COMMUNITY INTRODUCTION

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

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

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

ENVIRONMENT

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

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

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

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

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

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

HEALTH

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Radiation Exposure Compensation Act (RECA)

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

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

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

Radiation Exposure Screening and Education Program (RESEP)

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

The following are screening facilities:

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

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

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

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

BACKGROUND

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

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

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

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

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

MISSION STATEMENTS

NAVAJO NATION ENVIRONMENTAL PROTECTION AGENCY

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

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

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

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

Stephen B. Etsitty, Executive Director
NNEPA
Post Office Box 339
Window Rock, Arizona 86515
Telephone: 928-871-7692

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

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

NAVAJO ABANDONED MINE LANDS RECLAMATION PROGRAM (NAMLRP)

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

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

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

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

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

Main Office	Shiprock AML Reclamation Program	Tuba City AML Reclamation Program
Madeline Roanhorse, Department Manager AML Reclamation/UMTRA Department Post Office Box 1875 Window Rock, Arizona 86515 Telephone: 928-871-6982	Rose Grey, Program Manager Post Office Box 3605 Shiprock, New Mexico 87420 Telephone: 505-368-1220	Ray Tsingine, Program Manager Post Office Box 730 Tuba City, Arizona 86045 Telephone: 928-283-3188

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA)

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

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

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

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

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

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

GEOGRAPHIC INFORMATION SYSTEM (GIS)

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

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

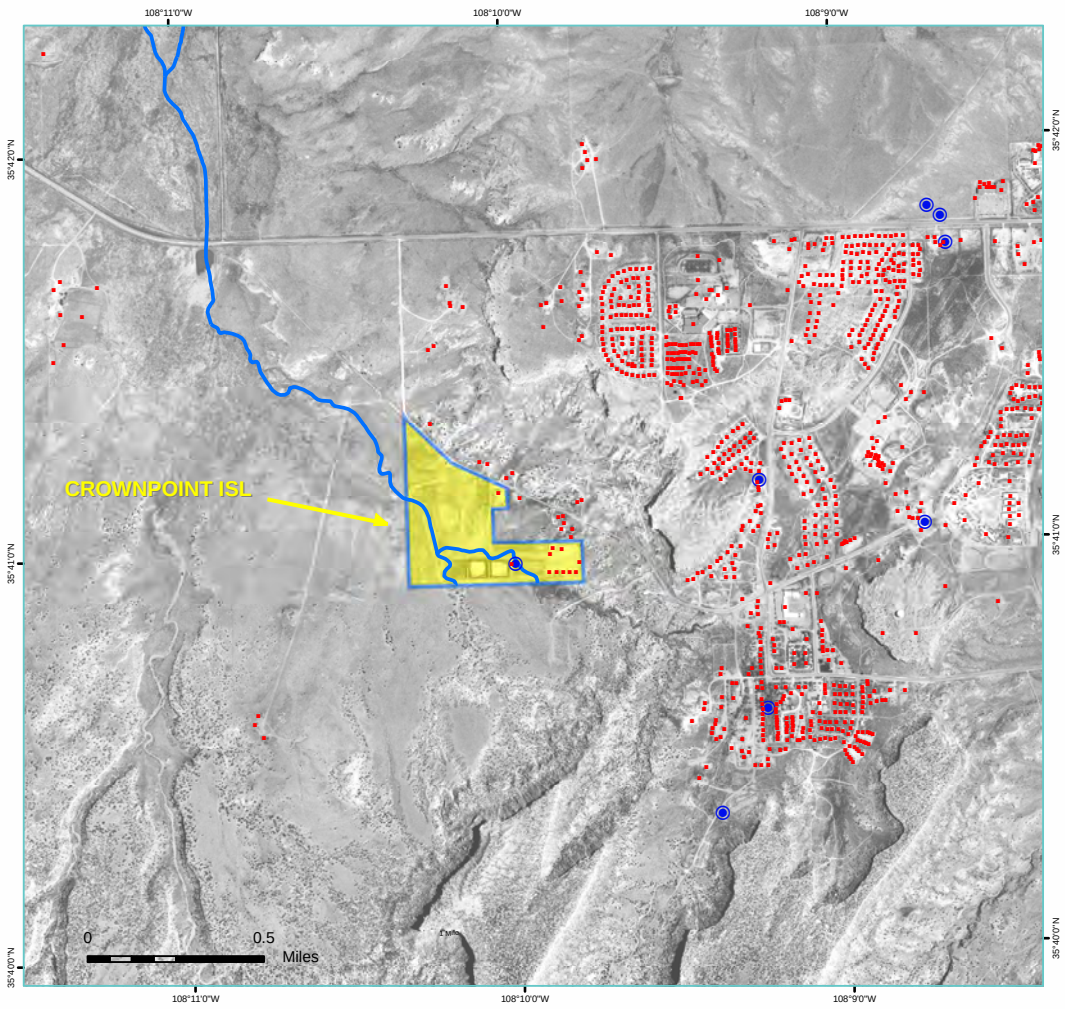


Figure 1. Points, Lines, and Polygons Displayed on Raster Imagery.

