Phase 3 Year 1 Annual Report

October 30, 2020

Revised December 28, 2020

UTAH FORGE
U.S. Department of Energy

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A. OVERVIEW OF PHASE 3 YEAR 1 ACTIVITIES

BACKGROUND

In 2018, the U.S. Department of Energy (DOE) selected a site in south-central Utah as the location of its Frontier Observatory for Research in Geothermal Energy (FORGE). The site is located 217 miles (350 km) south of Salt Lake City and a similar distance northeast of Las Vegas, NV (Figure A-1). The closest population center to the Utah FORGE site is Milford, a rural community of 1450 residents 10 miles (16 km) to the south.

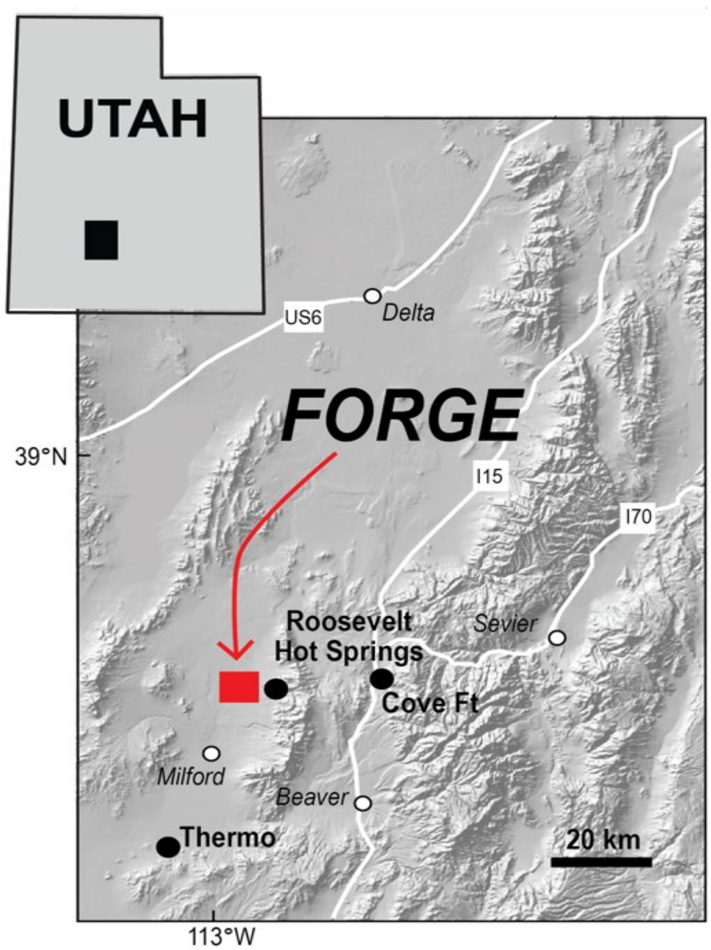

***Figure A-1**. Location of the Utah FORGE site.*

The Utah FORGE site is situated within Utah's Renewable Energy Corridor. A 306 MWe wind farm and a 240 MWe solar field lie immediately to the west (Figure A-2). To the east is PacifiCorp's 38 MWe Blundell geothermal plant at Roosevelt Hot Springs. A new biogas pipeline runs east-west across the Utah FORGE site. A biogas facility and Cyrq Energy's geotheral power plant are situated south of Milford (Figure A-3). Here, within the corridor the Utah FORGE project showcases the role of geothermal energy and Enhanced Geothermal Systems (EGS) as a renewable source of power for the nation. Our geoscientific investigations demonstrate the surrounding region holds significant potential for future EGS development. There are no cultural or environmental restrictions that limit drilling and research activities, and sufficient nonpotable water has been acquired for all testing needs. In addition, the risk of induced seismicity is low. The community, Beaver County, Utah State, and the regulatory agencies have enthusiastically supported the project.

