Office of Radiation & Indoor Air
Radiation Protection Division (6608J)
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Uranium Location Database Compilation

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URANIUM LOCATION DATABASE COMPILATION

Abstract

The Environmental Protection Agency's (EPA) Radiation Protection Division works to address hazards posed by technologically enhanced naturally occurring radioactive materials (TENORM). As one part of EPA's efforts to characterize risk from TENORM sources and to identify where TENORM problems may exist, we have been investigating the potential environmental hazards of wastes from abandoned uranium mines in the western United States. Between the 1940s and 1990s, thousands of uranium mines operated in the United States, mostly in the western continental U.S., leaving a legacy of potential radiological and chemical hazards.

In order to help us identify where potential problems may occur, we have compiled mine location information from federal, state, and Tribal agency partners to develop a database that can be used with geographic information system (GIS) software. Most mines producing uranium as a primary commodity are, or were located, in Colorado, Utah, Wyoming, New Mexico and Arizona, and are typically on federal and Tribal lands. The current number of locations associated with uranium, as identified in the EPA database, is around 15,000. Of these uranium locations, over 4,000 are mines having documented production.

Uranium mines, particularly conventional type operations, have the potential to become health hazards if they are not appropriately closed. Three uranium mines presently are on the National Priorities List (Superfund), while others are in the EPA Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) hazardous waste database. The database does not reflect the current reclamation status of the approximately 15,000 uranium locations.

Background

The focus of this Uranium Location Database (ULD) compilation is the western United States. Because most uranium mining occurred in the western United States, and this Agency effort coincided with a Colorado Plateau initiative in the Environmental Protection Agency's (EPA's) Region 8 office in Denver, Colorado, the initial database compilation efforts were focused there. Working cooperatively with the Bureau of Land Management (BLM), Forest Service (FS), EPA regional offices, Navajo Nation, and state agency offices, multiple western state databases have been incorporated into the master database. The U.S. Geological Survey's (USGS) Minerals Availability System/Minerals Industry Location System (MAS/MILS) and Mineral Resources Data System (MRDS) (McFaul et al. 2000) databases are also included (uranium locations identified in the eastern U.S. and Alaska are solely based on these two databases). Even though these national data sets are presented, it is the different state and more local federal databases that make the data in this effort more comprehensive than the previously released national data sets.

Efforts were made to eliminate redundant records, and steps were taken to determine the accuracy of the data and their reliability. A master database is included that represents the result of these efforts. However, the individual databases are included separately as well. The database was included as part of the peer review of two other technical reports by EPA (U.S. EPA 2006a, 2006b) discussed briefly below.

In this document, we provide some background on uranium mining, list the contents of the master database and the component databases, present some maps (see figures at the end of the document) for comparing the extent of the databases, and include a limited discussion on the data. Separate documents provide additional information on the database, including the metadata for the database. Some of this information, e.g., the metadata, is taken from documentation of the compact disc (CD) and has been edited and provided in this document for ease of use and readability.

Introduction

This technical report was developed as part of a larger effort to examine the potential hazards of wastes generated during the mining and processing of uranium, and particularly those wastes known as Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM). Information collected and analyzed in that effort will be presented in two additional reports. The first of those volumes, entitled *Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) from Uranium Mining: Volume I: Mining and Reclamation Background (U.S. EPA 2006a)* will provide background information on the occurrence, mining, and reclamation of uranium mines and mills. The second volume entitled *Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) from Uranium Mining: Volume II: Investigation of Potential Health, Geographic, and Environmental Issues of Abandoned Uranium Mines (2006b)*, will evaluate, in a general way, potential radiogenic cancer and environmental risks posed by abandoned uranium mines.

In these technical reports, Naturally Occurring Radioactive Materials (NORM) is defined as: **Materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products, that are undisturbed as a result of human activities.** Radiation levels presented by NORM are generally referred to as a component of "natural background radiation".

The term Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) is defined as: **Naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing**. "Technologically enhanced" means that the radiological, physical, and chemical properties of the radioactive material have been altered through having been processed (or beneficiated) or disturbed in a way that increases the potential for human and/or environmental exposures. The definition of TENORM used in EPA's reports does not include Atomic Energy Act materials.

Under the Atomic Energy Act, the U.S. Nuclear Regulatory Commission (NRC) regulates operations which produce and concentrate uranium and thorium. In accordance with terminology of the Act, the NRC has defined in 10 CFR 40.4 "source materials" **as 1) uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores which contain by weight one-twentieth of one percent (0.05%) or more of: (i) uranium, (ii) thorium or (iii) any combination thereof. Source material does not include special nuclear material.** It also defines the "by-product materials" (wastes) of those operations **as tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by such solution extraction operations do not constitute "byproduct material" within this definition.** Byproduct materials are also regulated by the NRC.

However, certain types of waste from conventional mining of uranium (surface and underground mining) are not subject to NRC regulation, and are considered to be TENORM. Thus, while these reports include information about uranium extraction, processing methods and wastes, only the wastes from conventional mining are considered to be TENORM, and subject to EPA and state agency oversight.

Previous EPA Reports

The U.S. Environmental Protection Agency has previously issued reports on the uranium mining industry in response to congressional mandates and programmatic needs. In 1983, EPA published its *Report to Congress on the Potential Health and Environmental Hazards of Uranium Mine Wastes* (U.S. EPA 1983 a, b, c), as required by the Uranium Mill Tailings Radiation Control Act of 1978. This study provided an important overview of the characteristics and generation of uranium mining TENORM wastes during a period when the uranium mining industry was still near its production peak. A subsequent 1985 *Report to Congress on Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale* (U.S. EPA 1985), carried out pursuant to requirements of the Resource Conservation and Recovery Act of 1976 (RCRA), as amended, provided additional risk information and characterization of uranium mining waste. In 1995, EPA issued the *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals: Uranium* as a technical update to provide a means of evaluating wastes that were exempt from or subject to regulation under RCRA (U.S. EPA 1995).

During the period 1989 to 1993, EPA worked on a draft scoping report (SC&A 1993), which compiled information on TENORM in several industries, including uranium mining. A preliminary risk assessment was also developed for certain public and occupational exposure scenarios to the known radiation levels in those industries. Comments received on the draft from industry, as well as EPA's Science Advisory Board (U.S. EPA 1994), resulted in further revisions of the scoping draft, though it was ultimately decided that a final report would not be issued.

Following a review of EPA's guidance for TENORM by the National Academy of Sciences (NAS 1999a), EPA's response to the NAS study (U.S. EPA 2000), and discussions with EPA's Science Advisory Board (SAB), EPA's Radiation Protection Division decided that a further review of the current hazards associated with uranium mining TENORM was warranted. The SAB (U.S. EPA 2001) agreed with EPA's intent to make TENORM documents useful to a broad audience, but also recommended that the whole life cycle of a TENORM source, in this case uranium extraction, be considered beyond regulatory or inter-agency considerations, and that the impacts of non-radiological contaminants also be examined in the Agency's technical reports. In addition to most sources of TENORM, EPA has authorities for environmental standard setting under the Uranium Mill Tailings Radiation Control Act, cleanup of hazardous waste sites which currently include some former uranium mines, and assistance to Native Americans that has included assistance in environmental reviews of proposed *in situ* leach (ISL) facilities.

