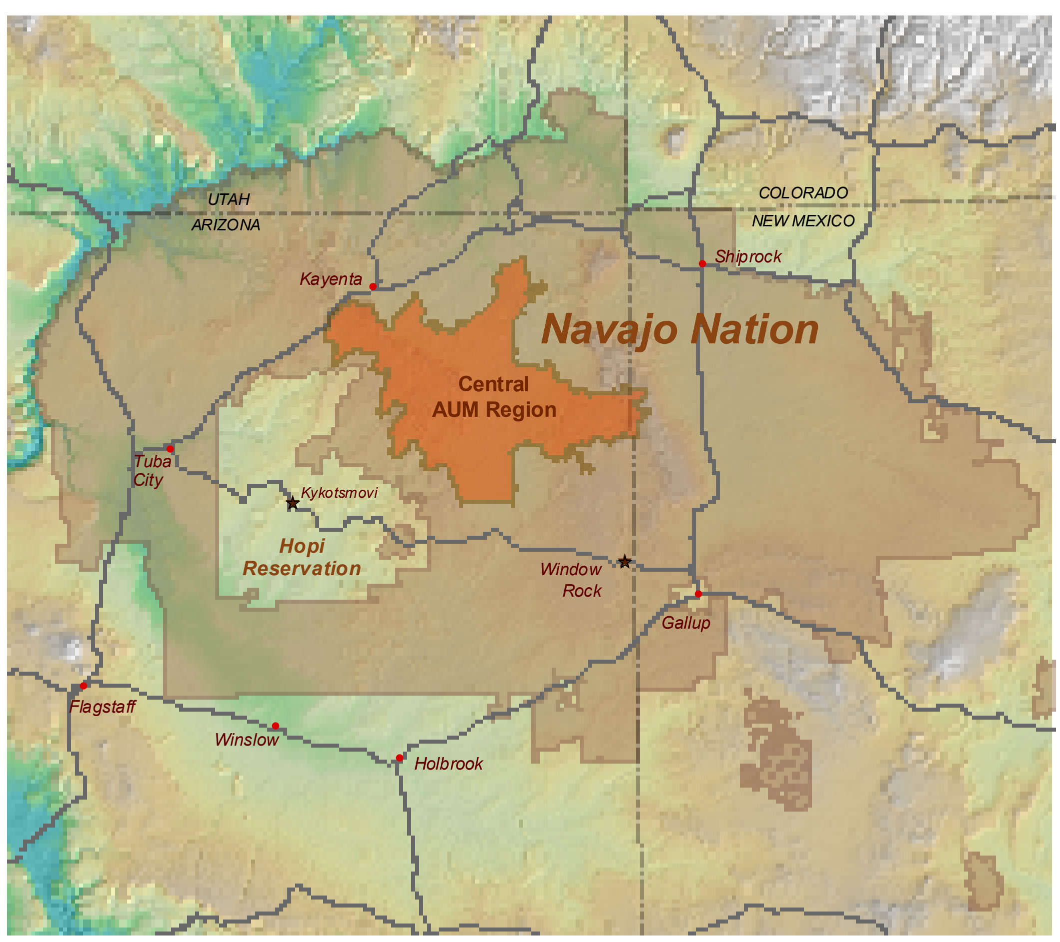
CENTRAL AUM REGION
SCREENING ASSESSMENT REPORT

Black Mesa, Chilchinbeto, Chinle, Many Farms, Rock Point, Rough Rock, Tachee/Blue Gap, Tsaile/Wheatfields, Tselani/Cottonwood












Navajo Nation
Environmental Protection Agency

U.S. Environmental
Protection Agency - Region 9

Navajo Abandoned
Mine Lands Reclamation Program

COVER PHOTOS

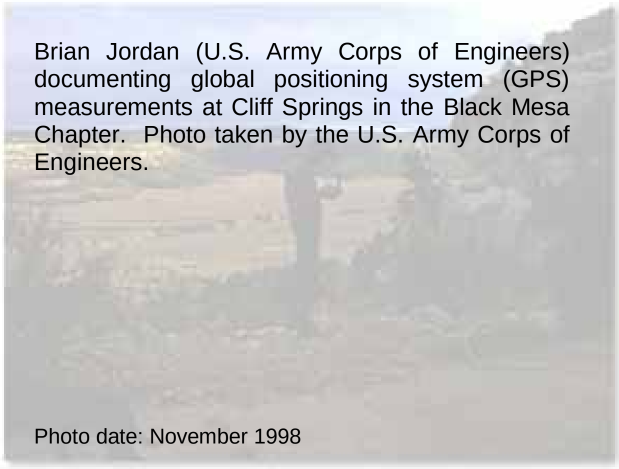

Brian Jordan (U.S. Army Corps of Engineers) documenting global positioning system (GPS) measurements at Cliff Springs in the Black Mesa Chapter. Photo taken by the U.S. Army Corps of Engineers.

Photo date: November 1998


Photo of Burro Spring located in Chilchinbeto Chapter. Photo taken by the U.S. Army Corps of Engineers.

Photo date: October 1998

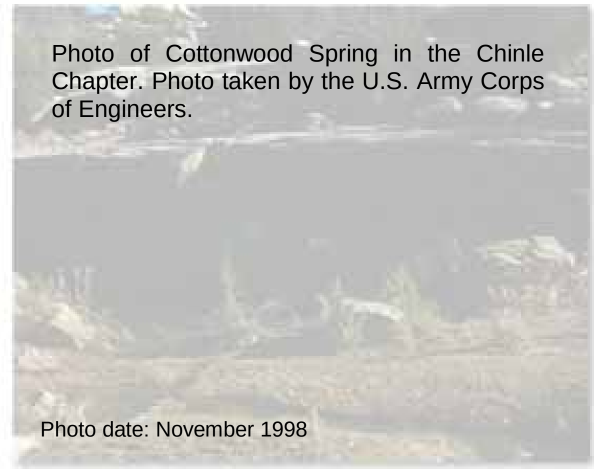


Photo of Cottonwood Spring in the Chinle Chapter. Photo taken by the U.S. Army Corps of Engineers.

Photo date: November 1998

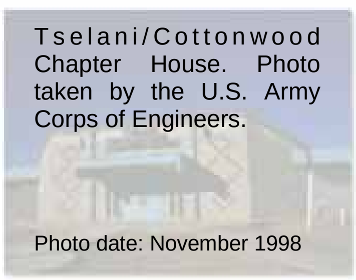

Tselani/Cottonwood Chapter House. Photo taken by the U.S. Army Corps of Engineers.

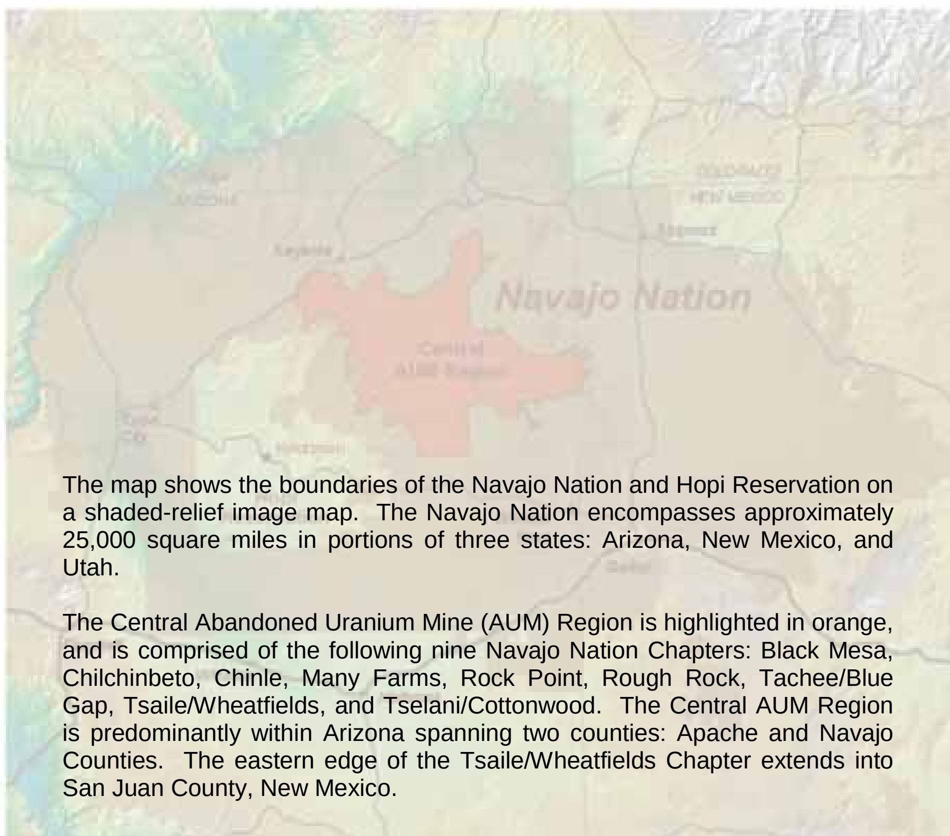
Photo date: November 1998


Black Mountain Well in the Tselani/Cottonwood Chapter. Photo taken by the U.S. Army Corps of Engineers.

Photo date: March 1999


Tsaile/Wheatfields Chapter House.

Photo from tsaile.nndes.org



The map shows the boundaries of the Navajo Nation and Hopi Reservation on a shaded-relief image map. The Navajo Nation encompasses approximately 25,000 square miles in portions of three states: Arizona, New Mexico, and Utah.

The Central Abandoned Uranium Mine (AUM) Region is highlighted in orange, and is comprised of the following nine Navajo Nation Chapters: Black Mesa, Chilchinbeto, Chinle, Many Farms, Rock Point, Rough Rock, Tachee/Blue Gap, Tsaile/Wheatfields, and Tselani/Cottonwood. The Central AUM Region is predominantly within Arizona spanning two counties: Apache and Navajo Counties. The eastern edge of the Tsaile/Wheatfields Chapter extends into San Juan County, New Mexico.

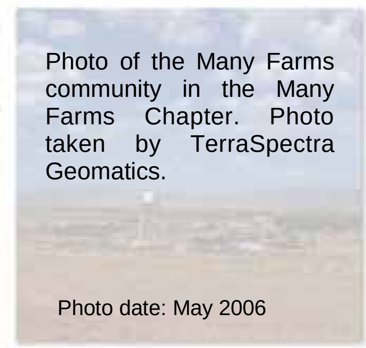


Photo of the Many Farms community in the Many Farms Chapter. Photo taken by TerraSpectra Geomatics.

Photo date: May 2006

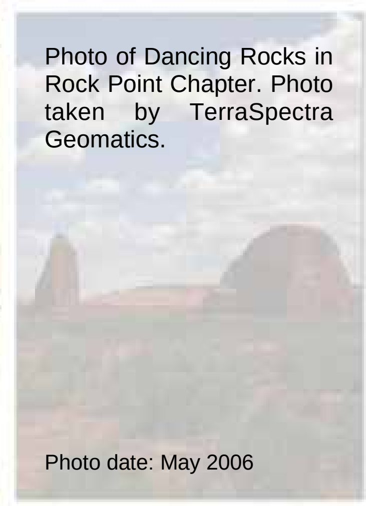


Photo of Dancing Rocks in Rock Point Chapter. Photo taken by TerraSpectra Geomatics.

Photo date: May 2006

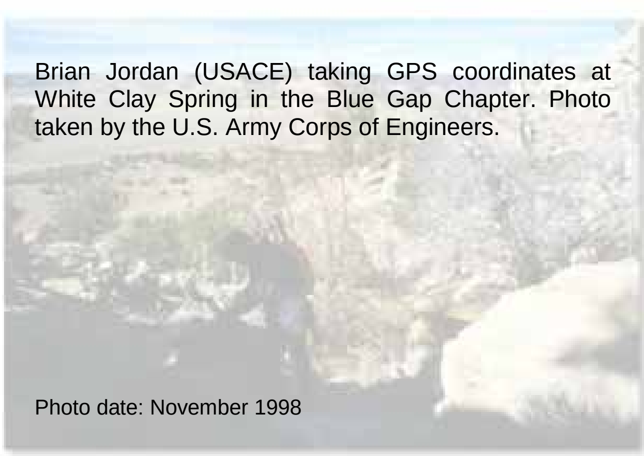

Brian Jordan (USACE) taking GPS coordinates at White Clay Spring in the Blue Gap Chapter. Photo taken by the U.S. Army Corps of Engineers.

Photo date: November 1998


Photo of Rough Rock Community looking south toward Black Mesa. Photo taken by TerraSpectra Geomatics.

Photo date: May 2006

We gratefully acknowledge William L. Chenoweth's significant contributions to this report.

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ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

CENTRAL AUM REGION SCREENING ASSESSMENT REPORT

NAVAJO NATION CHAPTERS INCLUDED IN THE CENTRAL AUM REGION:

Black Mesa
Chilchinbeto
Chinle
Many Farms
Rock Point
Rough Rock
Tachee/Blue Gap
Tsaile/Wheatfields
Tselani/Cottonwood

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August 2006

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

CONTENTS

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
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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 Central AUM Region 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). After all the data is collected, 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, are no longer being maintained, no further mining is intended, and the mine may pose a hazard. Based upon several chapter meetings, the following are frequently asked questions that the agencies have been 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 (groundwater 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 natural makeup of 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 found everywhere naturally 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 kidney 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)?

   In the Central AUM Region, the agencies looked at how close structures (e.g., homes, churches, businesses) were located to the 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.

[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 the 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*

   In the Central AUM Region, 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 5 through 8 for maps showing the locations of water sources and mines within the Central AUM Region.

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 that has come from a uranium mine area in your home or yard, call the Navajo Superfund Project Manager at 888-643-7692 or 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 Supply at 928-871-7715.
   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 down winders.

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

Uranium Office
Post Office Box 1079
Tuba City, Arizona 86045
Telephone: 928-283-3008 or
928-283-3009

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
Montezuma Creek Clinic
Post Office Box 130
Montezuma Creek, Utah 84534
Telephone: 435-651-3291

RESEP Coordinator
Lake Powell Medical Center
Post Office Box 1625
Page, Arizona 86040
Telephone: 928-645-8123, ext. 206

RESEP Coordinator
North Country Community Health Center
2301 N. 4th St, Suite 101
Flagstaff, Arizona 86003
Telephone: 928-779-7277

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.

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.

Funding for NNEPA is provided by Navajo Nation general funds, federal grants from the U.S. Environmental Protection Agency (EPA), the U.S. Department of Justice, and from fees that are collected under existing Tribal environmental laws.

The Navajo Superfund Program (NSP) is one of several programs within the WRCD. The NSP is funded by an EPA grant under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. 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 in the Central AUM Region.

NSP has conducted assessments at several abandoned uranium mine sites. Activities related to these assessments included collecting samples of soil sediments and both surface 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 the 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 the EPA may conduct remedial response actions.

For further information about NNEPA or the Central AUM Screening Assessment Report, you may contact the following:

Mr. Steven B. Etsitty, Executive Director
Navajo Nation Environmental Protection Agency
Post Office Box 339
Window Rock, Arizona 86515
Telephone: 928-871-7692

Ms. Arlene C. Luther, Environmental Department Manager
Waste Regulatory Compliance Department
Navajo Nation Environmental Protection Agency
Post Office Box 339
Window Rock, Arizona 86515
Telephone: 928-871-7993

Ms. Diane J. Malone, Program Manager
Navajo Superfund Program
Post Office Box 2946
Window Rock, Arizona 86515
Telephone: 928-871-6859

NAVAJO ABANDONED MINE LANDS RECLAMATION PROGRAM

The Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) is a program under the Navajo Nation Division of Natural Resources. The purpose of the program is to fulfill the requirements of Public Law 95-87 "Surface Mining Control and Reclamation Act (SMCRA) of 1977." Title IV of Public Law 95-87 addresses abandoned mine reclamation.

Through SMCRA, reclamation funds for abandoned mine lands were set up to address land and water resources impacted by abandoned mines for which there were no responsible parties. Reclamation under this program can only be addressed to lands that have tribal trust status.

A trust fund was established in the U.S. Treasury as the Abandoned Mine 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. 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.

The NAMLRP was established in 1988 and since then they have 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 III
Navajo Abandoned Mine Lands Reclamation Program
Post Office Box 1875
Window Rock, Arizona 86515
Telephone: 928-871-6982

Field Office: Rose Grey, Program Manager II
Navajo Abandoned Mine Lands Reclamation Program
Post Office Box 3605
Shiprock, New Mexico
Telephone: 505-368-1220

Field Office: Ray Tsingine, Program Manager II
Navajo Abandoned Mine Lands Reclamation Program
Post Office Box 730
Tuba City, Arizona 86045
Telephone: 928-283-3187

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

The mission of the U. S. Environmental Protection Agency (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 our headquarters offices in Washington, DC, 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 is producing a Geographic Information System (GIS) database and summary reports for EPA in support of abandoned uranium mine screening assessments on the Navajo Nation. The GIS database will identify the locations of all known uranium mines on the Navajo Nation and their proximity to structures, water sources, and surface water drainages. The reports 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. NNEPA, NAMLRP and EPA expect to complete the screening assessment phase by December 2006.

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

For further information about EPA or the Central AUM Region Screening Report, you may contact the following:

Andrew Bain, Remedial Project Manager (SFD-8-2)
U. S. Environmental Protection Agency
75 Hawthorne Street
San Francisco, California 94105
Telephone: 415-972-3167

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

PURPOSE

The purpose of the Abandoned Uranium Mines (AUM) and the Navajo Nation Project (AUM Project) is to conduct assessments to identify radiation sources, potential exposures, and to recommend methods to reduce exposure from AUMs on the Navajo Nation. There are more than 1,000 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.

The goal of the current phase of the AUM Project is to perform screening assessments to prioritize Navajo AUM sites using existing, readily available data. 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. Screening Assessment Reports and Geographic Information System (GIS) Data Packages will be developed for six regions of the Navajo Nation that experienced uranium mining. This Central AUM Region Screening Assessment Report is the fourth of these reports, and describes the screening assessment derived from the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) that was conducted for the Central AUM Region. A brief overview of the CERCLA process and a discussion of potential contaminants and exposure pathways related to AUMs is provided for background.

BACKGROUND

Widespread mining of uranium ore for Cold War weapons and nuclear energy production occurred 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.

It is probable that the mining activities led to dispersion of radioactive and heavy metal contaminated dusts, sediments, groundwater, 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 all the AUM sites.

Congressional hearings were conducted on November 4, 1993 to address these concerns (U.S. House of Representatives, 1993). During the hearings, the Navajo Nation presented testimony about the AUMs and requested assistance in determining if the uranium mines posed a health risk to residents. The U.S. Environmental Protection Agency (EPA) presented testimony to describe its federal authority under CERCLA and how the EPA could assist the tribe. The U.S. Department of Energy (DOE), the U. S. Department of Interior (DOI), the Navajo Nation Environmental Protection Agency (NNEPA), and the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) also participated in the hearings.