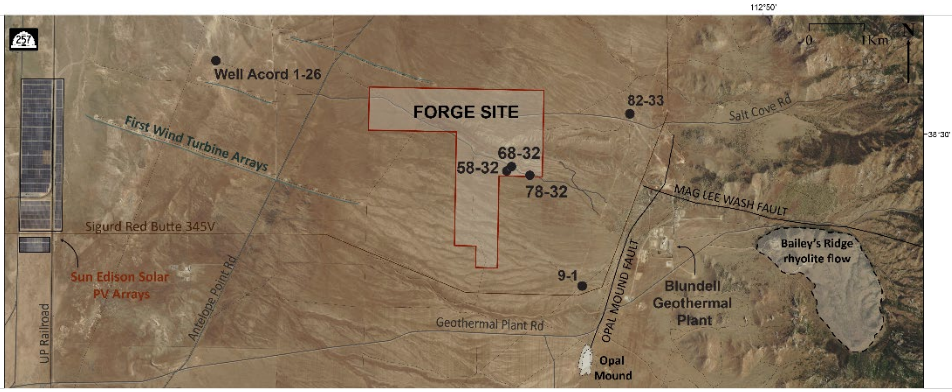

Figure A-2. *Renewable energy projects surrounding the Utah FORGE site.*

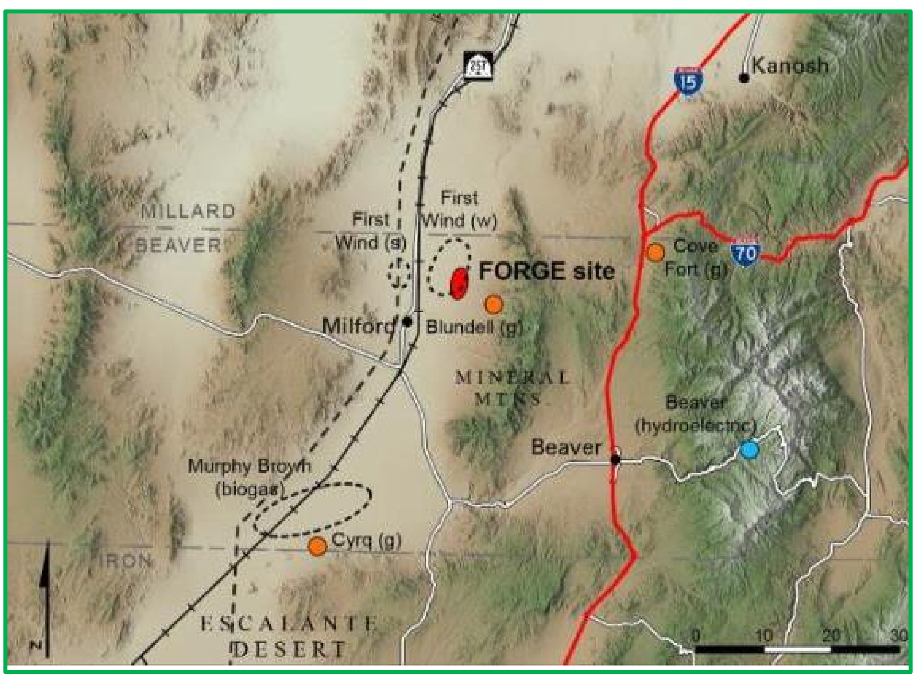

Figure A-3. *Renewable energy projects within the Renewable Energy Corridor. The Utah FORGE site is located within the red oval. Orange circles show the locations of the geothermal fields. The solar field west of the Utah FORGE site is labeled First Wind.*

PHASE 3 OBJECTIVES

The ultimate objective of Utah FORGE is to demonstrate the viability of Enhanced Geothermal System (EGS) energy development. The project will create a controlled environment where EGS technologies and approaches can be developed, tested and optimized. The laboratory will function as a dedicated site for technical interaction and public education to support the widespread adoption of EGS as an energy source. The current budget cycle consists of Years 1 and 2 of Phase 3, which include the following activities:

- Plan a seismic network for monitoring induced and natural seismicity.
- Build the supporting infrastructure and instrumentation necessary for monitoring the drilling and testing of well 16A(78)-32, which will serve as the injection well during creation of the Utah FORGE EGS reservoir.
- Design, plan, drill and test well 16A(78)-32, the first full-sized EGS well at the site.
- Plan and drill a deep seismic monitoring well north of the trajectory of well 16A(78)-32.
- Solicit, competitively award, and track Research and Development (R&D) awards.
- Provide outreach that showcases to the public, stakeholders, and the energy industry that EGS technologies have the potential to contribute significantly to power generation in the future.
- Provide educational and research opportunities for students at all levels.
- In collaboration with DOE, develop a comprehensive annual report summarizing activities, successes, and lessons learned at the Milford site.

PHASE 3 YEAR 1 ACTIVITIES

This report presents an overview of Phase 3 Year 1 activities. Year 1 activities transition the Utah FORGE project from site characterization and baseline monitoring to the initial creation of the EGS reservoir. Plans for the first deep well (16A(78)-32), which will form the centerpiece of the Utah FORGE laboratory, were approved and the majority of contracts are in place to begin drilling in late October 2020.

New infrastructure that will support the drilling, monitoring and R&D activities, including an electric distribution line, a communications network, and well pads and roads were constructed (Figure A-4). The electric distribution line, extending from west of Antelope Point Road eastward across the Utah FORGE site was completed. All but one of the spur lines that will provide electricity for operational and R&D activities were constructed by Rocky Mountain Power. The remaining spur line, and the electric connections from the spur lines to the pads for housing and support facilities, internet connections, communication, pumps and other infrastructure needs will be completed in Year 2.

Monitoring of the microseismicity surrounding the Utah FORGE site continued. No seismic events beneath the Utah FORGE site were recorded. An updated Probabilistic Seismic Hazard Analysis (PSHA) was completed. The results reduced previous estimates of seismic hazards; the risk from induced seismicity remains low.

A seismic monitoring network capable of detecting low magnitude induced and natural seismic events was designed and outlined in the seismic plans. Three wells currently comprise the central portion of the network; wells 58-32, 68-32 and 78-32 were drilled in Phase 2. The Plan for well 56-32, a 7500 ft monitoring well that will be instrumented with a high temperature DAS cable was approved and the DAS cable was purchased. The deep monitoring wells will be surrounded by 2 rings of shallow boreholes at 3 and 8 km (1.9 and 5.0 miles). Three shallow boreholes, BOR-1, BOR-2 and BOR-3, each ~100 ft deep and located on the edge of the Utah FORGE footprint on the 3 km (1.9 mile) ring were drilled. Broadband instruments will be deployed in these boreholes in early FY 2021.

Solicitation 1 was released in May 2020. Concept papers in five topical areas: zonal isolation, estimation of stress parameters, field-scale characterization of reservoir evolution, stimulation and configuration of the injection/production well pair, and integrated laboratory and modeling studies were submitted by applicants representing universities, National Laboratories, USGS, oil and gas and geothermal service providers and private consultants. Up to 19 awards, totaling $46 M will be awarded in the first half of FY 2021.

