

## Section 2

# MINE WASTE CHARACTERISTICS



## ABANDONED URANIUM MINE WASTE CHARACTERISTICS

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

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

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

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

## RADIATION SURVEYS

### NAUM AERIAL RADIATION SURVEYS

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

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

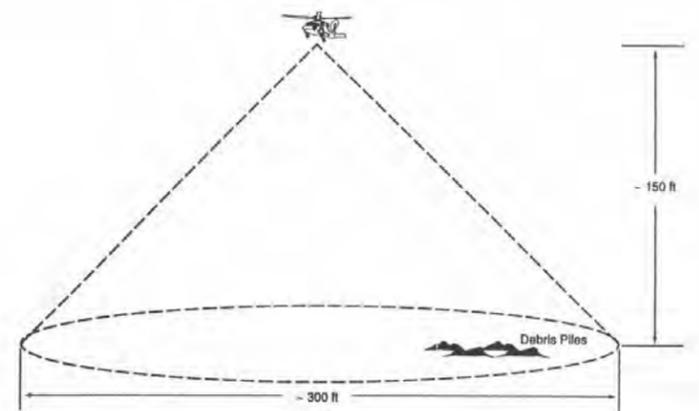


Figure 1. Aerial Radiation Survey Footprint Diagram.

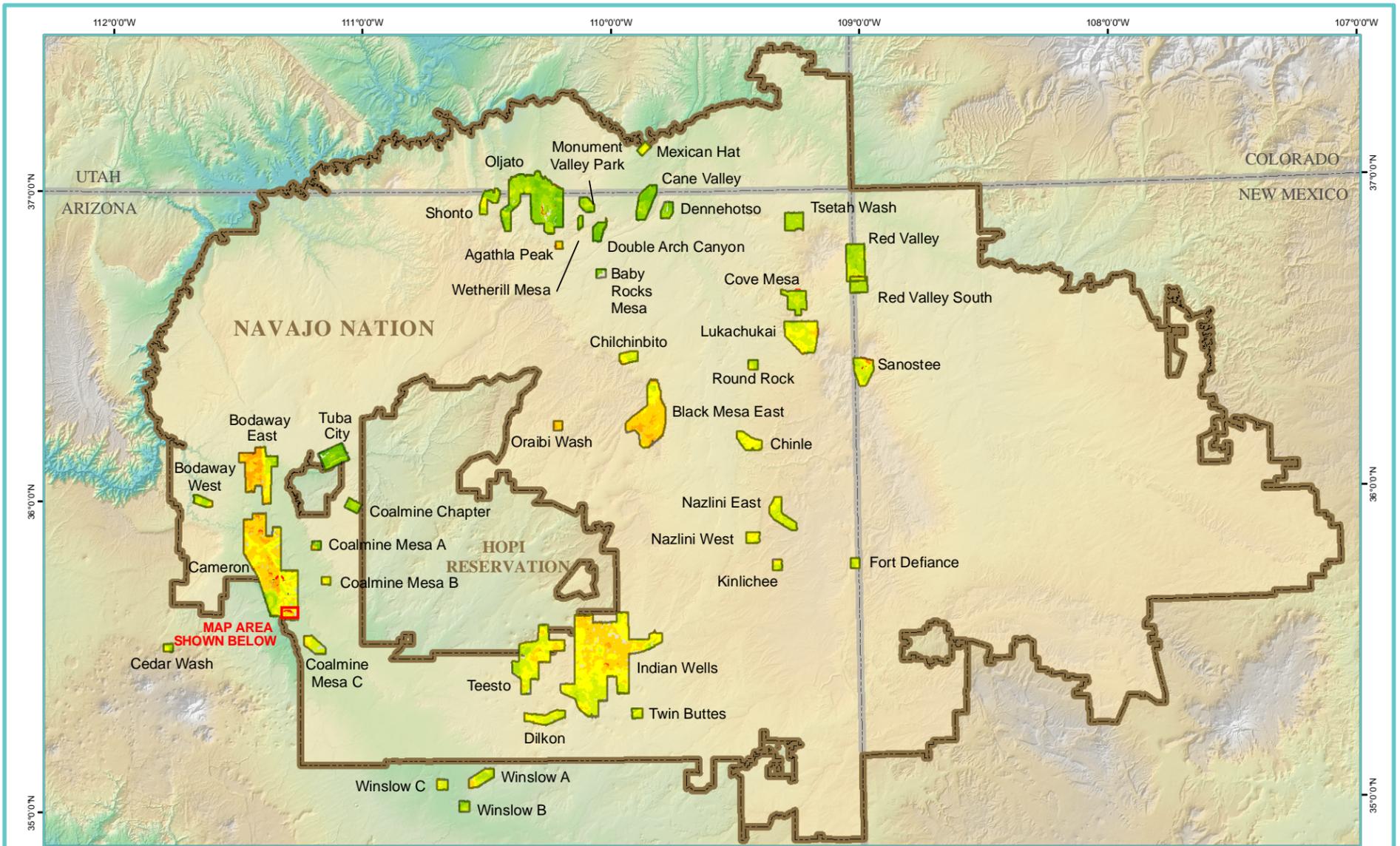
Aerial radiation surveys were flown over forty-one (41) uranium mining areas on the Navajo Nation (Figure 2). Aerial radiation surveys were not conducted over the Eastern AUM Region. A spreadsheet with summaries of the survey parameters for all areas is provided on the GIS Data DVD (DB/Radiation/NAUM\_Radsurveys.xls).

