Taking GIS from the Field to the World Wide Web[1]

Linda S. DeLay, Susan A. LucasKamat, and James R. Smith[2]

Abstract. How to collect and share uranium mine information in a meaningful, easy and accurate method is no small task. Having digital data and using web-based information makes our lives a bit easier, especially when partnering with multiple agencies of the Navajo Nation, federal and state government and contractors. Handing someone a database is good, but boring. Making your information come alive with pictures, maps and GPS details is worth 10,000 words.

The New Mexico Abandoned Mine Land Program (AMLP) returned to previously reclaimed uranium mine sites with the aid of aerial photos, survey maps and construction reports. Mine feature attributes, including radiation readings, mine features and disturbances, were collected using Trimble XH GPS units running a Pathfinder data dictionary. AMLP collected radiation readings using Ludlum Model-14C and Eberline ESP-1 radiation survey meters. Photo points were established using a Ricoh 500SE digital camera with GPS. ArcGIS 9.2 was used to build the geodatabase from the data dictionary and heads-up digitizing of aerial photos. Spatial analysis to describe mine feature distribution and proximity to other features/sites was performed using ArcGIS.

All information was shared through an Autodesk MapGuide 6.5 web application. Site and feature relationships were overlaid with land ownership, especially important in the checkerboard area of Indian trust, Indian allotment, federal, state and private surface ownership. Photos were hyperlinked in maps to illustrate changes in feature/disturbance from the time of initial reclamation to maintenance visits. The changes in radiation readings between visits and the change in redistribution of waste piles using GPS and imagery will now be tracked.

This is the wave of the future. Collecting all the data electronically replaces the sacred field book (almost) and allows vital information to be shared more easily in a way that makes people want to know what you have been doing.

Additional Key Words: Geodatabase, GPS, ArcGIS, abandoned uranium mines

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Background

New Mexico ranks second in uranium reserves in the United States, with 341 million pounds of U_3O_8 contained in 238 million tons of ore at $50 per pound (EIA, 2006). Uranium was mined in New Mexico from 1940 to 2002. Over 333 million pounds of U_3O_8 was mined in New Mexico during this time frame (McLemore, 2007a; Mine Registration Program 1989-2002). Most of this production was from the Grants uranium district in McKinley and Cibola (formerly Valencia) Counties, which during the period of 1951-1980, produced more uranium than any other district in the United States (McLemore, 2007b). Uranium was mined on private, state, federal and Indian lands. Mines ranged in size from small surface mines, with one to three workers, to large underground operations, employing hundreds of miners. New Mexico uranium mines began closing in the early 1980s; the last uranium ore was mined in January 1990. Uranium production continued through mine water recovery and ion exchange processing until December 2002.

The abandoned uranium mines left a legacy of probable radiological contamination. Mining activities, such as discharge of mine water, crushing of ore and transportation of ore, dispersed contamination. A systematic analysis of the former mining sites is required.

Purpose

The New Mexico Abandoned Mine Land Program (AMLP) needed to relocate and update maintenance on uranium mine sites they had reclaimed in 1990 and 1991. During the original reclamation, waste piles were not reclaimed. Due to past subsidence issues, AMLP needed to return to these sites to assess the need for maintenance.

In addition, the New Mexico Mining and Minerals Division (MMD) is collaborating with state, federal and tribal agencies to clean up other abandoned uranium sites. This requires data sharing through maps. AMLP needed updates of geographic locations of open shafts, waste piles and other features that may need additional reclamation. The program could also benefit from spatial analysis to track changes in radiation readings and waste redistribution for future maintenance visits.

The purpose of the New Mexico Abandoned Uranium Mine (AUM) inventory is to ascertain the extent and magnitude of the occurrence of abandoned uranium mines in New Mexico, especially those that have not been previously addressed by a tribal, federal or state entity. The AUM inventory is a database of information on mine location, reclamation status, mining history and production history. The data will be used to prioritize AUM's by potential or existing environmental harm. A goal of the inventory is to determine the appropriate means and remedy for rendering these sites safe to humans and returning the sites to beneficial use, including, but not limited to, a self sustaining ecosystem. Abandoned uranium mines include all uranium mines that have been deserted and are no longer maintained, and those mines that are inactive.

MMD initiated the AUM inventory project in December 2006.

Methodology

Reconnaissance / Location of Mines

MMD created a database of AUMs that included information on approximate geographic locations (latitude and longitude, UTM, Public Land Survey System) of sites, mining methods, mining features, mining history, surface and mineral ownership, production statistics, approximate disturbance areas, reclamation activities, radiological hazards, post-mining land use, and regulatory / jurisdictional agencies.

The first step in creating the database was to define a uranium mine. There are two extremes: 1.) a property with verifiable uranium production, or 2.) any prospect or a property that produced or was developed to produce uranium. For purposes of the AUM inventory, MMD only looked at mines that had verifiable uranium production.

MMD started with the most recent version of the Bureau of Geology and Mineral Resources publication "Database of the uranium mines, prospects, occurrences, and mills in New Mexico" (McLemore, 2007a; McLemore, et. al., 2002). This database was created for use in uranium resource analysis on a section and quarter section basis. According to this database, there are 1,534 occurrences, prospects and mines in New Mexico that have uranium production or mineralization associated with them. Out of those 1,534 records, approximately 330 occurrences had verifiable uranium production. MMD analyzed the database records and combined records

to create one AUM per shaft/pit complex. MMD identified 259 AUMs with verifiable production and 466 disturbances with no verifiable production.

The database records were supplemented with details from reports and records of field investigations. The primary source of field data is the 1981 AUM survey, contracted by AMLP to the New Mexico Bureau of Geology and Mineral Resources (Anderson, 1981). The Bureau of Land Management completed field investigations of selected uranium mines of federal lands in the mid-1980s (Schuster, 1985). These field locations were mapped using ESRI ArcInfo 9.2 (Figure 1, Appendix A).

Data Collection

The existing directions to the mine sites were often over twenty years old and referenced landmarks that no longer exist (Anderson 1981; State Mine Inspector, 1954-1980). Most of the roads have not been maintained during this same time period. Due to recent weather events, some roads were known to be washed out, and access would prove to be a trial and error process. We navigated to the abandoned mine sites with maps of overlaying 2005 digital orthorectified quarter quadrant (DOQQ) aerial photos at 1 m resolution, digital USGS topographic map digital raster graphics (DRG) and approximate site location survey maps and construction reports. Our field preplanning included examining the DOQQ imagery to trace out possible 2-track roads, canyon passageways and off-road routes.