Our outreach program has expanded geothermal awareness to the public, the scientific community, and regulatory agencies. The team has grown and now consists of a full-time communications specialist and two new student interns, and a PhD student specializing in K-12 education in the College of Education. Information about geothermal energy is distributed through online presentations, a podcast, published reports, a Capstone class in the Department of Communication at the University of Utah, an updated website, and an e-newsletter “At the CORE”

InSAR, gravity, water levels and GPS monitoring continued in order to document naturally occurring ground deformation. The gravity, water level and GPS data reflect temporal variations interpreted to result from seasonal changes in precipitation. No deformation was observed in the InSAR data. The conceptual geologic model has been updated with new results from the analysis of the regional magnetotelluric survey, which show the absence of conductive zones that could be related to hydrothermal alteration or hot fluids beneath the Utah FORGE site, consistent with all earlier data that indicate the EGS reservoir is made of hot dry granitoid.

Figure A-4. *Utah FORGE infrastructure. The dotted line shows the trajectory of well 16A(78)-32.*

B.1 SITE INFRASTRUCTURE & OPERATIONS

ELECTRIC INFRASTRUCTURE

The main electric distribution line was installed through the Utah FORGE site. Three additional spur lines were installed to the well 16A(78)-32/16B(78)-32 pad (Site B in Figure B.1-1), the well 58-32 pad (Site C) and the well 78-32 pad (Site D).

An additional spur line will be constructed to the north in order to provide power to the seismic monitoring well 56-32 (Site E). A contract for this additional line is in place with Rocky Mountain Power, pending easement approval from the land owners, the Utah School and Institutional Trust Lands Administration (SITLA). The new spur line is expected to be completed in mid FY 2021.

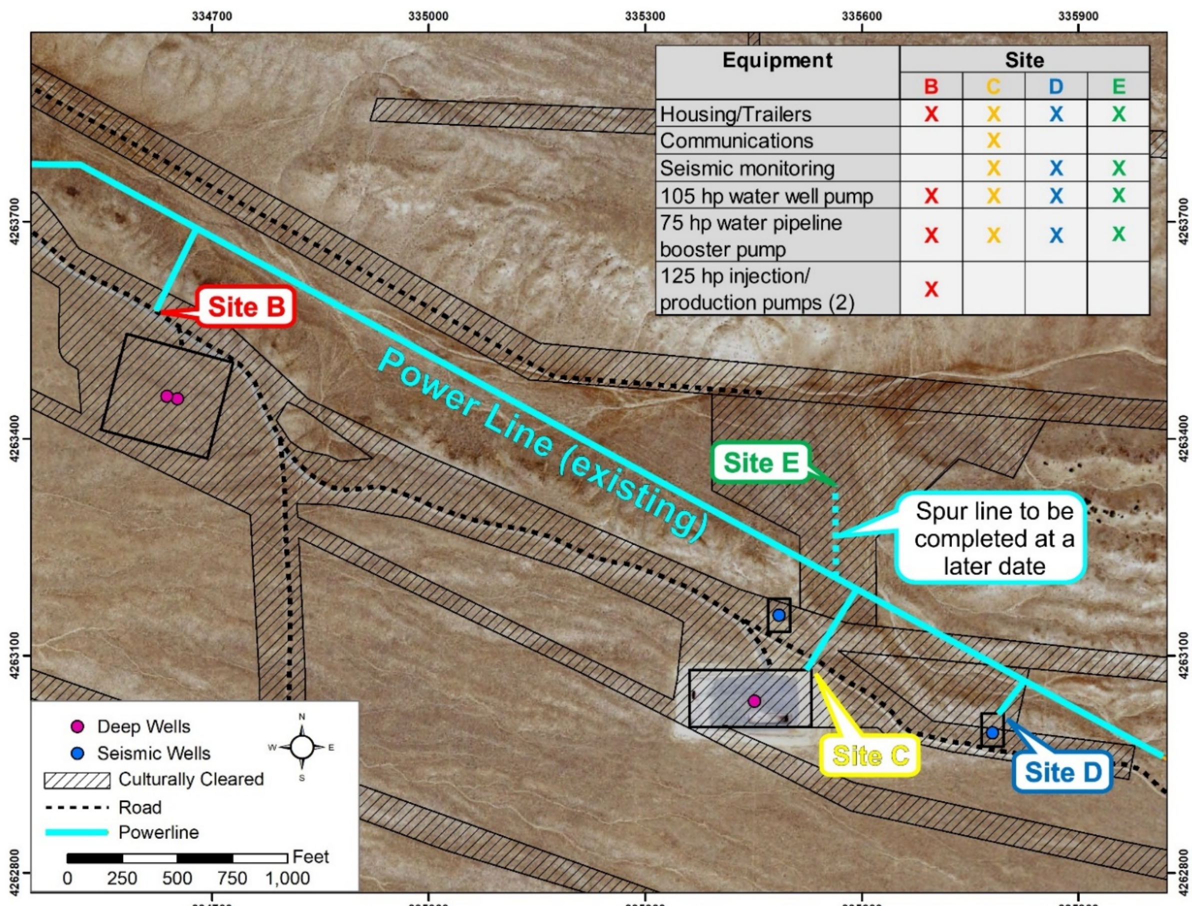

Figure B.1-1. *Map showing the main electric distribution line and its spurs within the Utah FORGE site. The main electric distribution line and the spur lines to sites B, C and D have been completed. The spur line to Site E will be completed at a later date. The black boxes around wellheads (pink and blue circles) are the approximate dimensions of the well pads.*

A contract is in place with a local electrician (A&F Electric) to install the electric infrastructure between the terminations of the spur lines installed by Rocky Mountain Power and the points of ultimate use within the FORGE site. The electric infrastructure will be completed in three phases to accommodate the developing needs at the site. The first phase is expected to begin in early FY 2021.