In response to the concerns raised by the Navajo Nation at the Congressional hearings, the EPA initiated the AUM Project in 1994. Under the authority of CERCLA, the EPA conducted field data collection efforts between 1994 and 2000 to determine the scope and impact of uranium mining on the Navajo Nation. These efforts were undertaken in cooperation with NNEPA, NAMLRP, and the U.S. Army Corps of Engineers (USACE). Independently, NAMLRP has reclaimed a large quantity of AUMs using Surface Mining Control and Reclamation Act (SMCRA) funds. In addition, DOE and the Nuclear Regulatory Commission (NRC) have authority for investigating and addressing the former mill sites under the Uranium Mill Tailings Radiation Control Act (UMTRCA) located near the Navajo communities of Shiprock, New Mexico; Mexican Hat, Utah; Tuba City, Arizona; and Monument Valley, Arizona.

During the first phase of the AUM Project, EPA conducted extensive aerial radiological surveys, collected water samples, and surveyed homes to determine if they were constructed with radioactive materials from the uranium mines. EPA prepared a draft Integrated Assessment for the King Tutt Mesa area (EPA, 1999). EPA released a Project Atlas in 2000, providing an overview of the AUM Project data collected from 1994 to 2000, including the water and aerial radiation survey data (EPA, 2000a).

In 2002, the Navajo Nation and EPA refocused the project approach, agreeing on the need to conduct a systematic review of existing data spanning the full spatial extent of the Navajo Nation to best address the CERCLA questions. NAMLRP provided EPA with mine site locations, representing the most accurate readily available source of such data. A GIS database was developed, concentrating on locational data about all known AUMs on the Navajo Nation. The resulting preliminary analysis will aid the agencies making CERCLA decisions and help plan for future use by the Navajo Nation.

The risk of human and ecological exposure on the Navajo Nation occurs in the following three ways, which may present risk on the surface and subsurface: 1) Naturally occurring radioactive material (NORM), 2) the uranium milling activities, and 3) the AUM sites. CERCLA only addresses wastes resulting from man-made activities, such as mining. EPA has no authority under CERCLA with respect to naturally occurring ore. EPA is also excluded from addressing mill sites; DOE and NRC have the authority and responsibility for mill site reclamation under UMTRCA.

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. 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 1,000 known AUM mine features on the Navajo Nation, EPA needed to screen and prioritize all sites before applying the CERCLA process shown in Figure 1. 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. Radiation and toxic metals that are released from an AUM site can travel through the air, through the soils, and through surface and groundwater. This model includes those pathways of potential contamination, and then evaluates the presence of structures as an indicator of population at potential risk to exposure.

The EPA project team created an HRS-derived model to compare the individual AUM sites by distance from the human receptors. This report presents the results from the model in data tables and maps 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.

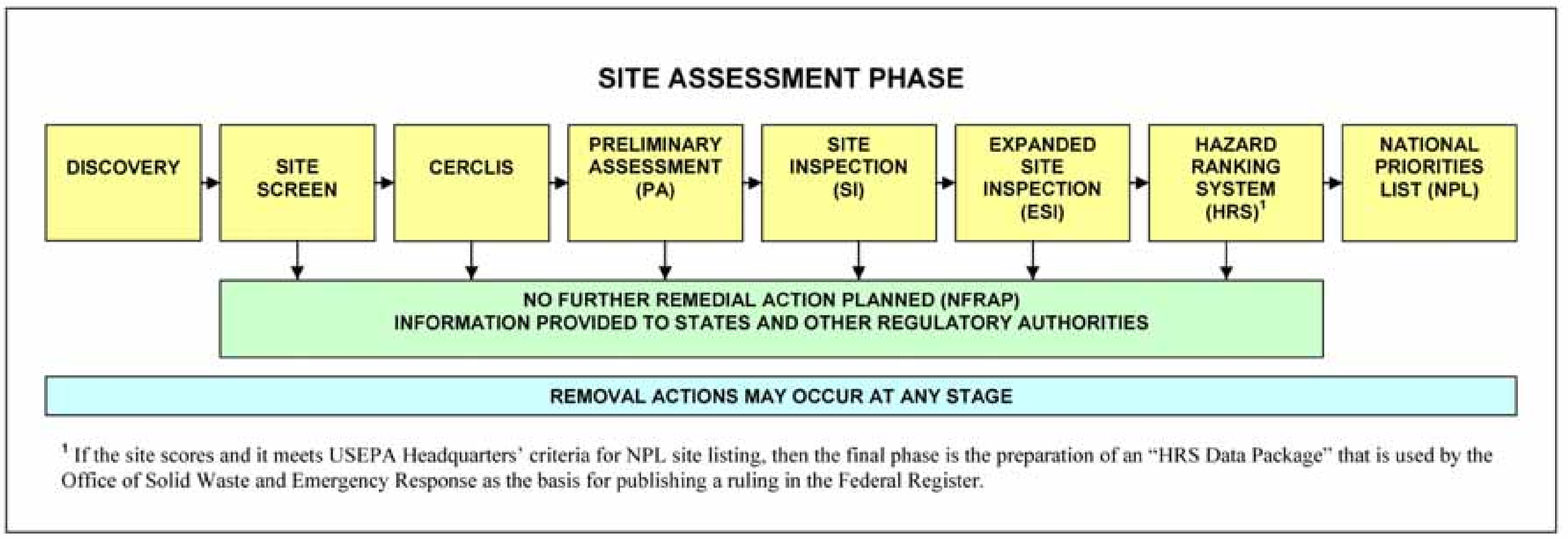


Figure 1. Superfund Process (modified after EPA, 1991).

The current phase of the AUM Project is limited to collecting existing and readily available data that can be used to: 1) identify potential radiation sources (AUMs), 2) screen for potential exposures, and 3) recommend follow-up actions. Table 1 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 1. Possible pathways, exposure routes, and human and ecological receptors (after EPA, 1991).

CONTAMINANTS AND EXPOSURE PATHWAYS

Although exposure to uranium in natural settings may be limited, mining activities often result in increased exposure risks. This includes both direct and indirect exposures that can occur via multiple pathways. Mining activities disturb mineralization that can affect exposures. 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. These activities can also change groundwater and surface water flow, which can lead to the release of hazardous materials into the environment (EPA, 2000b).

Radioactive decay of the parent Uranium^{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. 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. 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. 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).

CENTRAL AUM REGION

Uranium mining occurred in the Central AUM Region on the Navajo Nation. 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 counties: Apache and Navajo Counties in Arizona, and San Juan County in New Mexico. Figure 2 shows the location of the Central AUM Region which is comprised of nine Navajo Nation Chapters: Black Mesa, Chilchinbeto, Chinle, Many Farms, Rock Point, Rough Rock, Tachee/Blue Gap, Tsaile/Wheatfields, and Tselani/Conttonwood. Canyon de Chelly National Monument is located near Chinle, Arizona (see Appendix A-2). The National Park Service has responsibility for the management of cultural resources, administration, and visitor services facilities in the national monument. The Navajo Nation retains the control of the land and natural resources, and is responsible for surface and subsurface uses of the land (NNEPA, 2001).

The Central AUM Region covers approximately 2,196 square miles (1,405,485 acres) in the Black Mesa, Chinle Valley, and Defiance Plateau areas of the Navajo Nation. The region is generally sparsely populated. The 2000 Census estimated the total resident population for the entire region at 19,228. Appendix A - Structures (page A-1) describes the general physical and population characteristics for each of the chapters comprising the Central AUM Region.

Uranium was mined in the Central AUM Region between 1954 and 1968. Fifteen (15) AUMs with documented production were located in the region. Eleven (11) AUMs were mapped for which no records of uranium production were located. These AUMs had evidence of surface disturbance and were located within a mining claim.

METHODOLOGY

The methodology used to develop this Central AUM Region Screening Assessment Report applied the following steps:

- Develop a CERCLA 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 a composite scoring list

HRS-DERIVED MODEL

The EPA Superfund Site Assessment and Technical Support Team selected a subset of HRS criteria to develop 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) 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., uranium mines, 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, wetlands, 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 internal 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 waking 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 strong winds associated with dispersion effects and the difficulty in attributing sources. The HRS-derived model developed for the AUM Project 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, and
- For structures beyond 1 mile, assign 0 points.

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

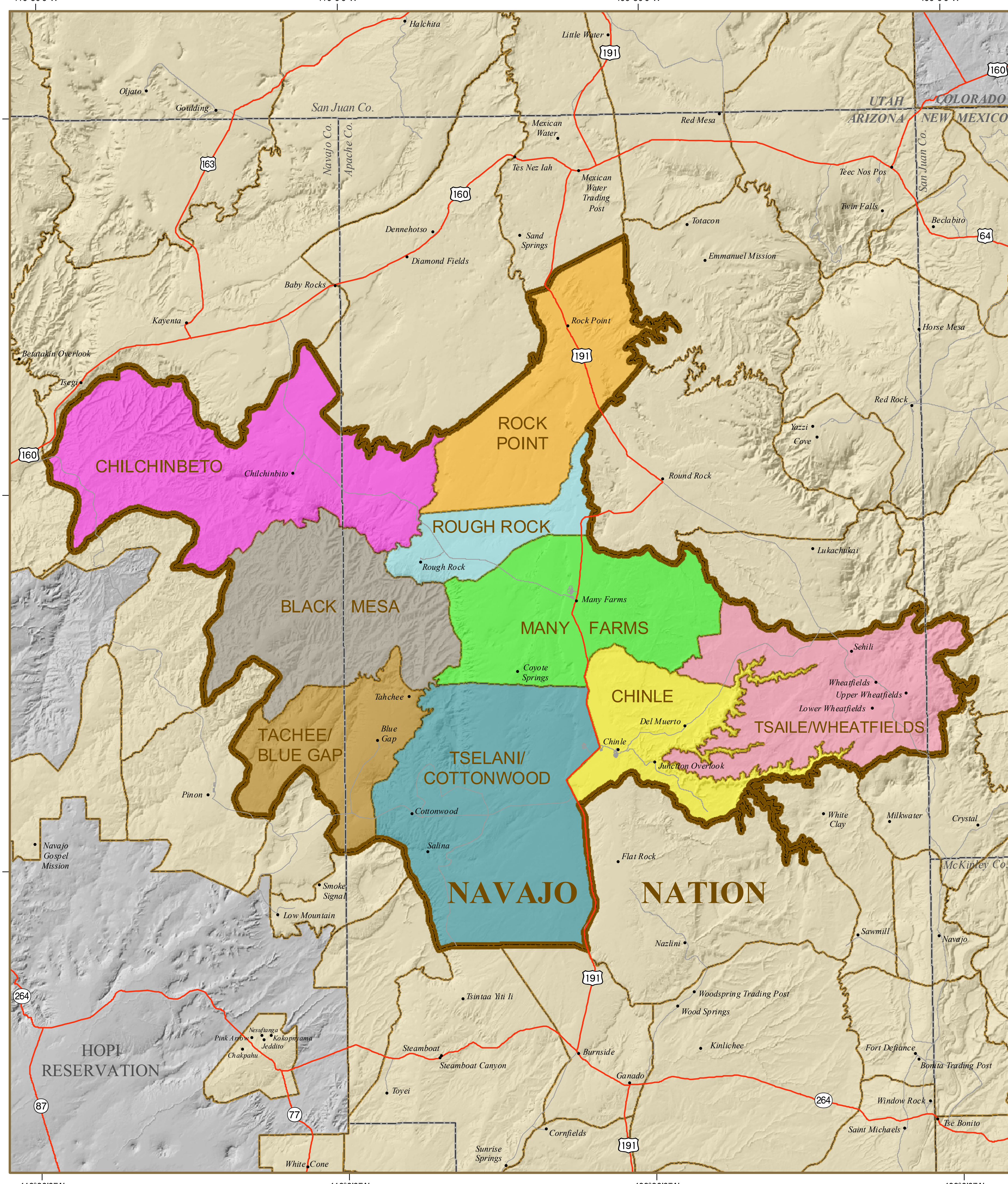
- For structures within 200 feet of an AUM site, assign 100 points per structure,
- For structures that exist between 200 feet and 1,320 feet, assign 25 points per structure,
- For structures that exist between 1,320 feet and 1 mile, assign 10 points per structure, and
- For structures beyond 1 mile,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

Groundwater 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, and
- 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.



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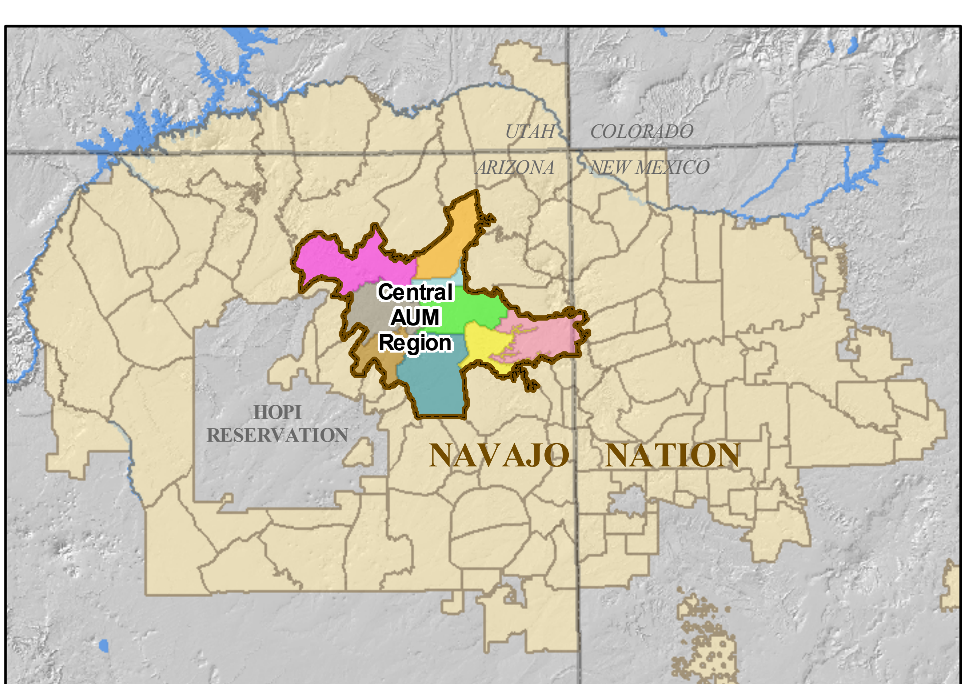


ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

CENTRAL AUM REGION

N
W E
S

0 20 Miles

Map Scale 1:600,000

Legend

- Central AUM Region
- Chapter
- Highway
- Paved Road

Figure 2. Central AUM Region Location on the Navajo Nation.

DATA

The following data were identified as required to perform the HRS-derived scoring algorithm for the AUM Project:

AUM sites - Locations for potential radioactive source material (i.e. AUMs) were derived from: NAMLRP Reclamation Project Area boundaries, uranium mining history reports by William L. Chenoweth (1989, 1990a and 1990b) and by Scarborough (1981), written communications from William L. Chenoweth (2006), U.S. Atomic Energy Commission Certification Reports, U.S. Department of Energy aerial radiation surveys funded by the 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 of the identified AUMs and unreclaimed mine features. These polygons were used to represent the surface extents and locations of AUMs.

Structures - Structures are buildings that are 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, USGS 7.5' topographic maps, and utility meter locations. Structures are the target for the air and soil pathways.

Wells - A wells dataset was acquired from the Navajo Water Resources Department and augmented using data from the Arizona Department of Water Resources, National Hydrography Database, Geographic Names Information System, U.S. Army Corps of Engineers water sample locations, USGS Ground-water Site Investigations Database, and USGS DRGs and DOQQs. Wells were used as a target for the ground-water pathway.

Drainages - The USGS/EPA National Hydrography Dataset (NHD), along with DOQQs and DRGS, were used to identify perennial and intermittent drainages downstream from AUMs.

Appendix A presents descriptions of the data sources, methods for data collection and automation into the GIS database, uses of the data, and data limitations. Appendix A also provides examples of map products that were developed from the GIS datasets. Figure 3 below shows example photographs of modified HRS scoring factors found in the Central AUM Region.

Abandoned Uranium Mine
Claim 28 mine in the Tachee/Blue Gap Chapter. Photo courtesy of TerraSpectra Geomatics (photo taken 05/18/06)

Structures
Structures in the community of Black Mesa in Black Mesa Chapter. Photo courtesy of TerraSpectra Geomatics (photo taken 05/18/06).

Wells
Tank 4T-386 in the Tachee/Blue Gap Chapter. Photo courtesy of the U.S. Army Corps of Engineers (photo taken 11/23/98).

Surface Water
Chinle Wash / Chinle Creek photo courtesy of Navajo Nation Environmental Protection Agency (photo taken 07/15/1999)

Figure 3. Example Photographs of Modified HRS Scoring Factors.

RESULTS

This section presents the results of the HRS-derived screening model for AUM sites located within the Central AUM Region. As previously stated, these scores are not intended to indicate actual risk, but will be used to assist with establishing priorities for future investigations.

Summary score tables were generated for the groundwater and the soil and air pathways for each AUM. A separate summary table for the surface water pathway was not prepared, as explained on the following page. The pathway summary tables include a MAP-ID, which is an arbitrary number to facilitate map labeling and is generally assigned so that MAP-ID increases from north to south and west to east. The MAP-ID numbers are unique to this report and do not correspond with MAP-ID numbers used in previous screening assessment reports. The tables include the name of the Chapter the AUM is located within. Each AUM was assigned a mine name or identifier using the following naming hierarchy: the mine or claim name (if available), or the NAMLRP reclamation project number, or finally, the NAMLRP point mine feature number. The groundwater pathway summary table presents the counts of wells that fall 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 for each AUM in Table 2.

The soil and air pathway summary table presents the counts of structures that fall within the 200 foot, 1/4 mile, and 1 mile buffers and the total number of structures within 1 mile of each AUM. The scores for each buffer zone are 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 are both shown in Table 3.

A summary table entitled “Combined Pathway Score” (Table 5) sums the total scores of each pathway for each AUM site to establish total scores. Maps showing the locations of the scored AUMs are presented at the end of this section.

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 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, 2000b).

Evaluation of the surface water pathway using the modified HRS required 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 of the AUM sites within the Central AUM Region were located within 1 mile of a downstream intermittent stream or drainage (see Figure 4) and scored 160 (score = 100+50+10). A separate table was not developed for the Surface Water Pathway score results, but the total surface water scores are shown in Table 5 “Combined Pathway Scores”.