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

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

These GIS datasets are provided on the GIS Data DVD (DB/Radiation). Aerial radiation survey boundaries (NN\_Flight\_Areas.shp) and radiation contour data files were converted to GIS-compatible digital files by the DOE RSL for gross count (NN\_Gross\_Count\_Contours.shp) and excess Bismuth-214 (NN\_Excess\_Bi214\_Contours.shp). Additional processing was performed under the NAUM Project to convert the vector contours to polygons (NN\_Gross\_Count\_Polys.shp and NN\_Excess\_Bi214.shp).

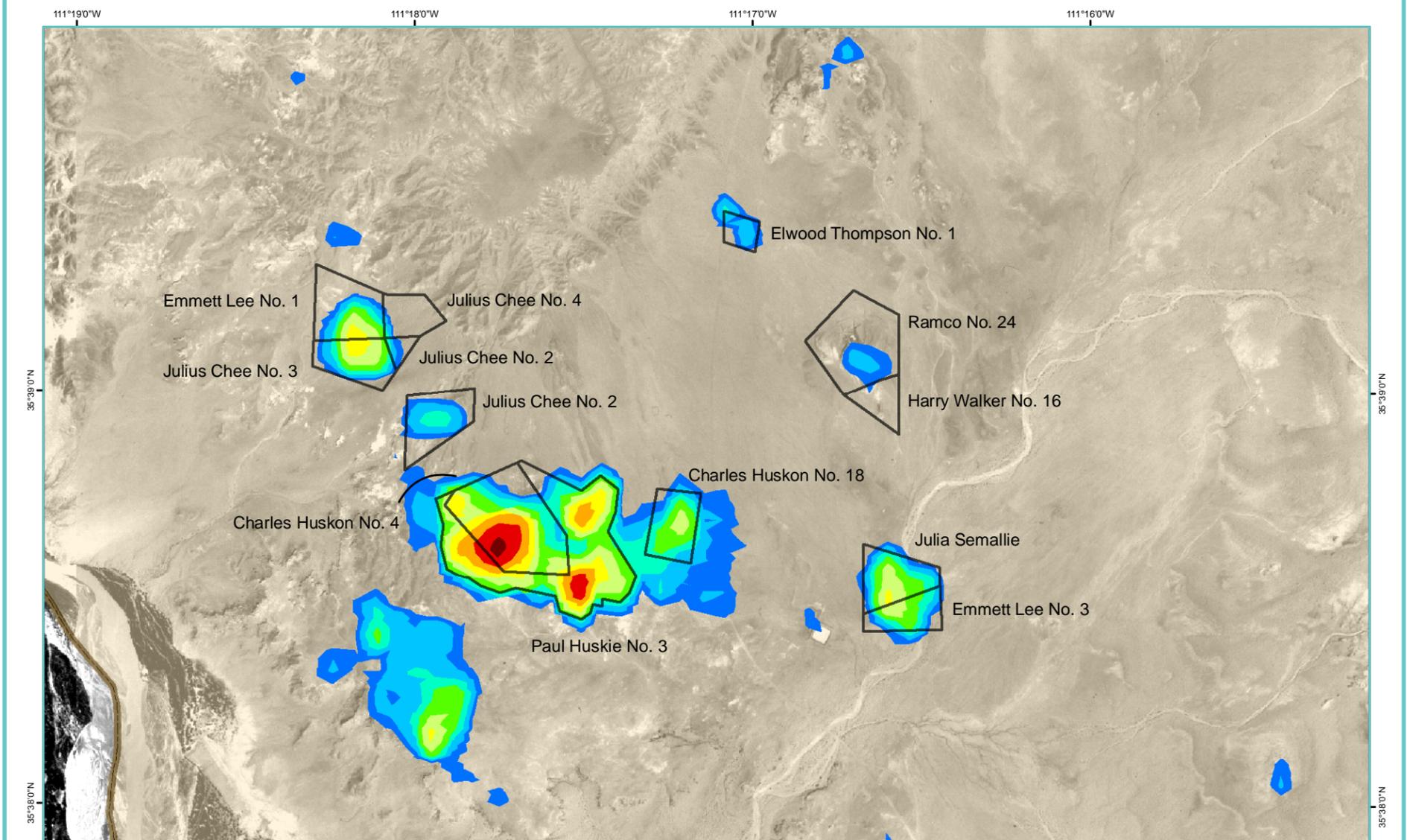
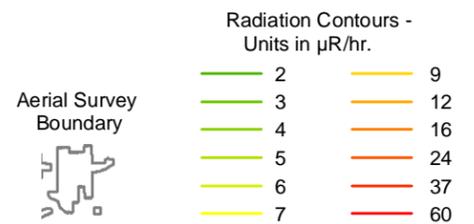
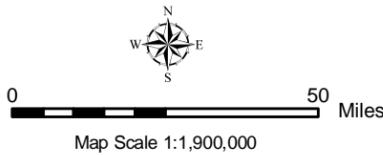