Map layers of land ownership helped us prioritize site visits and identify right-of-access contacts. We uploaded the digital topographic map to a Trimble XH GPS unit to help us navigate while in the field. We delineated access roads to the area with the GPS while driving so that we could retrace our visits and share the access route with contractors, state agencies and other AMLP personnel that may return and perform additional work (Figure 2, Appendix A).

Normal field equipment that we carry includes a field notebook, a GPS unit, a digital camera and assorted measuring tapes. For uranium mine investigations, we also need to include a survey meter to detect radiation readings. How much equipment can one person carry and use? Even with two people, this is a lot to carry. Trying to collect as much data as quickly as possible in a manner that can be useable with minimal re-copying was our goal. We have many uranium sites to worry about and building a procedure that works well helped us speed through each site.

The first step in this procedure was to identify the field data we needed to collect. Rather than fill out paper forms, we decided to use a data dictionary. We used Trimble XH and XT GPS units and Pathfinder data dictionaries (Figure 3, Appendix A) to collect features and attributes including radiation readings, mine features and disturbances, and mine roads and washed-out roads. The cultural resources reports (Fuller, 1989; Drake and Fuller, 1990) and AMLP project files helped us to locate features that had been reclaimed, that were still visible or that needed reclaiming at a future date. The data dictionaries allowed us to standardize the feature types, their geometry, data format, and particular feature information (attributes). We first examined feature names used in previous surveys and those currently utilized by our field staff. Repeated field work tested the utility of the data dictionary and necessitated several upgraded versions. The data dictionary was shared with contractors that surveyed and collected data on mines on adjacent areas. We found it very important to make sure that the same dictionaries were uploaded onto the multiple GPS units.

One of our goals was to identify areas within each mine disturbance that were above the average background radiation readings. These preliminary sample readings can be used in planning future work orders for additional systematic sampling and reclamation. Our first sampling attempts didn't start out smoothly. Some early hurdles we encountered came from using different types of radiation survey meters with measurements that were in different units. Confirming the units and conversions for each meter helped, but sticking to a Ludlum Model 14C meter with a 1" X 1" NaI Scintillator probe gave data processing a standard to work from. Radiation readings also get confusing when you might take a "fast" 4 second reading or a "slow" 22 second reading. We collected data for the typical features, like shafts, vent holes and adits. But since radiation is not visible or obvious in any sense of the word, we would wander around the sites listening for the Geiger counter beeps to go from many beeps to a constant beep to a whining beep. We would stop to take a measurement at both one meter (human exposure) and ground elevations (soil activity).

GIS played an important part of the field procedures for several reasons. Mine sites are in close proximity to one another. What appears to be large waste pile may not be high in radiation. High radiation was found in places that looked to be "safe." It is hard to differentiate between an ore stockpile, a waste pile or an overburden pile until you take the radiation measurements. Dangerous vent shafts and other features were found in areas both within and beyond reclaimed

site limits. You would expect that a standard grid transect of these sites would find all associated dangers at each mine, but many dangers were found outside of the boundaries of the original sites.

We found having a team of two or three people worked the best. Ideally we wanted everyone to have a GPS unit to record a radiation reading or a photo point or a site feature. When we started using the Ricoh 500SE digital camera with GPS we were able to have three people with GPS. Part of what we wanted to accomplish, in addition to the data collection for each site, was to evaluate the quality and accuracy of the GPS readings from the Ricoh 500SE compared to our readings from the Trimble Geo XH. Figure 4 includes a photo from the Ricoh camera and the Trimble GPS data. The numbers were exported directly from the Trimble Pathfinder software. The Easting/Northing coordinates were set to match the camera in using meters; the elevation was set to feet using Mean Sea Level. Comparing these numbers shows a difference up to two or three meters in either direction. For most uses this would be sufficient accuracy. This camera allows the convenience of taking a photo and recording the GPS reading in one step, plus, when used correctly, can even provide the compass heading for the direction you were standing when you took the picture. The compass heading on the picture is off by about 180° because of moving away from the shaft before taking the picture.

Data Processing

We used GPS Pathfinder Office to download files from our Trimble XT and XH GPS devices, perform minor edits of the feature geometry, and export files as ESRI shapefiles. We used the ArcInfo Merge tool to combine our features that were collected over a period of several months. Within ArcInfo 9.2 software, we cleaned up the table information (attributes) where needed. At times the cultural survey reports were a help in renaming uncertain features such as disturbed areas that had been trash dumps. Shapefiles were converted to SDF files (MapGuide native files) so that we could incorporate features and into an interactive web map (Autodesk MapGuide 6.5). Shapefiles were also converted to feature classes within an ESRI geodatabase. The geodatabase offers many advantages over shapefiles such as a better system for organization and grouping features and greater attribute management and editing capabilities.

We examined the aerial imagery (DOQQs) of our sites in an attempt to identify mine disturbance in advance of and between our visits to the mines. This imagery analysis was

helpful in identifying features that we had overlooked and planned to revisit. Once we had trained our eye in identifying roads and erosion features, we used ArcInfo editing tools to digitize (softcopy) information from the DOQQs in order to add to our road and erosion layers. Color and texture in the imagery suggested mine disturbance scattered throughout the district. Due to sparse vegetation cover of the area, many roads and vehicle track could be identified. Figure 5, Appendix A illustrates the comparison of mine disturbances identified with DOQQs with specific mine features, roads, and localized drainages that were collected with GPS.

GPS Photo-Link: Ricoh edition GeoSpatial Experts software was used to process pictures taken with the Ricoh GPS-enabled camera. We selected the option to "stamp" our digital pictures with geographic location (coordinate system and datum), time, and date at the bottom of each picture margin (Figures 4 and 6, Appendix A). We exported the files as shapefiles that consisted of points that corresponded to the geographic locations recorded by the camera and attributes that included information on GPS coordinates and datum, altitude, direction from camera to object, time and date of collection, picture file, camera settings, and GPS accuracy. The shapefile data table also contained a field that hyperlinked the location of the photos so that you could click on that point in ArcGIS and have the photo popup from the map in a separate window (Figures 6, Appendix A). Figure 6, Appendix A illustrates the GPS photo points symbolized within the map and the connection between the map location and the digital photo taken at that point.

