A PROPOSAL AND SCOPE OF WORK SUBMITTED TO:
Arizona Department of Environmental Quality

Investigation of Hydrogeologic Conditions in the Subsurface near Pinyon Plain Uranium Mine in the Grand Canyon Region

U.S. Geological Survey
Arizona and New Mexico Water Science Centers
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Summary

Problem. The hydrogeology in the Grand Canyon region is complex and there are limited observation points such as wells from which to better characterize the system. Uranium mining is occurring at locations in the Grand Canyon region, including at the Pinyon Plain Mine south of Grand Canyon. This mine is in closer proximity to water resources utilized for drinking water supply compared with other uranium mines north of Grand Canyon. Changes to groundwater chemistry from mining activities at the mine site are a cause for concern for communities in the area. Additional investigation into the hydrogeology south of Grand Canyon is needed to better understand groundwater movement, preferential subsurface pathways for groundwater, and possible short and long-term changes to the hydrologic system related to mining activities at Pinyon Plain Mine. Results from these investigations will assist in evaluating the potential for groundwater to move away from the mine and towards drinking water sources in the area, including those for the Havasupai Tribe of the Havasupai Reservation and the Town of Tusayan.

Objectives. The objectives of this proposed work are to utilize the best available and most cost effective scientific methods to better characterize the hydrogeologic conditions around the Pinyon Plain Mine and in the broader surrounding area south of Grand Canyon.

Approach. The work outlined here will include sample collection, data analysis, and interpretation for Arizona State Fiscal Years (SFY) 2026 and 2027. Tasks include geophysical and structural geology assessments of the area to investigate the potential for groundwater flow pathways from Pinyon Plain Mine, as well as collection and analysis of groundwater chemistry to establish conditions during mining and assess changes over time.

Relevance and Benefits. The proposed work includes data collection and interpretation that will improve understanding of the potential for groundwater movement away from the Pinyon Plain Mine, an important issue for regulators, tribal communities, and others in the region. The study directly supports the USGS Water Science Strategy by advancing understanding of processes that determine water availability, delivering timely hydrologic data and analyses to support water-resource decisions (Evenson and Orndorff, 2013), and strengthening linkages among Federal, Tribal, and State organizations (U.S. Geological Survey, 2021).

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Introduction

In the arid Grand Canyon region in northwestern Arizona, water resources are limited to primarily the Colorado River and associated tributaries and to groundwater in the form of seeps, springs, and wells. The Colorado River is fully allocated and currently unavailable for use by communities in the region. Groundwater resources in the region supply water for human use, baseflow for perennial streams, and support diverse and rich ecosystems in the locations surrounding the seeps and springs. Throughout the region, uranium resources occur and may interact with water resources in both mined and unmined uranium deposits. There is a need to better understand the movement and quality of groundwater in the region and potential effects on groundwater from uranium mining in order to manage limited water resources in the area.

Groundwater in the Grand Canyon area is present in a shallower perched system and a deeper regional groundwater system. Perched groundwater is discontinuous throughout the area, but where present, is located about 1,000 feet below land surface in the Permian-age Coconino Sandstone (C-aquifer) (Tillman and others, 2021). The regional aquifer (R-aquifer) is more than 3,000 feet below the plateau surface in the Mississippian-age Redwall Limestone, the Devonian-age Temple Butte Formation, and the underlying Cambrian-age Frenchman Mountain Dolostone and Muav Limestone of the Tonto Group and is present throughout the Grand Canyon region except within canyons where the aquifer units have been eroded away. The age of water in the perched and regional groundwater systems varies greatly in the area. At some spring sites along the Kaibab Plateau, water recharging the groundwater system can move quickly (on the timeframe of days to months) to discharge at springs (Jones and others, 2017; Beisner and others, 2025). At other wells and springs in the region, groundwater can take thousands of years to move through the subsurface (Solder and others, 2020). Owing to the remoteness of the area and depth to groundwater, few wells are available to delineate groundwater basins and flow paths (Tillman and others, 2021).

Problem

The hydrogeology in the Grand Canyon region is complex and there are limited observation points such as wells from which to better characterize the system. Uranium mining is occurring at locations in the Grand Canyon region, including at the Pinyon Plain Mine south of Grand Canyon (fig. 1). This mine is in closer proximity to water resources utilized for drinking water supply compared with other uranium mines north of Grand Canyon. Changes to groundwater chemistry from uranium mining activities are a cause for concern for communities in the area. Additional investigation into the hydrogeology south of Grand Canyon is needed to better understand groundwater movement, preferential subsurface pathways for groundwater, and possible short and long-term changes to the hydrologic system related to mining activities at Pinyon Plain Mine. Results from these investigations will assist in evaluating the potential for groundwater to move away from the mine and towards drinking water sources in the area, including those for the Havasupai Tribe of the Havasupai Reservation and the Town of Tusayan.

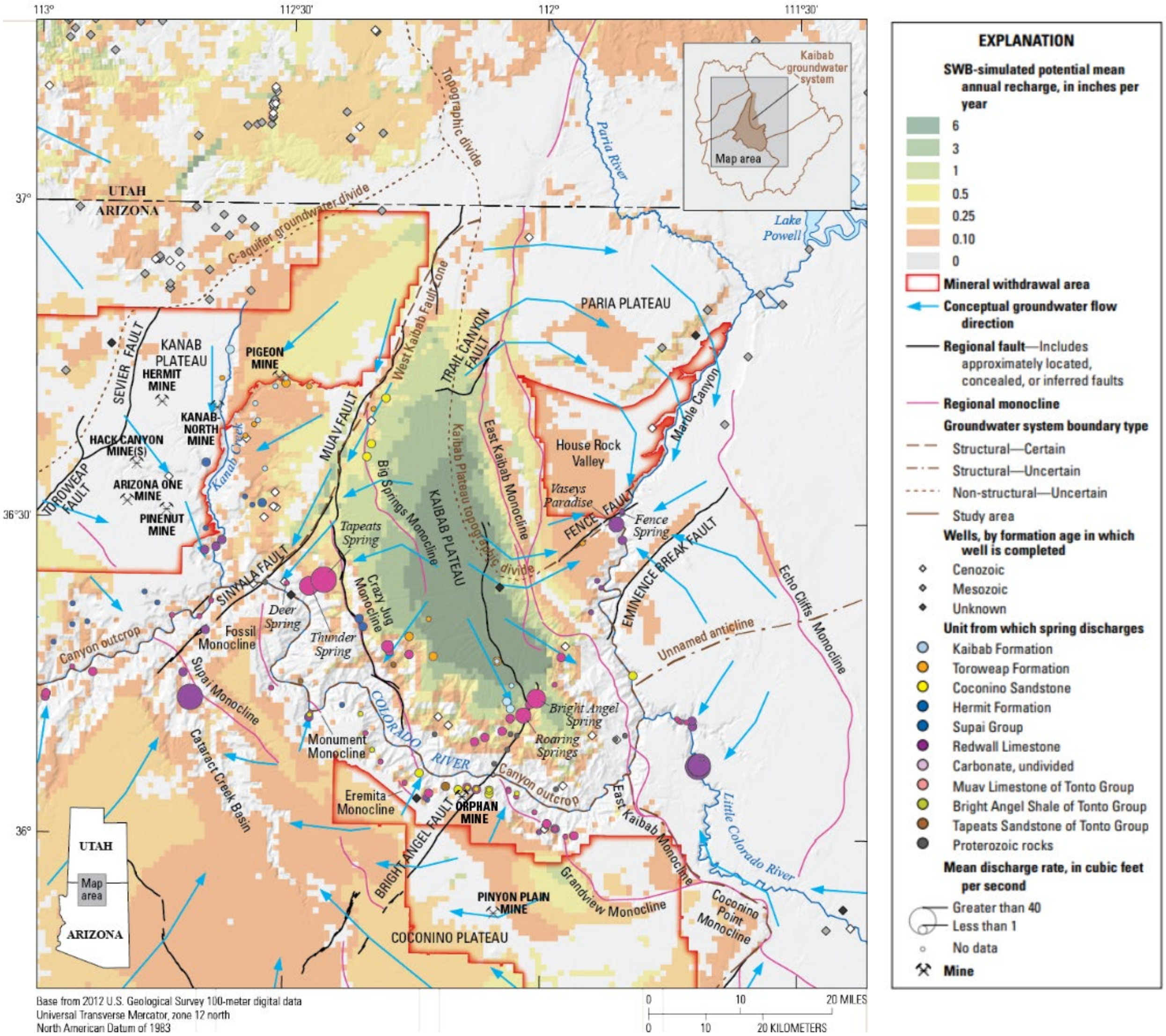


Figure 1. Map showing uranium mining locations near Grand Canyon with blue arrows indicating general groundwater flow directions (modified from Knight and Huntoon, 2022).