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

Table 1. Selected Attributes for the Water Source Dataset.

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

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

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

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

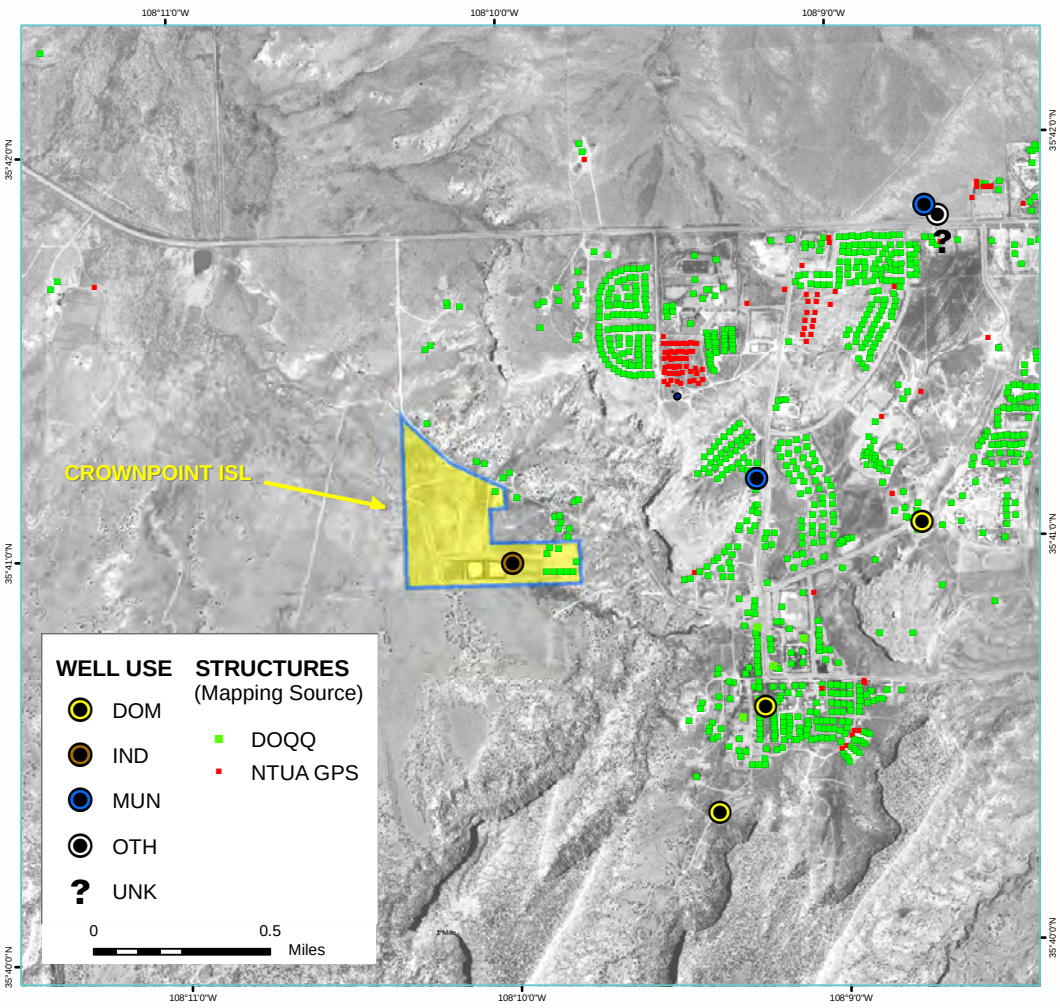


Figure 2. Using Attributes to Symbolize Information.

GEOGRAPHIC INFORMATION SYSTEM (GIS) (continued)