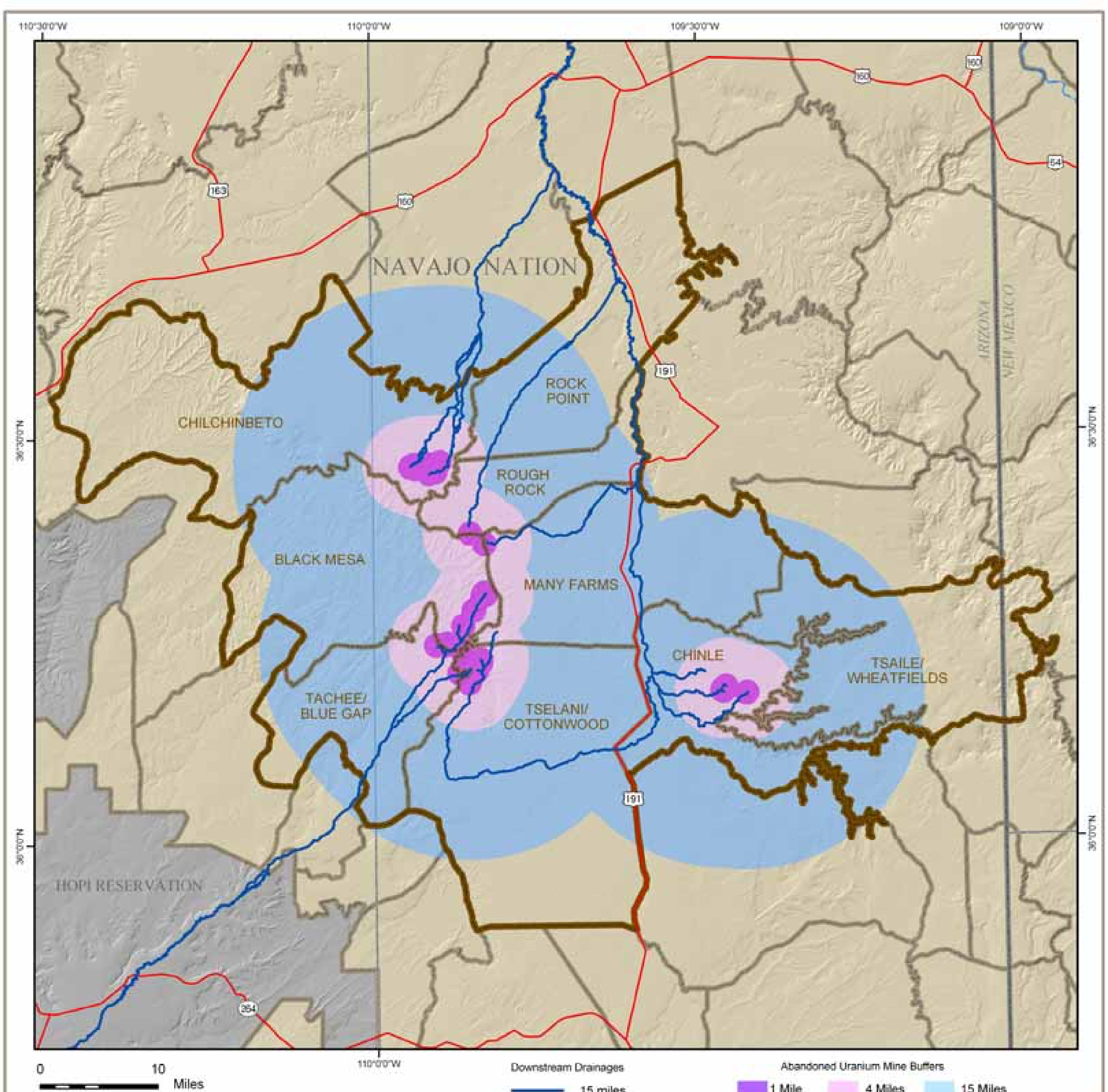


Figure 4. Surface Water Drainages Downstream from AUM Sites.

GROUNDWATER PATHWAY

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

Evaluation of the groundwater pathway using the HRS-derived criteria required the location of the AUM sites and distance to wells (including developed springs). The HRS criteria used to evaluate the groundwater 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 groundwater pathway assessment are shown in Table 2. The table was sorted by MAP-ID number. The highest groundwater pathway score is 280 and is located at the Tom Klee mine in the Chilchinbeto Chapter (MAP-ID #7). The total groundwater pathway score for this site is comprised of 0 wells within 1/4 mile of the AUM, 1 well in the 1/4 mile to 1 mile buffer, and 23 wells in the 1 mile to 4 mile buffer.

Table 2. Groundwater Pathway Score.

MAP-ID	Chapter	Mine Name / Identifier Name	1/4 Mile Wells Count	1 Mile Wells Count	4 Mile Wells Count	Total Wells Count	1/4 Mile Score	1 Mile Score	4 Mile Score	Total Groundwater Score
1	Chilchinbeto	Tom Wilson	0	1	11	12	0	50	110	160
2	Chilchinbeto	Tom Wilson	0	1	11	12	0	50	110	160
3	Chilchinbeto	Tom Wilson	0	1	10	11	0	50	100	150
4	Chilchinbeto	Tom Wilson	0	1	10	11	0	50	100	150
5	Chilchinbeto	Jim Hatattly	0	0	13	13	0	0	130	130
6	Chilchinbeto	Jim Hatattly	0	2	12	14	0	100	120	220
7	Chilchinbeto	Tom Klee	0	1	23	24	0	50	230	280
8	Chilchinbeto	Tom Klee	0	0	14	14	0	0	140	140
9	Rough Rock	Rough Rock Slope No. 9	0	0	18	18	0	0	180	180
10	Many Farms	Dan Taylor No. 1	0	0	20	20	0	0	200	200
11	Black Mesa	Frank Todecheenie No. 1	0	1	5	6	0	50	50	100
12	Black Mesa	Sam Charley No. 1	0	1	5	6	0	50	50	100
13	Black Mesa	Kasewood Bahe No. 1	0	1	5	6	0	50	50	100
14	Black Mesa	Thomas Begay No. 1	0	1	5	6	0	50	50	100
15	Black Mesa	Etsitty No. 1	0	0	3	3	0	0	30	30
16	Black Mesa	Blk029	0	0	5	5	0	0	50	50
17	Tachee/Blue Gap	Claim 35	0	0	4	4	0	0	40	40
18	Black Mesa	Claim 28	0	1	3	4	0	50	30	80
19	Black Mesa	Claim 28	0	1	3	4	0	50	30	80
20	Tselani/Cottonwood	Claim 16	0	0	2	2	0	0	20	20
21	Tselani/Cottonwood	Edward Steve No. 1	0	0	2	2	0	0	20	20
22	Tselani/Cottonwood	Blk022	0	0	2	2	0	0	20	20
23	Tselani/Cottonwood	Claim 10	0	1	3	4	0	50	30	80
24	Tselani/Cottonwood	Claim 7	0	1	3	4	0	50	30	80
25	Tselani/Cottonwood	Claim 6	0	1	3	4	0	50	30	80
26	Tselani/Cottonwood	Claim 3	0	0	4	4	0	0	40	40
27	Tselani/Cottonwood	Claim 3 / Claim 4	0	0	4	4	0	0	40	40
28	Tselani/Cottonwood	Arrowhead No. 2	0	0	4	4	0	0	40	40
29	Tselani/Cottonwood	Arrowhead No. 1	0	0	4	4	0	0	40	40
30	Tselani/Cottonwood	Black Mountain Vase	0	0	4	4	0	0	40	40
31	Chinle	Zhealy Tso	0	1	3	4	0	50	30	80
32	Chinle	Zhealy Tso	0	1	3	4	0	50	30	80
33	Chinle	Zhealy Tso	0	1	3	4	0	50	30	80
34	Chinle	Occurrence B	0	0	5	5	0	0	50	50

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 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, 2000b). Evaluation of the air pathway using the modified HRS also required the location of AUM sites and distance to structures.

The buffer distances around the AUM sites and the factors associated with each distance are the same for both the soil and air pathways under the modified HRS used for this assessment. Therefore, a single table was generated for both pathways. Table 3 "Soil Pathway and Air Pathway Score" 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 table was sorted by the MAP-ID number. The highest scored AUM for the soil and the air pathways is located at the Occurrence B AUM in the Chinle Chapter (MAP-ID #34). The soil pathway score for Occurrence B is 1970 and air pathway score is 1970 for a total soil and air pathway score of 3,940. The soil and air pathway scores calculated for this site are based on 2 structures within 200 feet of the AUM, 2 structures in the 200 foot to 1/4 mile buffer, and 172 structures in the 1/4 mile to 1 mile buffer, for a total of 176 structures within 1 mile of the AUM.

Table 3. Soil Pathway and Air Pathway Score.

MAP-ID	Chapter	Mine Name / Identifier Name	200 Foot Structures Count	1/4 Mile Structures Count	1 Mile Structures Count	Total Structures Count	200 Foot Score	1/4 Mile Score	1 Mile Score	Total Soil Score	Total Air Score
1	Chilchinbeto	Tom Wilson	0	1	11	12	0	25	110	135	135
2	Chilchinbeto	Tom Wilson	0	1	11	12	0	25	110	135	135
3	Chilchinbeto	Tom Wilson	0	4	8	12	0	100	80	180	180
4	Chilchinbeto	Tom Wilson	0	4	8	12	0	100	80	180	180
5	Chilchinbeto	Jim Hatattly	0	0	14	14	0	0	140	140	140
6	Chilchinbeto	Jim Hatattly	0	0	12	12	0	0	120	120	120
7	Chilchinbeto	Tom Klee	0	2	24	26	0	50	240	290	290
8	Chilchinbeto	Tom Klee	0	0	11	11	0	0	110	110	110
9	Rough Rock	Rough Rock Slope No. 9	0	0	4	4	0	0	40	40	40
10	Many Farms	Dan Taylor No. 1	0	0	1	1	0	0	10	10	10
11	Black Mesa	Frank Todecheenie No. 1	0	0	0	0	0	0	0	0	0
12	Black Mesa	Sam Charley No. 1	0	0	0	0	0	0	0	0	0
13	Black Mesa	Kasewood Bahe No. 1	0	0	0	0	0	0	0	0	0
14	Black Mesa	Thomas Begay No. 1	0	0	0	0	0	0	0	0	0
15	Black Mesa	Etsitty No. 1	0	0	9	9	0	0	90	90	90
16	Black Mesa	Blk029	0	0	14	14	0	0	140	140	140
17	Tachee/Blue Gap	Claim 35	0	7	35	42	0	175	350	525	525
18	Black Mesa	Claim 28	0	3	30	33	0	75	300	375	375
19	Black Mesa	Claim 28	0	3	30	33	0	75	300	375	375
20	Tselani/Cottonwood	Claim 16	0	0	0	0	0	0	0	0	0
21	Tselani/Cottonwood	Edward Steve No. 1	0	0	4	4	0	0	40	40	40
22	Tselani/Cottonwood	Blk022	0	0	4	4	0	0	40	40	40
23	Tselani/Cottonwood	Claim 10	0	0	1	1	0	0	10	10	10
24	Tselani/Cottonwood	Claim 7	0	0	1	1	0	0	10	10	10
25	Tselani/Cottonwood	Claim 6	0	0	0	0	0	0	0	0	0
26	Tselani/Cottonwood	Claim 3	0	0	0	0	0	0	0	0	0
27	Tselani/Cottonwood	Claim 3 / Claim 4	0	0	0	0	0	0	0	0	0
28	Tselani/Cottonwood	Arrowhead No. 2	0	0	0	0	0	0	0	0	0
29	Tselani/Cottonwood	Arrowhead No. 1	0	0	0	0	0	0	0	0	0
30	Tselani/Cottonwood	Black Mountain Vase	0	0	0	0	0	0	0	0	0
31	Chinle	Zhealy Tso	0	0	8	8	0	0	80	80	80
32	Chinle	Zhealy Tso	0	0	3	3	0	0	30	30	30
33	Chinle	Zhealy Tso	0	0	6	6	0	0	60	60	60
34	Chinle	Occurrence B	2	2	172	176	200	50	1720	1970	1970

COMBINED PATHWAYS

The GIS database was used to generate several maps depicting the combined pathways results. Figure 5 “Combined Pathways – Map Figure Index” shows the AUM sites and the extents of the aggregated buffers that were generated around the AUM sites. Also shown on Figure 5 are the extents of the three map enlargements for the combined pathways:

Figure 6 Combined Pathways in the Rough Rock Region
Figure 7 Combined Pathways in the Tachee Region
Figure 8 Combined Pathways in the Chinle Region

The map enlargements show the AUM sites labeled with their corresponding MAP-ID, as well as structures, wells, and drainages. Table 4 below lists the map figure number and the range of MAP-IDs on each map.

Table 4. MAP-ID Correspondence to Figure Number.

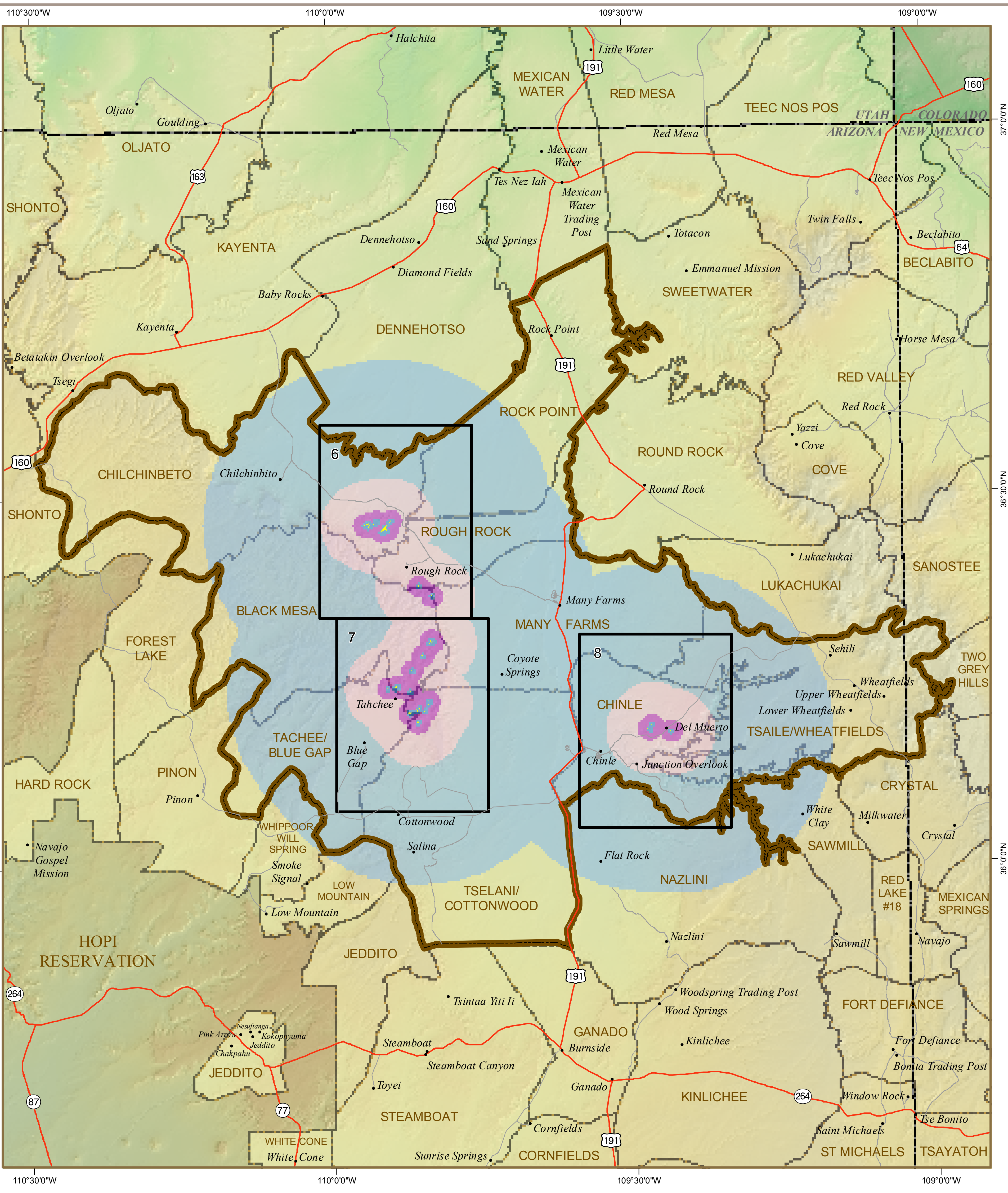
FIGURE NUMBER	RANGE OF MAP-IDS
Figure 6	1- 10
Figure 7	11 - 30
Figure 8	31 - 34

Once 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 groundwater were summed to obtain combined scores, which are presented in Table 5 “Combined Pathway Score.” The table was sorted by MAP-ID number.

Based on the modified HRS model used for this assessment, scores for AUM sites within the Central AUM Region range from 180 to 4,150. The AUM site identified by MAP-ID #34 (Occurrence B AUM) has the highest combined pathway score (4,150) within the Central AUM Region. Figure 8 shows the location of MAP ID #34. In this map figure it is possible to see the Air and Soil Pathway contributions of 2 structures within the 200 foot buffer around the AUM, 2 structure between 200 feet and 1/4 mile, and 172 structures between 1/4 mile and 1 mile. The Groundwater Pathway contributions are shown by 0 wells within 1/4 mile, 0 wells between 1/4 mile and 1 mile, and 5 wells between 1 mile and 4 miles of the AUM site. The Surface Water Pathway contribution is shown by the downstream drainage from the AUM site through each of the buffers.

Table 5. Combined Pathway Score.

MAP-ID	Chapter	Mine Name / Identifier Name	Total Groundwater Score	Total Soil Score	Total Air Score	Total Surface Water Score	Combined Score
1	Chilchinbeto	Tom Wilson	160	135	135	160	590
2	Chilchinbeto	Tom Wilson	160	135	135	160	590
3	Chilchinbeto	Tom Wilson	150	180	180	160	670
4	Chilchinbeto	Tom Wilson	150	180	180	160	670
5	Chilchinbeto	Jim Hatattly	130	140	140	160	570
6	Chilchinbeto	Jim Hatattly	220	120	120	160	620
7	Chilchinbeto	Tom Klee	280	290	290	160	1020
8	Chilchinbeto	Tom Klee	140	110	110	160	520
9	Rough Rock	Rough Rock Slope No. 9	180	40	40	160	420
10	Many Farms	Dan Taylor No. 1	200	10	10	160	380
11	Black Mesa	Frank Todecheenie No. 1	100	0	0	160	260
12	Black Mesa	Sam Charley No. 1	100	0	0	160	260
13	Black Mesa	Kasewood Bahe No. 1	100	0	0	160	260
14	Black Mesa	Thomas Begay No. 1	100	0	0	160	260
15	Black Mesa	Etsitty No. 1	30	90	90	160	370
16	Black Mesa	Blk029	50	140	140	160	490
17	Tachee/Blue Gap	Claim 35	40	525	525	160	1250
18	Black Mesa	Claim 28	80	375	375	160	990
19	Black Mesa	Claim 28	80	375	375	160	990
20	Tselani/Cottonwood	Claim 16	20	0	0	160	180
21	Tselani/Cottonwood	Edward Steve No. 1	20	40	40	160	260
22	Tselani/Cottonwood	Blk022	20	40	40	160	260
23	Tselani/Cottonwood	Claim 10	80	10	10	160	260
24	Tselani/Cottonwood	Claim 7	80	10	10	160	260
25	Tselani/Cottonwood	Claim 6	80	0	0	160	240
26	Tselani/Cottonwood	Claim 3	40	0	0	160	200
27	Tselani/Cottonwood	Claim 3 / Claim 4	40	0	0	160	200
28	Tselani/Cottonwood	Arrowhead No. 2	40	0	0	160	200
29	Tselani/Cottonwood	Arrowhead No. 1	40	0	0	160	200
30	Tselani/Cottonwood	Black Mountain Vase	40	0	0	160	200
31	Chinle	Zhealy Tso	80	80	80	160	400
32	Chinle	Zhealy Tso	80	30	30	160	300
33	Chinle	Zhealy Tso	80	60	60	160	360
34	Chinle	Occurrence B	50	1970	1970	160	4150



ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

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 Lands Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Buffers were generated by TerraSpectra Geomatics. Map index region boundaries are approximate.