ISL operations, as well as uranium mills, and mill tailings impoundments are regulated by the NRC or its Agreement States. Many of the physical and chemical processes used at uranium mills are the same as those which extract uranium at ISL operations. While wastes from the ISL operations and mill tailings are not legally considered TENORM in the United States, this phase of the uranium fuel cycle is described in the reports, and their locations included in the database in part because radiation protection standards for the tailings impoundments may have applicability to waste disposal for uranium mine TENORM wastes. Additionally, the NRC has decided to allow mill operators to dispose of wastes other than tailings in the impoundments, which is a possible disposal route for some currently unreclaimed conventional uranium mine TENORM.

Uranium

Uranium is a common element in nature that has for centuries been used as a coloring agent in decorative glass and ceramics. Uranium and its radioactive decay products are ubiquitous in nature, and contribute to natural background radiation found everywhere. In fact, it is important to note that many of the natural occurrences of uranium present radiation hazards without any disturbance from miners. By far, the greatest uses of uranium have been defense and electric power generation. The advent of nuclear weapons and nuclear power in the United States resulted in a full-blown exploration and mining boom starting immediately after World War II, making uranium the most important commodity in the mining industry. The uranium production peak spanned from approximately 1948 to the early 1980s (U.S. DOE/EIA 1992). Some uranium mining continues in the United States, and relatively high-grade resources in other parts of the world are being mined to meet continued demand. Through the first half of 2005 the industry had generated over 358,000 metric tons (MTs) of uranium (U_3O_8) to foster U.S. dominance in nuclear weapons technology, and later to feed the growing number of commercial power plants that utilized the enormous energy contained in the uranium nucleus.[1]

Another legacy of uranium exploration, mining, and ore processing were many unreclaimed land workings left behind where the uranium concentration in rock was either found or thought to be economically recoverable. Thousands of miners and prospectors, as well as large mining companies, searched the United States for mineral deposits concentrating the valuable metal, echoing the California gold rush 100 years earlier. In many instances before the 1970's, they left behind unreclaimed and exposed wastes elevated in radioactivity from uranium and its radioactive decay progeny, potentially exposing people and the environment to its hazards.

Most uranium mining in the United States took place in the expansive Colorado Plateau region straddling the Four Corners where Utah, Colorado, New Mexico, and Arizona meet and in Wyoming. However, uranium mining occurred in other areas throughout the western U.S., and in some eastern states as well.

Uranium Associations with Other Metal Mining

Quite typically, beginning in the 1940s, uranium mines would open based on the detection of radioactivity at the site and identification of uraniferous mineralization. While some deposits were mined solely for their uranium content, others produced a variety of other minerals, which co-exist with the uranium minerals (Table 1). In some cases, exploitation of uranium minerals was secondary to producing another mineral found in greater abundance, commanding a better market price, or less expensive to produce; nevertheless, their combined economic value contributed to the success of the mining venture.

[1] Data compiled from U.S. DOE/EIA 2003, 2003b, 2005b.

The presence of radioactive minerals was sometimes unexpected, unknown, or ignored in producing one or more minerals at a mine. Many mine sites operated prior to the 1940s, and even after, have not been recognized for the inherent hazards potentially posed by radioactivity in the discarded waste rock or subeconomic ore piles. The geological emplacement or geothermal phenomena that formed other valuable minerals may have concentrated radioactive minerals as well, or the process of mining, beneficiation, and milling may have resulted in a concentration of the radioactive minerals in the waste. In some instances, the mineral(s) being mined may have radioactive elements included in their molecular structure that impart radioactivity to the ore or even the finished product.

Table 1. Mineral Commodities with Uranium Associations

Several mineral ores often have TENORM-associated wastes resulting from the co-occurrence of uranium and radium.

Aluminum (bauxite)
Coal (and coal ash)
Copper
Fluorospar (fluorite)
Gypsum
Molybdenum
Niobium
Phosphate (phosphorus)
Potassium (potash)
Precious metals (gold, silver)
Rare earths: yttrium, lanthanum, monazite, bastanite, etc.
Tin
Titanium (leucoxene, ilmenite, rutile)
Tungsten
Vanadium
Zircon

Source: U.S. EPA 2003.

Data Discussion

A number of organizations allowed EPA access to their databases and the original information is provided as part of the publication. The component databases used to compile the uranium location master database are listed in Table 2, with notes regarding the verification and accuracy of the data. A complete listing of all data sources evaluated, including details regarding documentation and processing, is included at the end of this report. Because there were numerous sources of data used in this compilation, however, efforts were made to reduce mine duplication and compare with existing data sources for accuracy. This was done, in part, by comparisons with U.S. Geological Survey (USGS) topographic maps at different scales. We also attempted to develop some indication of the reliability of the data, such as the availability of documentation. The result of this effort produced the master database and composite shapefile that can be used as a layer with geographic information systems (GIS).

Table 2. Component Databases [2]

Database	Source	Number of Records
DB2	Colorado Bureau of Land Management Abandoned Mine Land Inventory. Point locations matched quadrangles very well. A high percentage of mines from the EPA data set matched mine names from the quadrangle maps. Point locations generally matched within 100 to 200 meters.	535
DB4	U.S. Geological Survey Mineral Resource Data System (MRDS) from U.S. Geological Survey Mineral Databases--MRDS and MAS/MILS by McFaul et al, U.S. Geological Survey Digital Data Series DDS--52 Two Discs, 2000. Location points rarely coincided with USGS mine positions although where they did, points were within 100 - 200 meters.	1729
DB5	U.S. Geological Survey MAS/MILS. U.S. Geological Survey Mineral Databases--MRDS and MAS/MILS by McFaul et al, U.S. Geological Survey Digital Data Series DDS--52 Two Discs, 2000. The point locations showed good positional accuracy when compared to the USGS mines. They were generally within 100 - 200 meters of mine locations on the USGS quadrangles. The mine names did match when they were ascertainable. In one portion of the study area reviewed, there was a noticeable trend whereby MAS/MILS mine locations were directly on top of section numbers placed within PLSS sections. This might be an indication that the mine was located to the nearest section centroid.	8478 (4078 of which are known mines)
DB6	Utah Bureau of Land Management Abandoned/Inactive Mine Land Inventory. The database lacks mine names. Point locations match many unnamed mine features found on quadrangle maps. Many points appear to be within 150 meters or less.	193
DB7	Utah Abandoned Mine Reclamation (AMR) Database, Utah Department of Natural Resources. The database lacks specific mine names. The points were also in question due to the references to mine structures e.g. shafts, tunnels, drill holes, waste dumps, etc. Accuracy was difficult to determine due to the high number of closely grouped locations. Many points appear to be within 50 meters or less.	549
DB11	Navajo Lands Project through U.S. EPA Region 9 and the U.S. Army Corps of Engineers. Location points did not coincide with any quadrangle mine points, but there was some field verification. This database has been updated since the information was compiled for this effort and the update was not included in the composite database.	887
DB12	State of Arizona. Location points rarely coincided with USGS mine positions. When there were nearby points they were within 100 - 200 meters of the USGS designated mines.	41
DB13	U.S. Forest Service. Location points were generally very accurate, generally within 50 - 200 meters, however 15% of the records had spatial coordinates that placed the locations outside of intended scope of the data set (Arizona and New Mexico). No names were assigned to any locational points.	9
DB14	U.S. Bureau of Land Management. Location points were generally very accurate, generally within 150 - 200 meters. Names were rarely assigned to locational points, but were accurate when applicable.	276

[2] In addition to these databases, one new mine in Nebraska, the Crow Butte Mine, has been included as a one record database separate from the master database.