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

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

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

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

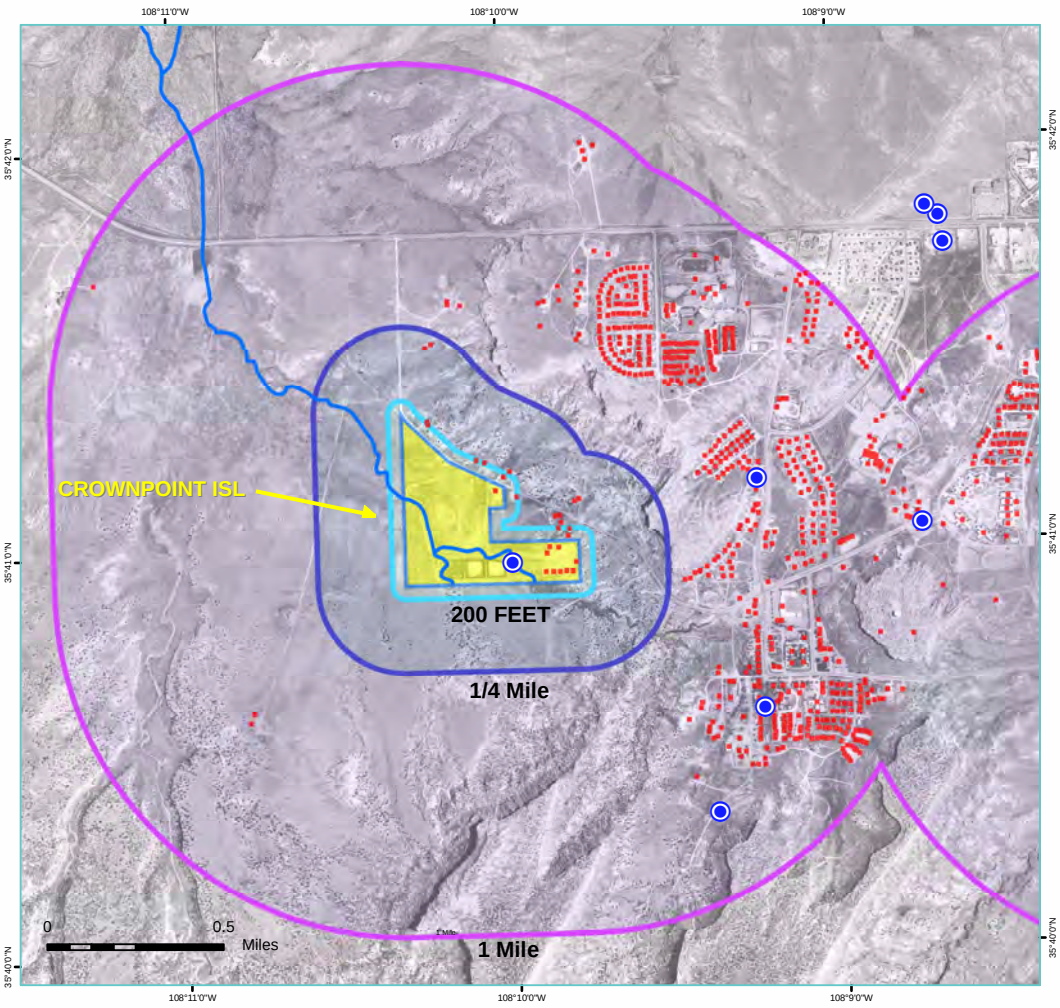


Figure 3. Using Buffer Analyses. Example of Crownpoint In Situ Leaching (ISL) Site.