EARTH WORK

The following earth work has been completed (Figure B.1-2):

1. The drill pad for wells 16A(78)-32 and 16B(78)-32, an access road and the sump for the wells (see also Figure B.1-3).
2. A ~5,000 ft access road along the bottom of the Mag Lee Wash to the proposed location of seismic monitoring well 56-32.
3. Construction of a 100 by 150 ft pad at the initial location of well 56-32.
4. Small drill pads for shallow seismic monitoring wells BOR-1, BOR-2, BOR-3 (Figure B.1-4).

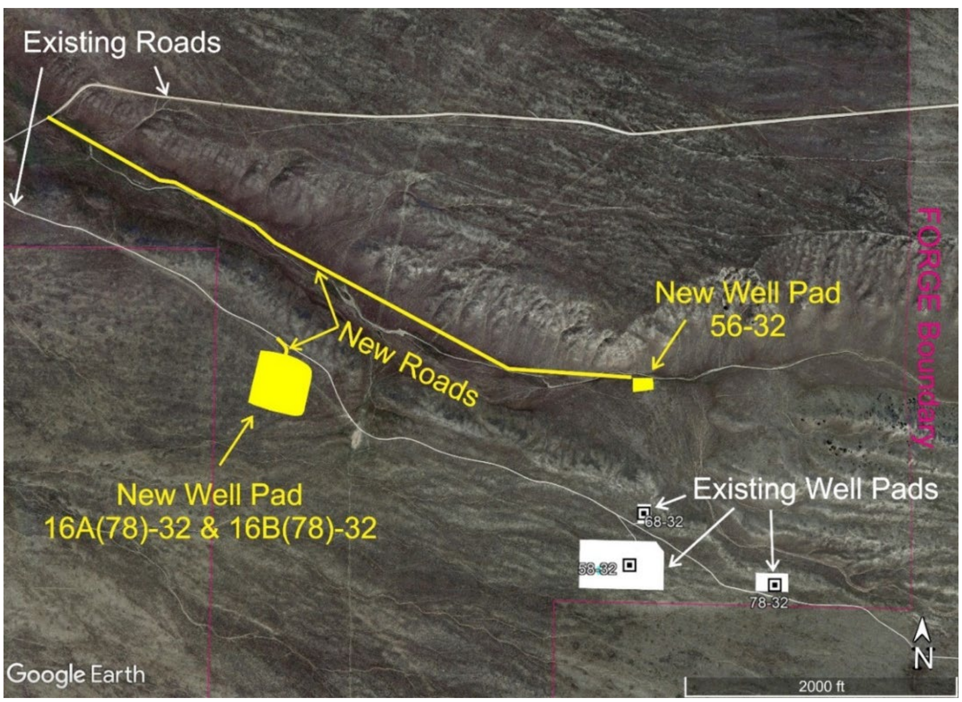

Figure B.1-2. *Summary of earth work developments; new developments are shown in yellow and preexisting developments are shown in white. The new well pad, 56-32 is located in the bottom of the Mag Lee Wash.*

Figure B.1-3. *Photo of the 16A(78)-32/16B(78)-32 well pad looking to the southwest, showing the sump under construction. The 16A(78)-32 conductor pipe and rat hole are just visible on the right side of the sump.*

INTERNET CONNECTION/COMMUNICATIONS

A microwave radio link to bring high-speed internet to the Utah FORGE site has been installed by Utah Education and Telehealth Network (UETN). The radio antennas have been installed at Milford High School and the communications mast on the well 58-32 pad (Figure B.1-4). Supporting equipment will be housed in the adjoining trailer on the drill pad. The radio link was installed at minimal cost with no additional recurring monthly charges for equipment or data, due to the University of Utah's and Utah FORGE's educational nature/mandate. Once power is brought from the termination of the spur line to the communications mast and trailer in early FY2021, the site will have full connectivity at speeds up to 100 Mbps. The communication link will be used to relay data from the seismic network and the continuous GPS stations, and to facilitate R&D activities at the site.

Figure B.1-4. *Aerial view of the 58-32 well pad looking to the southeast, with the 78-32 well pad in the background (upper left). The microwave radio link delivering high-speed internet from Milford High School is located on the communication mast, with supporting equipment housed in the trailer.*

CULTURAL CLEARANCES

In anticipation of future operational and R&D requirements, including recommendations from the STAT and DOE to relocate and deepen well 56-32 from 5000 to 7500 ft, new cultural surveys were conducted by SWCA (Figure B.1-5). The new surveys provide a contiguous block of cleared land between the western side of Mag Lee Wash south to wells 58-32 and 78-32 and several potential drill pad sites on the northern rim of the wash. The cleared land on the south slope of the wash will, in addition, allow for an uninterrupted surface connection between the DAS cables in wells 78-32 and 56-32 and new electrical spur lines.

The existing 56-32 well pad was constructed to accommodate DOE, Seismic Advisory Team (SAT) and operational requirements including: 1) drilling well 56-32 prior to 16A(78)-32; 2) locating well 56-32 within 1000 ft of the 16A(78)-32 trajectory; 3) locating the drill pad on culturally cleared land; and 4) minimizing the need for extensive earthwork on the slopes of Mag Lee Wash. The final location is to be determined following completion of well 16A(78)-32.

Figure B.1-5: *Additional areas that have been culturally cleared within the Utah FORGE site are shown in yellow. Existing culturally cleared areas are shown in orange. The trajectory of 16A(78)-32 is shown in white.*

MICROSEISMIC MONITORING

Monitoring of microseismicity surrounding the Utah FORGE site continued. Microseismicity remains at a low level and no activity was detected beneath the Utah FORGE footprint. The configuration of a seismic network for monitoring during drilling, stimulation and long-term flow testing was developed (Figure B.1-6). The proposed network comprises two concentric rings of shallow boreholes 100 ft deep, plus additional sites at distances of 3 and 8 km (1.9 and 5.0 miles) from the center of the Utah FORGE reservoir. Four wells, 58-32, 68-32, 78-32 and 56-32 (Figure B.1-2), located within about 1000 ft of the trajectory of well 16A(78)-32, will form the central part of the network.