Objectives and Scope

The objectives of this proposed work are to utilize the best available and most cost effective scientific methods to better characterize the hydrogeologic conditions around the Pinyon Plain Mine and in the broader surrounding area south of Grand Canyon. The proposed work includes geophysics, structural geology, and water quality investigations that will be compiled into an interpretive report and associated data releases.

Approach

Investigations will occur from July 2025 to June 2027 and are divided into tasks as presented below.

Task 1: Assess subsurface properties related to fast-flow pathways including structural and possible karst features near the Pinyon Plain Mine

Recent publications have presented evidence from fluorescent dye studies of fast flow pathways for water in the subsurface of some areas in Grand Canyon region, with results showing water moving several thousand feet vertically and tens of miles horizontally in weeks to months (Jones and others, 2017; Beisner and others, 2023a; Beisner and others, 2025). These studies suggest fast flow pathways may be controlled by karst and structural features in the subsurface that may follow specific subsurface routes. The location of dye entrance to the subsurface and subsurface saturation conditions resulted in dyes injected into different locations being detected only at certain springs (fig. 2). There are few wells south of Grand Canyon and existing wells may not be located in areas of structurally controlled fast flow pathways. Geophysical methods, geologic mapping and structural geologic measurements can be utilized to enhance the understanding of the subsurface properties and structural features.

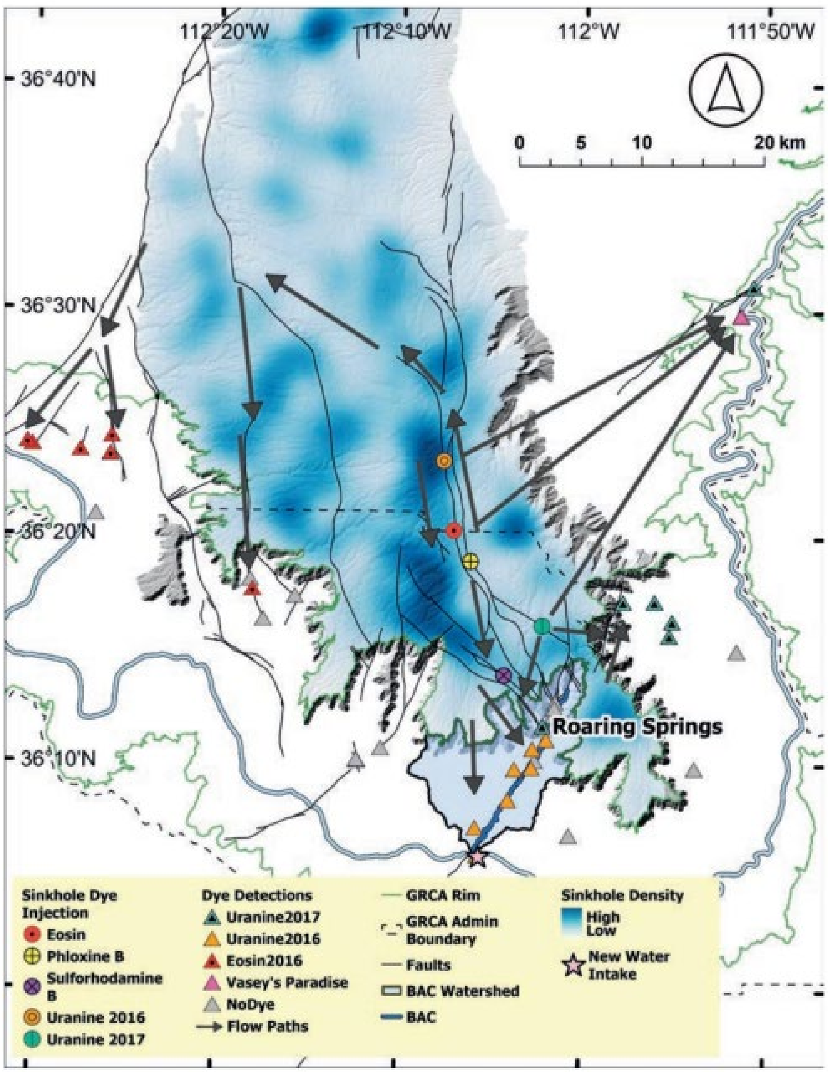


Figure 2. Map of dye trace injection and detections on the Kaibab Plateau north of Grand Canyon (modified from Chambless, 2023).

Subtask 1a. Geophysics Assessment

The subsurface in the Pinyon Plain Mine area will be assessed for evidence of potential fast-flow pathways using surficial geophysical methods. Controlled-Source Audio-frequency MagnetoTelluric (CSAMT; fig. 3) has been successfully utilized in other studies in the region with similar geologic units to assess subsurface electrical properties, including in the Big Chino Basin (fig. 4; Macy and others, 2019) and on the Hualapai Plateau (fig. 5; Mason and others, 2020). Since electrical resistivity changes with rock type and whether or not it is fractured or saturated, CSAMT results can provide an indication of subsurface structure (strata, faults and fractures) and the presence or absence of groundwater. Lower resistivity areas have been found to be associated with mapped surface geologic faults (fig. 5), providing valuable subsurface information over a larger area than would be possible from a single well. The CSAMT method requires the installation of a dipole transmitter source and receivers (fig. 3). The CSAMT method provides a representation of the resistivity in the subsurface which can be matched with well log information (fig. 4) for verification of the inferred lithologic units. Geologic cross sections will be constructed along the CSAMT transects for additional comparison utilizing geologic map information, well logs, and knowledge of geologic unit thickness in the region (which can vary spatially across the region).

For this investigation, four CSAMT transects surrounding the Pinyon Plain Mine footprint are proposed utilizing two transmitters to assess near-mine subsurface properties (fig. 6) in addition to areas for preferential water movement away from the mine (fig. 7). Additional CSAMT surveys utilizing the two transmitters required for the near-mine assessment will provide cost-effective information regarding subsurface hydrogeologic information across regional structural features (fig. 7) and proposed penetrative fractures (Gettings and Bultman, 2005). An additional proposed transmitter location and survey lines (fig. 7) designed to assess subsurface properties associated with faults near the start of the Cataract Canyon (fig. 1), which may capture groundwater that discharges at Havasu Spring on the Havasupai Reservation, can provide valuable information regarding potential pathways for water movement from the C- to the R- aquifers. Proposed CSAMT surveys will prioritize the transects around Pinyon Plain Mine in figure 6. Data will be collected utilizing a crew of 2 hydrologists and 3 hydrologic technicians over 7 weeks of field data acquisition expanding beyond the Pinyon Plain transects to cover as much of the additional proposed transects on figure 7 as possible during the 7-week field campaign. The majority of the proposed transects are on Forest Service Land, but there are some proposed areas on state trust lands. Land access on state trust land is contingent on agreement and cooperation from the state trust lands and associated lessee. CSAMT data will be reviewed during data collection to guide additional data collection in areas of proposed transect lines.

The CSAMT transect results will be published in a data release through the publicly available USGS ScienceBase website. Transect results will be analyzed and incorporated into the interpretive report associated with this proposed research.

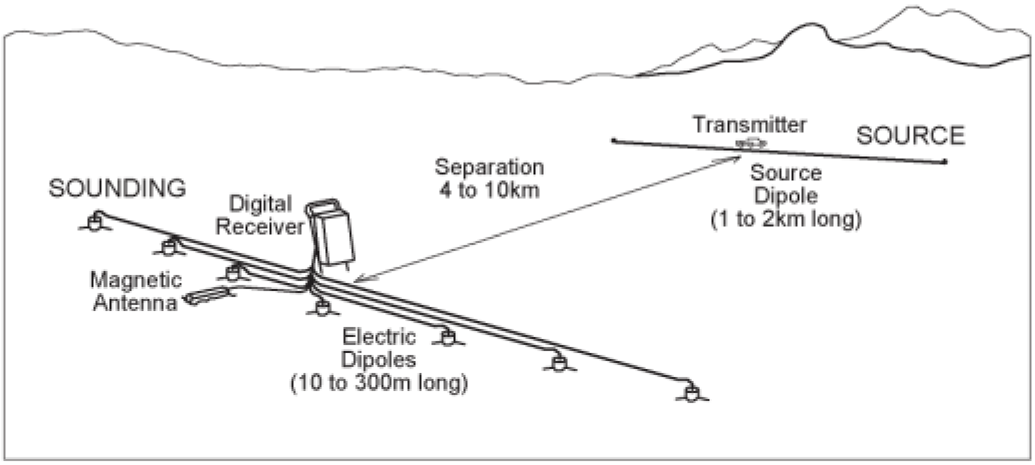


Figure 3. Schematic showing the setup for a controlled source audio-frequency magnetotelluric (CSAMT) survey (from Macy and others, 2019 (modified from Zonge, 1992)).