Map Index Region Designations

Figure

6 - Rough Rock
7 - Tachee
8 - Chinle

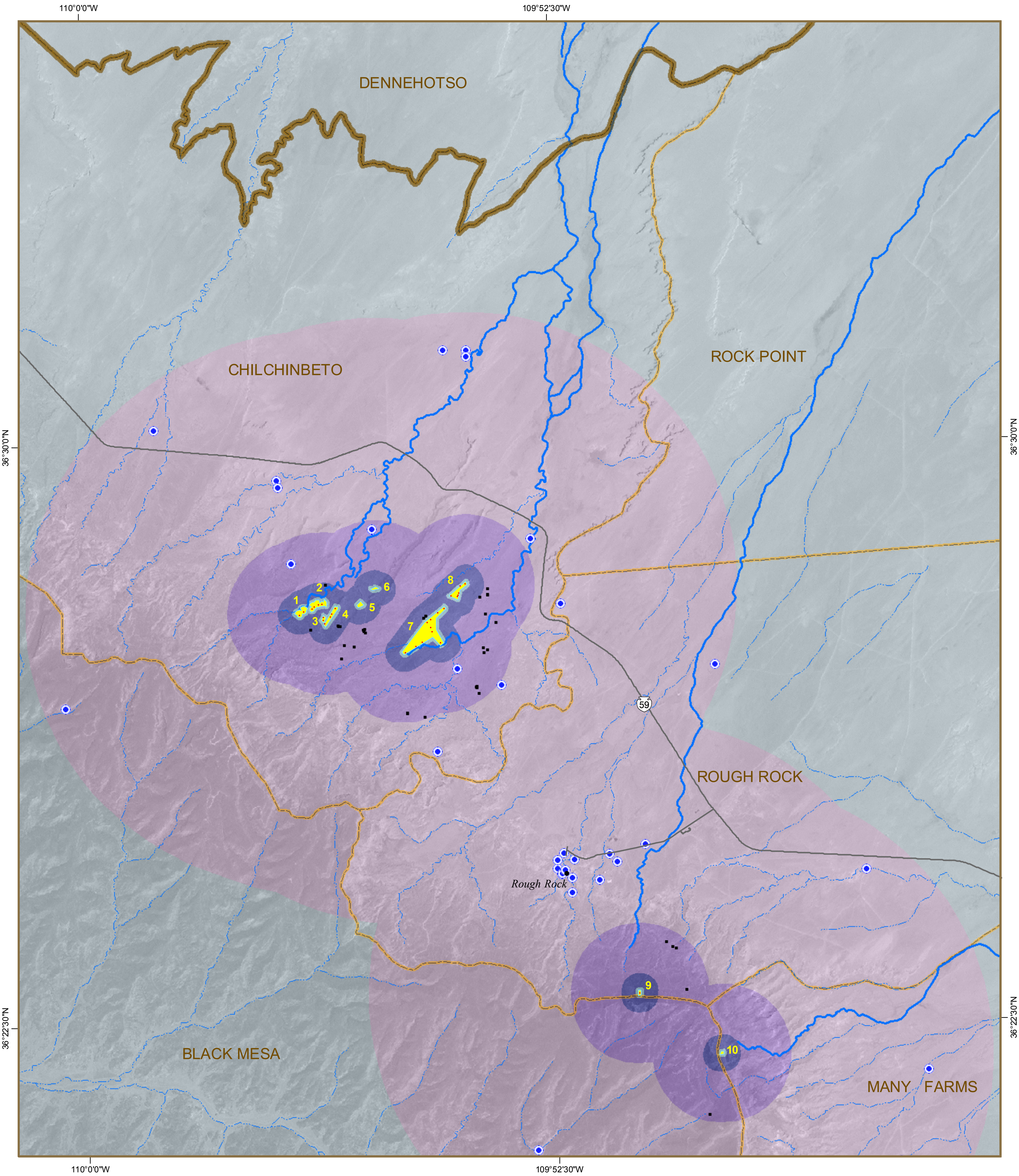
0 20 Miles

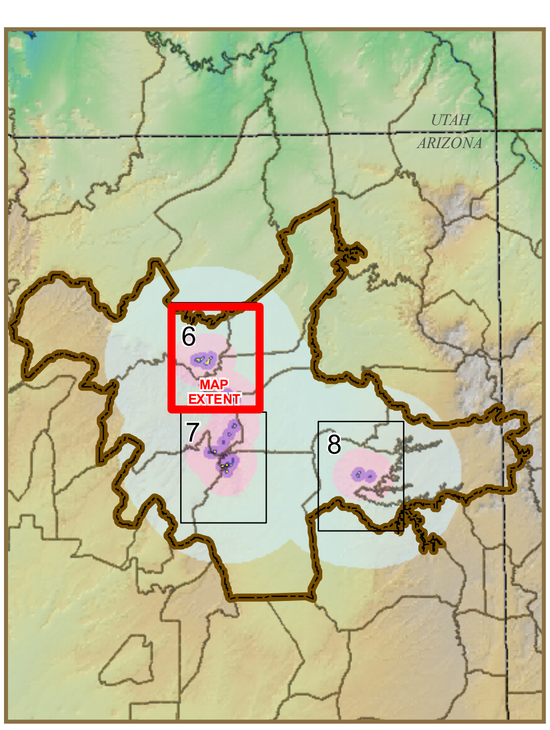
Map Scale 1:600,000

Legend

- Central AUM Region
- Chapter
- Highways
- Paved Roads
- Populated Places
- Uranium Mine
- Mine Buffers
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 5. Combined Pathways Map Figure Index.





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Central AUM Region Screening Assessment Report

COMBINED PATHWAYS - ROUGH ROCK

N
W E
S

0 5 Miles

Map Scale 1:95,000

Legend

MAP-ID

Mine Feature

Structure within 1 mile

Well within 4 milles

Downstream Water Pathway

Perennial Stream

Intermittent Stream

Central AUM Region

Chapter

Paved Road

Uranium Mine

Mine Buffers

200 Feet

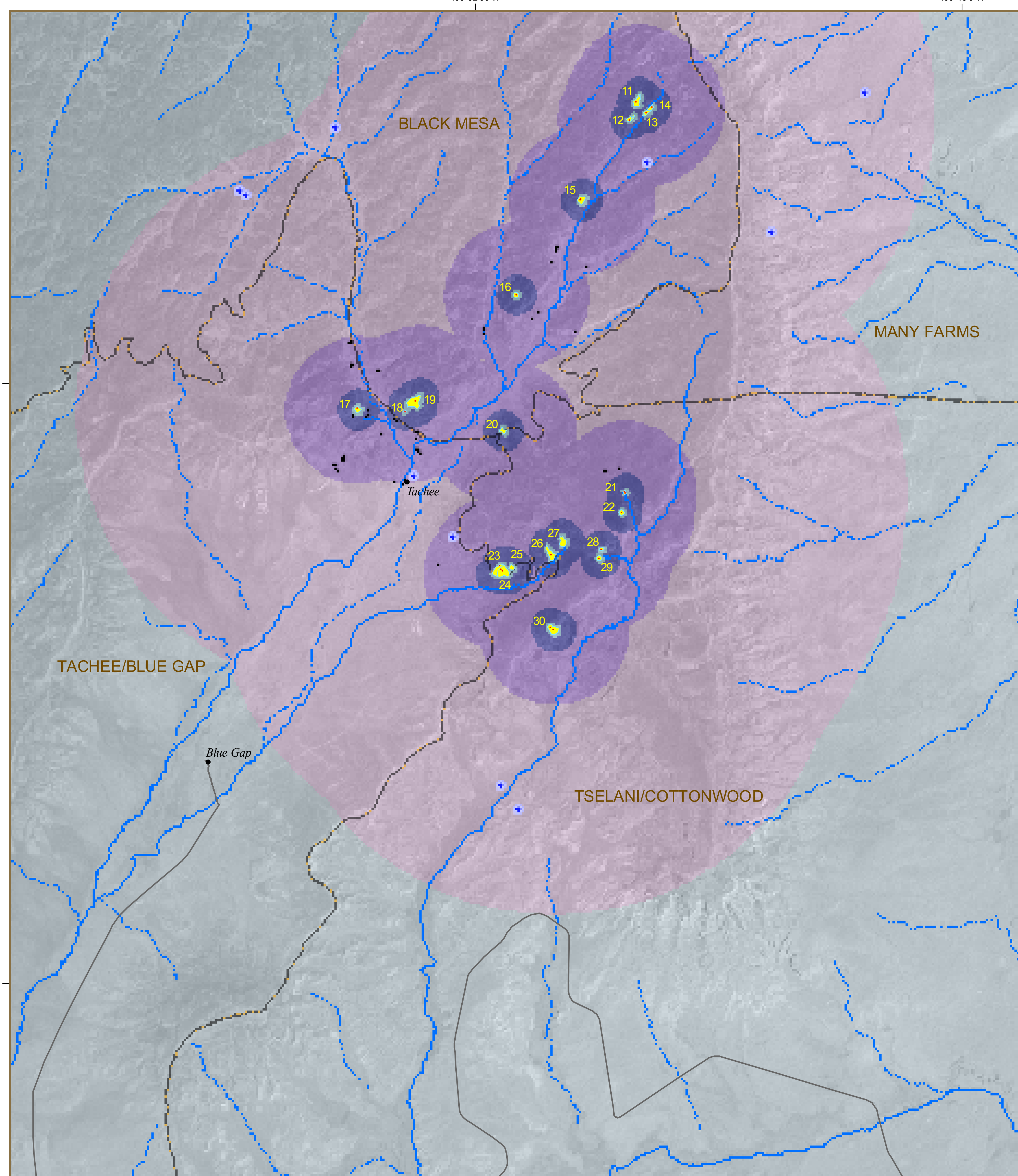
1/4 Mile

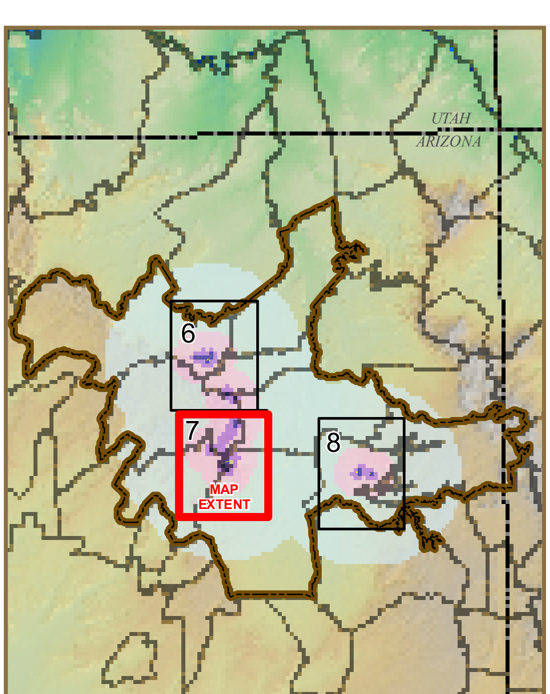
1 Mile

4 Miles

15 Miles

Figure 6. Combined Pathways in the Rough Rock Region.





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Central AUM Region Screening Assessment Report

COMBINED PATHWAYS - TACHEE

N W E S

0 5 Miles

Map Scale 1:95,000

Legend

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

Figure 7. Combined Pathways in the Tachee Region.

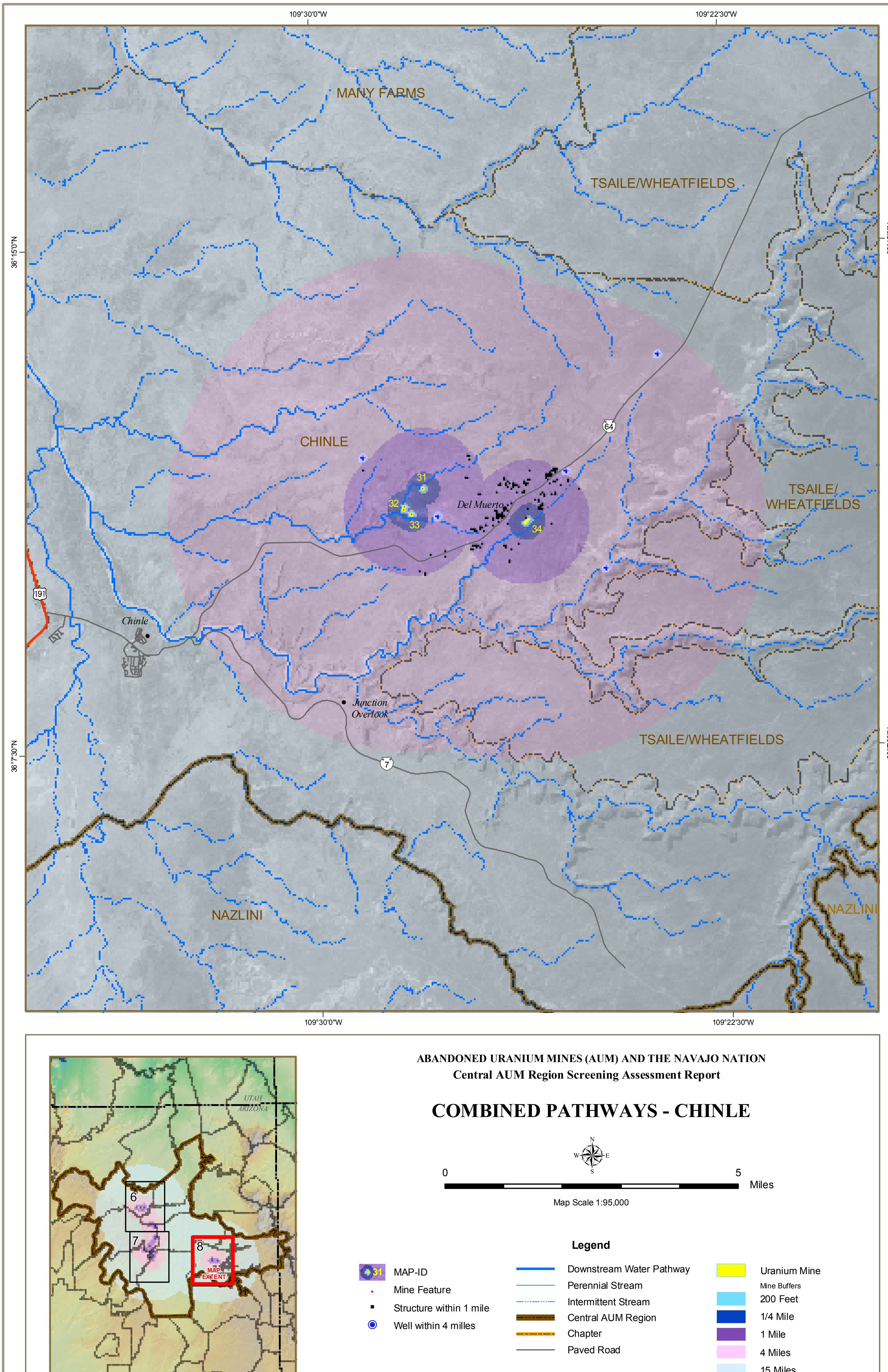


Figure 8. Combined Pathways in the Chinle Region.

DISCUSSION

The Central AUM Region predominantly falls within northeastern Arizona with only the eastern portion of the Tsaile/Wheatfields Chapter extending into northwestern New Mexico. The AUMs within this region are generally clustered in three geographic areas: 1) at the foot of the northeastern edge of the Black Mesa plateau which is located within the Chilchinbeto; 2) the eastern edge of the Black Mesa plateau which is located in the Black Mesa, Many Farms, Rough Rock, Tachee/Blue Gap, and Tselani/Cottonwood Chapters; and, 3) the Chinle Valley in the Chinle Chapter. Each of these three areas has different geologic settings that are briefly described below.

GEOLOGY

During the uranium boom of the 1950's a small amount of uranium was mined from the Salt Wash Member of the Morrison Formation in the Chilchinbeto Chapter. The Salt Wash Member caps benches at the northeastern foot of Black Mesa, but is absent on the east side of Black Mesa. Secondary uranium minerals in this area are associated with carbonaceous fossil logs and other plant debris in sandstone lenses 10 to 40 feet above the base of the Salt Wash Member (Chenoweth, 1989).

During the period 1954 through 1968, uranium and vanadium were mined in the Upper Cretaceous Toreva Formation on the eastern edge of Black Mesa. These uranium-vanadium deposits occur in tabular and lenticular sandstone units in the uppermost part of the upper sandstone member of the Toreva Formation. In general, the ore deposits consist of pods of ore-grade material surrounded by lower grade material. Individual ore pods vary in size from a pod ten feet long, four feet wide or less, and one foot thick to a large tabular body 180 feet long, 60 feet wide and averaging three feet thick. Some uranium occurs in the carbonaceous plant material. All of the known deposits in this area lie above the regional water table. Black Mesa and Gallup-Grants, New Mexico are the only areas in the United States with significant uranium production from sedimentary rocks of the Late Cretaceous age. Black Mesa is the only area in the United States with significant uranium production from rocks of the Mesaverde Group, of which the Toreva Formation is a member (Chenoweth 1990a).

During 1955, several uranium occurrences were discovered in the Shinarump and Monitor Butte members of the Chinle Formation on the Defiance Plateau. Near the village of Chinle in Apache County, Arizona the Shinarump Member is exposed on canyon rims, and to lesser extent, on mesa caps between canyons. Carbonized fossil plant material is common in the Shinarump Member. Overlaying the Shinarump is the Monitor Butte Member of the Chinle Formation. It forms low hills and slopes on the Shinarump-capped mesas (Chenoweth, 1990b).