For a more comprehensive explanation of the acquisition and processing methods used for the aerial radiation measurements, a report was developed by the DOE's RSL titled "An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation." (Hendricks, 2001 - S03310309). Two other aerial radiation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



### AERIAL RADIATION SURVEY AREAS AND GROSS COUNT RADIATION CONTOURS

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

Filenames: DB/Radiation/NN\_Flight\_Areas.shp  
DB/Radiation/NN\_Gross\_Count\_Contours.shp



### EXCESS BISMUTH 214 RADIATION DATA SOUTH AREA OF CAMERON SURVEY AREA

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

Filename: DB/Radiation/NN\_Excess\_Bi214\_Poly.shp

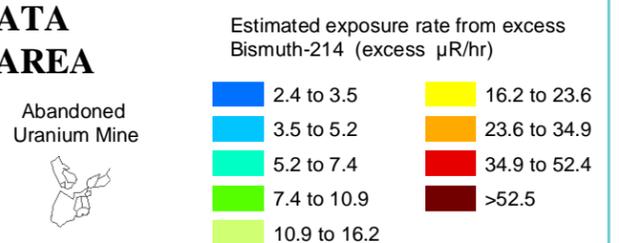
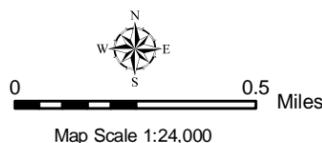


Figure 2. NAUM Project Aerial Radiation Survey Data.