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

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

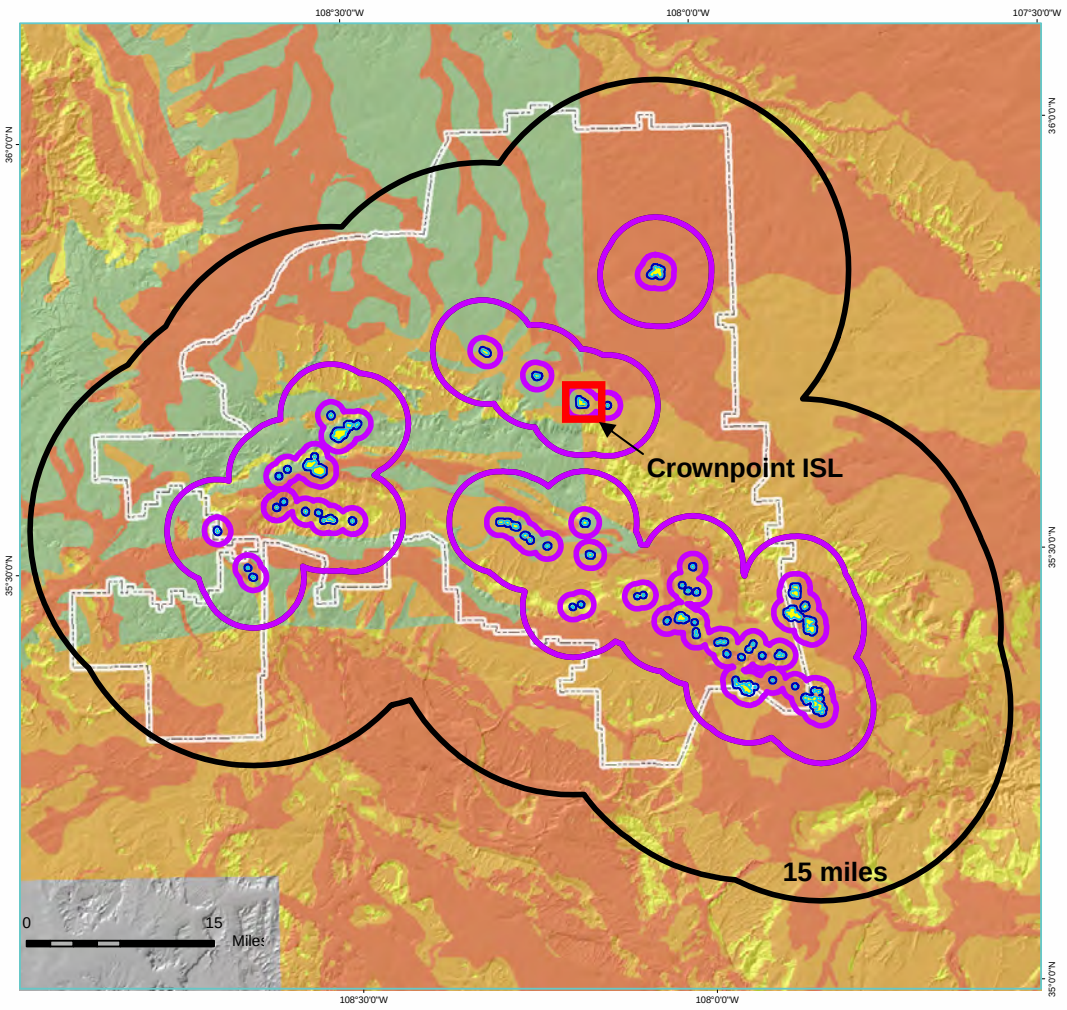


Figure 4. Developing Spatial Models.

- = Insignificant potential for contamination of the aquifer
- = Least potential for contamination of the aquifer
- = Intermediate potential for contamination of the aquifer, and
- = Most potential for contamination of the aquifer.