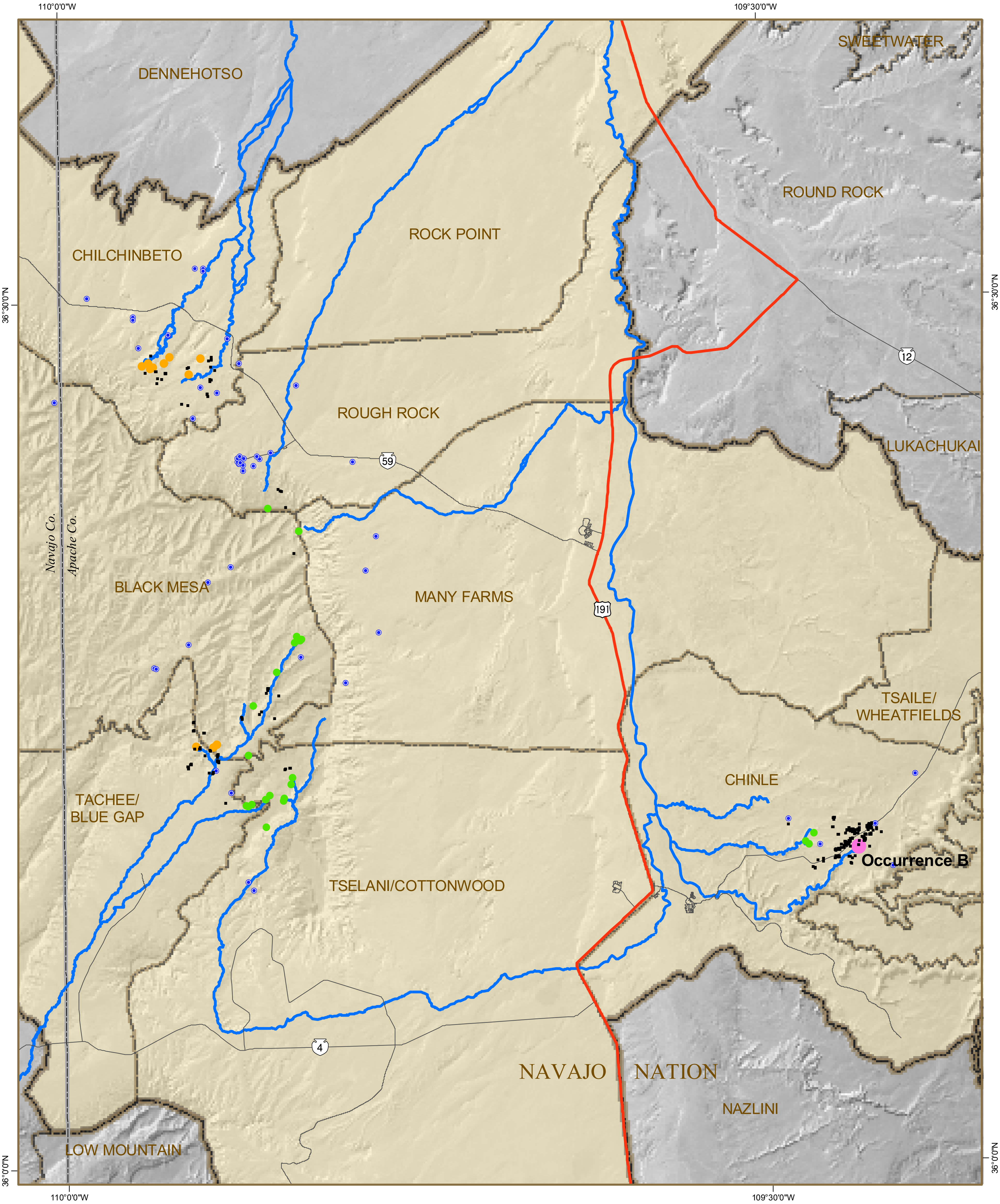
SCREENING ASSESSMENT SCORE RESULTS

Results from the HRS-derived screening model allowed the development of a scored AUM site list for the Central AUM Region. As noted earlier, the scoring is not intended to identify actual risks, but is 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 visualization of the data and analysis results.

Review of the Combined Pathway Scores (Table 5) and Figure 9 "Combined Pathways - Three Score Ranges" show that the highest scoring AUM site occurs in the Chinle Chapter (Occurrence B). 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 Central AUM Region is an example of an AUM site that scored high (4,150) 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 eastern Black Mesa, northeastern Tachee/Blue Gap, and northwestern Tselani/Cottonwood Chapters (shown in green on Figure 9).

High scoring AUMs did not necessarily produce large amounts of uranium. The Occurrence B AUM 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, 1990b). Conversely, one of the more significant uranium producing mines in the Central AUM Region was Claim 7 in Tselani/Cottonwood Chapter (MAP-ID #24). 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, 1990a).

As discussed under the METHODOLOGY section, the scores derived from this model are only an indicator of potential risk, not actual risks. As such, it is only the first stage in the process of decision-making as to which sites are a priority for more information gathering. Since many of the mine features may have had their risk reduced by reclamation or removal, that information will also need to be included and evaluated.



ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Central AUM Region Screening Assessment Report

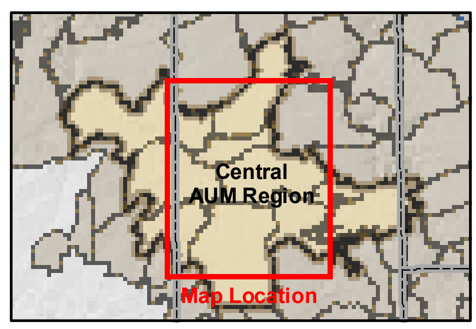
COMBINED PATHWAYS - THREE SCORE RANGES

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 Lands Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Structures were interpreted by TerraSpectra Geomatics. Wells are primarily from the Navajo Department of Water Resources and augmented by state water departments and USGS hydrographic datasets. The scores were calculated by TerraSpectra Geomatics using the modified Hazard Ranking System model developed by the U.S. Environmental Protection Agency, Region 9.

0 10 Miles

Map Scale 1:250,000



Legend

Range of AUM Scores

- 180 - 499
- 500 - 1499
- 1500 - 4,150

Targets

- Structures within 1 Mile of AUM
- Wells within 4 Miles of AUM
- Drainages 15 Miles Downstream from an AUM

Figure 9. Combined Pathways Map with Three Score Ranges.

RECOMMENDATIONS

Results from this CERCLA screening process will be used to assist with identifying AUM sites for possible further investigation. There are several paths a site might take, 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 is 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, 2000b). 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
  - Reclaimed AUM sites compared to unreclaimed AUM sites (determined by NAMLRP to have insufficient risk for reclamation according to Office of Surface Mining criteria)
  - Unmined prospects compared to productive AUM sites
  - Total uranium and/or vanadium production for each mine
  - $Bismuth^{214}$ aerial radiation data as an indicator of uranium above natural background levels
  - The presence of host geologic formations for uranium ore
  - Water or stream sediment samples

- 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)

EPA recommends a thorough review of available information prior to additional field investigations. Much of the available data and historic reports have already been provided to the NNEPA. A complete archive is also available in the Navajo Abandoned Uranium Mines Project files located in the EPA Region 9 Superfund Records Center, located in San Francisco, California. Emphasis on the following documents is recommended:

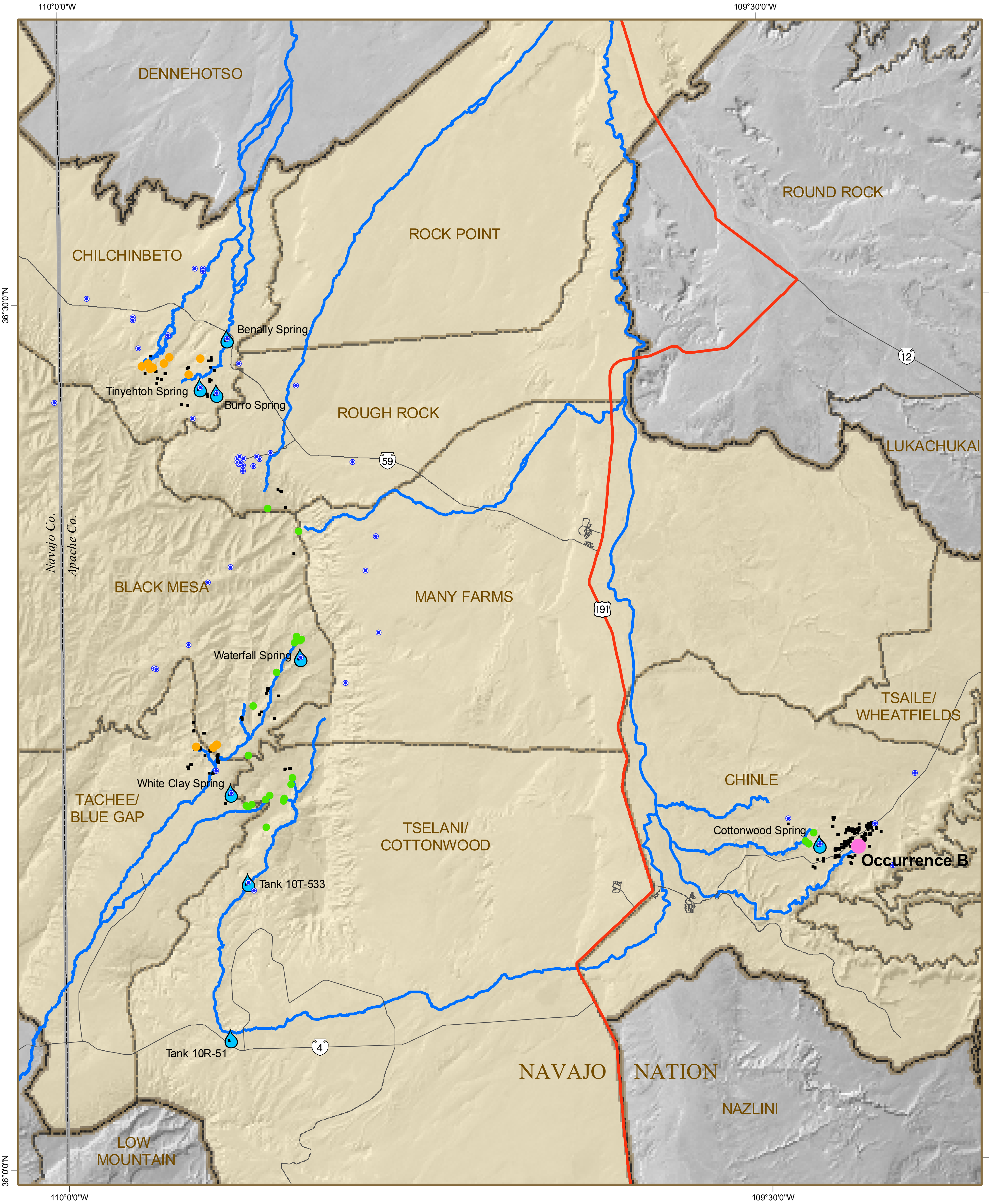
- Phase I
  - EPA Region 9 Superfund Records Center Archive Index
  - Maps, Documents, and Data (CD-ROM)
  - Project Atlas (CD-ROM)
- Phase II
  - EPA Region 9 Superfund Records Center Archive Index
  - Uranium Mining Summary Reports (Chenoweth)
  - State Mineralogy Department - Open File Reports
  - NAMLRP - Mine Reclamation Reports

WATER SAMPLES WITH URANIUM EXCEEDING MAXIMUM CONTAMINANT LEVELS

The sites listed in Table 6 (page 22) have come to EPA's attention due to elevated radionuclide activity in water samples (EPA, 2000a). 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, 2000a). The locations of these water samples with elevated uranium levels are displayed on Figure 10 "Water Sample Locations with Elevated Uranium." It is important to note that the water samples cited were not sampled from Public Drinking Water Systems. The results were from one-time sampling events by EPA and are not definitive with respect to attribution from anthropogenic versus naturally occurring sources. Water sampling was conducted prior to NAMLRP reclamation activity and current conditions may differ. The MCLs were use for comparison purposes only.

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

[2] USEPA, 2002. "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.



ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Central AUM Region Screening Assessment Report

WATER SAMPLE LOCATIONS WITH ELEVATED URANIUM

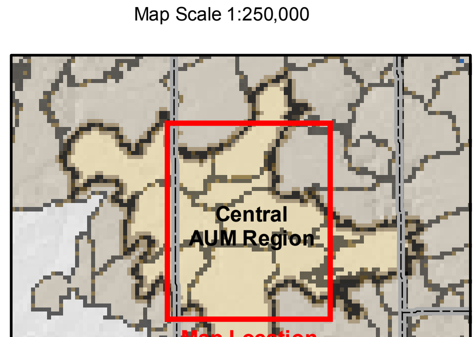
Sources

Abandoned Uranium Mine (AUM) locations are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by other sources. Water samples were collected by the U.S. Army Corps of Engineers for the U.S. Environmental Protection Agency (EPA) Region 9. The Navajo Nation and Chapter boundaries are from the Navajo Lands Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Structures were interpreted by TerraSpectra Geomatics. Wells are primarily from the Navajo Department of Water Resources and augmented by state water departments and USGS hydrographic datasets. The scores were calculated by TerraSpectra Geomatics using the modified Hazard Ranking System model developed by the EPA, Region 9.

N W E S

0 10 Miles

Map Scale 1:250,000



Legend

Water Sample - USACE

RANGE OF AUM SCORES

- 180 - 499
- 500 - 1499
- 1500 - 4,150

TARGETS

- Structures within 1 Mile of AUM
- Wells within 4 Miles of AUM
- Drainages 15 Miles Downstream from an AUM

Figure 10. Water Sample Locations with Elevated Uranium.

Table 6. EPA Water Samples with Elevated Uranium.

USACE Sample Name	Sample ID	Site Type	Sample Date	Total Uranium (pCi/L)
Benally Spring	KY981008CHS001	Spring	10/08/1998	47.1
Burro Spring	KY981008CHS002	Spring	10/08/1998	60.1
Cottonwood Spring	CH981123CHS001	Spring	11/23/1998	22.4
Tank 10R-51	CH990316TCW004	Wind Mill	03/16/1999	22.3
Tank 10T-533	CH981119TCW003	Wind Mill	11/19/1998	73.0
Tinyehtoh Spring	KY981008CHS003	Spring	10/08/1998	39.9
Waterfall Spring	CH981104BGS001	Spring	11/04/1998	61.7
White Clay Spring	CH981124BGS002	Spring	11/24/1998	45.9

NEXT STEPS

- NNEPA, NAMLRP and EPA should jointly review the report findings.
- NNEPA, NAMLRP, and EPA should collect post-reclamation water samples for water chemistry.
- NNEPA, NAMLRP and EPA should develop a joint prioritization of sites for possible action.
- EPA shall continue to support the Navajo Nation with additional assessment activities at NNEPA and shall address identified high priority areas of concern via the EPA Removal Program, at the request of the Navajo Nation.

REFERENCES

NOTE: Reference documents used in the preparation of this Screening Assessment Report were scanned. The electronic versions are included in the accompanying data package, with the exception of documents that are copyrighted, unpublished, draft, considered limited distribution, confidential, sensitive, or proprietary by the document providers. References that are followed by a source reference number (e.g., S02240306) are provided in electronic format and the source reference number is used as the document filename.

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APPENDIX A - GIS DATASETS

STRUCTURES

SCREENING ASSESSMENT TARGETS

One of the data collection objectives for this study is to obtain existing information to support preliminary screening assessments. The primary purpose of screening assessments is to distinguish between abandoned uranium mine (AUM) sites that pose little or no threat to human health and the environment and those sites that may require further investigation (EPA, 1991). AUM sites in the Central AUM Region are potential sources of hazardous materials. An important component of assessing potential threats is to identify whether there are any possible "targets" such as people, livestock, or wildlife located near the sites or potentially impacted through some type of exposure. Some terms related to "targets" that are used throughout this document are provided here.

Target

A target is defined as: "*a physical or environmental receptor that is within the target distance limit for a particular pathway* (ground water, surface water, soil, or air)" (EPA, 1991). Examples of potential targets include wells and surface water used for drinking water, livestock, fisheries, and sensitive environments, such as wetlands and riparian areas.

Target Distance Limit

A target distance limit is the maximum distance over which targets are evaluated. These distances vary by pathway (EPA, 1991). The target distance limits used in the HRS-derived model for the Central AUM Region screening assessment are:

- Soil Exposure Pathway 1-mile radius around the AUM site
- Air Pathway 1-mile radius around the AUM site
- Groundwater Pathway 4-mile radius around the AUM site
- Surface Water Pathway 15 miles downstream from the probable point of entry to surface water

Target Population

The target population is the human population associated with an AUM site and/or its targets. 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 within target distance limits.

CENTRAL AUM REGION

The Central AUM Region is sparsely populated throughout a land area of approximately 2,196 square miles (1,405,485 acres) in the Navajo section of the Colorado Plateau physiographic province (Cooley et al., 1969). The 2000 Census estimated the total resident population for the entire region at 19,228. The summary table below provides the estimated land areas and estimated populations from the 1980, 1990, and 2000 Census for each of the nine chapters within the Central AUM Region.