RADIATION SURVEYS (continued)

NATIONAL URANIUM RESOURCE EVALUATION (NURE) AERIAL GAMMA RAY SURVEYS

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

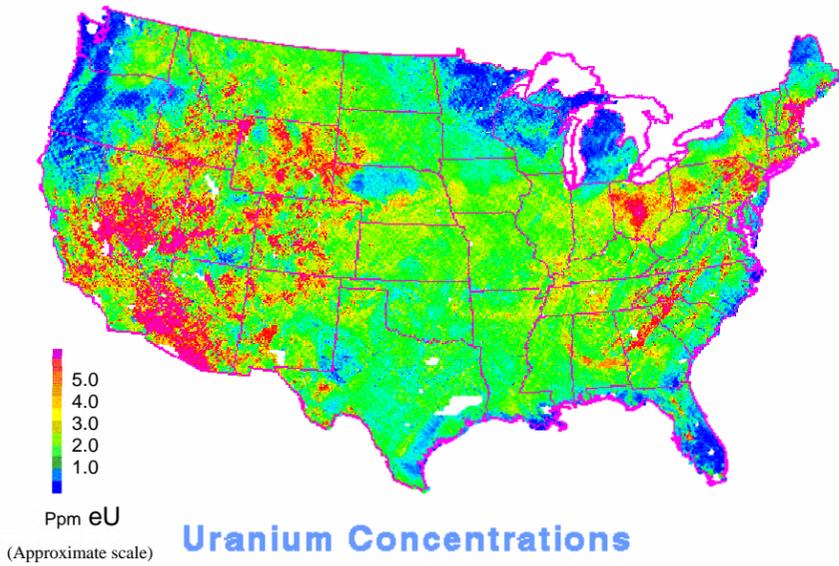


Figure 3 shows an image of the equivalent uranium for the Conterminous United States. This image was generated from NURE aerial gamma-ray data presented in United States Geological Survey Digital Data Series DDS-9, "National Geophysical Data Grids: Gamma-Ray, Magnetic, and Topographic Data for the Conterminous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