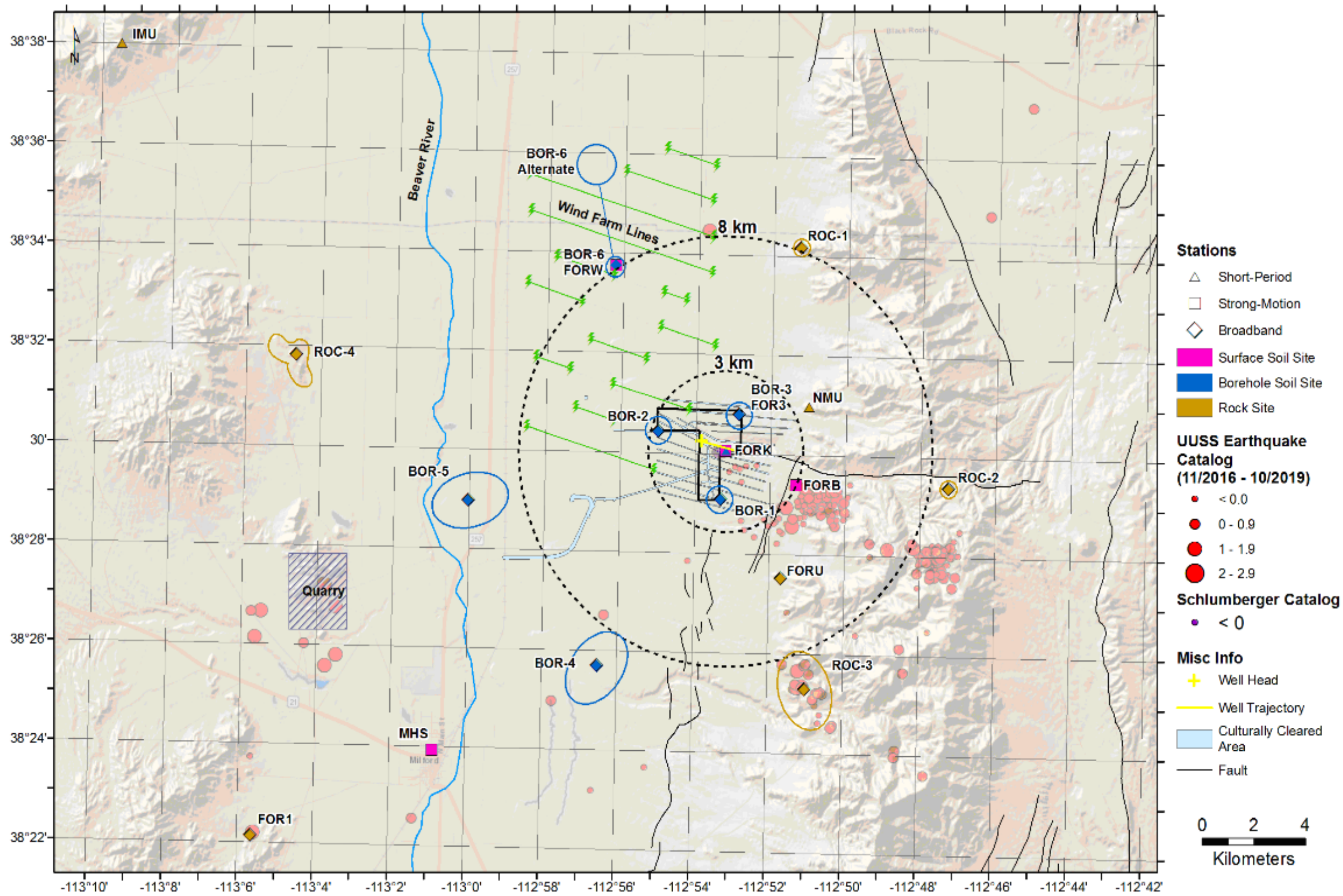

Figure B.1-6. *Map showing the locations of landmarks, seismic events since November 20. A strong motion sensor that had previously been installed at Milford High School (MHS) will be reinstalled in early FY 2021. Hog farms (not shown) are located west of the Utah FORGE footprint between the windmill rows.*

A detailed well plan was prepared for seismic monitoring well 56-32, which will be drilled vertically to 7500 ft north of the 16A(78)-32 well trajectory in the Mag Lee Wash (Figure B.1-2). A DAS cable containing Silixa's high-resolution Constellation fiber will be installed to total depth. The cable has a temperature rating of 300°C. The DAS cable can be tethered to the cable in 78-32, allowing both cables to be monitored simultaneously.

WELL 16A(78)-32

Detailed plans were prepared for well 16A(78)-32, which will be spudded in late October 2020 (https://gdr.openei.org/submissions/1216). It will have a true vertical depth of 8540 ft, a deviation angle 65° and a total length of 10,938 ft (Figure B.1-7). The lateral will be 4000 ft long. The temperature at total depth is predicted to be 227°C (442°F). The well will be cased with 7-inch casing to within approximately 200 ft of the toe. Diagnostic Fracture Injection Tests (DFITs) will be conducted at the heel and toe of the well. One-hundred and twenty feet of core will be collected in two sixty-foot sections. The first core will be taken at 5,500 to 5,560 ft in the vertical portion of the well, and the second at 10,878 to 10,938 at the toe of the well.