Data Delivery / Sharing

Our mapping data and associated digital photos were shared with interested parties through both maps created in ArcInfo and through MapGuide 6.5 interactive web maps (Figures 8 and 9, Appendix A). Figure 8 illustrates the reclaimed open pit on a 2005 DOQQ and the locations of the waste piles that need to be revisited and reclaimed. Digital photos from 1990 and 2007 contrast the current condition of the pit to the conditions prior to reclamation.

The MapGuide application allows MMD to easily share the AUM information with interested parties through their web browser. It is also possible to save the map and embedded data on a CD or DVD for distribution to our partners (e.g. tribal, state and federal agencies). Digital photos were also hyperlinked in the MapGuide application. Through the MapGuide web map, we can access separate html web pages (via hyperlinks) that contained embedded photos

and descriptive text by clicking on a map feature (Figure 9, Appendix A). MapGuide also allows the user to access text information about a mine feature through a "Map Tip" pop-up box, displayed when the mouse cursor hovers over that feature.

Results/Conclusions

The use of GIS, and the resulting map products and interactive web maps, has streamlined the exchange of data between programs and agencies. Our use of digital aerial imagery (DOQQ 1 m resolution) has been helpful in identifying general mine disturbances and potential feature location within the area. MMD would like to look more closely at image interpretation and analysis, and its use in detecting mine disturbances.

Preliminary sampling of general mine disturbances, waste piles, mine openings (shafts, adits, holes and wells) and mine access roads at 15 AUM sites (Table 1) shows a wide range of radiation values at ground contact. The average background radiation reading was 18.8 μR/h (n = 5). The information gives us an idea of how we might start to prioritize site clean-up and create a contract for a more detailed sampling measure.

Table 1. Radiation readings at ground contact (μR/h).

Feature	General Disturbance	Waste Piles	Shaft, Adit, Well	Mine Road
Sample size (n)	5	47	10	9
Average (μR/h)	297.8	387.7	197.0	159.5
Range (μR/h)	17 to 457	32 to 2343	21 to 486	26 to 400

Being able to spatially delineate areas that were subject to prior uranium mining and determine the surface ownership and proximity to wells, surface streams and structures will make it possible to analyze contamination pathways and begin to prioritize the cleanup and remediation of abandoned uranium mines in our state. Our preliminary analysis shows that 5 of our 15 AUM sites are within 6.5 to 68 meters of a major stream/drainage area (Figure 10, Appendix A).

Using the Ricoh camera combined several tasks into one step and made georeferencing photos easier though not necessarily simple. These are steps forward to ultimately process field

data electronically from start to finish. Was this process worth the effort? A definite YES but there are still hurdles to be overcome. Of the sites visited so far, all need additional work, though some only require minor amounts of waste material to be cleaned up.

Future Work

Further work is needed to relocate and delineate feature collection, comparing the number of field-identified features with those recorded in reports. We need to compare the disturbances detected using imagery with the disturbances and features detected on the ground.

Spatial analysis of the AUM sites in relation to erosion features, homes and structures, wells and waterways needs to be completed. We plan to use the locations of mine features collected with GPS, and erosion areas both collected with GPS and delineated in our imagery, to aid in selecting additional radiation samples points to investigate at how far-reaching the spread of waste rock and radiation concentration extends. The question of whether washed-out ore haul roads, in particular, contributes to the spread of waste material and higher than background levels of radiation needs to be investigated.

MMD would like to continue testing the utility of the GPS-enabled Ricoh camera, especially in our reconnaissance work, and incorporate the photos into our GIS.

MMD plans to continue to build on the "Before and After" portion of the MapGuide web application, integrating historic radiation measurements and historic photos.

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Schuster, F. P. 1985. Pilot Project Field Report: Hazardous waste inventory, abandoned uranium mines, McKinley County, New Mexico. United States Department of the Interior, Bureau of Land Management, New Mexico Office. Santa Fe, New Mexico.

State Mine Inspector. 1954-1980. Inactive uranium mines card file. 1954-1980. New Mexico Bureau of Mine Safety. Socorro, New Mexico.