Figure 3. Equivalent Uranium Map for the Conterminous United States

CHURCH ROCK GAMMA SCAN

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

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

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

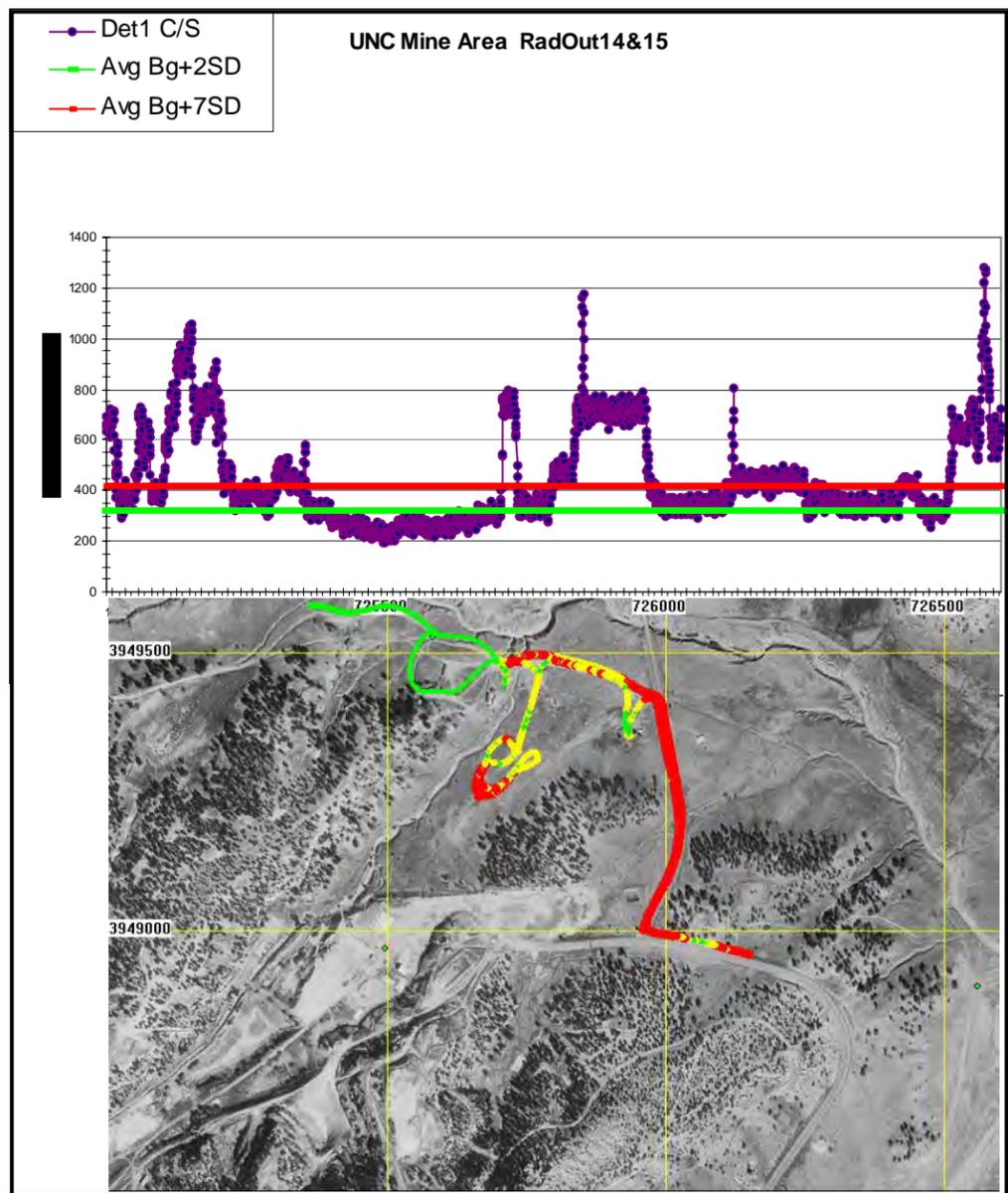