Database	Source	Number of Records
DB15	South Dakota Abandoned Mine Lands Inventory. No mines on USGS maps to compare with, and no apparent match with MAS/MILS mines in same location. However, information provided with this database indicated that seventy of the sites on U.S. Forest Service property were field verified with a GPS unit.	36
DB16	California-U.S. Forest Service Mines. No matches apparent.	17
DB18	New Mexico Mines Database produced by New Mexico Bureau of Geology and Mineral Resources. Names match, perfect alignment with USGS mines. Locations greatly outnumber mines portrayed on USGS map.	1531
DB19	Wyoming Abandoned Mine Land. No documentation was received with this data set. No apparent match with mine names on USGS maps, or with mine names.	119
DB20	Nevada Bureau of Mines and Geology. Where USGS mines available, name matches were noted. Locations seemed to be off by at least 200 meters.	73
DB21	Texas Mines from Adams & Smith Report. No apparent match for either names or locations, but data include mine names.	26
DB22	Dakotas Mines from U.S. Atomic Energy Commission Map, 1967. No names on USGS mines to compare with. Better source for this area than MAS/MILS or MRDS.	181
DB23	Montana State Library. Some name matches where available. Some locations 0-1 km off from name matches. Locations may have been drawn from MAS/MILS as their spatial locations are highly correlated.	8
DB24	Inactive Mineral Production Sites – University of Texas. Perfect match with MAS/MILS; no USGS mines to compare with.	7
DB25	Railroad Commission of Texas Uranium Mines. Local area specialists combined aerial photography with some field-truthing in order to verify mine locations.	101

Verification Using USGS Maps

The basic approach to assess locational accuracy was to compare ULD locations to U.S. Geological Survey mines (which includes mines of all types), located on maps by means independent of those used to locate mines from the source databases, on 1:100,000 and 1:24,000 scale maps. In keeping with the EPA goals for creating quality information, the methodologies, applied here to quality assure the location data, were a simple effort, in the absence of field verification information, to determine the relative accuracy inherent in the locational attributes (i.e., latitude and longitude) of each data source.

Due to the large study area, ICF Consulting, Inc. conducted quality assurance tests of samples of the total location data set. The sample selection was partially random, however, there was a bias in the sample, in that the areas chosen for quality assurance were characterized by being areas of higher location densities than areas not chosen for the sample. The exact locations within these areas were unknown prior to being assessed and were therefore random in nature.

The sample set was chosen in this manner in order that the greatest number of locations could be analyzed. If location selection had been totally random, then the number of locations assessed would have been lower and possibly less representative in terms of locational accuracy. Excel spreadsheets entitled By24K.xls and By100K.xls are included in the GIS data directory. These spreadsheets show the pivot tables that were used to determine which USGS quadrangles held the most locations, and which set of USGS quadrangles would cover all databases most evenly. These tables were created by spatially overlaying the locations collected in fiscal year 2002 with the USGS 24K and 100K quadrangle indices. The results were brought into Excel so that we could develop a pivot table showing how many locations, from each data source, were located in which quadrangles. It should be noted that although DB23 and DB24 are not included in these spreadsheets, they were quality assured since most locations in these data sets were in pre-selected quadrangles. The number of locations quality assured from each database and the methods and results are detailed below.

A point coverage of USGS mines appearing on USGS 1:100,000 scale 30 by 60 minute series was created by digitizing on a CalComp digitizing tablet. Of the 126 maps that cover the States of New Mexico and Arizona, 62 maps were digitized. Sixty-two additional 1:100,000 scale maps were digitized for the remaining part of the study area. This is in addition to the 18 quadrangles that were digitized by URS-Techlaw to QA a subset of the study area in Colorado and Utah under an earlier part of this effort.

By taking a total of the locations in each quadrangle then selecting the quadrangles that contained a high density of mines ICF derived a new group of mines for comparisons. This new group represented roughly half of all the ULD mine records. A point was generated for each mine symbolized on the maps in an ArcInfo coverage and mine names were entered where available. This resulted in a geographic coverage with 8,343 USGS mine locations. Of these locations 5,280 locations had names. These mine locations from the USGS maps were buffered to an eighth, quarter, and half of a mile in accordance with the QA/QC methodology established by URS-Techlaw. This QA method proved less useful in areas of few and scattered uranium locations, as USGS maps do not show all mine locations, and only report names for less than one-quarter of the locations that they do show.

The locations shape file was converted to a coverage and intersected with the 1/8, 1/4, and 1/2 mile buffers. These were inspected, initially manually, and later by using a simple automation tool developed in MapBasic precisely for this task, for name matches with the USGS mines. For New Mexico and Arizona, this test revealed that 97 of 501 named locations examined were accurate within an eighth of a mile, 131 were accurate within a quarter mile and 143 were accurate within a half mile. For Utah and Colorado, this testing revealed that 50 locations were accurate within an eighth of a mile, 56 were accurate within a quarter mile, and 64 were accurate within a half mile. This testing resulted in only a limited number of points being checked; therefore a second method of QA/QC was performed. For the remainder of the states, a shape file (converted to a MapInfo tab file for processing) was created and intersected with the same buffers.

When this process was automated by a MapBasic program, name matches were found for 28 locations within an eighth of a mile of a USGS mine, 31 locations within a quarter-mile of a USGS mine, and 36 within a half-mile of a USGS mine. Mine location matches, regardless of name matches were found to number 90 within an eighth of a mile of a USGS mine, 163 within one-quarter of a mile, and 428 within a half-mile. Of the total 6,603 locations checked, 5,036 had names.

The second method of QA/QC involved a visual proximity test between the final locations coverage and USGS 1:24,000 quadrangle maps. Due to the large number of quadrangles involved, a sample of locations was selected for QA/QC. The sample was determined by selecting quadrangles where the majority of all mines were located, as limited by the number of quadrangles which could reasonably be reviewed in the contract period. A third criterion is that locations from each of the data sets is represented in the QA subset. From the sixty USGS 1:24,000 quadrangles that were included in the

QA/QC process, 3,343 locations were sampled for New Mexico and Arizona. Of the 6,603 locations in the remainder of the study area, 2,168 locations were analyzed.