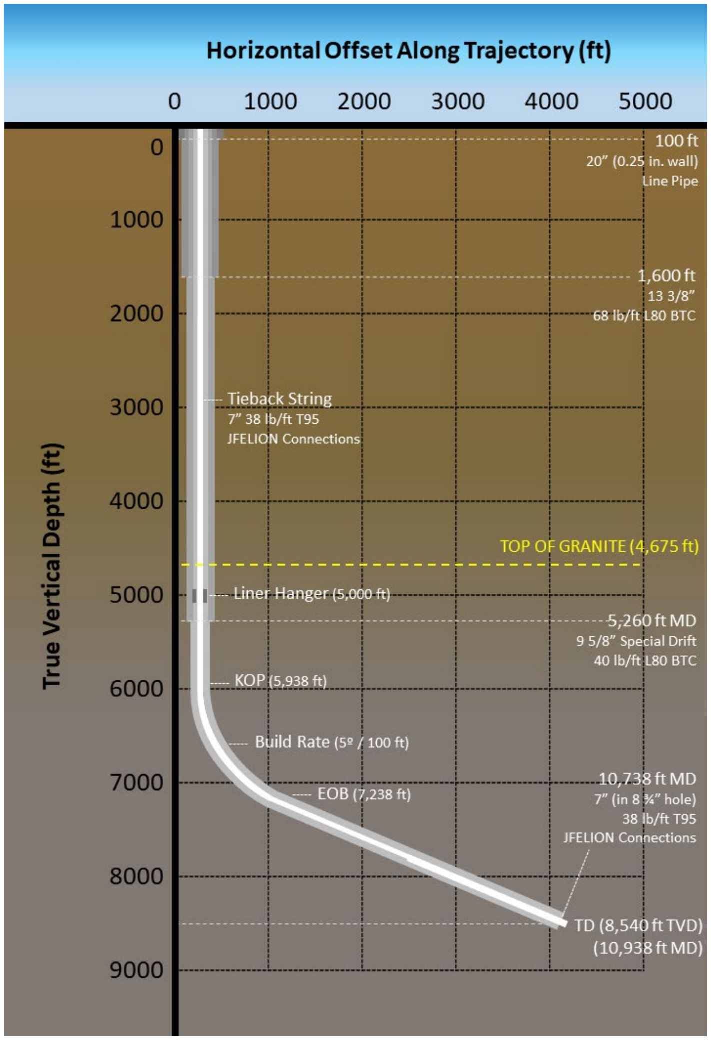

Figure B.1-7. *Wellbore plan of well 16A(78)-32. The top of granite is estimated to be at 4675 ft.*

HIGH RESOLUTION MAGNETOTELLURIC SURVEY

High-quality tensor magnetotelluric (MT) data, including the vertical magnetic field and utilizing ultra-remote referencing, were acquired at 122 sites over the Utah FORGE project area near the close of Phase 2C. The MT data coverage is displayed in topographic form in Figure B.1-8. The dataset abuts against existing MT coverage of the DOE/GTO-supported EGI SubTER project over the Mineral Mountains and Roosevelt Hot Springs (RHS) to the east, and scattered State of Utah and Play Fairway Analysis MT sites. All of these data were merged into a single coherent regional set, covering a total of 470 sites (https://gdr.openei.org/submissions/1255). From these, a finite element inversion was used to generate a 3D understanding of the resistivity structure to >20 km depth.