Appendix A – Figures

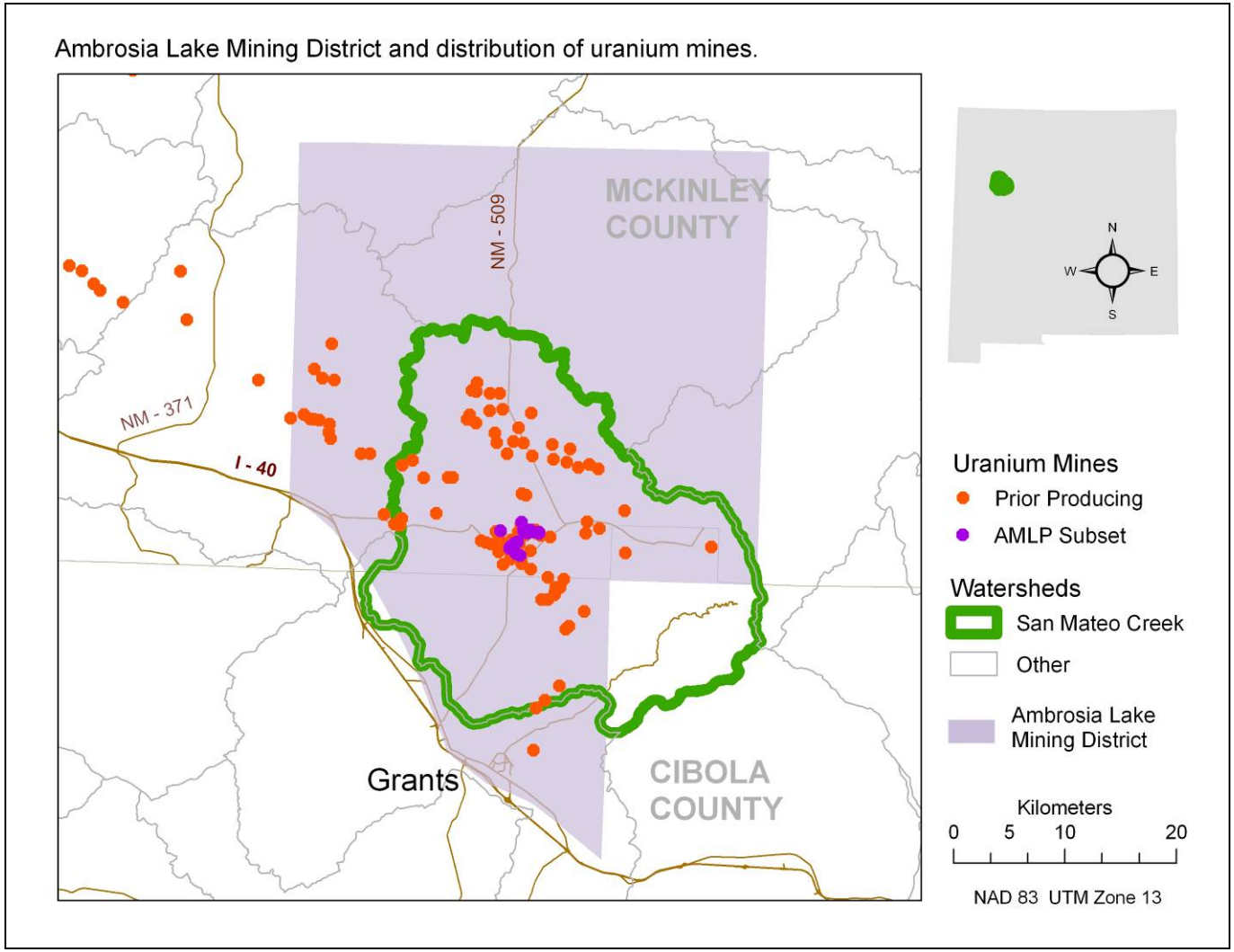


Figure 1. The distribution of abandoned uranium mines in the Ambrosia Lake Mining District.

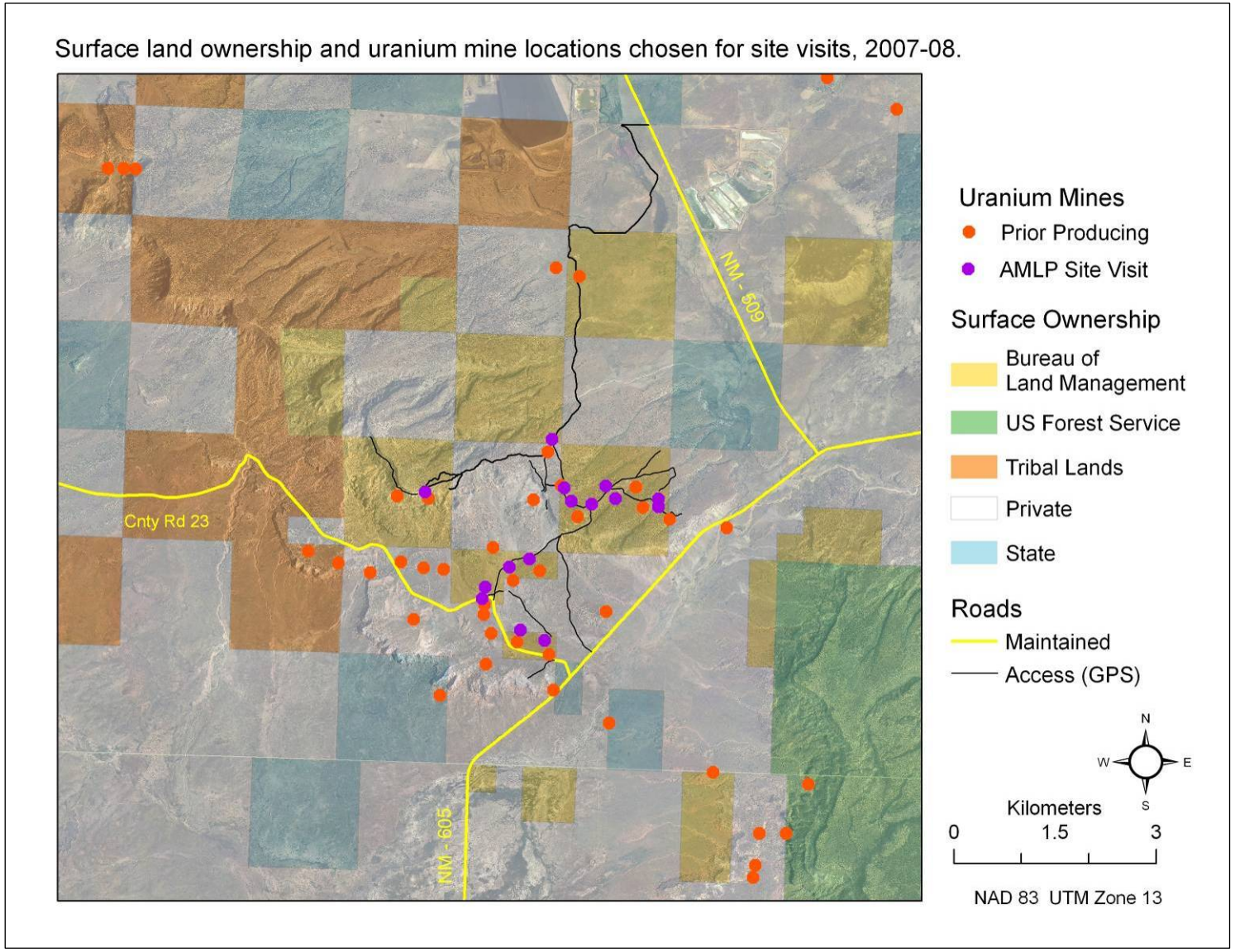


Figure 2. Reconnaissance and navigation routes to AUMs based on surface ownership and topographic access.