The point locations for the mines were drawn on-screen with the Digital Raster Graphic (DRG) 1: 24,000 scale quadrangles displayed in the background. These were compared with the locations of mining activities on these USGS maps. This allowed for an assessment of positional accuracy between the two data sets. This process was also partially automated, this time using Arc Macro Language on UNIX workstation ArcInfo version 7.x. The automation tool allowed the operator to quickly view one DRG at a time for all 60 DRGs reviewed, with a thematic mapping of all locations color-coded by data source. The information in Table 3 is a summary of the results according to data source.

Table 3. Number of Locations Quality Assured Against USGS Mapped Mines
(See text for discussion.)

Database	Locations Reviewed at 1:100,000 scale	Locations Reviewed at 1:24,000 scale
DB1	56	none
DB2	459	none
DB3	4	none
DB4	1919	324
DB5	6391	1684
DB6	127	none
DB7	903	none
DB11	751	173
DB12	329	108
DB13	2475	1034
DB14	1885	1387
DB15	36	28
DB16	5	8
DB17	21	5
DB18	1155	507
DB19	120	91
DB20	62	16
DB21	43	19
DB22	145	100
DB23	8	8
DB24	43	19

Completeness

Completeness, in the sense of whether or not all uranium deposits are listed in this composite database, can never be fully determined. We have attempted to better understand how complete the database may be by comparing the deposits in the composite to the authoritative source of producing mines for Texas, available from the Texas Railroad Commission (RRC) in database 25. All of the mines in this source are represented in some fashion in the composite database, therefore the composite appears to be complete in this regard. In fact, the reverse finding, that more records of locations in Texas are present in the composite database than in the RRC database, highlights the fact that the composite contains records that may represent individual mine features, "dogholes," and other features which may not meet the definition of a producing mine, but which could be the site of uranium mining wastes.

In terms of specific results from the RRC-ULD uranium location comparison, regardless of the existence of redundant and compound mine names in the RRC data set, all 71 locations were found in the ULD. If Texas is reflective of the success of building a complete data set for the other states, the ULD should be an extensive repository of potential uranium mine locations. As mentioned above, the ULD contained many more records of locations in Texas than the RRC data set: 363 to 71. (The other databases with Texas data include MAS/MILS, University of Texas, and Texas Department of Health.) Many of these represent duplicates related to the 71 RRC mines (about one-third). However, many more (two-thirds), represent spatially unique deposits that are possibly indications of areas where exploration was performed but production may never have begun.

Accuracy

As for a preliminary assessment of the locational accuracy of the ULD, of the 130 locations in the ULD that appeared to match the 71 deposits in the RRC database, the average distance between the RRC mine and the potential matches or duplicates in the ULD was approximately 1200 meters. The duplicate identification process discussed below was applied to the entire ULD. The RRC mines were simply added as though it was another data source, and each record was treated as the authoritative record against which ULD mines found to be nearby and named similarly, were matched. The minimum distance between the matched ULD and RRC mines was just under 5 meters, from ULD duplicate to RRC, and the maximum was approximately 8500 meters. Both minimum and maximum distance values represent outliers, although with or without outliers, the average spatial offset remains in vicinity of 1100-1200 meters.

The accuracy range represented in the composite database is generally between 0 and 1500 meters for database records compared to mines on USGS topographic maps. While this range is broad, it represents an average discrepancy between coordinate information available in the database and the USGS map location where the deposit in question may be found. The ends of this range were determined by comparing a small sample of ULD mine records (chosen for being located within the bounds of USGS 1:24,000 scale maps that contained the most mines) to mines represented on USGS 24K maps. The USGS mine locations were deemed authoritative since they were identified from 1:24,000 scale maps (or better) and sometimes confirmed and labeled with mine names using local authoritative data when available.

MAS/MILS and MRDS are the uranium location data sources relied upon to provide location information. These data sets have no reported accuracy but were both judged to be off by an average of 200 meters when compared to USGS 24K mines in the quality assurance steps performed on the ULD mentioned below.

Duplicate Record Identification and Reliability Value Assignment

Due to the various overlapping data sets used to compile this composite database, many duplicate records exist. The reliability characteristics of the individual records were assessed so that, based on a single reliability value, the least reliable location records might be identified. In addition to this process, duplicate records were identified based on proximity of coordinates and approximate match of mine name. Since mine names may differ due to user entry differences but still represent the same mines, mine names were manually reviewed for likeness. Additionally, since a single mine or uranium activity could have many coordinate pairs associated with it, a buffer of 2400 meters (~1.5 miles) was ultimately used to consider the nearby mines for duplication. Additionally, when comparing mine names and assigning Dup_MatchName levels, the operators used a conservative measure in order that mine records with even the smallest chance of being unique were left in the database. As a result, duplicates remain, but none that could be removed beyond the shadow of a doubt.

It should also be noted that in response to reviewer comments, the RRC database of Texas mines, and MAS/MILS mines for the rest of the U.S. (apart from the original western study area) were added to the ULD at the end of the contract period. As a result, the reliability and duplicate record codes are not populated for these records.

A program was written to assist an operator in tagging likely duplicate records, based on name similarity and proximity, with the following fields of information: Dup_MatchName, Dup_MatchID, and Dup_Dist. The likelihood of being a duplicate record, combined with the reliability information, allows for the removal from the ULD of the least reliable records or the most likely to be a duplicate location.

Each of the following fields of information was added based on assumptions about what constitutes a reliable record of information. Since few fields were reliably populated other than LATITUDE, LONGITUDE, and MINE_NAME – these fields formed the basis for the decision-making regarding which records to keep. The reliability fields (see below) were populated in such a way that their content could be summed into a single reliability score. Since there are 10 reliability fields, the maximum reliability score is theoretically "10", and each field is either populated with a "1" or "0" (or blank) for each record.

The basic premise in the reliability scoring is that a record is worth keeping if it is either completely unique (by way of name and location) or if it cannot reliably be equated to any other record due to subtle or great differences in the mine name.

Reliability Value Assignment

Below is a listing of all fields populated used to establish each uranium location record's relative reliability:

BLK_UNIQLL
A value of "1" in this field indicates that the record has a non-blank mine name or that it has a non-blank mine name AND a unique coordinate pair. *[Note: Records with blank mine names, that shared coordinate pairs with records with non-blank mine names, were considered to be marked for deletion during the duplicate identification process.]*

GEN_UNIQLL
A value of "1" in this field indicates that the record has a non-generic mine name or that it has a non-generic mine name AND a unique coordinate pair. *[Note: Records with generic mine names but that shared coordinate pairs with records with non-generic mine names, were considered to be marked for deletion during the duplicate identification process.]*

IDENT_WI
A value of "1" in this field indicates that the record contains a unique coordinate pair as compared to all other records in the source database, e.g., in DB1.

IDENT_WO
A value of "1" in this field indicates that the record contains a unique coordinate pair as compared to all other records across all source databases, e.g., a coordinate pair not found elsewhere in DB1-DB24.

SPAT_ISOL
A value of "1" in this field indicates that the record is spatially isolated. Spatial isolation is defined here as a uranium activity with no other uranium activity within 2400 meters (1.5 miles).