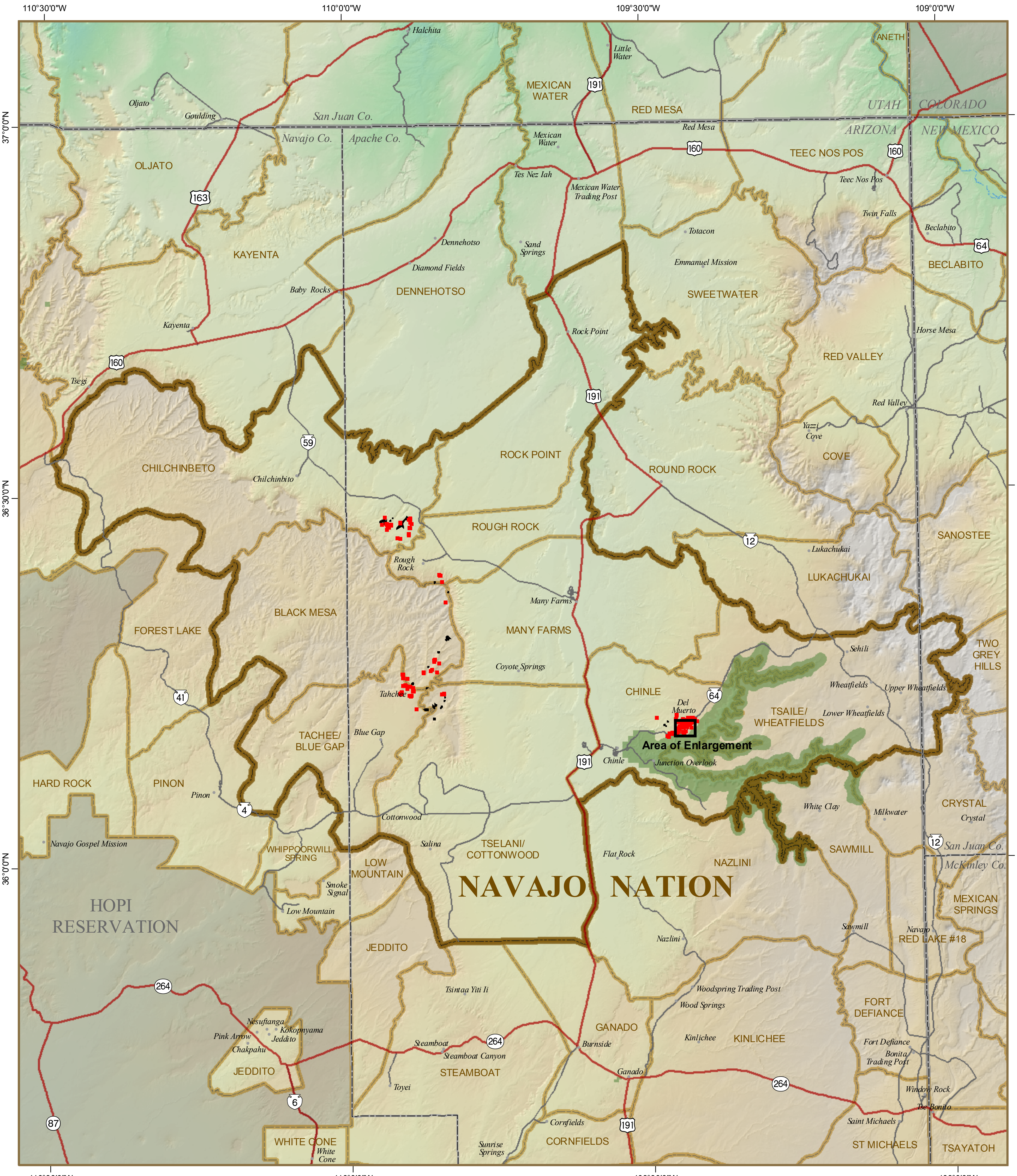
	Estimated Land Area (Acres)	Estimated Land Area (Sq. Miles)	1980 Census	1990 Census	2000 Census
BLACK MESA[1]	157,320	246	352	455	398 [2]
CHILCHINBETO[3]	242,949	380	1,028	1,177	1,310
CHINLE[4]	114,656	179	4,893	7,000	8,294
MANY FARMS[5]	168,006	263	2,048	2,133	2,620
ROCK POINT[6]	138,758	217	920	1,184	1,350
ROUGH ROCK[7]	52,680	82	778	1,009	901
TACHEE/BLUE GAP[8]	116,103	181	1,022	1,058	1,428
TSAILE/WHEATFIELDS[9]	162,494	254	1,212	1,391	1,983
TSELANI/COTTONWOOD[10]	252,519	395	1,084	1,422	1,342
	1,405,485	**2,196**	**13,337**	**16,829**	**19,228**

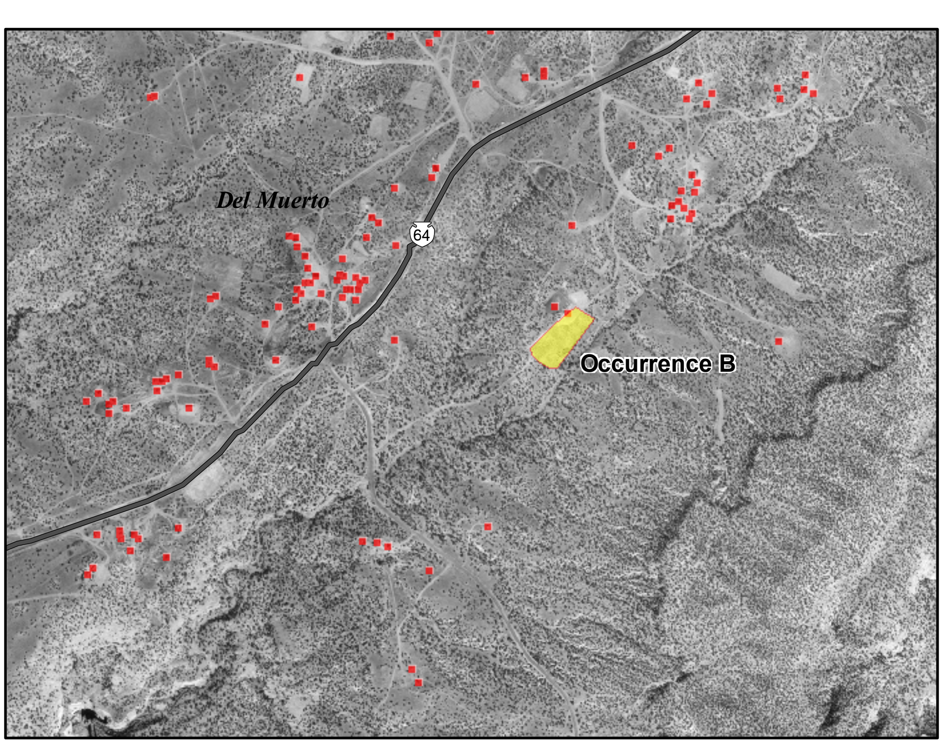
[1] Rodgers, 1997 (all Black Mesa statistics except 2000 Census)
[2] Choudhary, 2000
[3] chilchinbeto.nndes.org (2006)
[4] chinle.nndes.org (2006)
[5] manyfarms.nndes.org (2006)
[6] rockpoint.nndes.org (2006)
[7] roughrock.nndes.org (2006)
[8] tachee.nndes.org (2006)
[9] tsaile.nndes.org (2006)
[10] tselani.nndes.org (2006)

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 Central AUM Region. Existing USGS topo graphic 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 Navajo Tribal Utility Authority (NTUA) provided point locations for utility meters for the NTUA service areas within the Central AUM Region. The meter locations were collected 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 mapping or verifying the location of probable structures constructed after 1998.

It was not possible to consistently 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[11]. All of these structures, however, are indicative of locations where people might be present in the Central AUM Region. The structures that were mapped were used as an indicator for the probable location of the target population. The map of structures within 1 mile of an AUM site is shown on the facing page.

[11] Field verifications were not undertaken for this mapping effort.





Inset showing structures and Occurrence B AUM in the Chinle Chapter. Presented on the USGS Del Muerto SW and Del Muerto SE digital orthophoto at 1:24,000 map scale (1"=2,000 feet).

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Central AUM Region Screening Assessment Report

STRUCTURES

N W E S

0 10 Miles

Map Scale 1:600,000

Legend

- Structures Within 1 Mile of an AUM
- Abandoned Uranium Mine
- Canyon de Chelly National Monument

Sources

Structures within 1 mile of abandoned uranium mines were mapped by TerraSpectra Geomatics using USGS Digital Orthophoto Quarter Quadrangles (DOQQs), USGS topographic maps, and utility meter locations provided by the Navajo Tribal Utility Authority (NTUA).

APPENDIX A - GIS DATASETS

ABANDONED URANIUM MINES

URANIUM MINING

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 (OSM, 1999). The excavation of uranium ore bodies is associated with hazards due to both physical hazards and radiation exposure. 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 abandoned uranium mines (AUMs) include open portals, adits, vertical openings, inclines and declines, pits, radioactive waste piles, radioactive dust, rim cuts, high walls, and embankments (OSM, 1999).

During the period 1954 through 1968, uranium and vanadium were mined on Black Mesa, which is located in northeastern Arizona. Black Mesa is a southwest dipping cuesta, with a diameter of approximately 60 miles. The mesa is capped with sedimentary rocks of the Upper Cretaceous Mesaverde Group. All of the uranium deposits on Black Mesa occur in the fluvial upper sandstone member of the Toreva Formation. Ore was mined by shallow open pits, rim cuts, and underground methods (Chenoweth, 1990a).

During the uranium boom of the 1950's a small amount of uranium was mined from the Salt Wash Member near the Rough Rock Trading Post in northwestern Apache County, Arizona. All mining at this location was by rim stripping and shallow bulldozer cuts (Chenoweth, 1989).

During 1955, several uranium occurrences were discovered in the Shinarump and Monitor Butte members of the Chinle Formation near the village of Chinle in Apache County, Arizona. However, no AUMs were mapped in the Monitor Butte Member. The workings in this area consisted of rim stripping, bulldozer cuts and prospect pits, and small open pits (Chenoweth, 1990b).

RECLAMATION

Since May 1990, the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) has worked to reclaim eligible AUMs on the Navajo Nation. A scheme for prioritizing non-coal mine sites was established, with Priority 1 sites exhibiting extreme physical hazards, easy access, and danger to life and property. Priority 2 and 3 sites have less physical danger, more difficult access, and lower visitation. Inventories and priority assessments of AUMs were conducted by the NAMLRP during the period August 1988 through October 1990. NAMLRP compiled information about each reported occurrence of past uranium activity on the Navajo Nation. Field inventories and investigations were then conducted to develop a comprehensive inventory of the AUM sites.

AUM POINT FEATURE LOCATIONS

AUM point feature locations (e.g., portals, shafts, rim strips, prospects, waste piles) were provided by the NAMLRP on 7.5 minute USGS topographic maps and coded by mine feature type. These maps were georeferenced and a GIS point dataset was created. There are fifty-four (54) mapped point mining features associated with the AUMs in the Central AUM Region. The mining features are comprised of Portals (4), Rim Strips and Pits (44), Prospects (5), and one (1) waste pile. Examples of AUM sites and features in the Central AUM Region are shown on the facing map figure.

AUM POLYGON BOUNDARIES

NAMLRP provided maps for the location of AUM Reclamation Project Areas. 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 of about 50 feet extending around the mining operations. These NAMLRP project polygons provided excellent mine operation locations and extents.

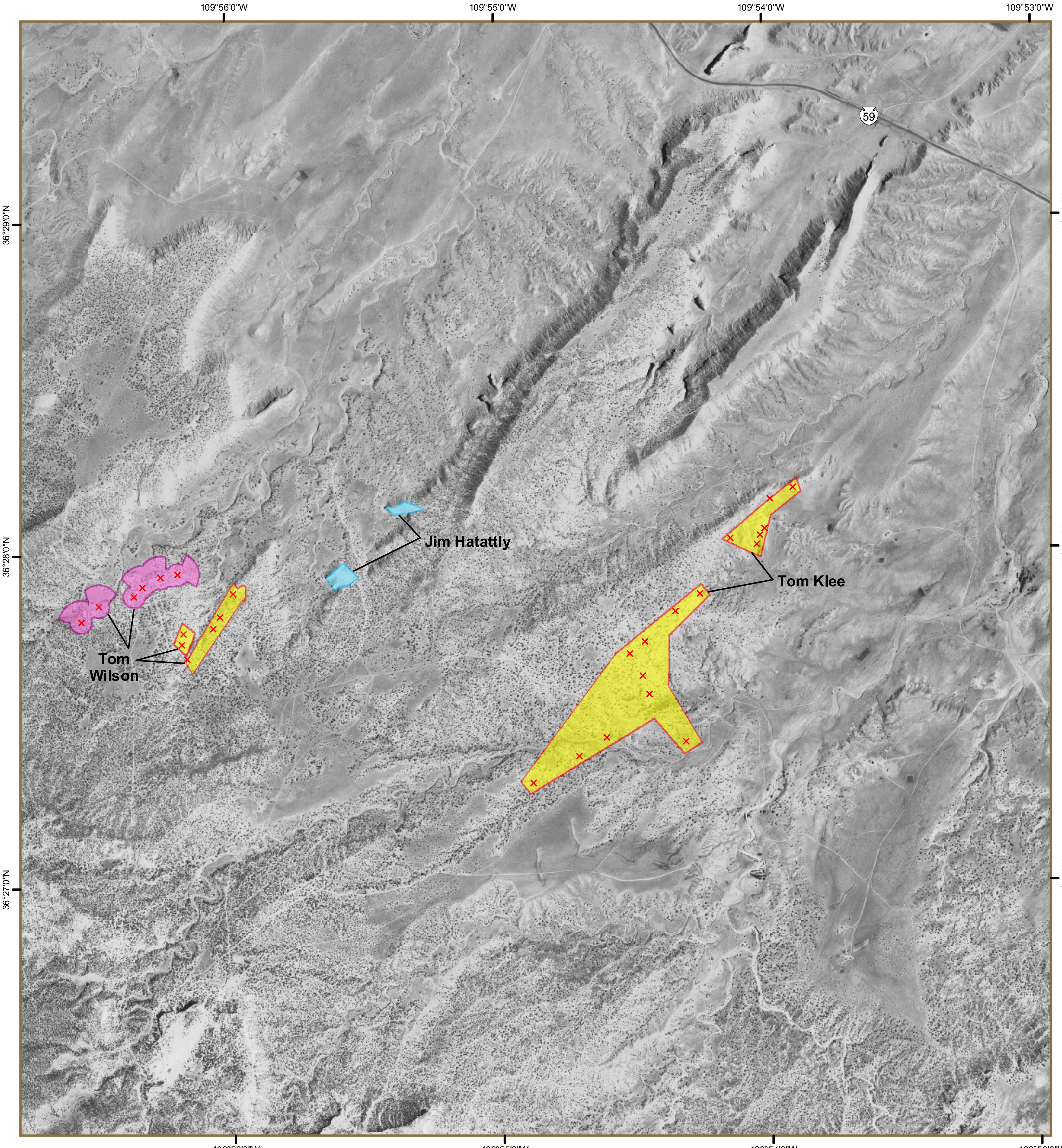
Some NAMLRP project boundaries were modified based on aerial radiation data collected in 1998 and 1999 by the U.S. Department of Energy Aerial Measuring System (Hendricks, 2001). USGS DOQQs were also inspected around each NAMLRP project. Boundaries were extended where photointerpreted mine related disturbances could be mapped outside and adjacent to the NAMLRP project. Some NAMLRP projects encompassed more than one mine. In these cases, NAMLRP projects were split into two or more polygons 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.

There are thirty-four (34) AUM polygons in the Central AUM Region GIS dataset. Eighteen (18) of the AUM polygons were derived from NAMLRP reclamation project boundaries. Six (6) AUM polygons were generated for unreclaimed mine features that were inventoried by NAMLRP but were not included as reclamation projects. These AUM polygons were developed by creating a 200 foot buffer around the feature. Locations for ten (10) AUM polygons were added from reports and documents provided by William Chenoweth (1989, 1990a, 1990b, and 2006e).

<u>Production Records and Mine Name</u>
Efforts were made to associate a name with the AUM polygon boundaries (e.g., mine or permit name). Fifteen (15) AUMs with documented production were located in the region. Eleven (11) AUMs were mapped for which no records of uranium production could be found, but had evidence of surface disturbance and were located within a mining permit or claim. Names were determined for all but two of these AUMs (BLK022 and BLK029). Several of the AUMs had more than one disturbed area associated with the mining or exploration activities. Examples are shown right for the Tom Wilson Mine with two reclaimed polygons and two unreclaimed polygons, Tom Klee Mine with two reclaimed polygons, and the Jim Hatattly property of unknown reclamation status. The occurrence of multiple disturbance areas for a single mine or permit resulted in more polygons (34) than named AUMs (24).

<u>Underground AUM Workings</u>
Four (4) AUMs in the Black Mesa area used underground methods (Claim 7, Dan Taylor No. 1, Etsitty No. 1 and Rough Rock Slope No. 9) (Chenoweth, 1990a). 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.

Examples of AUM surface boundaries in the Chilchinbeto Chapter area are shown on the facing map figure.



Location map showing the map extent for the enlargement above. The location map scale is 1:1,250,000.

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

ABANDONED URANIUM MINES (AUM)

N W E S

0 — 1 Miles

Map Scale 1:24,000

Legend

- Reclaimed AUM Sites
- Unreclaimed AUM Sites
- Unknown
- × Rim Strip / Pit

Sources

The primary source of AUM polygon locations was the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP). These were augmented by other key sources, such as Chenoweth reports. Designations of the specific type of mine point features (e.g., portal or prospect) were also provided by NAMLRP.

NAMLRP determined that some AUM sites were not feasible for reclamation. These unreclaimed mine features were buffered by two hundred feet in order to create Unreclaimed AUM Site polygons.

Base images are portions of Rough Rock NW NE and Rough Rock NW NW Digital Orthophoto Quarter Quadrangles (DOQQ) generated from 1997 aerial photography.

APPENDIX A - GIS DATASETS

WATER SOURCES AND DRAINAGES

WATER SOURCES

Proximity to water sources is a significant consideration when performing a screening assessment. The closer a well or developed spring is located to an AUM, the higher the likelihood that it may be exposed to hazardous substances. The following provides a brief discussion about water resource management on the Navajo Nation and information about the water sources within the Central AUM Region.

The rivers, washes, and aquifers constitute the water of the Navajo Nation which are under the jurisdiction of the Navajo Nation Water Code and are subject to the Navajo Nation's water management. The Navajo Department of Water Resources (NDWR) reported in July 2000 that the total domestic water consumption on the reservation was approximately 12,000 acre-feet annually. Per capita water use on the reservation ranges from between 10 and 100 gallons per day depending upon the availability and accessibility of the water supply. By comparison, the average per capita use for neighboring non-Indian communities in Arizona is 206 gallons per day. Approximately 40 percent of the Navajo population on the reservation is without tap water in their homes, and are required to haul water long distances to provide water for their homes. Water haulers sometimes rely on non-potable water sources, such as stock tanks, for potable purposes (NDWR, 2000).

Groundwater is the most heavily used and dependable water source for the Navajo Nation. The NDWR Water Management Branch maintains water resource databases and provides hydrologic information needed to serve the interests of the Navajo people. The Water Management Branch maintains an extensive database of groundwater well information, which is the primary data resource for groundwater information on the Navajo Nation. The database includes over 8,000 well records for the entire Navajo Nation. Data is provided on new wells based on the information documented in the well-drilling permits and the water-use permits. All locations for water sources in the NDWR well database were used for the screening analysis (only oil wells and possible oil wells were excluded).

The map shown on the facing page shows the locations of wells and developed springs or water sources within 4 miles of an AUM for the Central AUM Region. The well locations are from the NDWR well database, and augmented or corroborated using Arizona Department of Water Resources, National Hydrography Database, Geographic Names Information System, U.S. Army Corps of Engineers water sample locations, USGS Water-Resource Investigation Reports, USGS Groundwater Site Investigations database, and USGS topographic maps and digital orthophoto quarter quadrangles.

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 to migrate via surface water, and if so, whether any targets (intakes supplying drinking water, fisheries, or sensitive environments) are likely to be exposed to the hazardous substance. In the Central AUM Region, where mean annual precipitation ranges from 6 to 9 inches per year, intermittently-flowing waters qualify as surface water.

Erosion is a concern for abandoned uranium mine 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. Hazardous constituents (e.g., radionuclides and heavy metals) associated with discharges from mining operations may be found at elevated levels in sediments (EPA, 2000b). Uranium mining potentially contributed sediment, tubidity, suspended and dissolved solids, trace elements, and radionuclides to water resources (NNEPA, 2001)

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. (Cooley et al., 1969). Perennial streams have visible water flowing above the streambed year-round. The Colorado and San Juan Rivers are the only major perennial streams on the Navajo Nation. Other perennial streams include McElmo Creek, the groundwater-fed streams of the Navajo–Glen Canyon area, the lower part of the Chinle Wash, the Chuska Mountains-Defiance Plateau area, and portions of the lower part of the Little Colorado River and Moenkopi, Dinnebito, Oraibi, and Pueblo Colorado Washes (NNEPA, 2001).

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 in the Central AUM region 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 drainage basin of a creek may create large flows, which are commonly of limited duration and extent (Cooley et al., 1969).