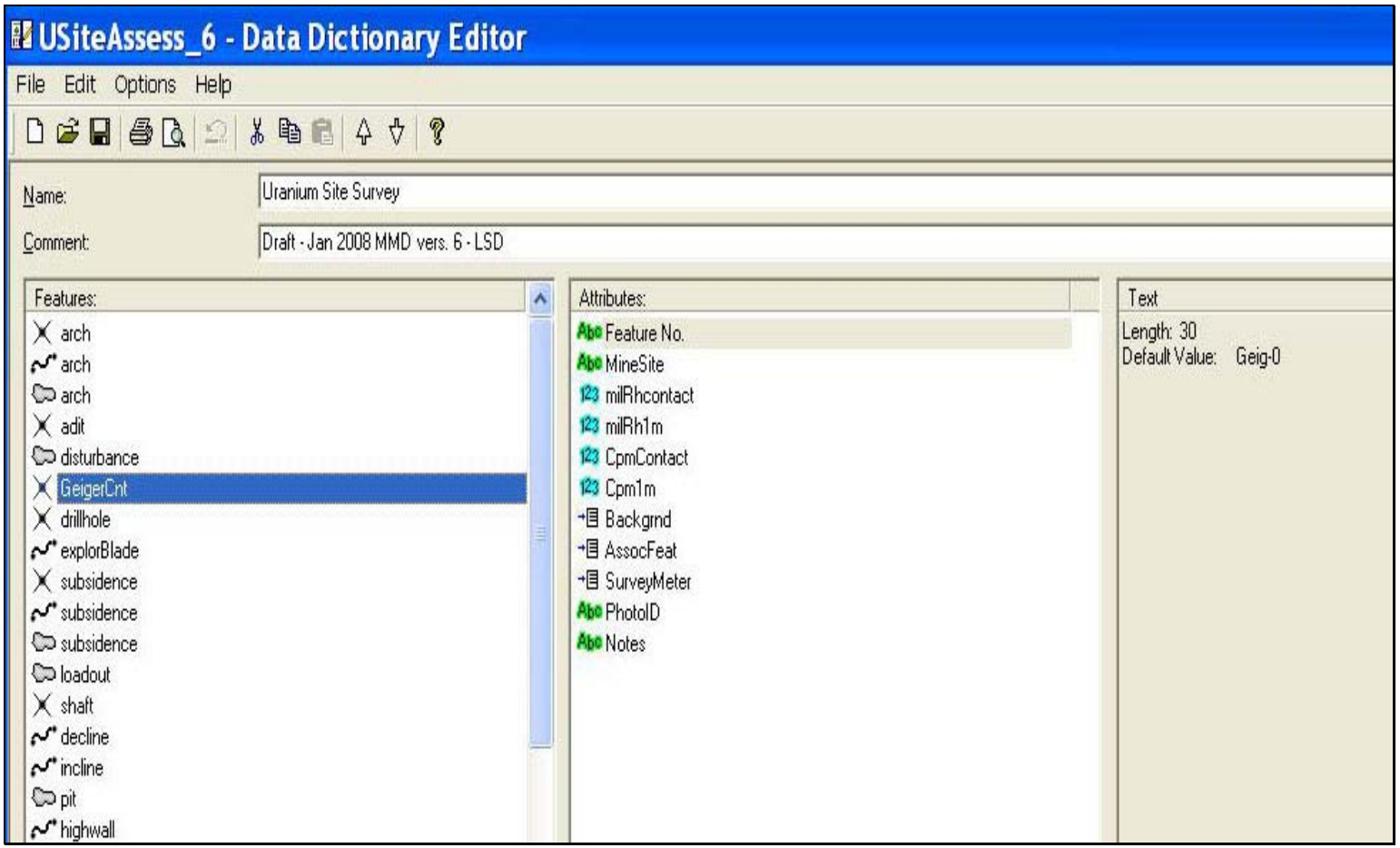


Figure 3. Data dictionary within the Pathfinder Office Editor.

shaft						
Easting	Northing	Elevation	ClosureType	PhotoID	GPS Date	GPS Time
747874.643	3936706.739	7450.36	Backfill	792	12/18/2007	1:25:27 PM

Figure 4. Photo of shaft from Ricoh camera and corresponding Trimble GPS data.

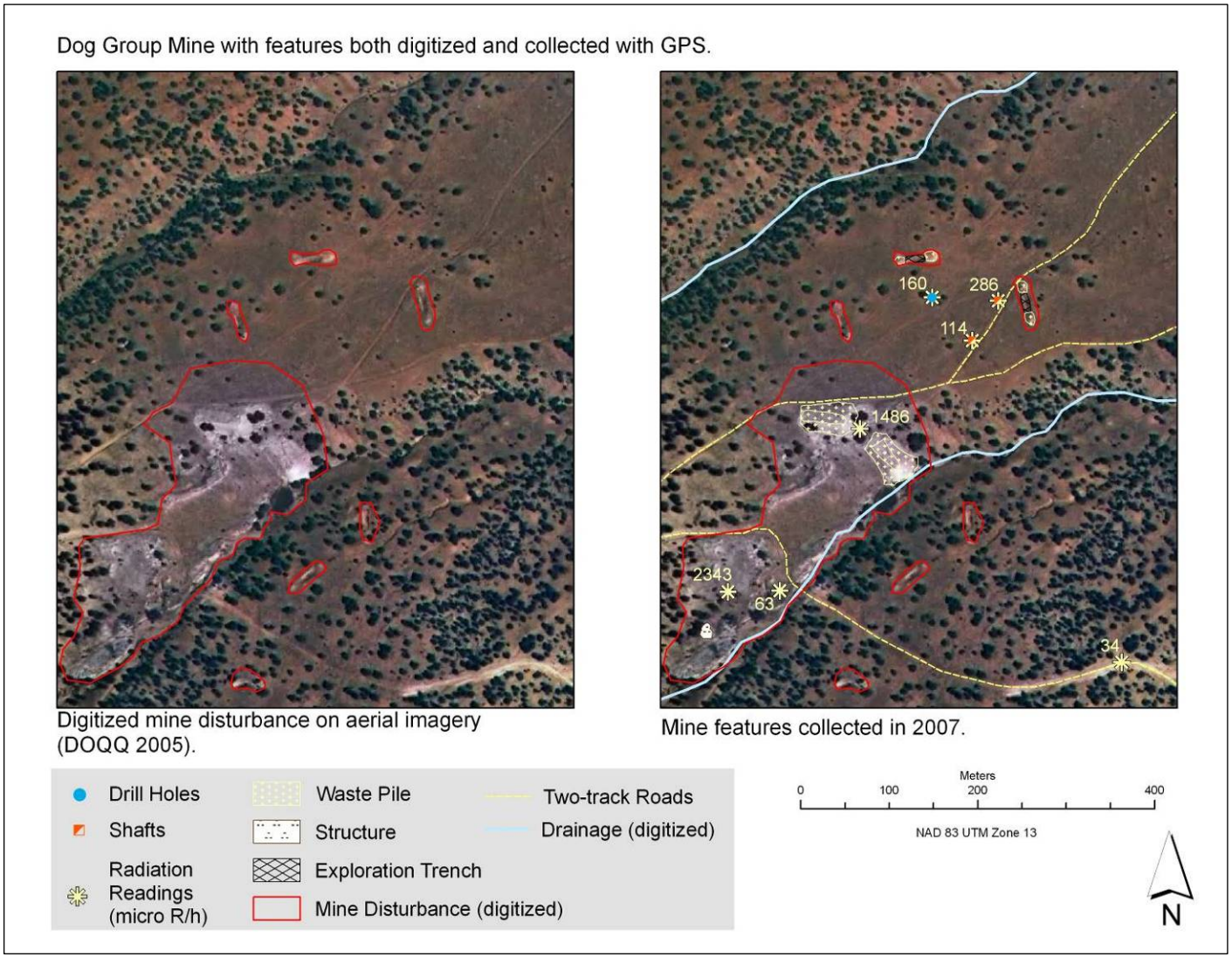


Figure 5. Dog Mine. Potential mine disturbance was digitized from DOQQ and mine features were collected on the ground with GPS units and supplemented with digitizing. Radiation readings (μ R/h) were taken both on and off the disturbance site.