DOCS
A value of "1" indicates that the data source has documentation.

IDENT_NMAEC
A value of "1" indicates that the uranium activity shares the precise name of a uranium activity listed in the authoritative U.S. Atomic Energy Commission's Uranium Mine and Properties Database (UMPD) within the same State. *[Note: Tthe UMPD mine list only covers uranium mine activities in the 4 Colorado Plateau states.]*

IDENT_IDMILS
A "1" indicates that the record is not known to have originated from MAS/MILS. *[Note: For example, all but approximately one dozen records from DB12 (State of Arizona) were tagged with a MILS ID, rendering nearly the entire data source a duplicate of records available from DB5 (MAS/MILS).]*

QA_FLAG
A “1” indicates that the record was not identified as a spatial outlier based on comparing the State attribute field contents with the actual State in which a point-in-polygon procedure locates the coordinate pair. For example, the coordinates for a few records from DB18 (New Mexico Mines Database) that are known uranium activities in New Mexico, actually appeared in neighboring States. This field was de-populated and re-populated with “9”s where the location placed the record outside of the states.

IDENT_COORD
A “1” indicates that the record does not share identical coordinates with any other record in the entire database. *[Note: A non-unique coordinate pair may be an indication of either a duplicate record OR of unreliable location information in the case where a Public Land Survey System (PLSS) section centroid is substituted for multiple uranium activity occurrences in the absence of true coordinate information. A repeated coordinate pair may also be a sign that an approximate central location (such as the entrance to a uranium deposit or area) was recorded for multiple physically unique mine features (such as shafts, openings, adits, etc.). Such a location may be less reliable when trying to identify the size of nearby at-risk populations, as the coordinate pair is an approximation.]*

Not all records were considered in the duplicate identification process. Records that would be kept without needing to be run through the name and proximity match process, include:

- Spatial outliers (where SPAT_ISOL = 1)
- The “unmatchables” (where BLK_UNIQLL = 0 or GEN_UNIQLL = 0)
- The “already matched” (where IDENT_IDMILS = 0)
- Supposed mine features (all but one record from a group of records originating from a single data source with identical names and coordinates: IDENT_WI = 0) *[Note: The thought process here is that records with identical coordinate information do not contribute to a better estimate of impacted populations and environmental resources. Furthermore, the premise is that multiple identical records that originate from the same data source are likely to represent physically distinct features of the same uranium activity.]*
- Records added after the duplicate process had already been performed.

Duplicate Records

Below is a listing of fields that were populated in a partially automated procedure to identify those records that are likely to be duplicates or provide redundant uranium activity information. Some terminology used below:

- *keeper* – this term refers to uranium activity records that will be kept in the final ULD.
- *duplicate* – this term refers to uranium activity records that have similar or identical names AND that are within 2400 meters (~1.5 miles) of each other.

Dup_MatchID
This field reports the ICF_ID of the duplicate record that will be kept in the database – the keeper ID. If the ICF_ID and Dup_MatchID are the same it means that the record is unique, spatially isolated, does not contain a name or proximity match with any other record in the database, or, for other reasons, is considered a “keeper.” A sort on this field will show which records were found to be alike and considered duplicates.

Dup_MatchName
This field records the quality of the name match with the keeper by assigning a value of 1-4, where:

- 1 = the names are a perfect match;
- 2 = the names are slightly off (e.g., Mary vs. Mary Mine; Mary Prospect vs. Mary Mine; Margie 2 vs. Margie #2; Buck Shot vs. Buckshot; Tramp #2 Group vs. Tramp #2 Mine Group);
- 3 = the names are more than slightly off but still considered a match (e.g., Buffalo Head Mining Co. Claim # vs. Buffalo Head Mine; Mammoth-Lincoln vs. Mammoth Mine); and
- 4 = the name of one record, that shares identical coordinates with another record, is a generic name (e.g., Lucky Strike versus Uranium Prospect) or blank.

Dup_Dist
This field records the distance (meters) between a duplicate and its keeper. For keepers, the value of this field is zero.

Other Criteria Applied When Tagging Duplicate Records

Records with names that include the word "Group" were not considered duplicates of other records with identical names excluding the word "Group" in case they represent distinct mine features (e.g., Dorothy Mine vs. Dorothy Mine Group). *[Note: This criterion was observed to leave in many possible duplicates.]*

Records with names that include a number were not considered duplicates of other records with identical names excluding the number in case they represent distinct mine features (e.g., Dorothy Mine vs. Dorothy Mine #4).

Originating Data Source Reliability

For each state, all contributing data sources were ranked so that when duplicates are identified, the record from the most reliable data source might be designated the "keeper" (see ranking list below). It was furthermore decided that records with either identical or approximate mine names AND approximate (but not identical) coordinates, originating from the same data source, would be kept in the likelihood that they represented true geographically distinct mine feature locations. In Table 4 below, the data sources are listed for each State in order of most to least reliable, moving left to right. The least reliable data sources are those for which documentation was poor or unavailable, attribute information was limited or mostly unpopulated, and the spatial accuracy of the locations associated with the data source, relative to the USGS mine locations, was low.

Table 4. Data Source Ranking By State

(Numbers refer to numbers assigned to each original data source and recorded in the each uranium location record in the DB_ALIAS field.)

State	Database Number, in order of most to least reliable from left to right
AZ	12, 5, 4, 13, 11, 18
CA	16, 5, 4, 13
CO	2, 5, 4, 13, 3 (DB1 removed entirely for spatial unreliability)
MT	23, 5, 4, 22
ND	5, 4, 22
NM	18, 5, 4, 13, 11
NV	5, 4, 20
SD	15, 5, 4, 22
TX	5, 24, 17, 13, 4, 21
UT	2, 7
WA	5, 4
WY	2, 19, 5, 4, 15

Using the Reliability Factors and Identified Duplicates to Remove Duplicates

Once the potential duplicates, based on name match and proximity are identified, the records are tagged with the above reliability factors. No records were ultimately removed based on a low reliability score, however many were removed based on the findings of the duplicate removal process. Table 5 lists the reliability score distribution for ULD records.

Table 5. Distribution of Reliability Values

Reliability Score	Record Count
4	54
5	874
6	1548
7	5567
8	8159
9	6221
10	176

The first step was to separate out the keepers and remove the duplicates from the subset of records included in the duplicate identification process. This step could theoretically have been modified by only removing those duplicates that also had low reliability scores. Also, only those records that were within a tighter Dup_Dist could have been removed (such as closer than 1000 meters instead of 2400 meters). However, it was decided here to remove all duplicates.

Data Sources

More than 20 data sources were collected to compile the ULD. These data sources are discussed below. They were combined into a composite Microsoft Access 2000 database, Master03.mdb and also into shape files (e.g., ULD_albers.shp) that can be readily used by ESRI ArcGIS software.