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

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

REPORT ORGANIZATION

PART I - NAVAJO NATION AUM SCREENING ASSESSMENT REPORT

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

PART II - ATLAS AND GEOSPATIAL DATA

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

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

Mining History and Mine Site Information

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

Mine Waste Characteristics

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

Environmental Setting

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

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

Geospatial Data

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

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

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

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

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

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

PURPOSE

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

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

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

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

PROJECT APPROACH

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

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

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

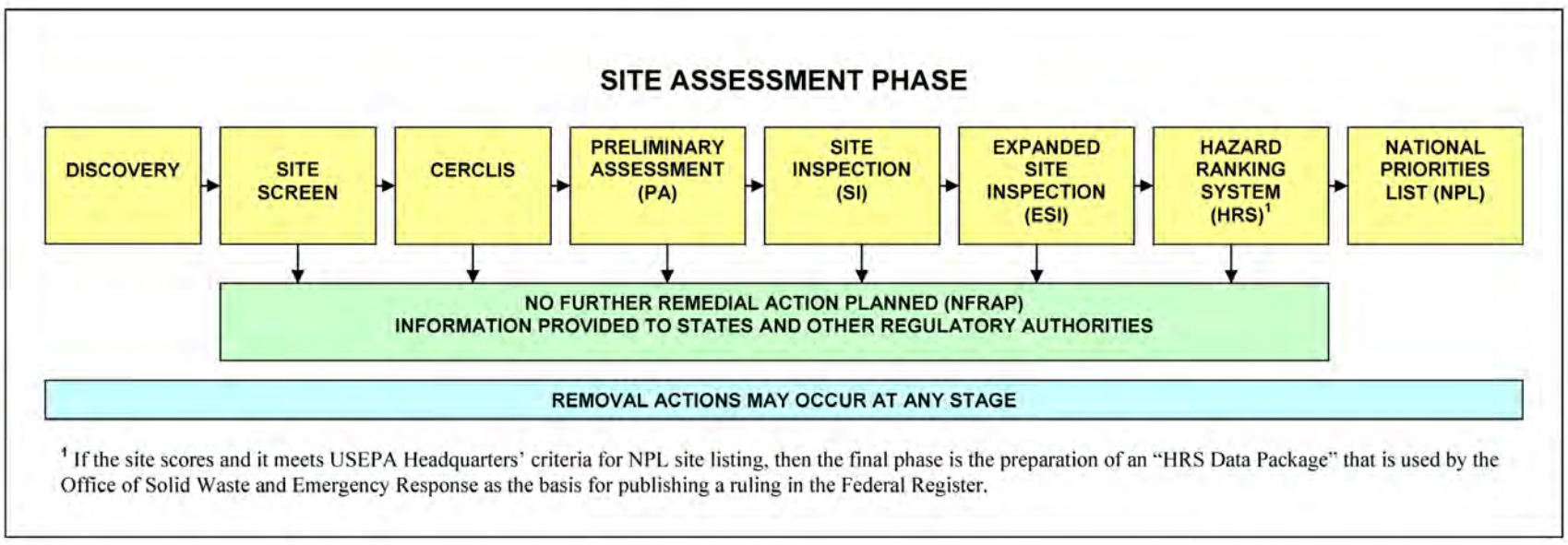


Figure 5. Superfund Process (modified after EPA, 1991– S01230301).

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

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

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

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

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

CONTAMINANTS AND EXPOSURE PATHWAYS

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

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

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

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

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

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

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

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

NAVAJO NATION AUM REGIONS

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

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

NORTH CENTRAL AUM REGION

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

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

NORTHERN AUM REGION

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

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

WESTERN AUM REGION

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

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

CENTRAL AUM REGION

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

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

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

SOUTHERN AUM REGION

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

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

EASTERN AUM REGION

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

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

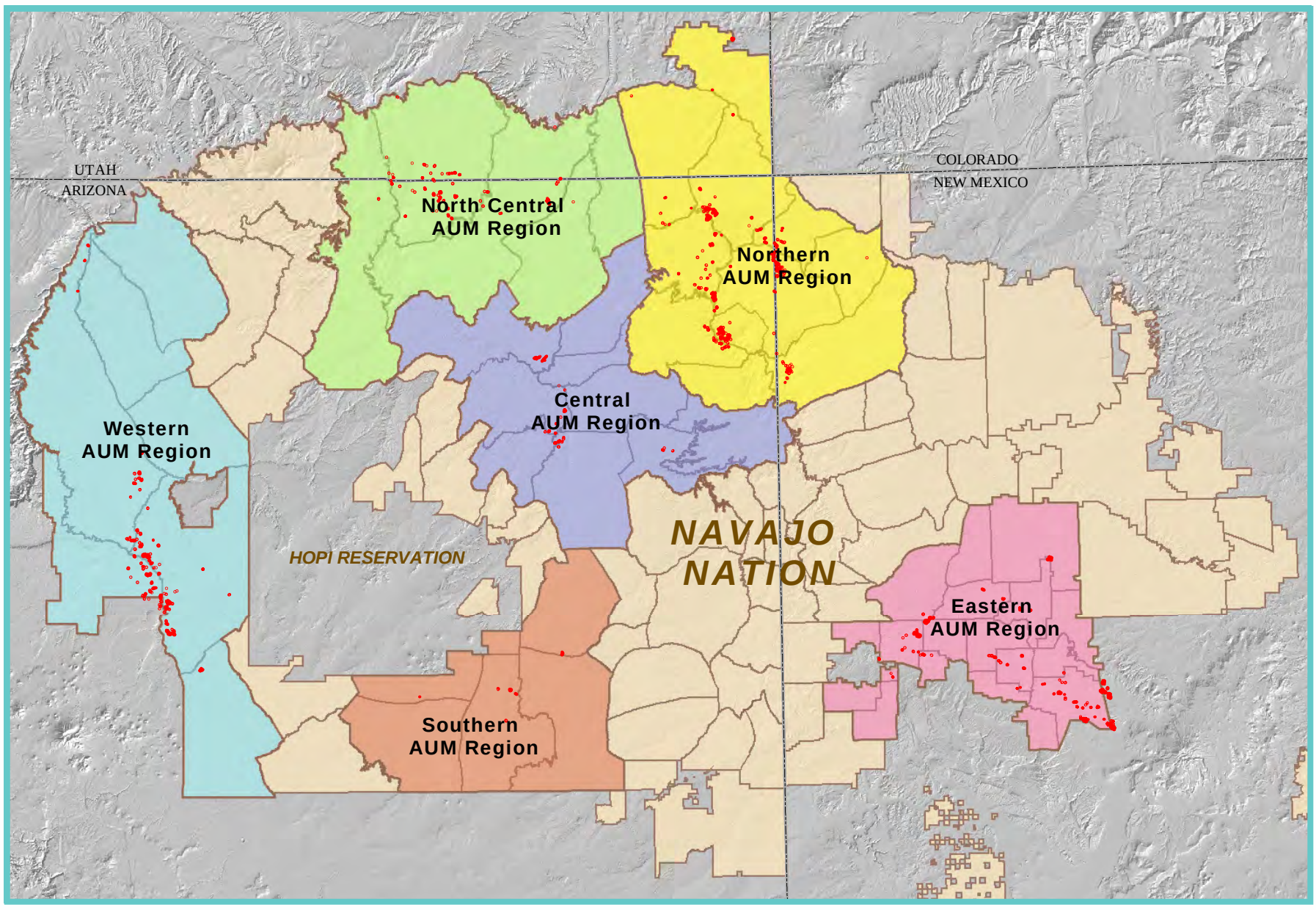


Figure 6. Locations of AUM Regions on the Navajo Nation.