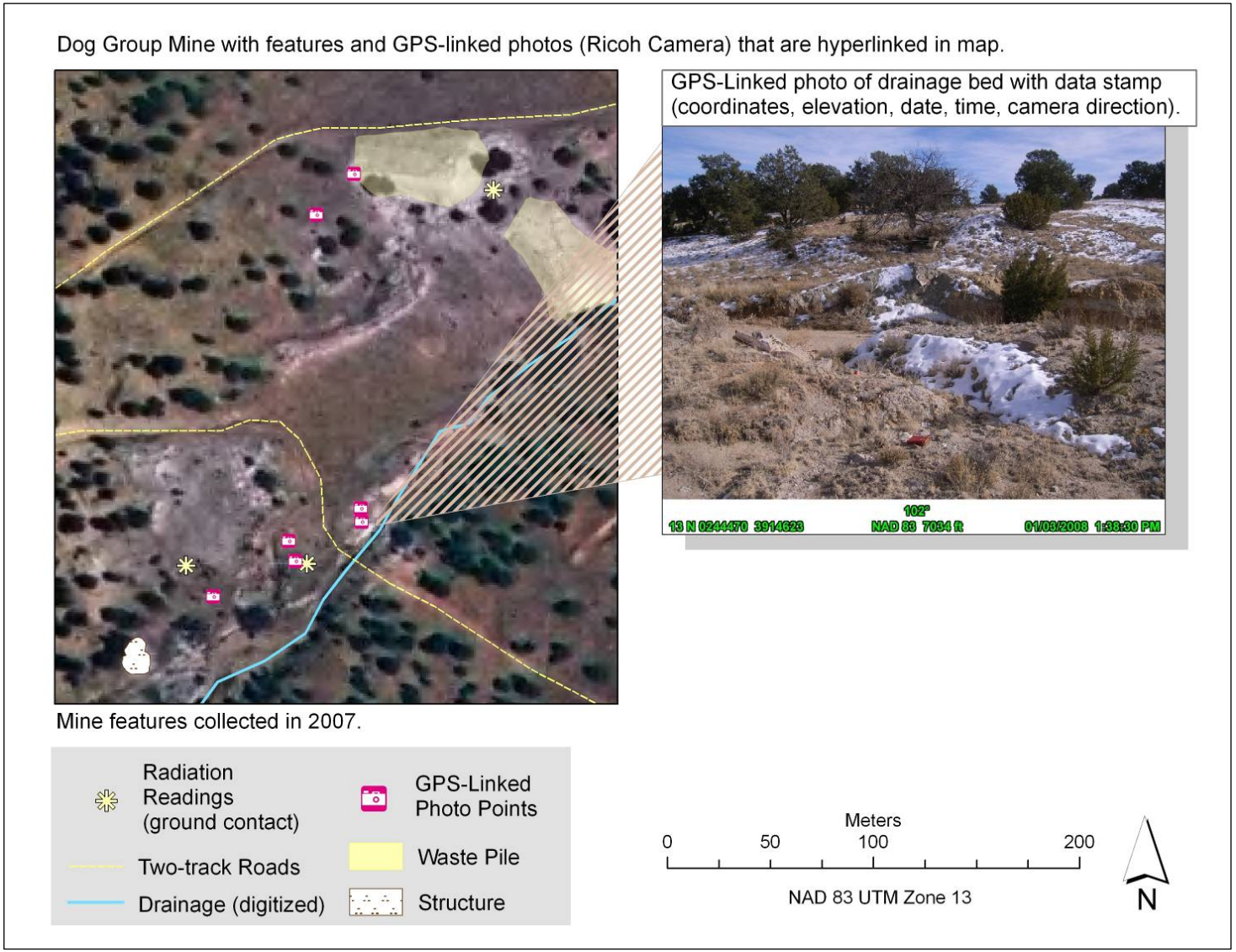


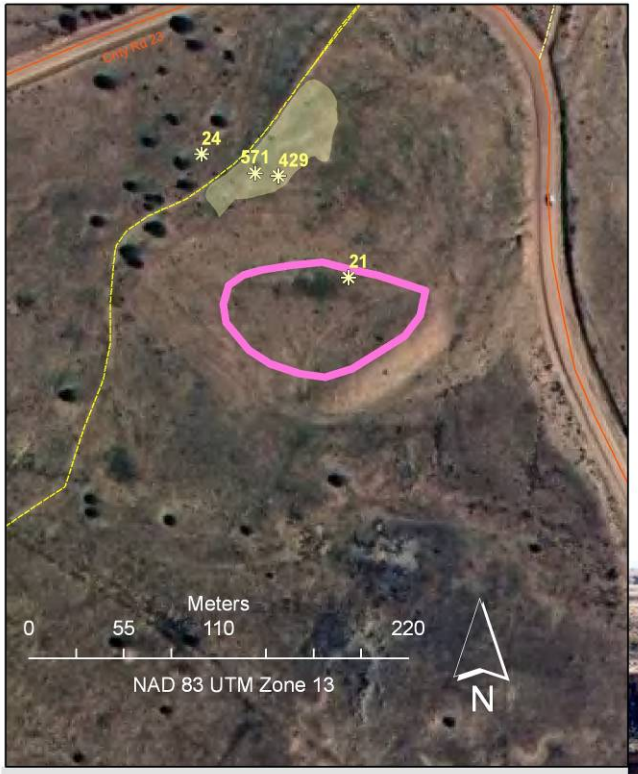
Figure 6. Dog Mine with Ricoh camera GPS-linked photo points. ESRI shapefiles were exported from the GPS Photo- Link software and appear in the map as a hyperlinked popup.