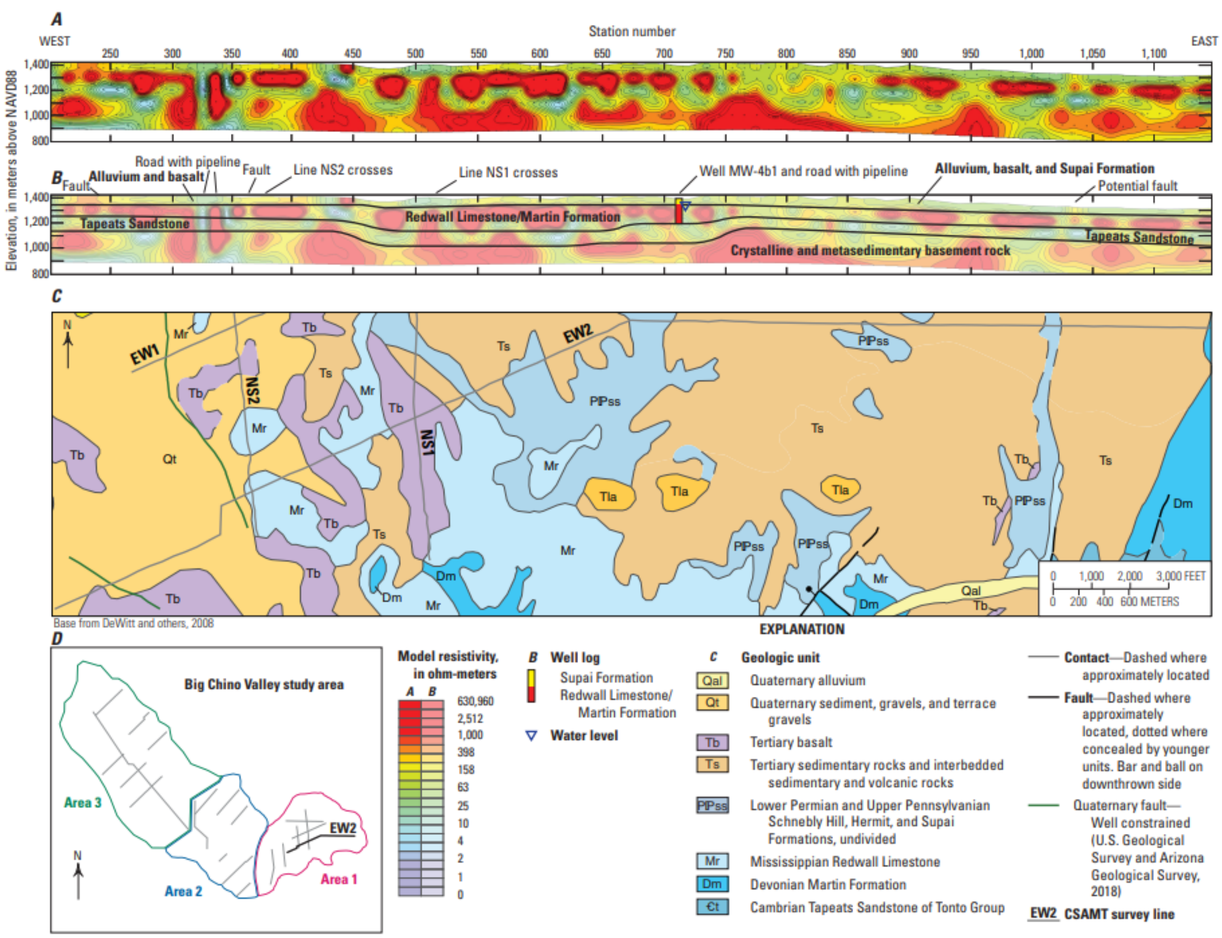


Figure 4. Example results for a controlled source audio-frequency magnetotelluric (CSAMT) transect from the Big Chino Subbasin in Macy and others (2019).

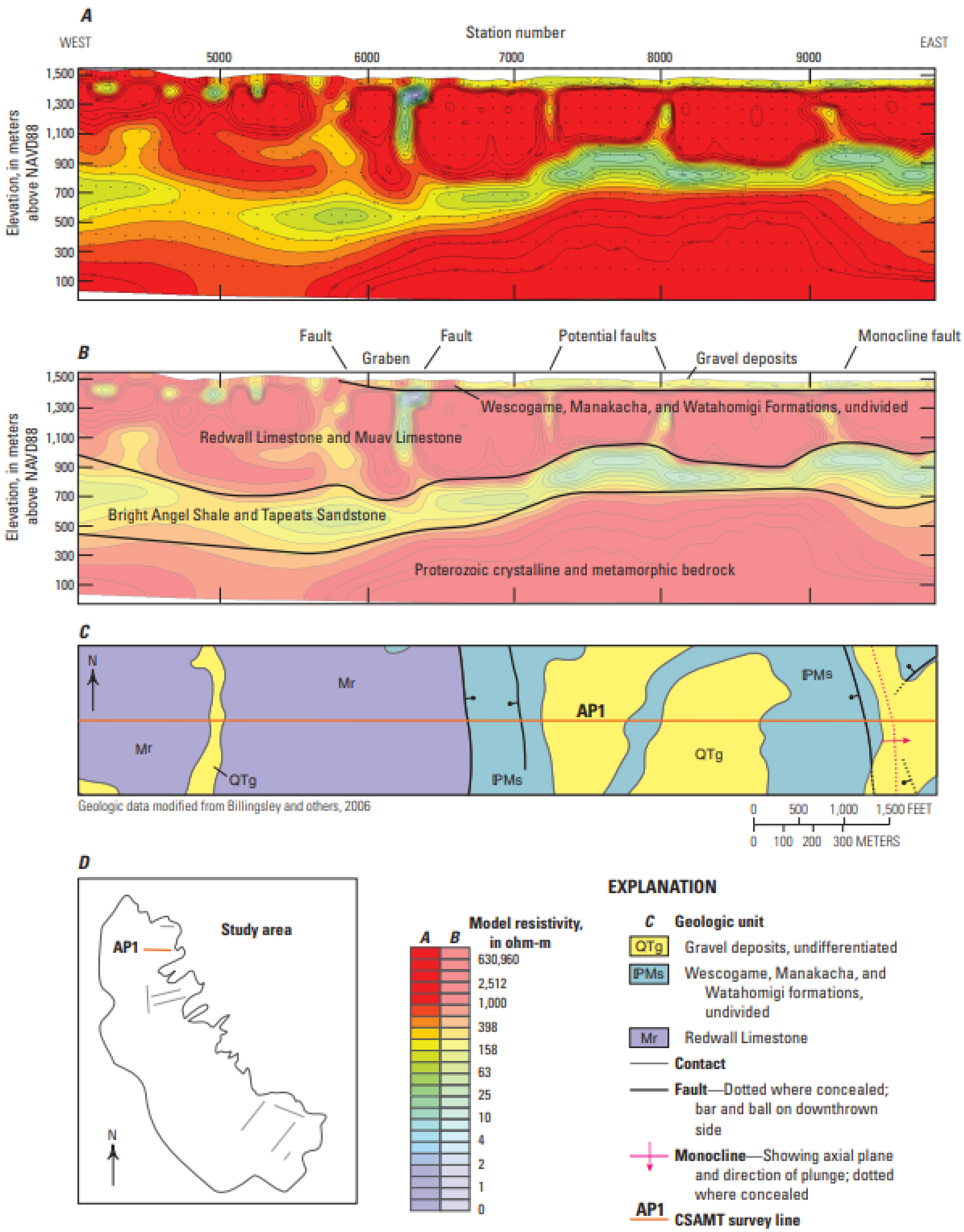


Figure 5. Example controlled source audio-frequency magnetotelluric (CSAMT) transect showing fault influence on subsurface resistance from the western Hualapai Plateau in Mason and others (2020).