Figure 4. Truck Mounted Gamma Survey Near the United Nuclear Corporation Mine

WATER AND SEDIMENT SAMPLES

NURE HYDROGEOCHEMICAL AND STREAM SEDIMENT RECONNAISSANCE (HSSR) DATA

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

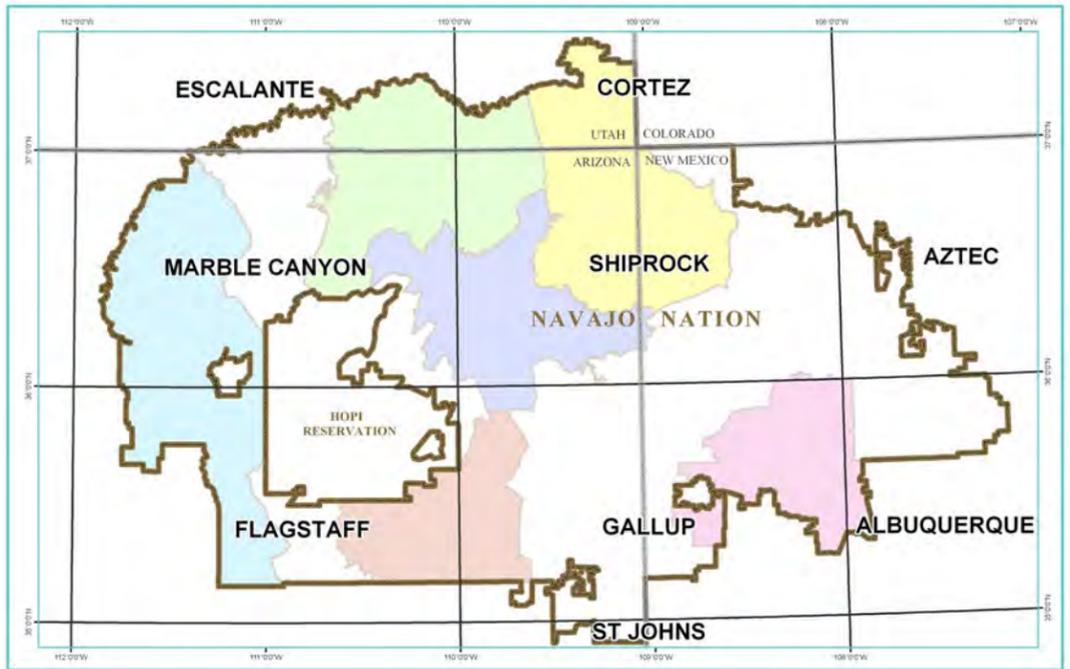


Figure 5. NURE Quadrangles Covering the Navajo Nation.