Attributes of GPSRicoh_final

FID	Shap	EAST	NORTH	ZONE	ALTITUDE	DIRECTION	HEADING	DATUM	TIMESTAMP	PICTURE	DOP	DISTANCE	FNUMBER	A
0	Point	748959.84	3935309.82	12 N	7440.945	319	319	NAD 83	18-Dec-2007 19:01:33	2007-12-18_12-01-33_tag.jpg	3	200	4.7	
1	Point	749021.5	3935386.18	12 N	7440.945	327	327	NAD 83	18-Dec-2007 19:03:04	2007-12-18_12-03-04_tag.jpg	3	200	4.3	
2	Point	748990.39	3935471.05	12 N	7421.26	325	325	NAD 83	18-Dec-2007 19:07:08	2007-12-18_12-07-08_tag.jpg	1.6	200	8.8	
3	Point	748969.99	3935497.32	12 N	7437.664	304	304	NAD 83	18-Dec-2007 19:07:37	2007-12-18_12-07-37_tag.jpg	1.6	200	8	
4	Point	748965.14	3935499.65	12 N	7431.103	291	291	NAD 83	18-Dec-2007 19:09:01	2007-12-18_12-09-01_tag.jpg	1.7	200	5.6	
5	Point	748993.97	3935577.56	12 N	7440.945	144	144	NAD 83	18-Dec-2007 19:11:57	2007-12-18_12-11-57_tag.jpg	1.6	200	7.5	
6	Point	748993.98	3935577.25	12 N	7444.226	175	175	NAD 83	18-Dec-2007 19:12:09	2007-12-18_12-12-09_tag.jpg	1.6	200	6.4	
7	Point	748967.42	3935580.52	12 N	7444.226	293	293	NAD 83	18-Dec-2007 19:13:18	2007-12-18_12-13-18_tag.jpg	1.6	200	4.7	
8	Point	748961.81	3935582.83	12 N	7417.979	153	153	NAD 83	18-Dec-2007 19:15:39	2007-12-18_12-15-39_tag.jpg	1.6	200	8.1	
9	Point	748955.57	3935634.78	12 N	7437.664	15	15	NAD 83	18-Dec-2007 19:22:27	2007-12-18_12-22-27_tag.jpg	1.6	200	8.1	
10	Point	748955.57	3935634.78	12 N	7437.664	15	15	NAD 83	18-Dec-2007 19:22:27	2007-12-18_12-22-27-1_tag.jpg	1.6	200	8.1	
11	Point	748986.04	3935618.05	12 N	7424.541	56	56	NAD 83	18-Dec-2007 19:23:49	2007-12-18_12-23-49_tag.jpg	2.1	200	8.1	
12	Point	748988.33	3935617.19	12 N	7424.541	174	174	NAD 83	18-Dec-2007 19:24:01	2007-12-18_12-24-01_tag.jpg	1.6	200	10.1	
13	Point	749015.25	3935429.18	12 N	7434.383	64	64	NAD 83	18-Dec-2007 19:28:39	2007-12-18_12-28-39_tag.jpg	1.7	200	6.6	
14	Point	749015.76	3935429.2	12 N	7434.383	67	67	NAD 83	18-Dec-2007 19:28:49	2007-12-18_12-28-49_tag.jpg	1.7	200	4.7	
15	Point	749016.28	3935428.59	12 N	7434.383	96	96	NAD 83	18-Dec-2007 19:28:59	2007-12-18_12-28-59_tag.jpg	1.7	200	4.7	
16	Point	749016.28	3935428.59	12 N	7434.383	152	152	NAD 83	18-Dec-2007 19:29:07	2007-12-18_12-29-07_tag.jpg	1.7	200	4.7	
17	Point	746798.84	3937201.23	12 N	7457.349	257	257	NAD 83	18-Dec-2007 19:57:54	2007-12-18_12-57-54_tag.jpg	0	200	8.1	

Figure 7. Shapefile attributes from the GPS- linked photo points. Information can include GPS coordinate values and datum, altitude, direction from camera to object, time and date stamps, picture file, camera information, and GPS accuracy information.

Piedra Trieste Mine and the main pit.



Mine features collected in 2007. Pit depression visible in aerial photo (2005).

Radiation Readings (ground contact)

Maintained Road

Two-track Road

Pit (filled-in)

Waste Pile

Photo of the reclaimed pit (2007). Reclamation consisted of soil backfill.

Photo of the abandoned mine pit in 1990. Prior to reclamation.

Figure 8. Piedra Trieste mine and reclaimed pit with photos taken before and after the reclamation.