The individual databases are numbered 1-25[3] and this ID is recorded in the DB_ALIAS field of the ULD. The field ICF_ID records a unique ULD record number in addition to the data sources' inherent unique ID that is recorded in the DBUNIQUE field. Here are brief descriptions of the data sources:

DB1: BRASSCAP
This database is managed by the Colorado Department of Natural Resources, Division of Minerals and Geology. This database contains 3491 uranium sites but only 420 of these sites contain geographic coordinates. Geographic coordinates are in latitude and longitude, NAD27 Datum. This source has been eliminated from the final data set due to the uncertainty of its reliability.

DB2: Colorado (BLM) Abandoned Mine Land Inventory (AML)
The Colorado BLM AML database is managed by the BLM Colorado State Office. The Bureau of Land Management's National Database was the source for these records. The original projection of the data was UTM.

DB3: Colorado (FS) Abandoned Mine Land Database
The Colorado-Forest Service-AML database is managed by the Forest Service, Region 2. All data were collected under contract by the Colorado Department of Natural Resources, Colorado Geological Survey. The contractor used Arc/Info to create a GIS layer for each Forest Service Ranger District. Information in this database is for the Creede, Cebolla, and Norwood Ranger Districts. Only 13 records of this database are in the composite shape file (ULD_albers.shp).

DB4: U.S. Geological Survey Mineral Resources Data System (MRDS) database (McFaul et al, 2000)
While the original MRDS database is global in geographic extent, a United States only Access version of the database was filtered for only uranium commodity mines in the states of interest. A spatial database was created from the provided latitude/longitude information, projected to an Albers projection, and the records were tagged with ICF IDs. Spatial correlation with USGS mines is 100-200 meters based on small comparison sample.

[3] Four sources, i.e., DB1, and DB8-DB10, were eliminated from the master database due to concerns about reliability.

DB5: U.S. Geological Survey Minerals Availability System/Minerals Industry Location System (MAS/MILS) database (McFaul et al, 2000)
Spatial data were created from the latitude/longitude coordinates provided, projected to the Albers projection, and then tagged with ICF_IDs. Additional information on ownership and production are available for these records and can be joined from the DBF files provided (DB5_Owners, DB5_Production)[4]. The MAS/MILS data contained in the ULD may show different numbers of locations than the BASINS repository for each state since the ULD data have been filtered in the following manner: (1) only records with Uranium in the commodity field were included, (2) only records with both required coordinates were included, and (3) some mine records from DB5 have been replaced by mines from more authoritative data sets. Spatial correlation with mines noted on USGS topographic maps is 100-200 meters based on a small comparison sample.

DB6: Utah (BLM) Abandoned/inactive Mine Land (AML) Inventory
The Utah BLM AML database is managed by the Bureau of Land Management, Utah State Office. Spatial correlation with USGS mines is within 150 meters based on comparison sample.

DB7: Utah Abandoned Mine Reclamation (AMR) Database
The Utah Abandoned Mine Reclamation Database is managed by the Utah Department of Natural Resources, Division of Oil, Gas and Mining. Spatial correlation with USGS mines is within 50 meters or less based on comparison sample.

DB11: Navajo Lands Project
An ArcView shape file containing nearly one thousand mine locations, but unsupported by any metadata, was provided via the CDROM series "Abandoned Uranium Mines Project Arizona, New Mexico, Utah – Navajo Lands Project Atlas, 1994-2000." These records were tagged with ICF_IDs ranging from 10,413 to 11,299. Since no projection information was available, it was assumed to be geographic with North American Datum 1927, and was projected to Albers. The location shape file was culled from dozens of maps and mining claim documents, and these locations are approximate. The data are of varying accuracy and were assembled to obtain a general idea of mine concentrations to target remote sensing forays of the Navajo Study. Updated information related to this project became available too late for inclusion into this database effort (NAMLRP, 2004).

DB12: State of Arizona
These data were also provided undocumented and in the form of an ESRI shape file.

DB13: Forest Service
These data were received in shape file format with an accompanying data dictionary and Users Guide. Records were projected to Albers. Approximately 15% of the records had latitude/longitudes that placed the locations outside of Arizona and New Mexico. Only nine records of this database are in the composite shape file (ULD_albers.shp).

[4] Note that ownership and production information is only available for 11 western states included in this compilation, however, such information is available in MAS/MILS and can be extracted by linking to the original MAS/MILS data sets using the DBUNIQUE field which corresponds to the MAS/MILS.SEQ field.

DB14: Bureau of Land Management
These data were received in shape file format but without accompanying projection information or other documentation. However, the data do have information for numerous fields. The records were tagged with ICF_IDs ranging from 14,987 to 16,935, and projected to Albers, assuming they were unprojected to a datum of NAD27. Thirty-one records appeared outside of the United States. These data were removed from the single data set as they appear to represent mines other than uranium and a commodity field is not available for filtering purposes.

DB15: South Dakota Abandoned Mine Lands Inventory
These data were received as part of a Microsoft Access 2.0 and Microsoft Access 95 application that allow users to query this relational locations database. Uranium locations were not flagged such that they could be identified, however, a contributing member of the team that developed the database reported that all locations in Fall River County, South Dakota, unless otherwise identified, were uranium locations. These locations, and their associated data from the related data tables, were exported from the Access application. Some export difficulties regarding MEMO fields required that these larger fields were not brought along into this compendium.

A report entitled "Comprehensive Inventory of Known Abandoned Mine Lands in the Black Hills of South Dakota" from January 26, 1998, accompanied the application. This report identified three input sources, including (1) USGS database for Metallic Mineral Districts and Mines in the Black Hills, (2) USFS inventory of sites on National Forest lands, and (3) a South Dakota database compiled from literature search of known AML sites in the Black Hills. The final database had single records for locations and removed any duplication. All USFS locations were field verified. About 70 of the remaining non-USFS locations were field verified with a GPS unit. The report stated that none of the locations visited were deemed to be in need of remediation, however some seemed to pose "considerable" environmental risk. Apart from this report an install manual was made available. Latitude and longitude information were available (based on the nearest one quarter of a quarter section to the location) and were assumed to be NAD83. A GIS file and a DBF file were generated in MapInfo. ICF_Ids and the DB_ALIAS field were added in Excel. There was no apparent match to USGS mines.

DB16: California (FS) Mines
These data were received partly in the body of an email and partly as an Excel spreadsheet. Spatial files were generated in MapInfo from provided coordinates; datum was assumed to be NAD83. There were no apparent matches to USGS mines. Only 17 records of this database are in the composite shape file (ULD_albers.shp).

DB17: Texas Department of Health
Twenty-seven locations with driving directions to the sites were received via fax. Delorme Streetmap Version 9 was used to locate the locations by placename and then by major route intersection. A staff member of the Texas Department of Health assisted our effort by reviewing the mine locations for about a half dozen mines and sending in corrections. Most mines had been placed within one-tenth of a mile (160 m) of the actual location. However, one was off by over a half-mile (800 m). There was a limited match to USGS mine locations. None of these are included in the composite shape file (ULD_albers.shp).