The map figure on the facing page shows the locations of water sources (wells and developed springs) within 4 miles of an AUM and intermittent/ephemeral and perennial surface water stream drainages in the Central AUM Region. Also shown are drainages that were identified as potential downstream surface water pathways. This line dataset documents streams within one mile overland and down slope of AUMs for a distance of at least fifteen miles. The primary source for these stream courses is the medium resolution (1:100,000 scale) USGS National Hydrography Dataset (NHD), and is augmented by streams automated from USGS 7.5 minute topographic maps (1:24,000 scale Digital Raster Graphics - DRGs) and USGS Digital Orthophoto Quarter Quads (DOQQs).

Tank 10T-533 in Tselani/Cottonwood Chapter.

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

WATER SOURCES AND DRAINAGES

N W E S

0 10 Miles

Map Scale 1:600,000

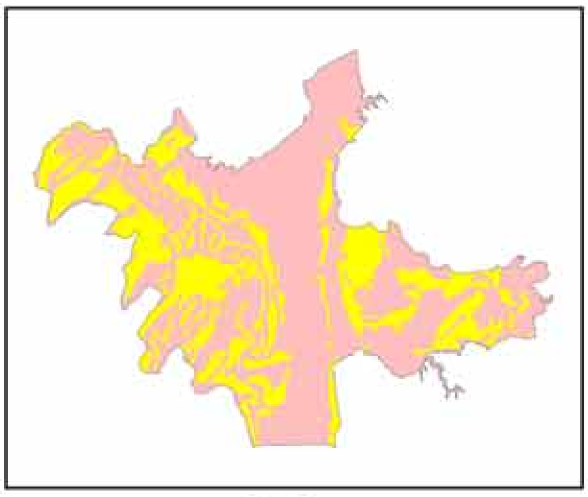
Legend

- Wells Within 4 Miles of an AUM
- Intermittent Stream
- Perennial Stream
- Downstream Water Pathway
- Abandoned Uranium Mine

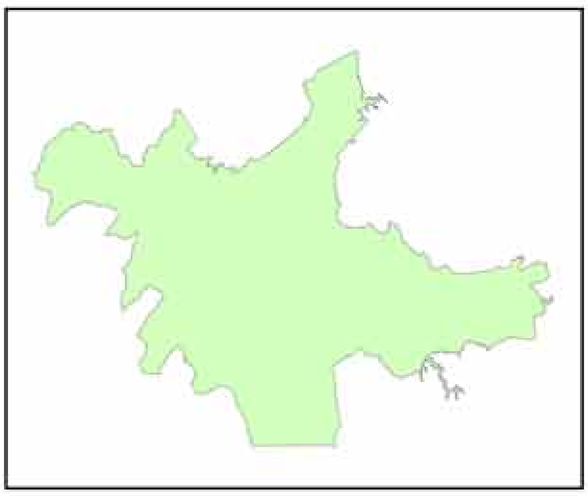
Sources

Water sources are primarily from the Navajo Department of Water Rsources (NDWR) and augmented with data from state water departments and U.S. Geological Survey (USGS). The water sources include wells and developed springs. The perennial and intermittent streams are from the National Hydrography Dataset (NHD).

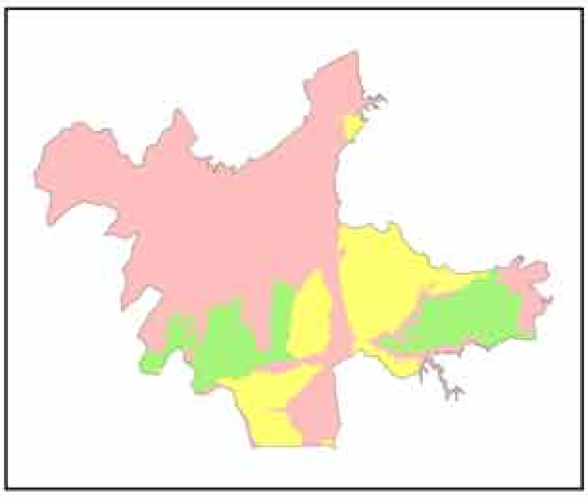
AQUIFER SENSITIVITY



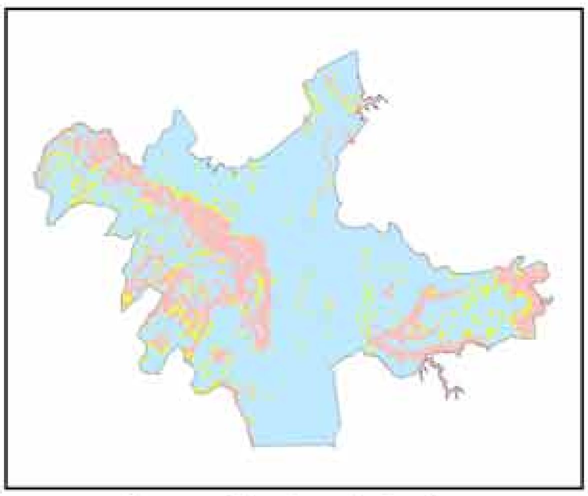
Geology



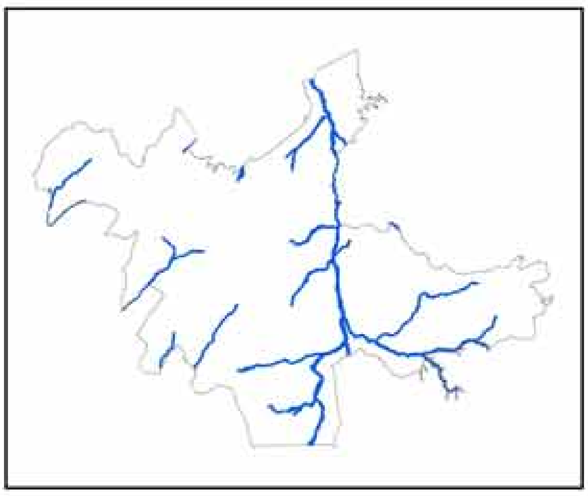
Precipitation



Soil Properties



Slope of the Land Surface



Fourth-order Stream Courses

Blanchard (2002) 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 model can be applied to the movement of radionuclides and heavy metals to the underlying groundwater. The aquifer sensitivity model complements the screening assessment presented in this report, but was not used in the scoring model.

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

The geology was developed from Cooley et al. (1969). It identifies where consolidated rocks are recharged and unconsolidated deposits are at the surface and facilitate aquifer contamination (pink on the geology map at top left). Geology acts as a surrogate for impact of the vadose or unsaturated zone. Yellow identifies areas that do not contribute to recharge.

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 at left, green indicates relatively uniform intermediate precipitation and potential to facilitate aquifer contamination for the entire Central AUM Region.

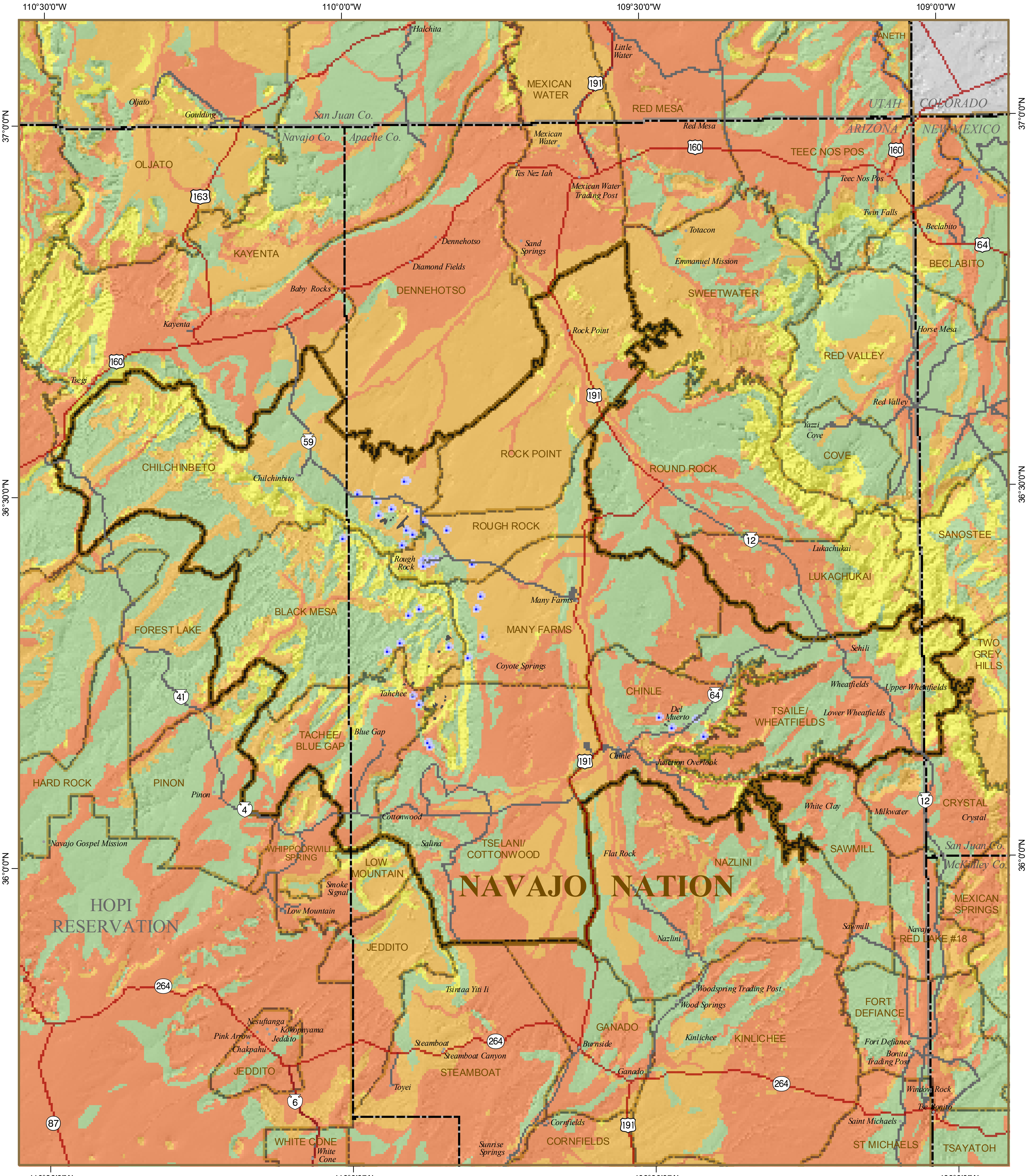
Several soil properties contribute to the potential to facilitate aquifer contamination, including: texture, infiltration rate, drainage, and organic content. These properties were developed from a modified version of the STATSGO, or State Soil Geographic database created by the U.S. Department of Agriculture, National Resources Conservation Service (Schwartz and Alexander, 1995). Blanchard further describes 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. A soil with the most potential to facilitate aquifer contamination (green on the soil properties map at left) is coarse-grained, has a high infiltration rate, is well drained, and has a low organic content. Yellow indicates areas with intermediate potential, and pink 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.

Land surface slope affects the ability of precipitation to infiltrate soil. Slopes less than 6 degrees (blue in the slope map at left) 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 yellow) and steep slopes greater than 12 degrees (pink 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. 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 highly 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 the map figure on the facing page. The highest scores represent the most potential for contamination, low scores are in 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 not areas of unconsolidated deposits (stream alluvial deposits).

Aquifer sensitivity was not incorporated into the screening assessment scoring model used in this report. It is presented here to illustrate the concept of how this type of geospatial information could be used to develop additional screening criteria.



ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

AQUIFER SENSITIVITY

0 10 Miles

Map Scale 1:600,000

Sources

The 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 a 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.

Legend

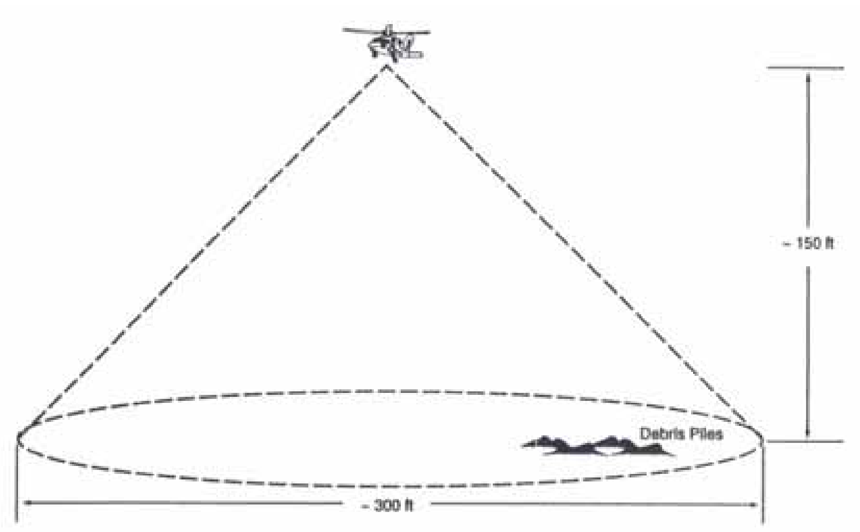
Aquifer Sensitivity Class

- 0 - Insignificant Potential
- 1 - Least Potential
- 2 - Intermediate Potential
- 3 - Most Potential
- Wells
- Abandoned Uranium Mines

APPENDIX A - GIS DATASETS

AERIAL RADIATION SURVEYS

Aerial radiation surveys were flown by the U.S. Department of Energy's (DOE) Remote Sensing Laboratory to evaluate whether the remote sensing technology could provide useful information for locating and characterizing AUMs. The surveys were flown using a helicopter-based acquisition platform equipped with custom 2 x 4 x 16 inch log type thallium-activated sodium iodide (NaI[Tl]) scintillation detectors. The BO-105 helicopter was configured with a total of 8 log detectors. Aircraft position was established using real-time differential Global Positioning System (GPS) equipment and a radar altimeter. Gamma rays detected by the NaI(Tl) detectors were digitized and sorted in the data acquisition system to produce second-by-second records of the gamma ray spectrum. Because every radioactive material has a unique set of gamma rays, a spectrum can be used to identify and separate the sources of the detected gamma radiation.



The large-footprint aerial radiation surveys were useful in characterizing large areas and in identifying areas requiring higher spatial resolution measurements on the ground.

The survey was flown at an altitude 150 feet above the terrain, resulting in a nominal footprint of 300 feet and a line spacing of 250 feet. The system on-board the helicopter records the gamma spectrum every second which is averaged over the ground sample area (i.e., 300 foot diameter footprint under the helicopter). The radiation sources within the ground sample area could be evenly distributed or 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 radiation levels. If there is a source on the ground with a high level of excess ground level activity that is appreciably smaller in size than the detector footprint (300 feet), then the average activity seen by the detector is weighted heavily by the large relative contribution of normal activity surrounding the source. This results in an underestimation of the peak source activity. This means the data does not pinpoint the radiation levels within the ground sample area. Obtaining finer detail measurements of an individual radiation source requires additional ground-based measurements.

The DOE Aerial Measuring System (AMS) survey capability was used to measure and map radiation sources within known uranium mining areas across the Navajo Nation. Helicopter surveys in the Black Mesa East, Chilchinbeto, Oraibi Wash, Chinle, and Round Rock survey areas were conducted in 1998-1999. These surveys were flown at a line spacing of 300 feet (Hendricks, 2001).

The table below provides summary information for the aerial radiation surveys that were flown in the Central AUM Region.

Aerial Radiation Surveys in the Central AUM Region - Summary Information

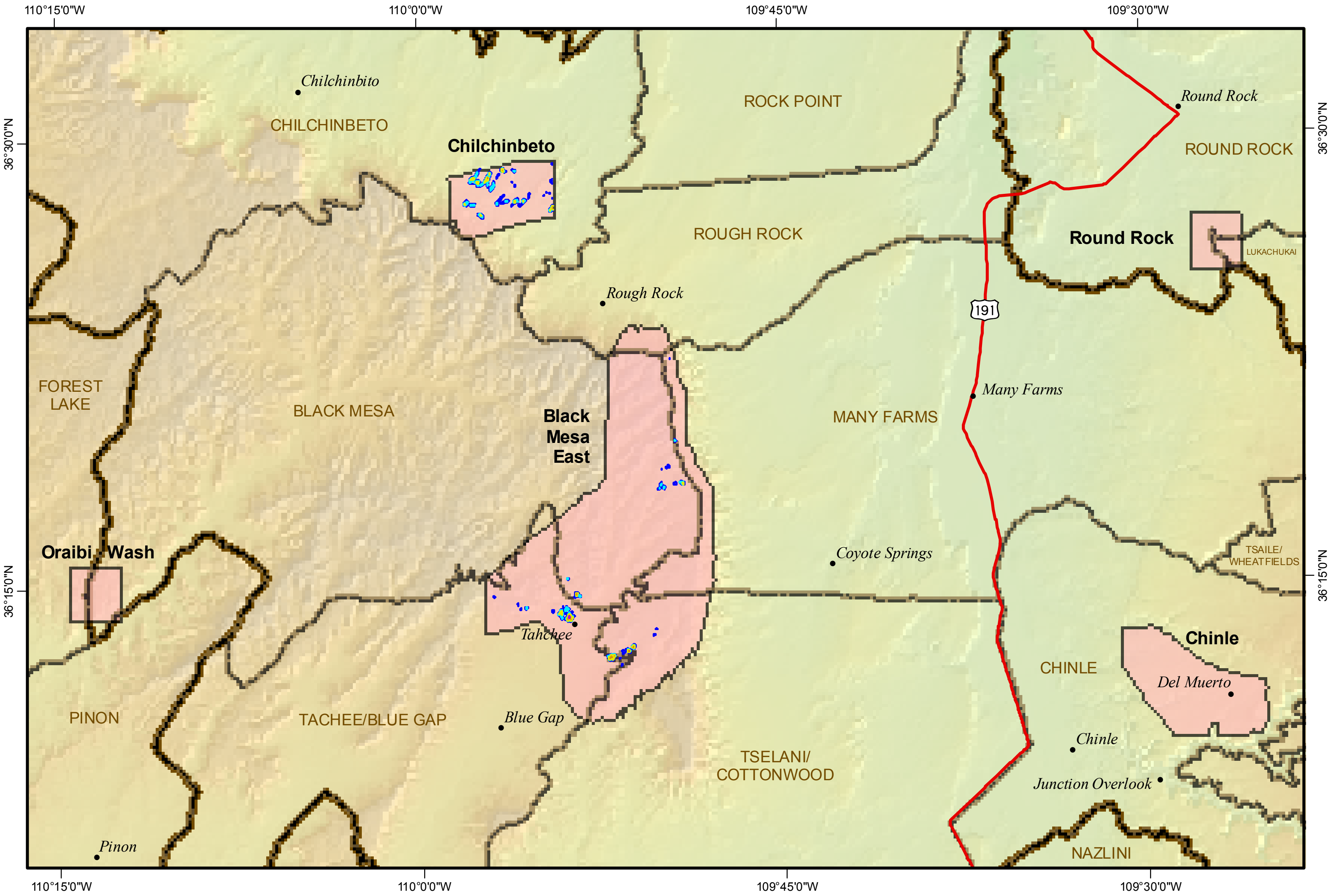
Area Name	Sub Area Name	Survey Start End	Survey Areas (sq. miles)	Terrestrial Exposure Rate in uR/hr Does not include cosmic which ranges from 5.1 @ 4000 ft to 9.7 @ 9000 ft elevation				Total # Survey Samples	Excess Bismuth Greater than 80 cps (Approx 3.5 uR/hr)		Notes
				avg	dev	min	max		# of samples	Approx acres	
Central	Black Mesa East	10/10/98 05/25/99	72.56	9.03	1.86	3.31	30.51	47,475	236	230.8	2,4
	Chilchinbeto	05/24/99	11.53	6.96	1.81	3.7	22.45	6,553	377	424.5	2,4
	Oraibi Wash	05/24/99 05/25/99	4.02	10.02	1.12	7.24	15.97	2,859	0	0.0	2,4
Chinle	Chinle	05/25/99 05/26/99	15.00	6.74	1.03	3.49	16.37	10,278	47	43.9	2.4
Four Corners	Round Rock	05/25/99	4.35	5.45	1.39	2.55	13	2,998	1	0.9	2,4

Key for Notes: 2 = B412 helicopter with 12 (2x4x16) gamma detectors
4 = 300 foot line space

The radiation data that were collected for the Central AUM Region are provided in two forms: gross count and excess $Bismuth^{214}$. $Bismuth^{214}$ radiation is indicative of 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 aerial survey areas and the excess $Bismuth^{214}$ radiation contours are shown in the top map figure on the facing page. These aerial radiation contours were used as an aid in locating and defining the surface extents of abandoned uranium mines.