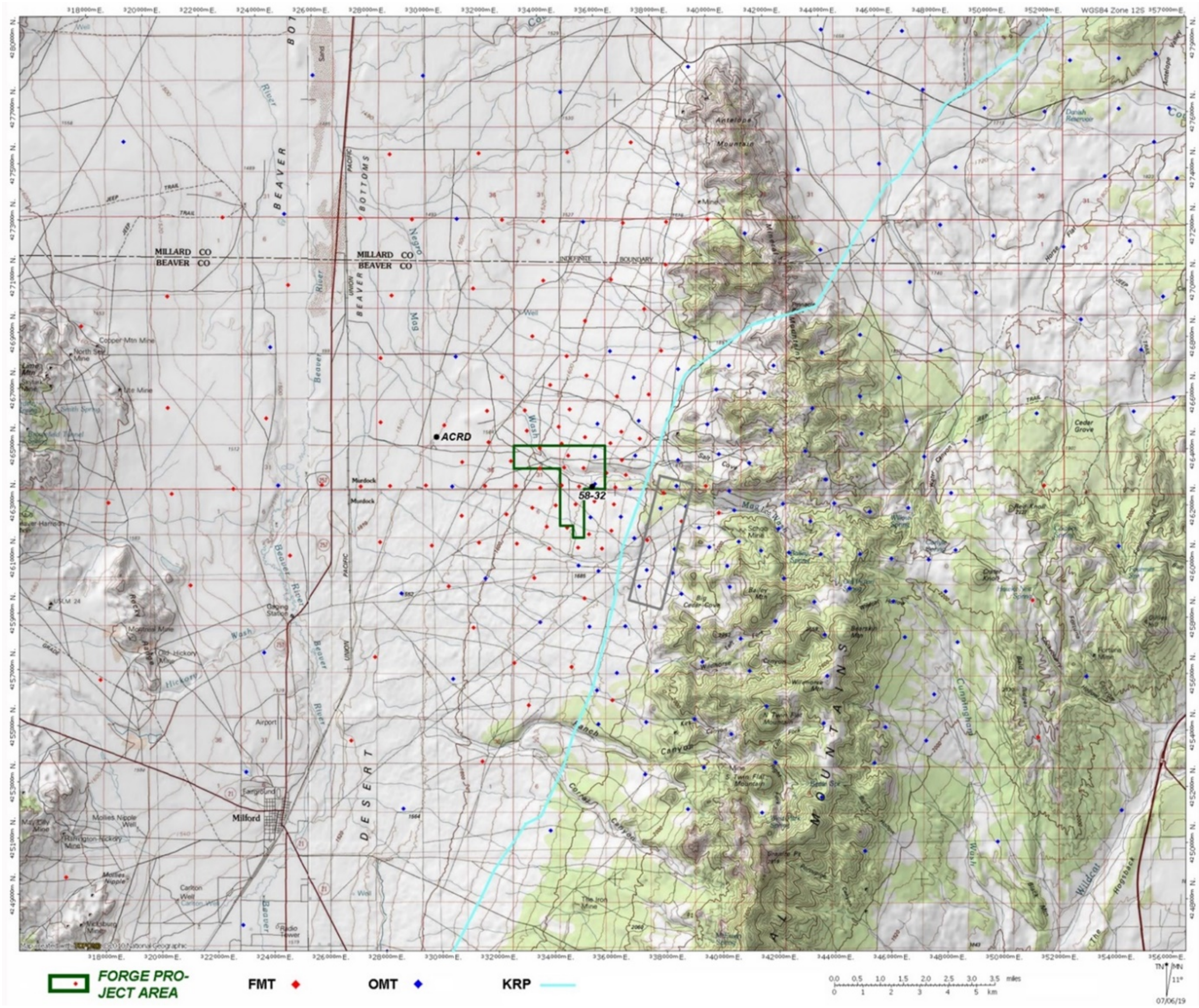

Figure B.1-8. *MT site map over the Utah FORGE project area showing prior (blue, other MT - OMT) and new station coverage (red, FORGE MT - FMT). The cyan trend running NNE-SSW through the project area is the Kern River Pipeline (KRP). The Utah FORGE property boundary is shown as a dark green right polygon, and Acord-1 (ACRD) and 58-32 wells are marked as black filled circles. The dark grey rectangle shows the approximate area of the Roosevelt Hot Springs (RHS) geothermal production field.*

WATER GEOCHEMISTRY AND HYDROLOGY

Ten samples were collected for standard major ion, trace constituents, metal isotopes of Sr and B, stable isotopes of C, H, and O, and dissolved He concentrations (Figure B.1-9). Sample sites are located near the Utah FORGE site and across Milford Valley. Analysis of the samples is underway. In addition, water levels at WOW2 and WOW3 have been recorded continuously since February 2019 (https://gdr.openei.org/submissions/1252).

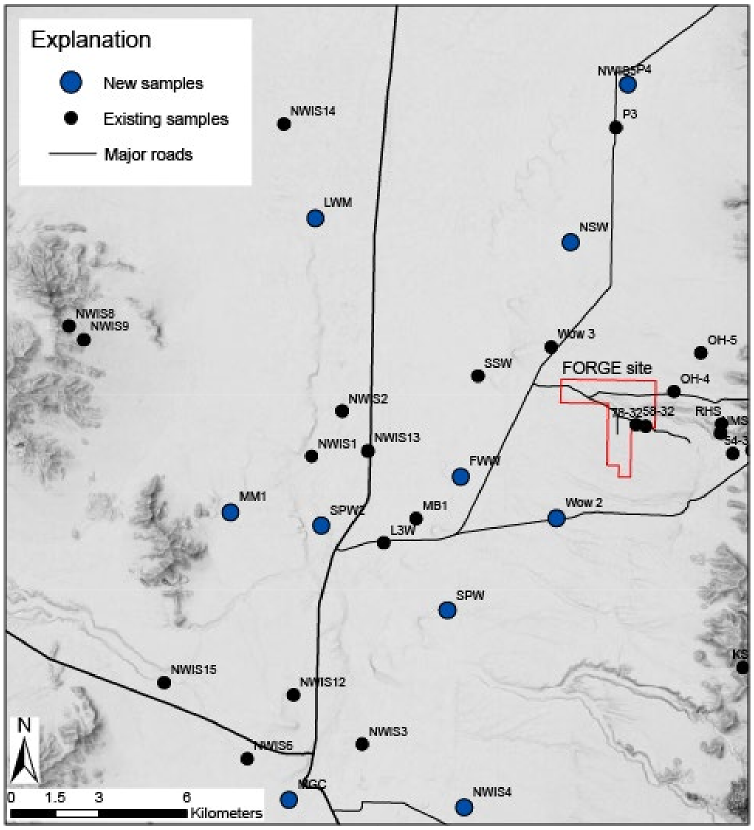

Figure B.1-9. *Location map of new and previous geochemical samples.*

INSAR

The SAR data (https://gdr.openei.org/submissions/1251) from early January 2019 (20190131) through August 2020 (2020814) consists of satellite images acquired by TerraSAR-X and TanDEM-X satellite missions operated by the German Space Agency (DLR). Many interferometric pairs were calculated but no deformation has been detected (Figure B.1-10).