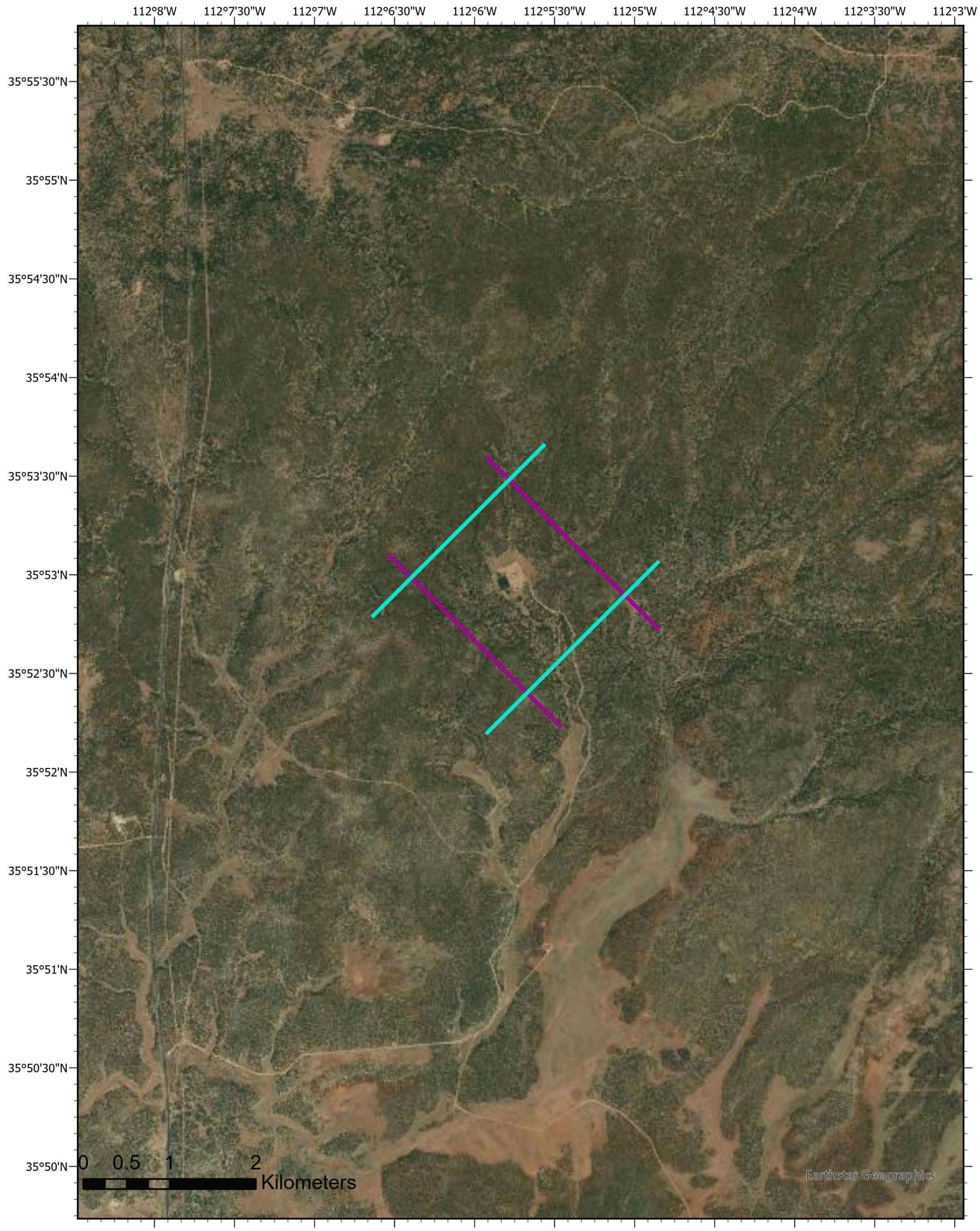
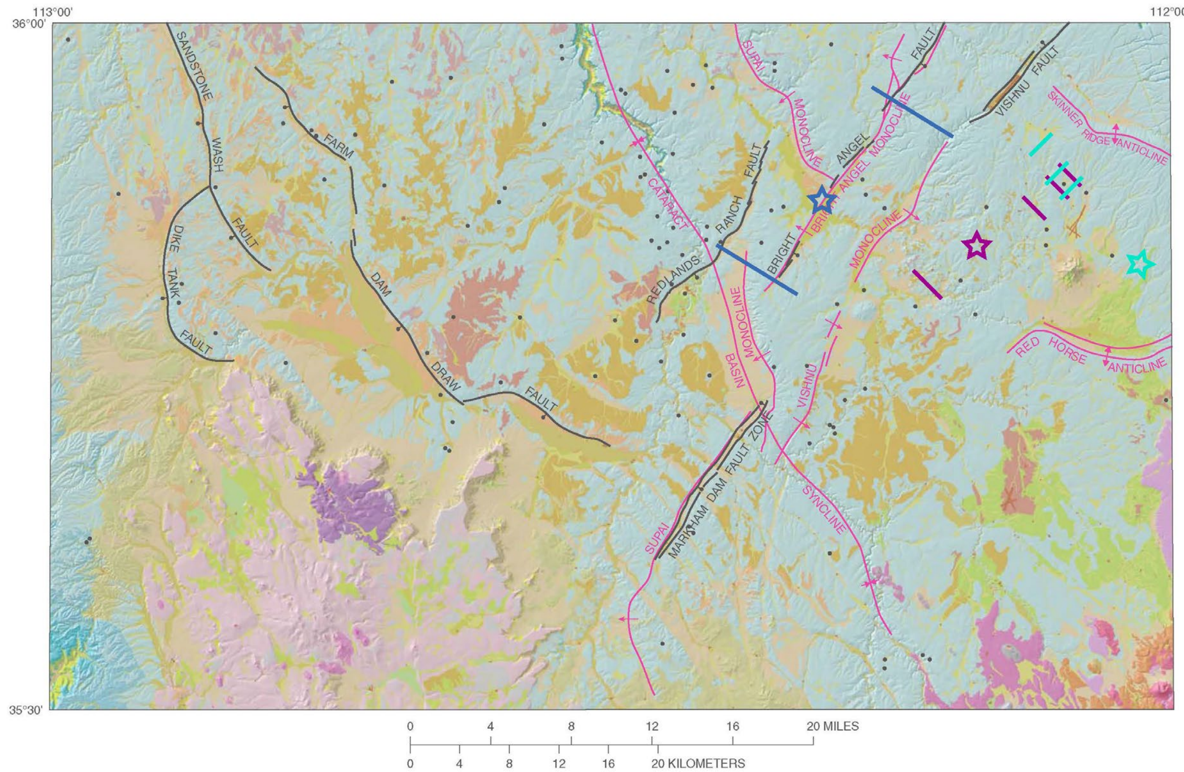


Figure 6. Proposed controlled source audio-frequency magnetotelluric (CSAMT) survey transects surrounding Pinyon Plain Mine. Colored stars on figure 7 indicate proposed locations of transmitters with transect lines corresponding to transmitter color.



Map showing Valle geology with hillshade derived from 30-meter digital elevation model (DEM). Black dot represents collapse structure.

Figure 7. Proposed expanded network of controlled source audio-frequency magnetotelluric (CSAMT) survey transects across structural features using the same transmitter locations as the near-mine assessment plus one additional transmitter shown as a blue star. Colored stars indicate proposed locations of transmitters with transect lines corresponding to transmitter color. Geology map from Billingsley and others (2006).