METHODOLOGY

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

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

HAZARD RANKING SYSTEM (HRS) DERIVED MODEL

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

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

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

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

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

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

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

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

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

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

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

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

DATA

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

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

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

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

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

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

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

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

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

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

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

Figure 7. Example Photographs of Modified HRS Scoring Factors.

RESULTS

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

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

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

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

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

SOIL PATHWAY AND AIR PATHWAY

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

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

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

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

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

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

GROUND WATER PATHWAY

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

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

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

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

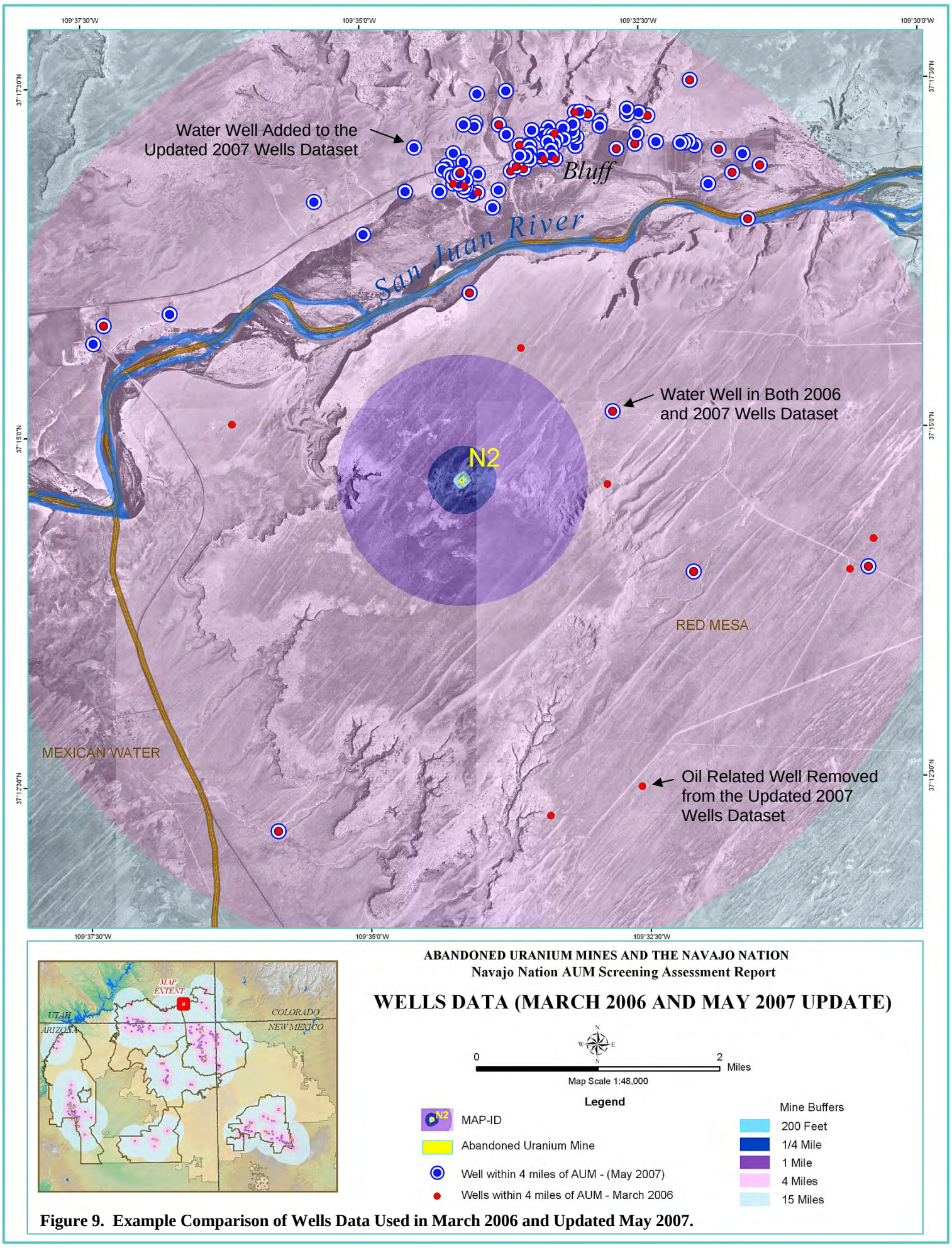


Figure 9. Example Comparison of Wells Data Used in March 2006 and Updated May 2007.