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

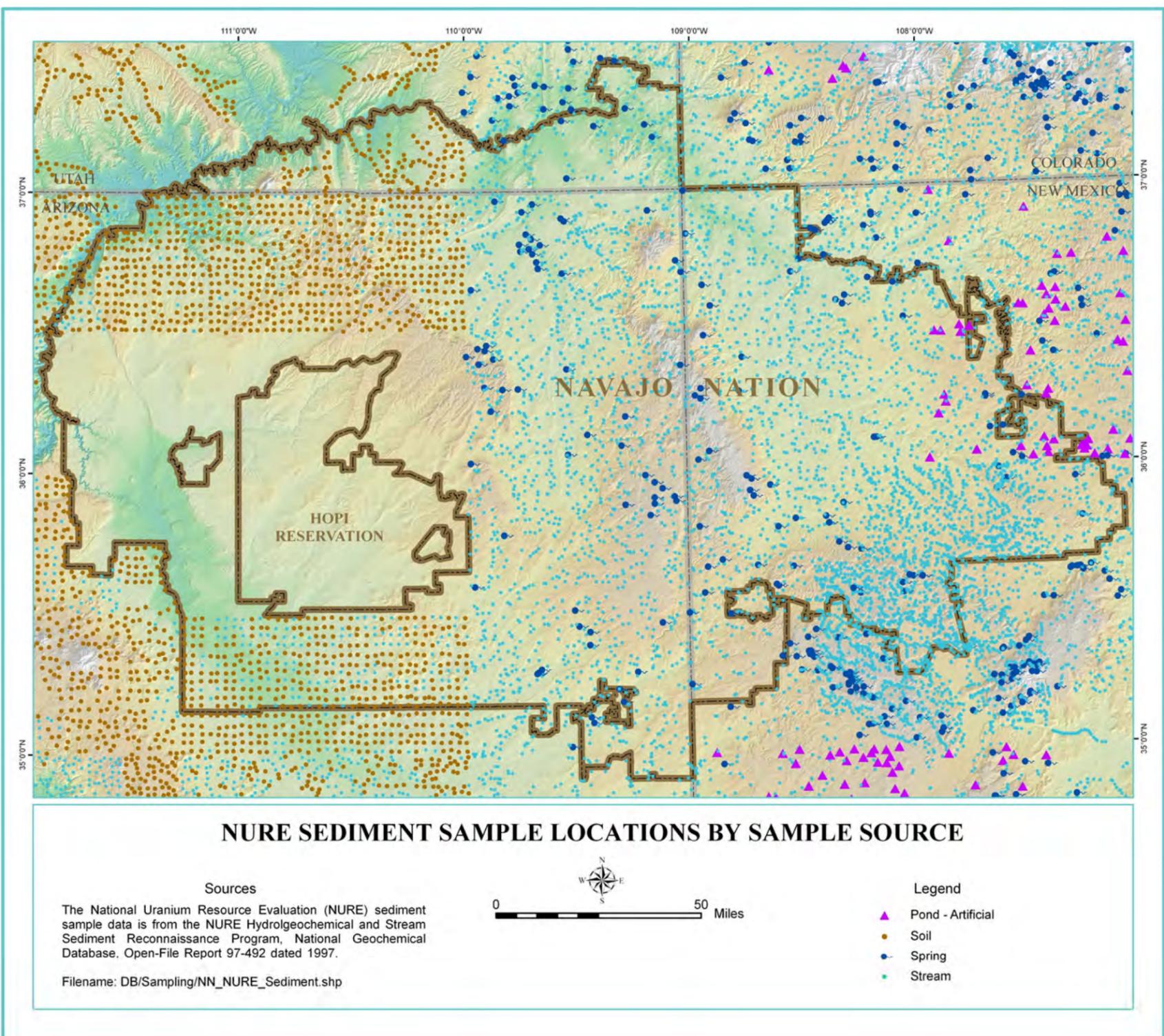


Figure 6. NURE Sediment Sample Locations by Sample Source.