Subtask 1b. Structural Geology Assessment

Geophysical analysis can be enhanced with independent geologic mapping and structural measurements of faults and joints which can localize karst and can serve as fluid flow pathways. Efforts to seamlessly compile and update geologic mapping of the Grand Canyon region are currently being conducted by a team from the USGS's Geology, Minerals, Energy, and Geophysics science center in Flagstaff, Arizona. While that effort will include this area eventually, adding a focused assessment of fault and joint mapping using both Lidar and field observations in the area around Pinyon Plain Mine would benefit the ongoing mapping effort as well as characterization of the hydrogeology. Recent high-resolution Lidar coverage allows for not only the identification of unrecognized faults, especially in wooded areas (fig. 8) but also the quantification of the amount that beds are offset. Joints can also be seen in these data but are often better characterized by field measurements. Joint sets or networks are expected to vary laterally and vertically. Detailed mapping of these throughout the study area and within the variably exposed rock layers in the canyon and its tributaries would allow for an assessment of how these pathways change throughout the area of interest. This would complement earlier more regional

(1:250,000 scale) studies focused on identifying areas of penetrative fractures by correlating surficial features with geophysical lineaments (Gettings and Bultman, 2005). That study identified some potential penetrative fractures in the general mine site, but their analysis only provided a lower bound on fracture density.

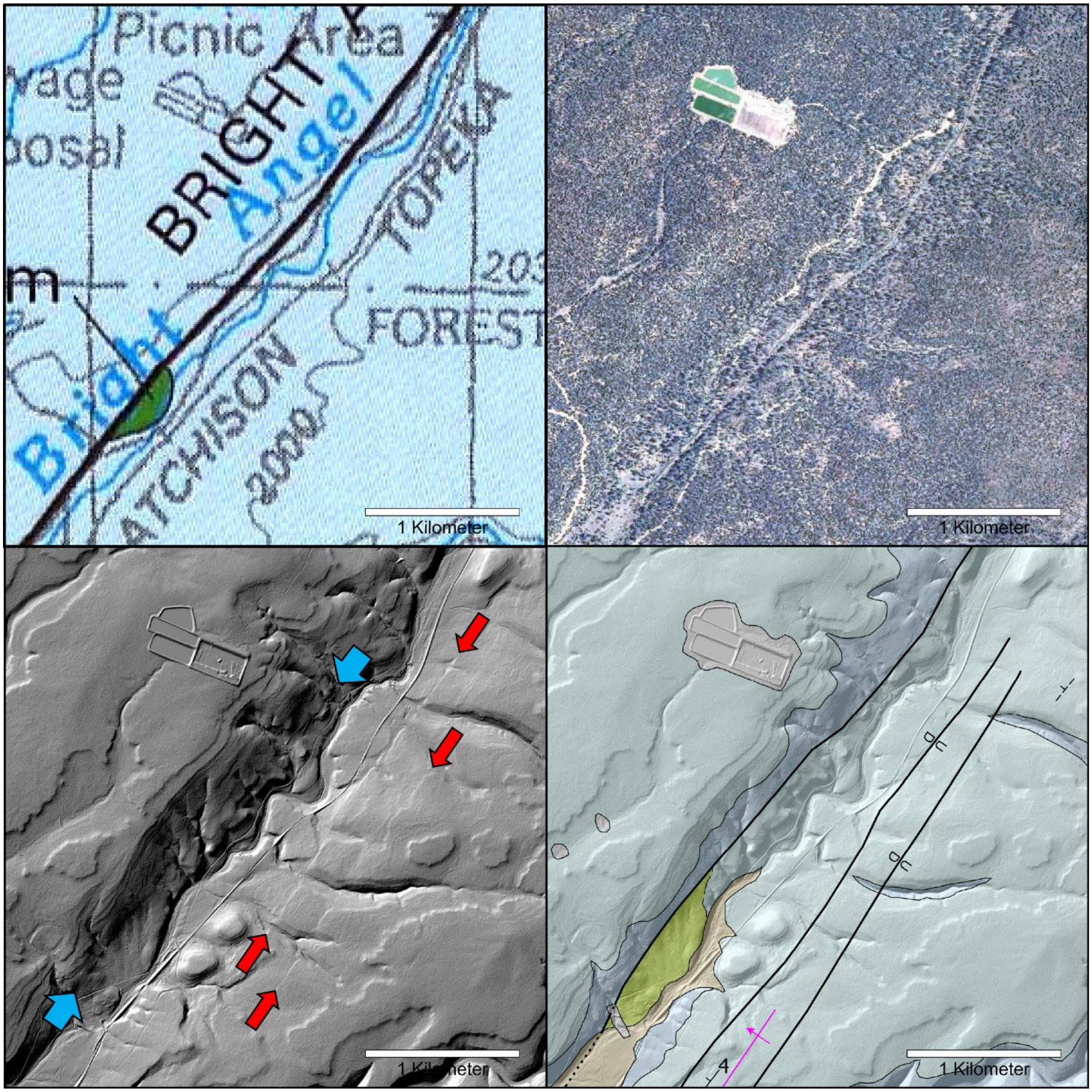


Figure 8. Example from the Bright Angel fault southeast of Grand Canyon Village of how high-resolution Lidar allows geologic mapping of subtle structural features that could influence possible fluid pathways. Upper left: Example of legacy geologic mapping prior to Lidar availability, which depicts a single strand of the Bright Angel fault (Billingsley and others, 2006). Upper right: NAIP aerial imagery, which does not readily facilitate recognition of structural features in forested areas. Lower left: Hillshade imagery of 1-meter Lidar. Blue arrows align along the primary topographic lineament of the Bright Angel fault, where the fault had been

previously depicted by legacy mapping. Red arrows highlight two newly-identified fault strands. Lower right: New unpublished geologic mapping, depicting the newly identified fault strands.

Recent dye trace studies from Jones and others (2017) and Beisner and others (2025) suggest water movement may be occurring along faults and in directions antithetical to them, likely along joints or fractures in the subsurface. The regional stress regime in the region (Lund Snee and Zoback, 2022) can influence which joints and fracture orientations may be open to fluid flow and which may be closed to fluid flow. Additional influences on restriction of fluid flow can be related to mineralization within joint and fractures. Joint and fracture orientation and character may also be dependent on the properties of the geologic unit and spatial location within the Grand Canyon region (fig. 9a). Our proposed work includes: field measurements of joints and fractures in the area surrounding Pinyon Plain mine, where such data are sparse; assessment of Lidar imagery for faults and lineaments in the area of Pinyon Plain mine that could potentially affect groundwater flow; assessment of joint patterns in the area of Cataract Canyon that leverage previously collected but unpublished joint measurements; and construction of geologic cross sections for each line of the CSAMT geophysical survey.