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

SURFACE WATER PATHWAY

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

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

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

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

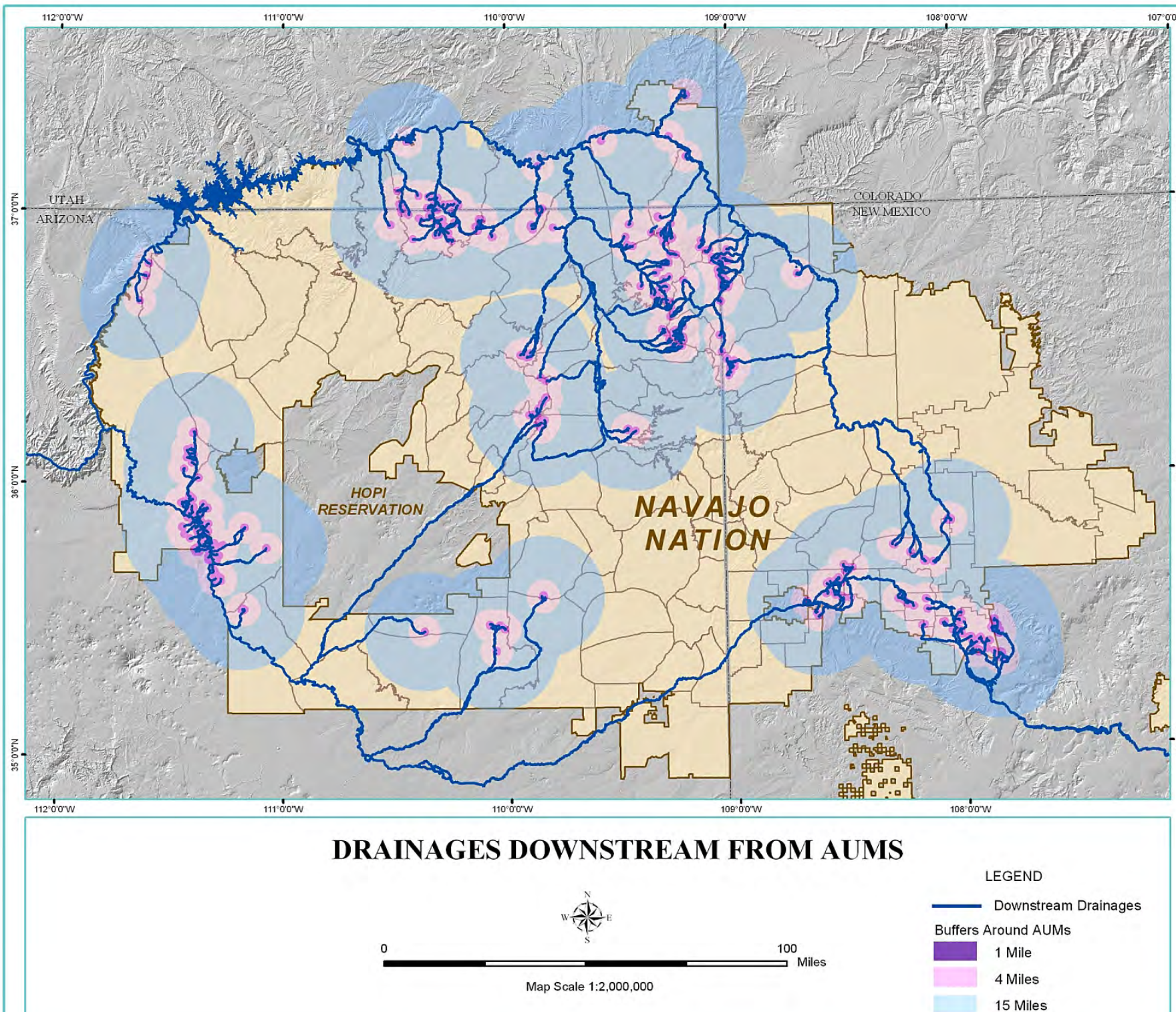


Figure 10. Surface Water Drainages Downstream from AUM Sites.

COMBINED PATHWAYS

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

Table 4. North Central Combined Pathway Scores Table

Table 5. Northern Combined Pathway Scores Table

Table 6. Western Combined Pathway Scores Table

Table 7. Central Combined Pathway Scores Table

Table 8. Southern Combined Pathway Scores Table

Table 9. Eastern Combined Pathway Scores Table

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

Table 3. MAP-ID Correspondence to Figure Number.