DB18: New Mexico Mines Database
EPA's Office of Radiation and Indoor Air (ORIA) funded the digitization of this collection of location data that, in part, dates back to the DOE NURE Program in the 1970s. Paper files were converted to a relational Access database by staff at the New Mexico Bureau of Geology and Mineral Resources, a division of the New Mexico Institute of Mining and Technology. Full documentation was received with this data set. The Access tables were converted to GIS format in MapInfo and then converted to DBF in Excel. Perfect spatial alignment was observed with USGS mine locations.

DB19: Wyoming Abandoned Mine Land
No documentation was received with this data set. There was no apparent match with mine names on USGS maps, or with mine names.

DB20: Nevada Bureau of Mines and Geology
These locations were digitized from a book that contained a mine location map. Names were hand-entered from entries in the book. Only those locations that did not appear in other data sources were digitized. This was determined by comparing the hardcopy map to a GIS map of Nevada locations from MAS/MILS and MRDS. Some names and locations matched USGS mine locations.

DB21: Texas Mines from Adams & Smith Report.
These locations were digitized from a map contained in the report. No documentation or location information was included with the map. No apparent match was found with USGS mines for either names or locations.

DB22: Dakotas Mines from USAEC Map 1967
Locations were digitized from this map. No documentation was available, apart from a brief legend and symbolization that identified two types of uranium available from the mines. There was no apparent match with USGS mine locations.

DB23: Montana State Library (MILS)
These location data were accompanied by full metadata detailing accuracy mine location information. It appears however that these locations may have been drawn from MAS/MILS as their spatial locations are highly correlated. Some name matches were found for USGS mines; locations were off by 0-1000 m. Only eight records of this database are in the composite shape file (ULD_albers.shp).

DB24: Inactive Mineral Production Sites – University of Texas
These locations were hand-entered from a fax. No documentation accompanied this data source. No USGS mine correlations were found. Only seven records of this database are in the composite shape file (ULD_albers.shp).

DB25: Railroad Commission of Texas (RRC) Uranium Mines
No metadata were available as it was a work in progress, however information about how the locations were verified was available. Local area specialists combined aerial photography with some field-truthing in order to verify the mine locations. This is the most authoritative collection of uranium mines currently available in Texas, although it appears to be incomplete from the perspective of uranium occurrences. Sources at the USGS report NURE (National Uranium Resource Evaluation) folio evidence of uranium production from additional locations in Texas. However that data was not available at the time of this compilation.