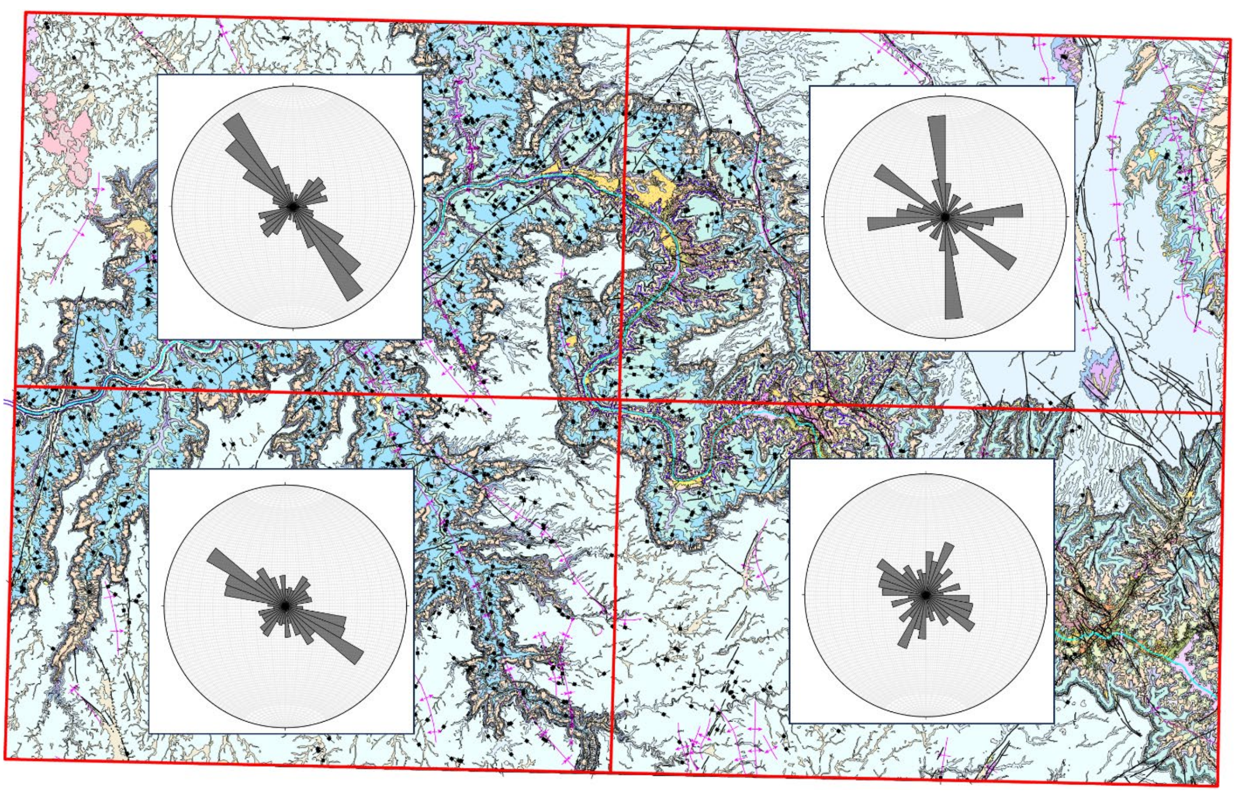


Figure 9a. Spatial differences in the patterns of joint measurements across the Grand Canyon region. Rose diagrams plot the relative proportions of joint strike. Data are from the in-progress Geologic Map of the Grand Canyon 30’ x 60’ Quadrangle (background) and are subdivided into quadrants of the map area. Differences in joint orientations may reflect spatial differences of jointing within and between stratigraphic units.

To assess jointing patterns in surface outcrops surrounding the Pinyon Plain mine, fieldwork will be conducted (two geologists for one week) to measure the patterns of observed fractures in the greater vicinity of the Pinyon Plain mine (south of Tusayan and north of Red Butte). The best available geologic mapping indicates a dearth of measurements in the region of the mine (fig. 9b), which inhibits the ability to assess jointing patterns in this area. Using Lidar to identify the areas of most promising outcrop, USGS geologists will survey this area and record measurements of jointing and other relevant fractures that could potentially affect fluid flow. Any mineralized joints will be noted as these may be sealed to fluid flow. The results will be presented with a rose diagram figure with joint orientations, text describing the methods and results, and a ScienceBase data release of joint measurements.

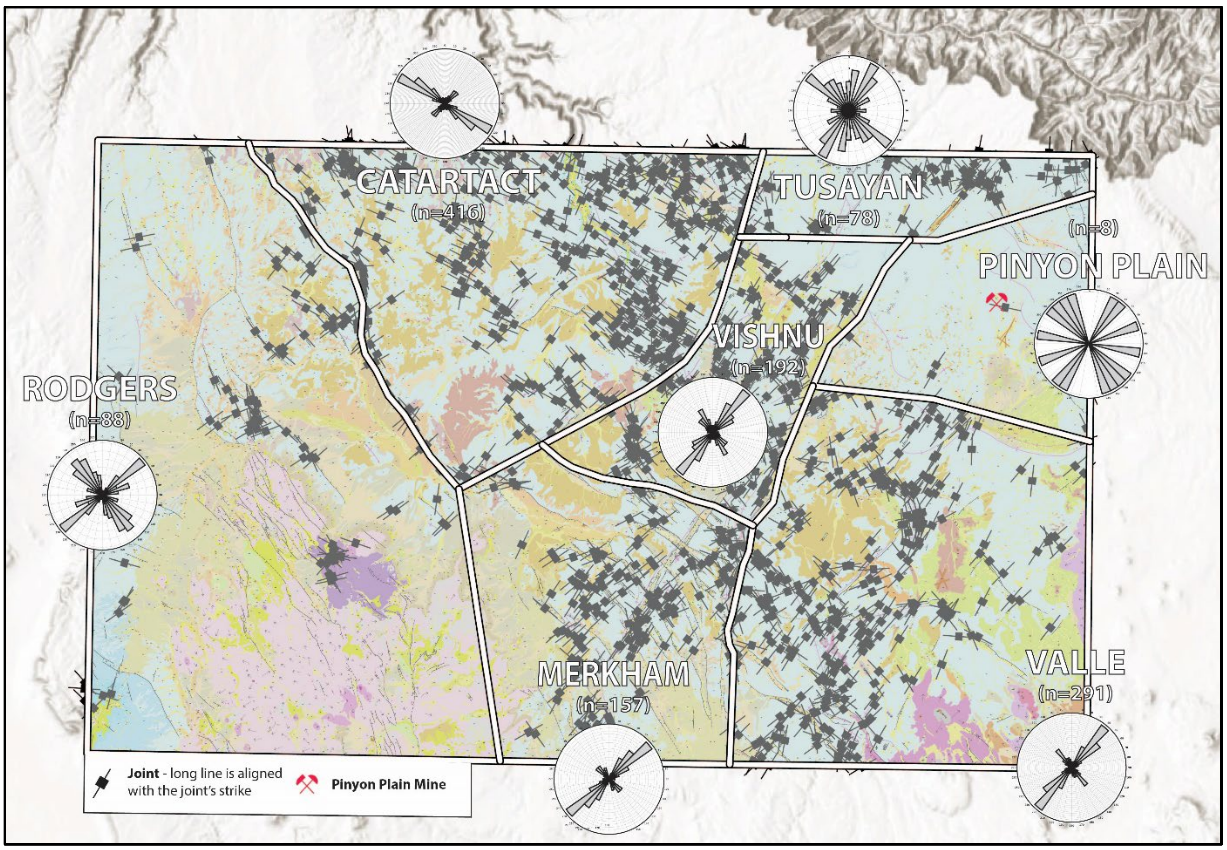


Figure 9b. Spatial differences in the patterns of joint measurements across the Valle 30’ x 60’ quadrangle. Rose diagrams plot the relative proportions of joint strike. Data are from Billingsley and others (2006) and are subdivided into named zones defined by faults and folds. The vast majority of joints measured are in the Kaibab Formation, so variations dominantly reflect spatial differences across the area, but stratigraphic differences are also expected in the subsurface and Cataract Canyon. Note that the area around the Pinyon Plain mine has almost no joint measurements. That area would be the focus of new measurements as well as Cataract Canyon, given access, to characterize stratigraphic variations in joint orientation. Colored polygons in the background indicate different rock types from Billingsley and others (2006).

Existing geologic mapping predated the advent of Lidar, which allows a greatly improved ability to map faults and lineaments in forested areas where traditional aerial imagery is obscured by tree cover. Assessment of Lidar imagery will occur in the office over a week for one geologist to assess the wooded area south of Tusayan and north of Red Butte for any potential unmapped faults and lineaments. The geologist will employ a variety of illuminations and stretches of the Lidar imagery, targeted to best reveal subtle structural features. Any such lineaments identified in the office will be visited in the field to assess their nature. The scope of this work will be limited to the forested areas as less vegetated areas to the west are likely already mapped sufficiently on published geologic maps. This work will produce a figure with Lidar of the area investigated, highlighting any identified linear features, and a written description of the methods and results.

An in-progress USGS geologic mapping effort to update the Grand Canyon 30’ x 60’ quadrangle includes new measurements of jointing in the Cataract Creek drainage at roughly quadruple the measurement density of existing published data in that area. In conjunction with published joint measurements from the Valle 30’ x 60’ quadrangle, these data present an opportunity to analyze spatial and stratigraphic patterns of jointing in the lower portion of the watershed that includes the Pinyon Plain Mine. Cataract Canyon exposes stratigraphic levels below those exposed in the vicinity of the Pinyon Plain Mine, particularly the Esplanade Sandstone of the Supai Group, which commonly has a well-defined structural fabric defined by jointing surfaces. USGS geologists will assess the quality of these existing data, including evaluating and correcting for rotational errors introduced by legacy methods. Where satellite imagery depicts jointing not reflected by existing measurements, geologists will digitize new measurements to add additional density to the dataset. These data will then be analyzed using rose diagrams, separating diagrams by the stratigraphic units in which the joints were measured to evaluate the differences in jointing pattern across stratigraphic levels. These efforts will produce rose diagram figures and written descriptions of the methodology and patterns in the observed results. Jointing measurements will be released as a ScienceBase data release.

As an independent constraint and to guide the geological plausibility of interpreted geophysical sections, geologic cross sections will be developed along the lines of the CSAMT surveys. These cross sections will be constructed by USGS geologists working independent of the geophysical surveys and will be used to guide interpretation of CSAMT data. Geologists will synthesize the relevant geological data closest to each cross section, including geologic mapping, borehole records, and the nearest measured stratigraphic sections. The resulting products will include geologic cross sections to accompany each geophysical survey line, presented in figure format.