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

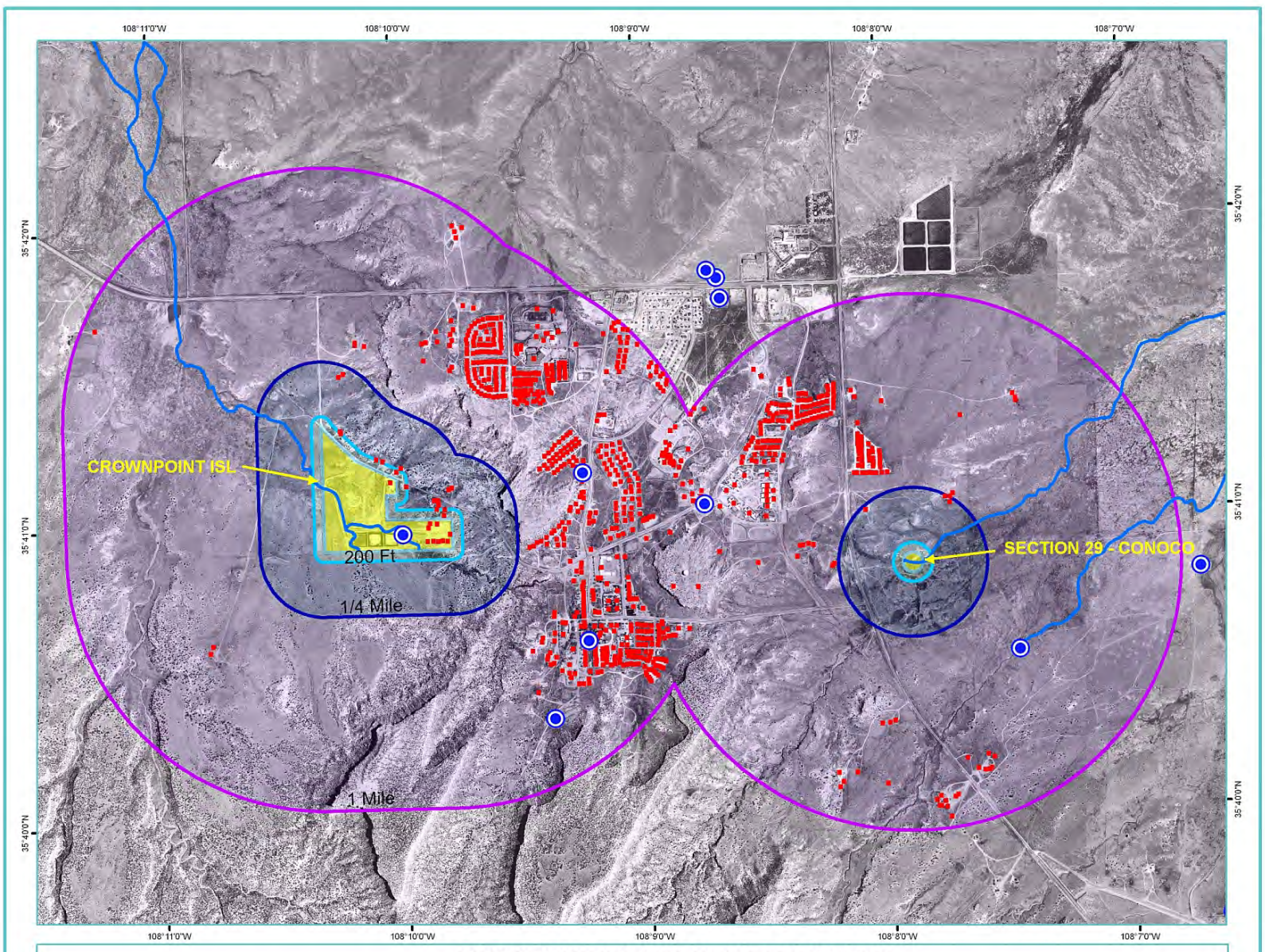
* Indicates MAP-ID ranges where AUM polygons were added, deleted, or merged, resulting in gaps in the MAP-ID numbers.

COMBINED PATHWAYS (continued)

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

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

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



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

COMBINED PATHWAYS - CROWNPOINT ISL AND SECTION 29 CONOCO AUMS

Sources

The base imagery used for this map are USGS 1 meter resolution Digital Orthophoto Quarter Quadrangles (DOQQ): Crownpoint_NE, Crownpoint_SE, Heart Rock_NW, and Heart Rock_SW quarter quads. The imagery was flown in 1997.

0 1 Miles
Map Scale 1:30,000

Legend
- Abandoned Uranium Mine
- Mine Buffers
- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- Downstream Water Pathway
- Structure within 1 Mile
- Well within 4 Miles

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