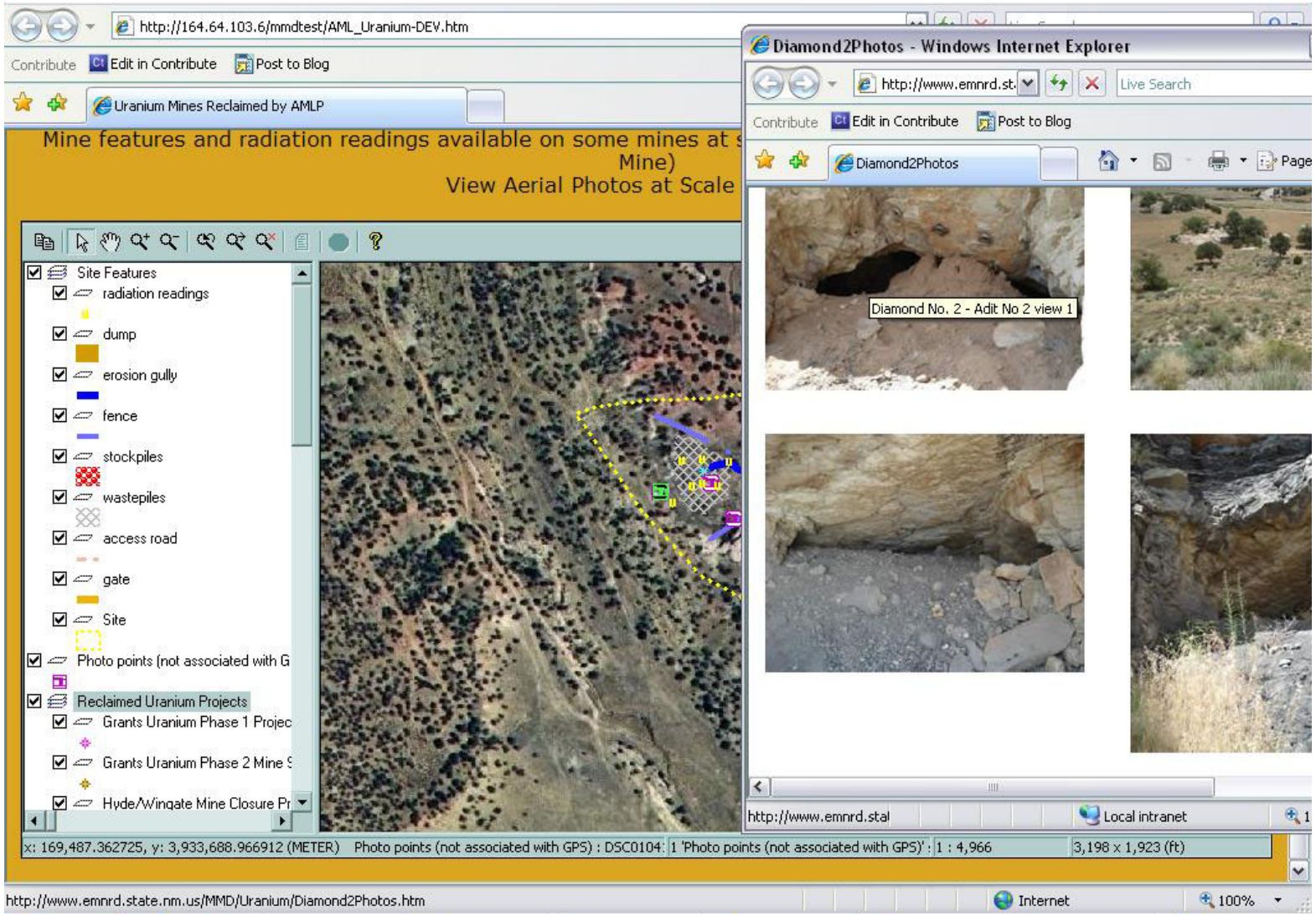


Figure 9. MapGuide interactive web map with an AML site and features. Photo points have been hyperlinked to a web page that contains a series of photos of the adits of that location.

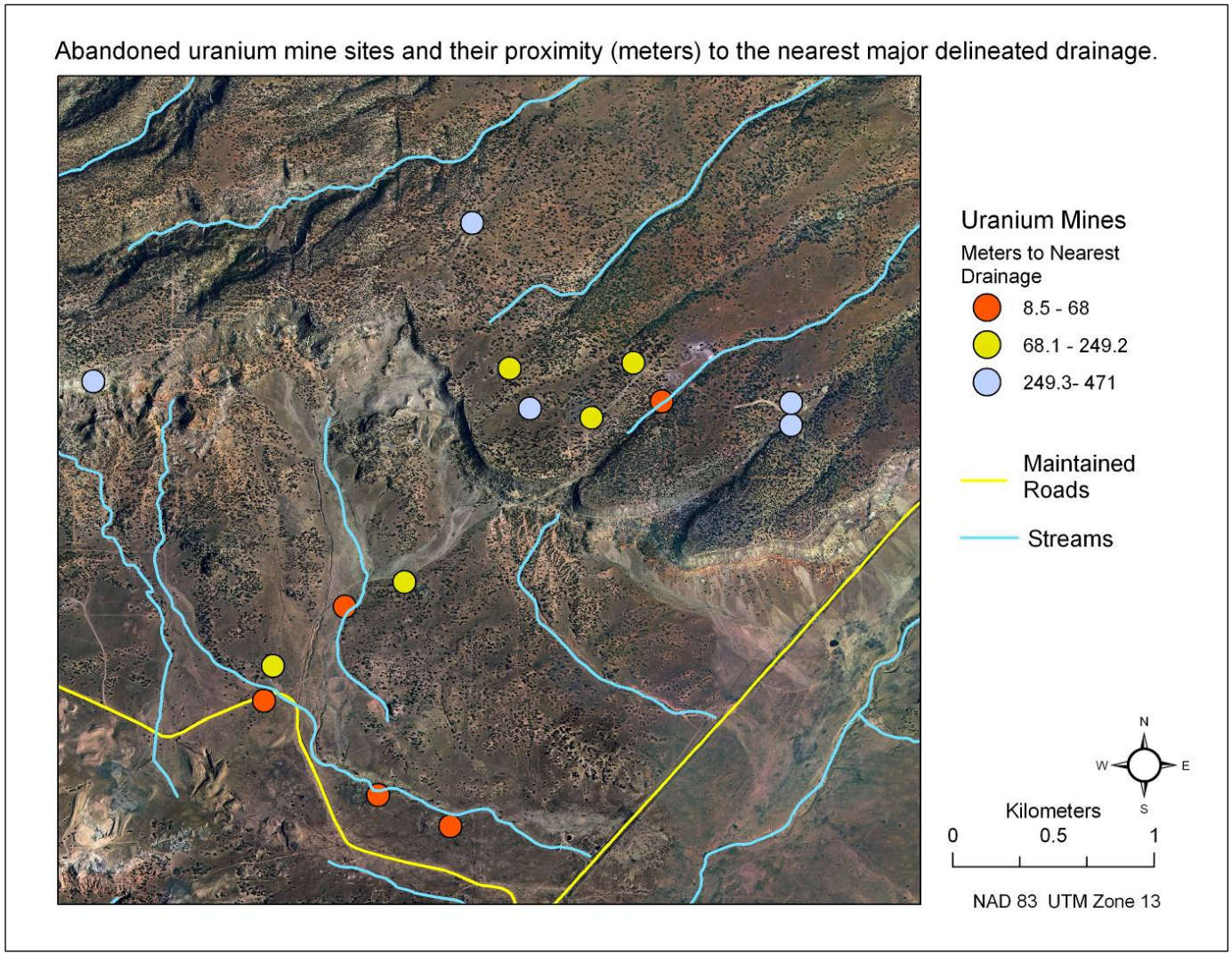


Figure 10. Proximity of AUM site point locations to the nearest major stream as delineated in the USGS National Hydrography Dataset. Distances are in meters and calculated as the distance at a 45 degree angle to the nearest point on the stream polyline (ESRI ArcInfo 9.2, Near Tool).

Appendix B – GIS Datasets Used in the Geodatabase

Land Surface Ownership shapefiles,
Mineral Ownership shapefiles,
Public Land Survey System shapefiles
U.S. Bureau of Land Management. New Mexico State Office. 2006.

Navajo Lands Checkerboard Area shapefiles.
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