**WATER AND SEDIMENT SAMPLES (continued)**

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

**NATIONAL URANIUM RESOURCE EVALUATION (NURE) WATER SAMPLES**

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

**NAVAJO ABANDONED URANIUM MINES STUDY WATER SAMPLES**

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

**U.S. GEOLOGICAL SURVEY WATER SAMPLES**

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

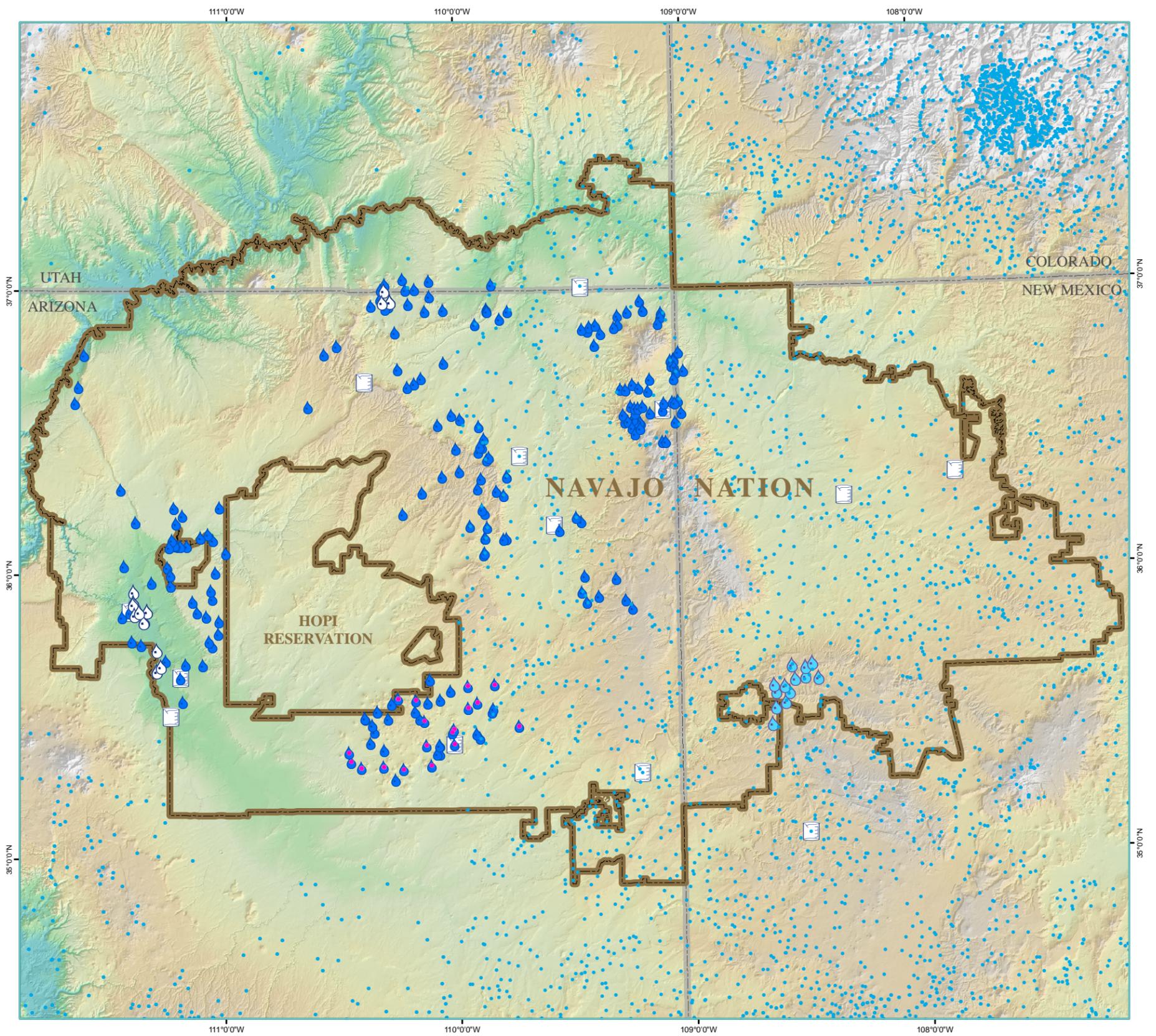
Eighteen (18) water sample locations in the Hopi Buttes area, that were previously sampled by the USACE, were resampled by George Breit and Margaret Hiza, USGS. Water samples were collected during six sampling periods (6/2001, 9/2001, 10/2001, 7/2002, 5/2003, and 6/2004). Results for 35 samples (several locations were sampled up to three times) were provided for: temperature, specific conductance, pH, aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, cobalt, chromium, copper, iron, lead, potassium, magnesium, manganese, mercury, nickel, selenium, silver, sodium, thallium, thorium, uranium, vanadium, and zinc. Uranium concentrations are reported in units of µg/L, and range from 0.02 - 17.0 µg/L. The original spreadsheet provided by George Breit is on the GIS Data DVD (DB/Sampling/USGS\_Breit\_Sampling\_COE\_5-28-07.xls), which contains notes on the methods used for the analyses. A GIS dataset was developed for the data and is provided on the GIS Data DVD (DB/Sampling/USGS\_Breit\_Samples.shp). No unit conversions were made to these data.

**NAVAJO NATION ENVIRONMENTAL PROTECTION AGENCY WATER SAMPLES**

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

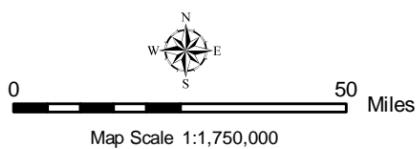
**CHURCH ROCK URANIUM MONITORING PROGRAM WATER SAMPLES**

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



ABANDONED URANIUM MINES AND THE NAVAJO NATION

**WATER SAMPLES WITH ANALYSES FOR RADIONUCLIDES**



Sources

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

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

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

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

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

Church Rock Uranium Monitoring Project (CRUMP) water sample data is from a spreadsheet "CRCWellsWaterQuality2003" provided by Andrew Bain, EPA Region 9 in January, 2005.  
 Filename: DB/Sampling/CRUMP\_Samples.shp

Legend

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



Cameron Open Pit Mine (Field Filtering Sample)  
 23 July 1998, CT980723CAM004

**Figure 7. Water Samples on the Navajo Nation with Analyses for Radionuclides.**