Gross count measures total terrestrial gamma activity, much like a Geiger counter, without considering its source. 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 on the bottom map figure on the facing page.

For a more comprehensive explanation of the acquisition and processing methods used for the aerial measurements of radiation, a report has been developed by the DOE's Remote Sensing Laboratory titled "An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation." (Hendricks, 2001).



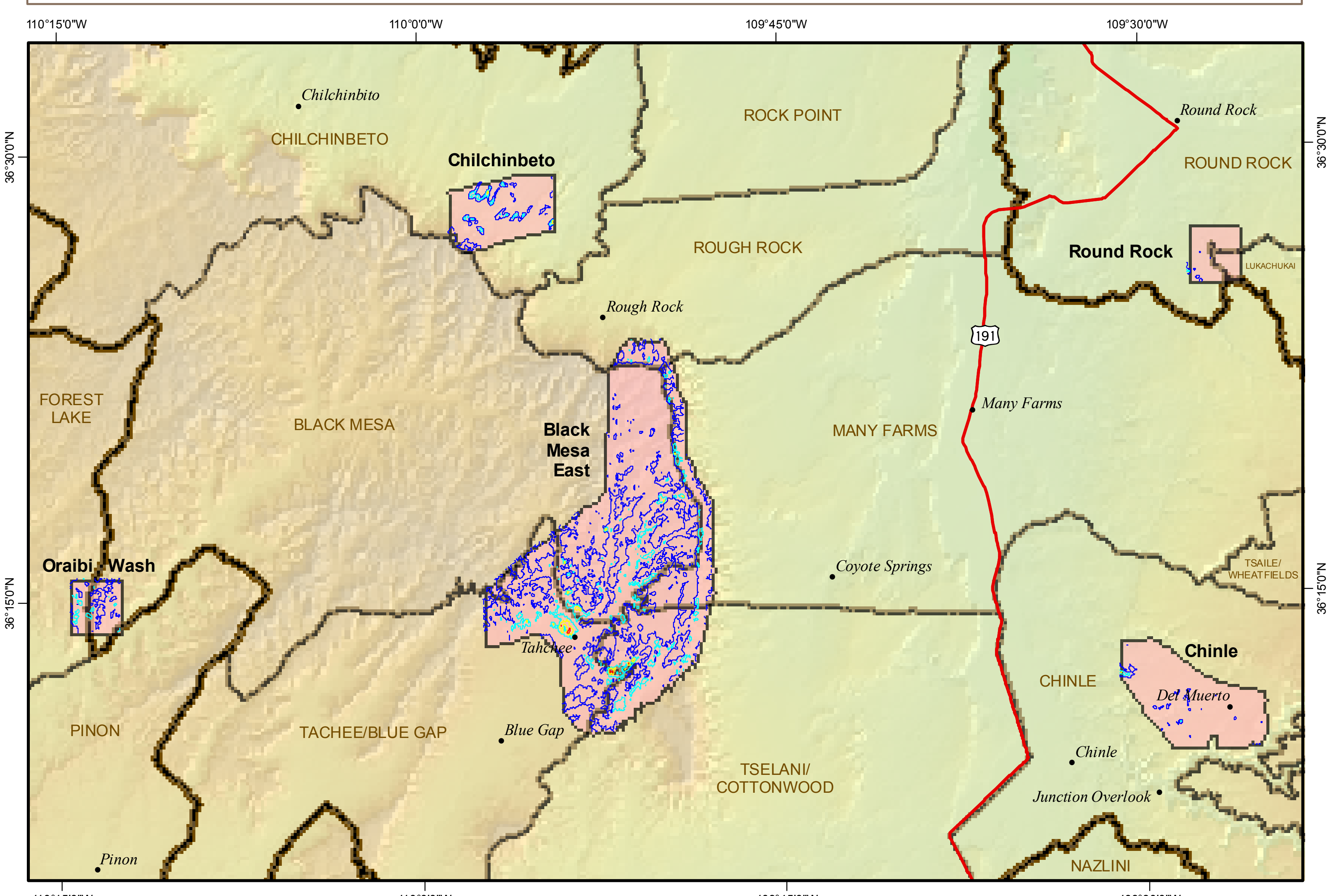
Radiation Contours	Derived contour level Bismuth-214 photo peak (excess counts/sec)	Estimated exposure rate from excess Bismuth-214 (excess µR/hr)
(blue)	80	3.5
(cyan)	120	5.2
(yellow)	170	7.4
(orange)	250	10.9
(purple)	370	16.2

AERIAL RADIATION SURVEY AREAS AND BISMUTH 214 RADIATION CONTOURS

0 10 Miles

Map Scale 1:350,000

Aerial Survey Boundary



Radiation Contours	Derived terrestrial exposure rate at 1 meter above ground level. Does not include cosmic contribution. Units in µR/hr.
(blue)	9
(cyan)	12
(yellow)	16
(red)	24

AERIAL RADIATION SURVEY AREAS AND GROSS COUNT RADIATION CONTOURS

0 10 Miles

Map Scale 1:350,000

Aerial Survey Boundary

APPENDIX A - GIS DATASETS

DIGITAL ORTHOPHOTO QUARTER QUADRANGLES (DOQQ)

While a conventional aerial photograph looks very similar to an orthophotograph (referred to as orthophoto hereafter), it contains image distortions caused by the tilting of the camera and terrain relief (topography). These distortions result in a non-uniform scale across the aerial photo. Distances cannot be accurately measured on an aerial photograph like on a map, and the effect worsens as the terrain increases.

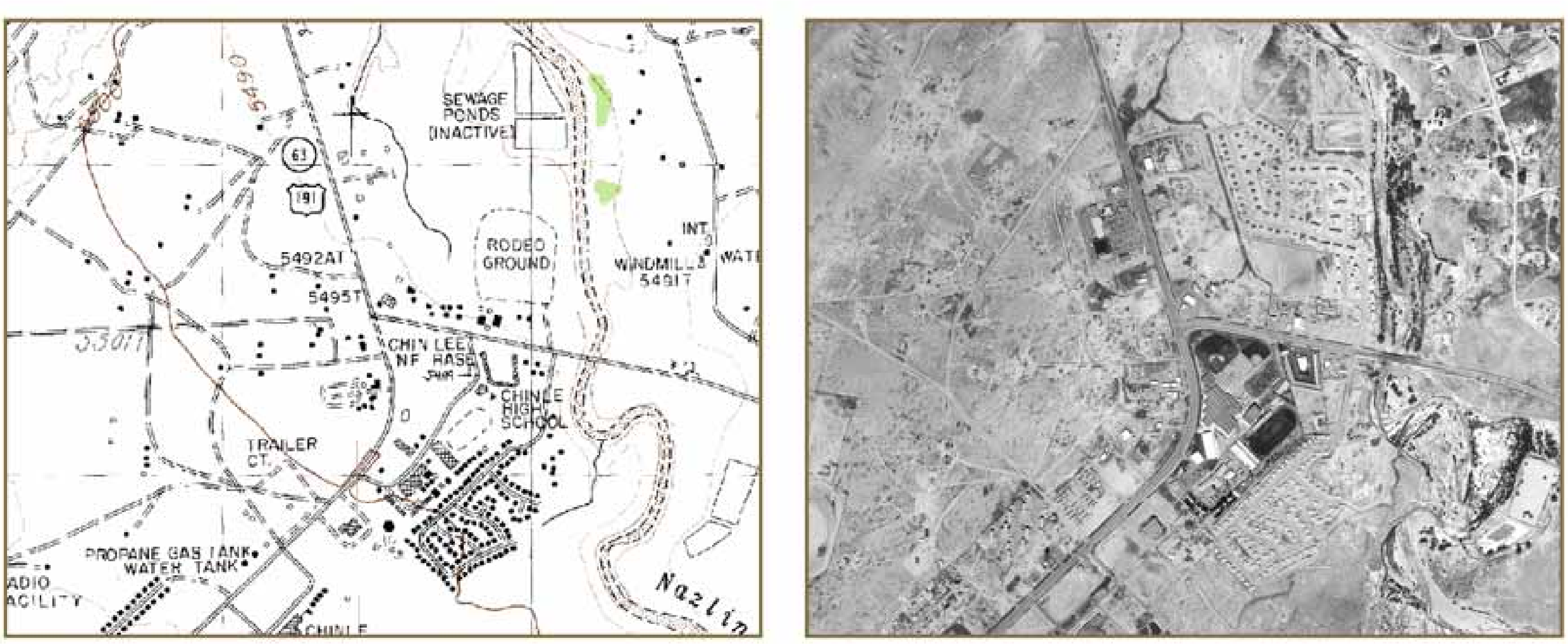
The effects of camera tilt and relief can be removed from aerial photographs by a mathematical process called rectification. Digital orthophotos are computer-generated images of an aerial photograph in which image displacements caused by terrain relief and camera tilts and lens distortions have been removed. The aerial photographs are scanned and processed to create a georeferenced and planimetrically accurate digital image. The production of an orthophoto requires accurate ground control points, camera orientation and lens parameters, and a digital elevation model. The resulting digital orthophoto combines the image characteristics of a photograph with the geometric qualities of a map.

DOQQs produced by the U.S. Geological Survey (USGS) are either gray-scale, natural color, or color-infrared images. Currently, only gray-scale DOQQs are available from the USGS for the Central AUM Region. A DOQQ covers an area measuring 3.75-minutes longitude by 3.75-minutes latitude, or 1/4 of the area covered by a USGS 7.5-minute topographic quadrangle. The names of DOQQs are based on the USGS 7.5-minute quadrangles, followed by a NE, NW, SW, or SE. An index of 7.5-minute topographic quadrangle boundaries and quadrangle names, and the associated DOQQ boundaries are shown on the map figure on the facing page.

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 the DOQQ allow users to evaluate their data for accuracy and completeness, make modifications to their data, and even generate new thematic layers. The DOQQs were used extensively in the review and correction of several spatial datasets prepared for this Central AUM Region screening assessment. The DOQQs were also used to generate new data layers, such as mapping structures.

The DOQQs for the Central AUM Region were generated by the USGS using aerial photographs acquired in 1997 and 1998. Any developments after this period, such as new roads or buildings will not be present on the DOQQs.

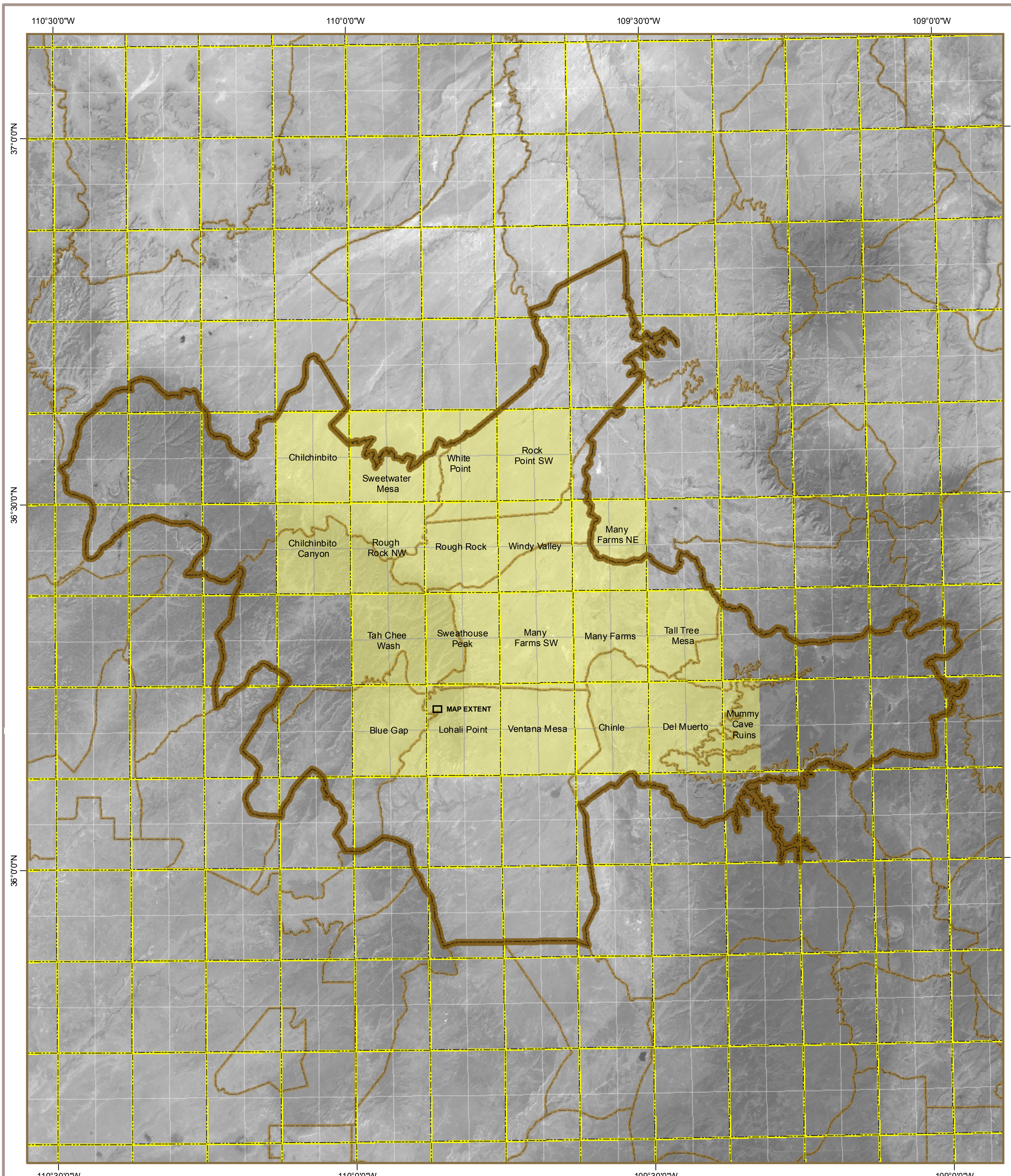
The accuracy and quality of USGS DOQQs meet National Map Accuracy Standards at 1:12,000 scale. DOQQs have a 1-meter ground resolution, and accuracy of +/- 33 feet.

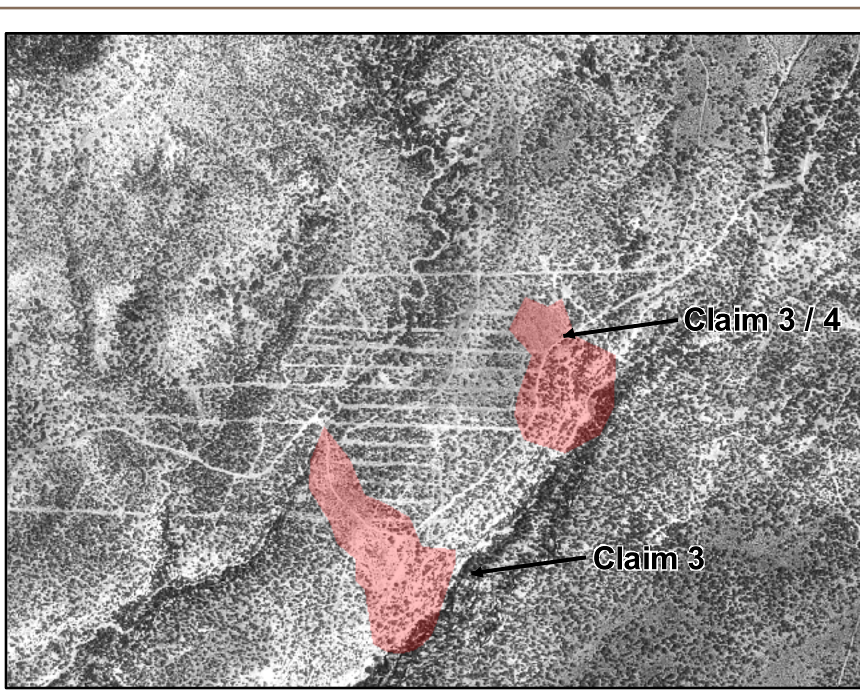


Example of a scanned USGS topographic quadrangle map (dated 1982) and a DOQQ (1997 source imagery) of the Chinle Community in the Chinle Chapter. These images are presented at a matched scale of nominally 1:24,000 (1" = 2,000 feet) and are shown to illustrate the different information that each can provide.

Example of a scanned USGS topographic quadrangle map overlain on a DOQQ.

U.S. Geological Survey, 2001. "Digital Orthophoto Quadrangles, Fact Sheet 057-01." (S05150301)





Portion of DOQQ in the Tselani/Cottonwood Chapter shown at 1:12,000 scale (1" = 1,000 feet). Horizontal grids associated with exploration drilling can be seen proximal to AUM Claims 3 and 3/4.

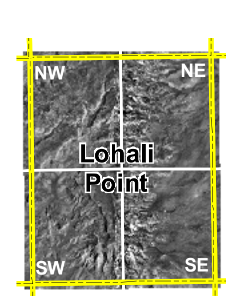
ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Central AUM Region Screening Assessment Report

DIGITAL ORTHOPHOTO QUARTER QUADRANGLE (DOQQ) INDEX

N W E S

0 10 Miles

Map Scale 1:600,000



Digital Orthophoto Quarter Quadrangles (DOQQ) are developed by the U.S. Geological Survey (USGS).

USGS 7.5-minute topographic quadrangle boundary (yellow grid) is shown for the region. DOQQ quadrangle names, boundary (white grid) and their quadrant designations (left) are also shown.