Task 2: Assess changes in water chemistry in the C- and R-aquifers at and nearby the Pinyon Plain Mine

Water chemistry is currently distinct between the shallower C-aquifer and deeper R-aquifer in wells at the Pinyon Plain Mine site especially for stable isotopes of oxygen and hydrogen (fig. 10) and uranium concentration (fig. 11; Beisner and others, 2020; Solder and Beisner, 2020; Beisner and others, 2023b). The distinct chemistry provides a useful geochemical tracer for assessing future changes in water chemistry related to mixing of water between the aquifers. Reduction and oxidation (redox) conditions in the aquifers can influence the trace element mobility, which can have different effects on elements of concern associated with mineralized breccia pipe deposits.

For example, uranium is generally more mobile in groundwater with oxidizing conditions (Tillman and others, 2021) while arsenic is generally more mobile in groundwater with reducing conditions (Tillman and others, 2023). Uranium concentration in the Pinyon Plain observation well in the C-aquifer is low (less than 5 µg/L with half of the 8 samples to date less than 1 µg/L) (fig. 11). Regional average uranium concentration from 28 groundwater sites south of Grand Canyon in the R-aquifer was 6.1 µg/L and the lowest concentration was 1 µg/L from Grapevine Spring (Beisner and others, 2020). The low uranium concentration in the Pinyon Plain observation well may be influenced by the lack of dissolved oxygen in water from the well, but could change if redox conditions become more oxidizing. A change to more oxidizing conditions is expected in the areas dewatered during mining and changes in redox conditions could occur following mining operations as groundwater interacts with the mine workings. Continued monitoring of water chemistry from groundwater in the C- and R-aquifers in the Pinyon Plain Mine wells in addition to other sites in the region is needed to understand changes during and after mining activity at Pinyon Plain Mine.

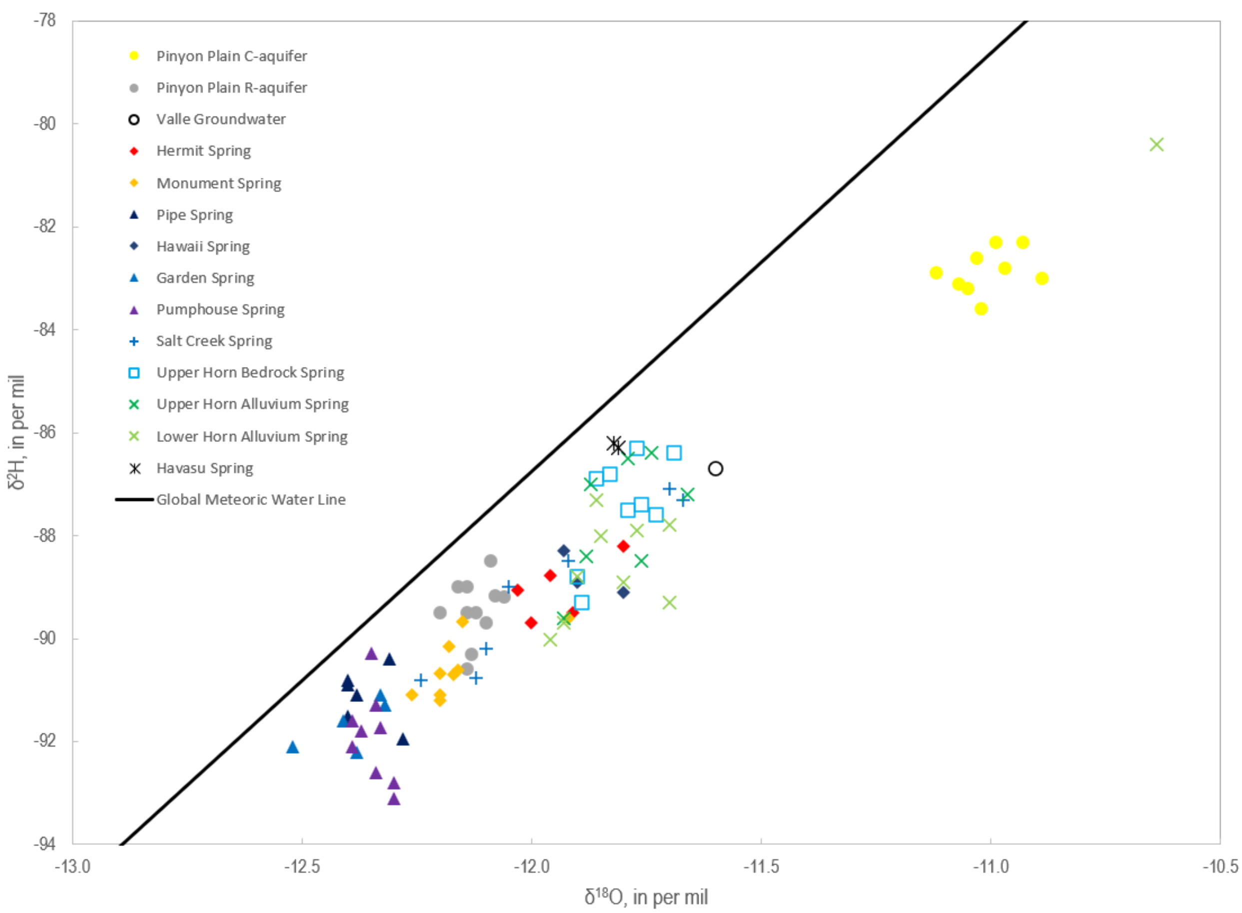


Figure 10. Stable isotope values from groundwater in the region (modified from Beisner and others, 2023b with additional data from the Pinyon Plain wells collected in 2022-2024).

Recently, several investigations focusing on effluent from the wastewater treatment plant on the South Rim of Grand Canyon National Park have been published, and results from these studies are relevant to our understanding of the potential for fast groundwater flow paths near Pinyon Plain Mine. Beisner and others (2023a) found wastewater tracers (including PFAS, artificial sweeteners, and pharmaceutical compounds) at Monument Spring along the South Rim of Grand Canyon as well as detections of fluorescent dye added to the wastewater effluent discharged to Bright Angel Wash from Grand Canyon National Park (Beisner and others, 2025). The combination of wastewater tracers and dye detection was not observed at several other springs in the Hermit Creek through the Pipe Creek drainage along the South Rim of Grand Canyon. Crossey and others (2024) proposed that wastewater from Grand Canyon National Park may be present at every spring along the South Rim of Grand Canyon, and also in the groundwater at Pinyon Plain Mine, based on evidence using stable isotopes of water as an indicator of wastewater. Direct measurements of wastewater tracers at other springs along the South Rim of Grand Canyon do not support wastewater presence at all springs along the South Rim of Grand Canyon and stable isotopes are not a unique tracer of wastewater in the Grand Canyon system (Beisner and others, 2023a). Additionally, no sampling of specific wastewater tracers has occurred in the groundwater wells at Pinyon Plain Mine to assess the assertion of wastewater contribution (U.S. Environmental Protection Agency, 2024). It would be important to sample directly for human made compounds associated with wastewater including PFAS, artificial sweeteners, and pharmaceutical compounds to assess the possibility of a groundwater flow path from the South Rim wastewater treatment plant to the groundwater at Pinyon Plain Mine.