Figure 1. Western Uranium Locations From the EPA Uranium Location Database

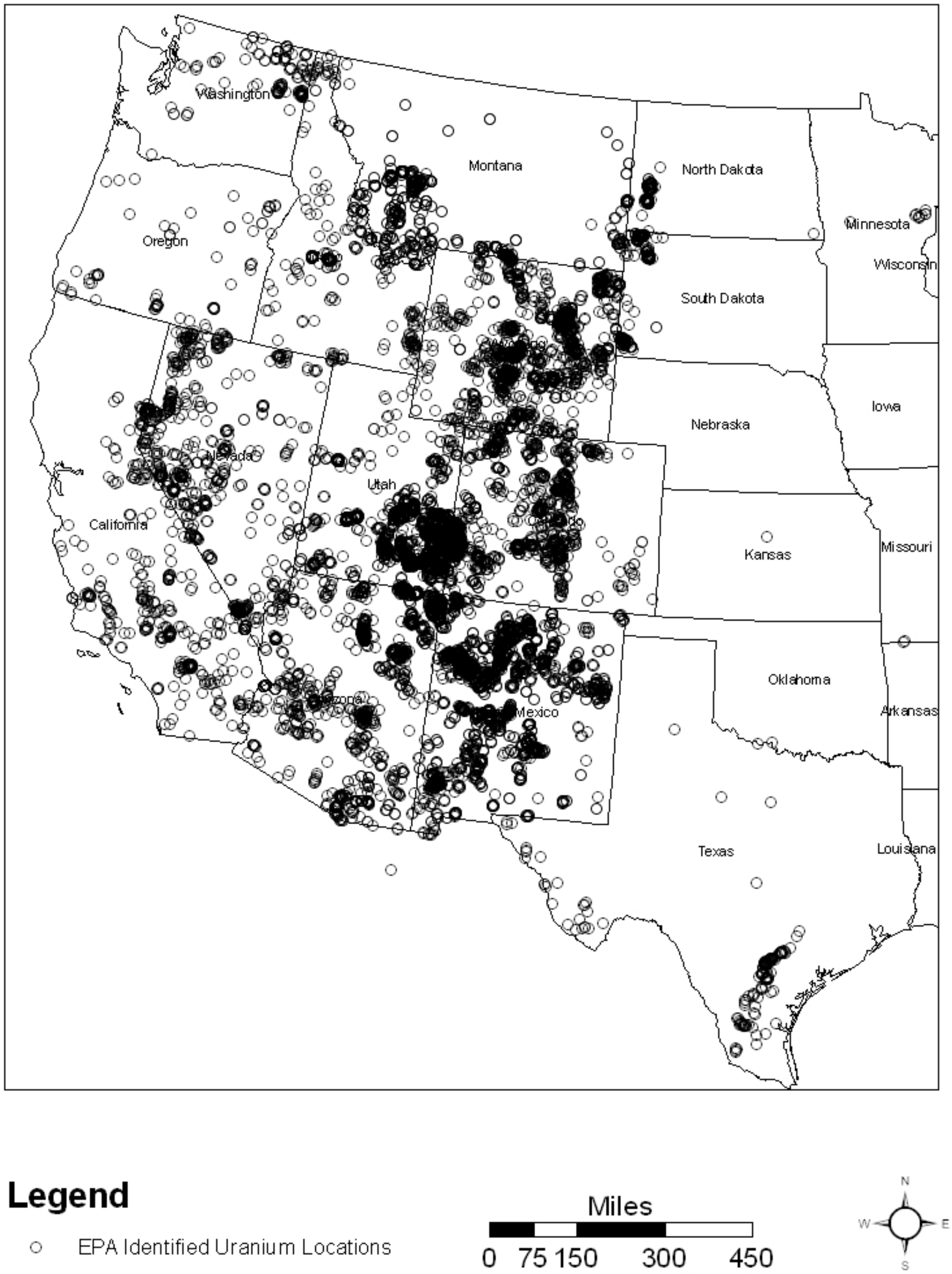


Figure 2. Western Uranium Locations from the USGS MRDS Database

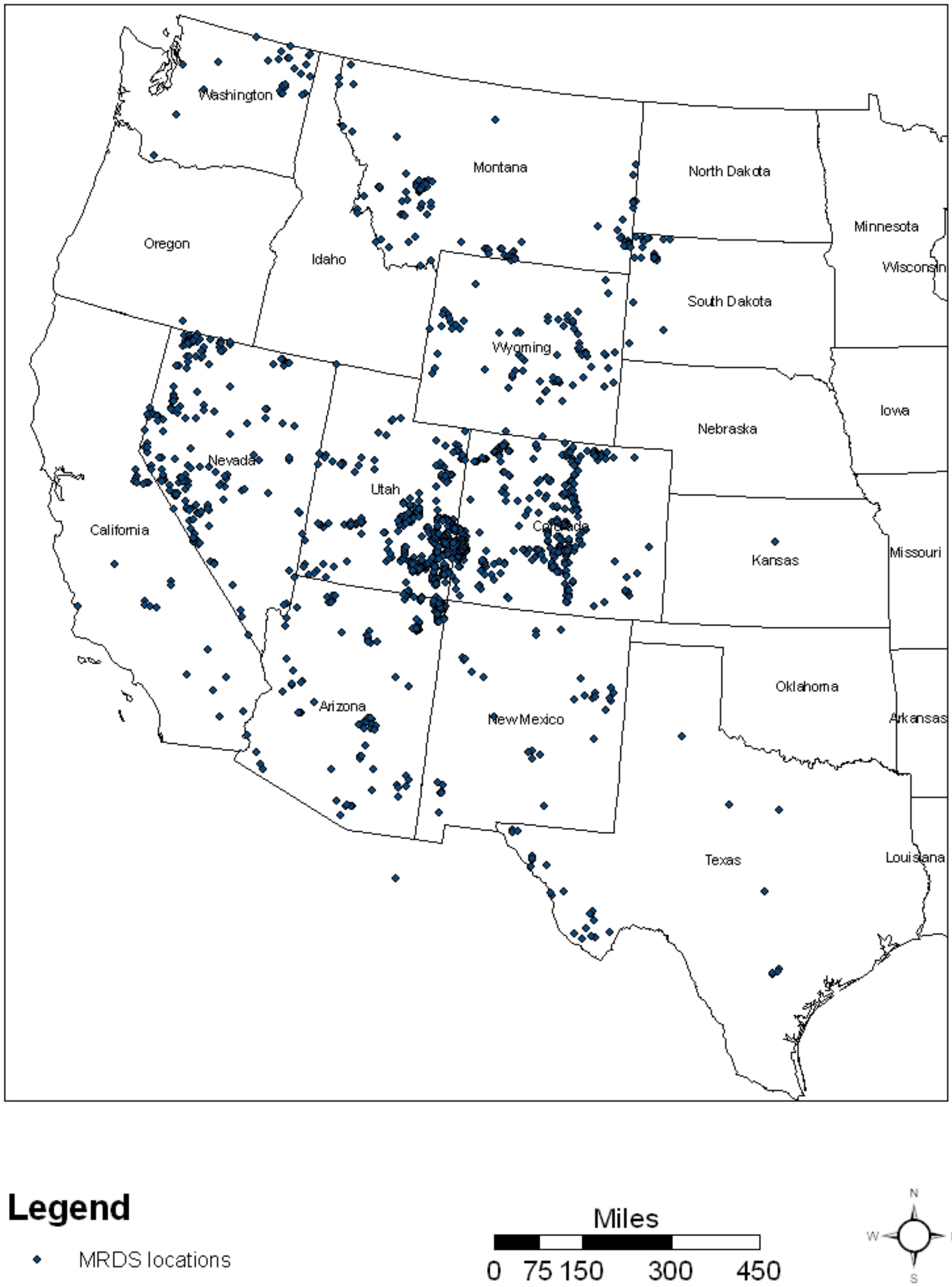
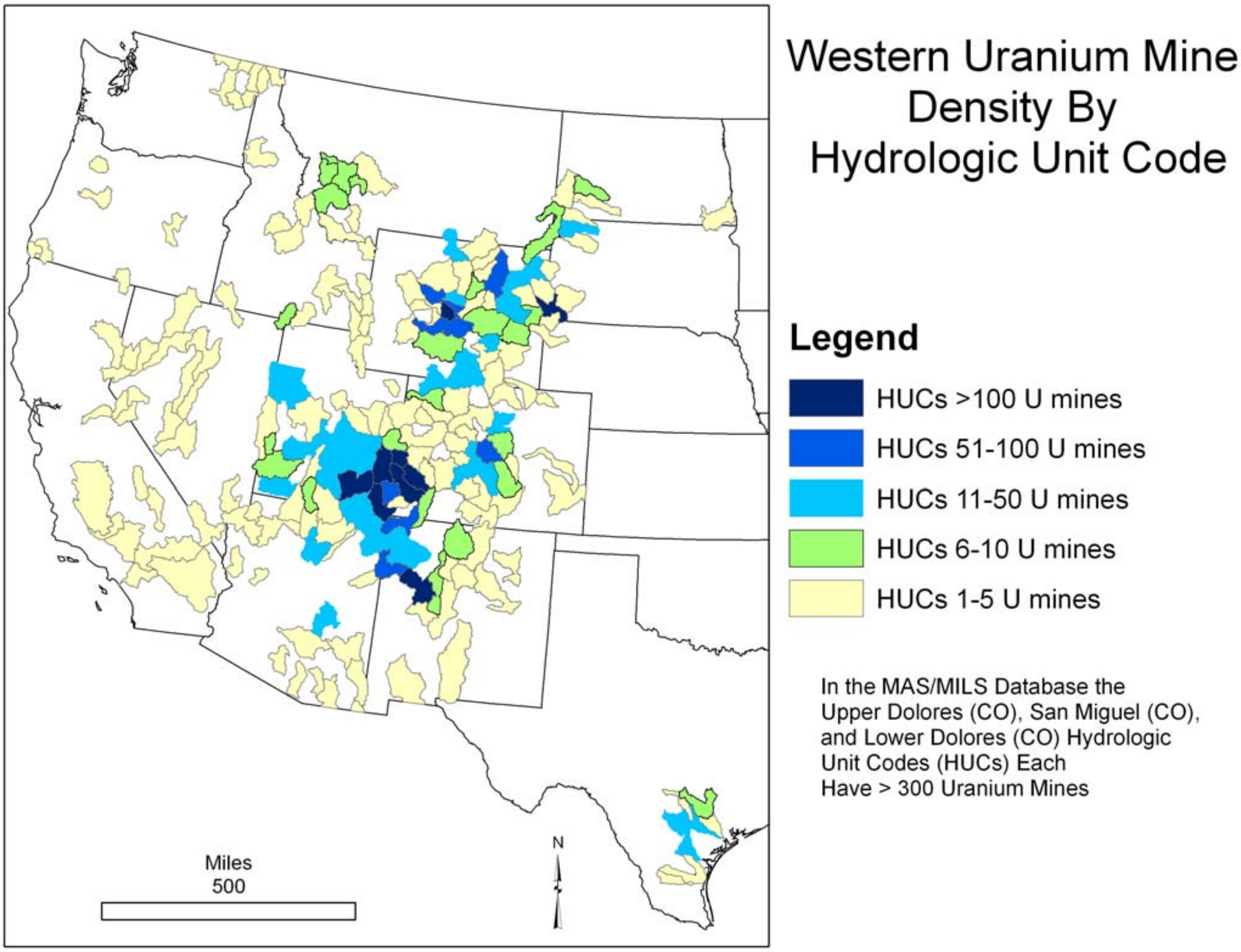


Figure 3. Density of Western Uranium Mines
Using the MAS/MILS Database Portion of the Uranium Location Database



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