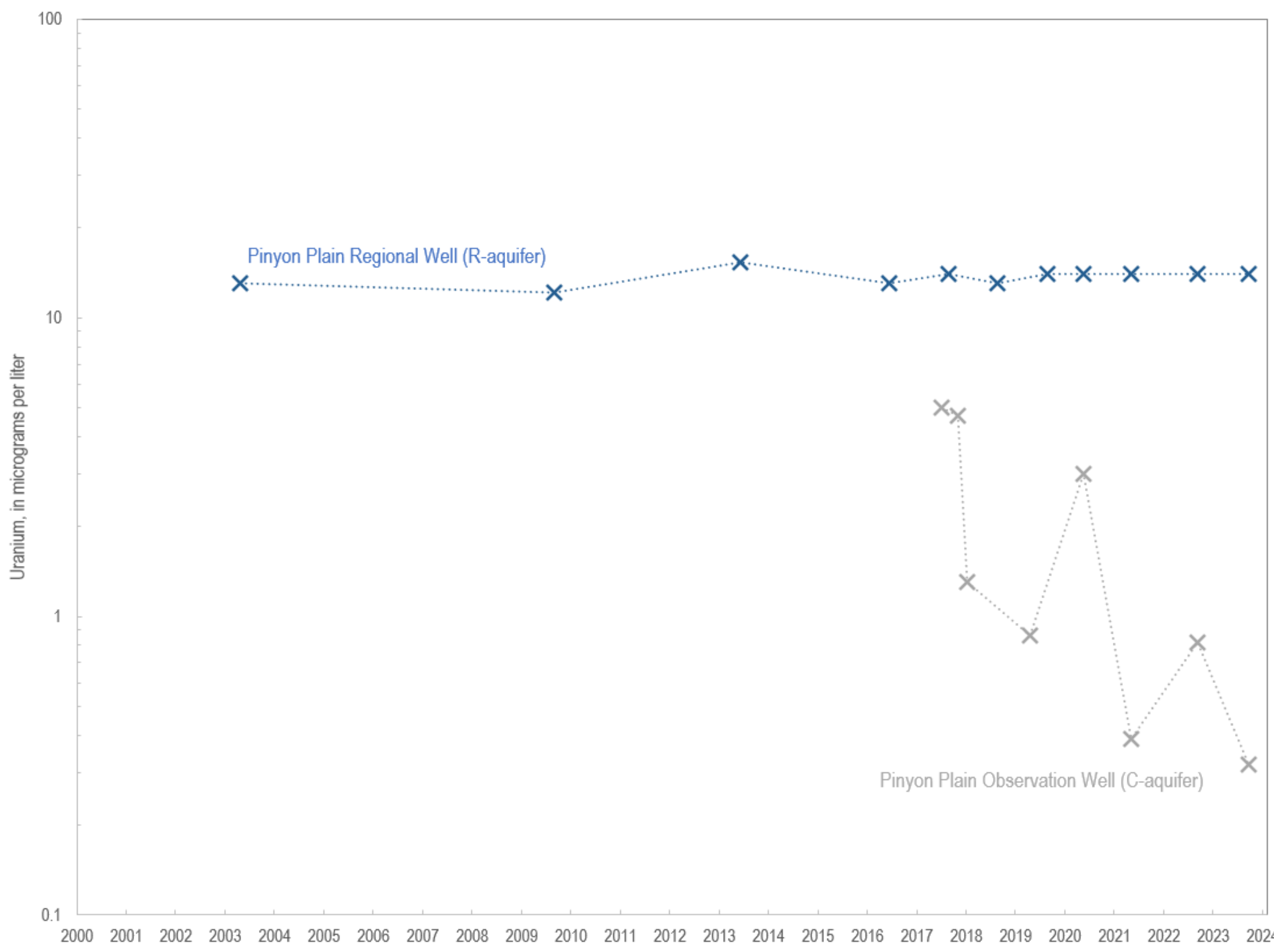


Figure 11. Uranium concentration variability over time from groundwater near Pinyon Plain Mine (data from U.S. Geological Survey, 2025).

Water chemistry samples have been collected on an annual basis at the USGS-installed Pinyon Plain observation well in the C-aquifer and from the Pinyon Plain regional well in the R-aquifer since 2017, with additional sample results available from 2003, 2009, 2013 and 2016 (fig. 11). Expanding water chemistry sample collection to semi-annually during mining activity would provide valuable information on variability and changes in water chemistry. Sampling of the Pinyon Plain regional well is contingent on permission from the mining company.

Groundwater sites in the R-aquifer south of Grand Canyon are limited and one of the largest springs in the region is Havasu Spring, which is understood to be representative of an integration of water in the R-aquifer south of Grand Canyon (Bills and others, 2007). Water quality samples were collected by USGS from Havasu Spring in 1994 and 2016 (U.S. Geological Survey, 2025). Additional samples from Havasu Spring are needed to assess natural variability as well as to provide baseline water chemistry to evaluate changes in groundwater over time. If permission is granted from the Havasupai Tribe, annual water samples will also be collected from Havasu Spring in addition to the wells near Pinyon Plain Mine.

Water samples will be collected once a year and analyzed for water quality parameters (temperature, specific conductance, pH, dissolved oxygen, and oxidation reduction potential), stable isotopes of oxygen and hydrogen, major ions and trace elements, uranium isotopes (^{234}U and ^{238}U), tritium, PFAS, and wastewater tracers at the same laboratories that have been utilized for previous sampling (USGS Reston Stable Isotope Laboratory, USGS Integrated Water Chemistry Assessment Laboratory, USGS Denver Radiogenic Isotope Laboratory, University of Miami Tritium Laboratory, SGS Orlando, and USGS Kansas Organic Chemistry Laboratory). It is important to consider that absence of observed water quality change at monitored sites does not exclude the possibility of water quality change occurring in the aquifer at other locations or at later times.

Data Analysis and Review

Geophysical survey data and structural geology measurements will be analyzed and reviewed following collection. Water quality data will be released as preliminary data to the publicly available NWIS database (U.S. Geological Survey, 2025) and then will be reviewed and approved. Rerun and verification requests will be made for water quality data with issues that arise during the review process and will be documented and values updated as necessary.

Interpretations and Reporting

In the second year of the project, a peer-reviewed journal article or USGS series report will include publication of the geophysics, structural geology, and water chemistry data collected during this project, along with interpretations of these data. Geophysical survey data and structural geology measurement data will be published as ScienceBase products.

Relevance and Benefits

Data and interpretation from the proposed work will improve understanding of current hydrologic conditions at the Pinyon Plain Mine site and the potential for groundwater movement away from the site towards water sources, an important issue for regulators, tribal communities, and others in the region. The study directly supports the USGS Water Science Strategy by advancing understanding of processes that determine water availability, delivering timely hydrologic data and analyses to support water-resource decisions (Evenson and Orndorff, 2013), and strengthening linkages among Federal, Tribal, and State organizations (U.S. Geological Survey, 2021).

Quality Assurance Plan

Quality assurance (QA) measures will be followed to ensure completeness of the information communicated during the study. The QA objectives for collection and communication of information will:

- Withstand scientific scrutiny
- Be obtained by methods appropriate for the information and its intended use, and
- Be representative and of known completeness and comparability.

All data will be collected in adherence to USGS standards and methods and water quality samples will be collected according to the USGS National Field Manual for the Collection of Water Quality Data (U.S. Geological Survey, variously dated).

All data will be reviewed by USGS personnel to ensure proper documentation. The project and project budget will be reviewed by USGS management on a semi-annual basis to ensure project timelines are met. USGS products are impartial, credible, relevant, provide timely information, and are equally accessible and available to all interested parties.

Quality assurance samples provide important context for the environmental samples to understand potential contamination from sampling equipment or ambient sources near sampling sites (blanks) and variability of concentrations at each site (replicates) and one of each will be collected once per year with the environmental samples.

Deliverables

Geophysical survey results and structural geology measurements will be published in ScienceBase. Water quality data will be entered into USGS National Water Information System (NWIS), and the data will be publicly available as the results are released from the laboratories as preliminary data, then reviewed and approved. A report summarizing the findings of the investigations will be published as a journal article or USGS series report.

Timeline and Budget

Table 1. Timeline is based on state fiscal year (SFY) where Q1 starts July 1 and Q4 ends June 30.

Task	SFY2026				SFY2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1a: Geophysical Assessment								
Task 1b: Structural Geology Assessment								
Task 2: Water Quality Assessment								
Data Analysis and Review								
Interpretations and Reporting								

*Note: Havasu Spring samples and joint assessment in Cataract Canyon are dependent on permission from the Havasupai Tribe.

Personnel

Geophysical data acquisition and interpretation will be conducted by experienced hydrologists who have applied these techniques in other areas of northern Arizona. Structural measurement and Lidar interpretation will be conducted by experienced geologic mappers some of whom have been working in the area for decades. Water chemistry samples will be collected by experienced hydrologic technicians who have taken the USGS Field Methods for Water Quality Sample Collection class. An experienced hydrologist who specializes in water quality will oversee data collection, review and data approval.

References

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Beisner, K.R., Paretti, N.V., Jasmann, J.R., and Barber, L.B., 2023a. Utilizing anthropogenic compounds and geochemical tracers to identify preferential structurally controlled groundwater pathways influencing springs in Grand Canyon National Park, Arizona, USA, Journal of Hydrology: Regional Studies, 48 101461, https://doi.org/10.1016/j.ejrh.2023.101461.

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