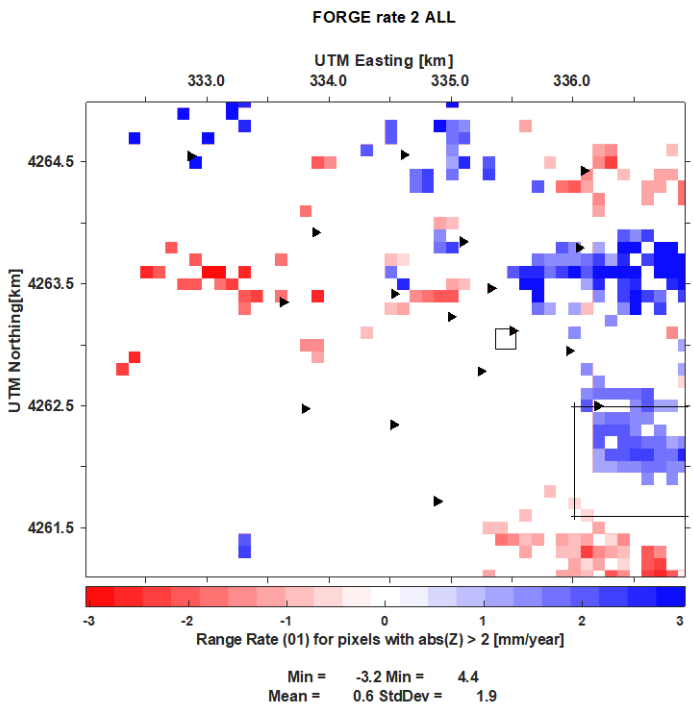

Figure B.1-10: *Mean rate of range change in mm/year for stack of interferograms, showing only pixels with rates that are significantly different from zero with 95% confidence. Increasing range denotes motion away from the satellite, e.g., downward motion or subsidence. Coordinates are UTM (zone 12) easting and northing in kilometers. The small black box denotes location of well 58-32. The large black box outlines the area taken as reference. Black triangles denote GPS stations.*

4D GRAVITY

Three complete campaigns consisting of five trips were conducted in 2020 (https://gdr.openei.org/submissions/1256). In June 2020, two new geophysical benchmarks (GDM-21, GDM-22) were installed bringing the station total to 22 (Figure B.1-11). Changes in the gravity field are interpreted to reflect seasonal variations in water level.

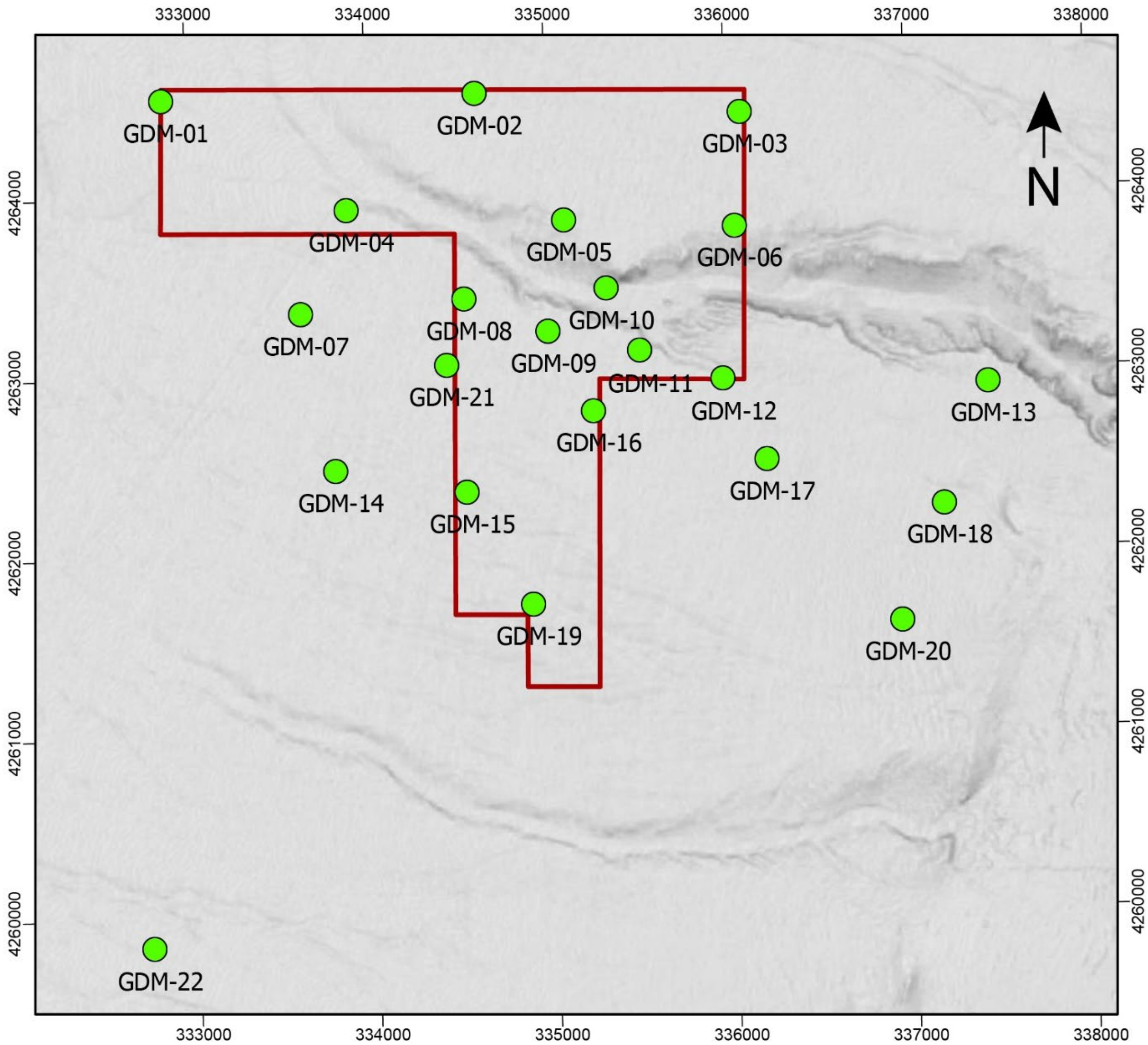

Figure B.1-11. *Map of Utah FORGE 4D gravity station locations for 2020. New benchmarks and gravity stations were installed at GDM-21 and GDM-22.*

GPS MONITORING

Four GPS surveys where undertaken in November 2019, December 2019, March 2020 and September 2020 in which data were acquired for all benchmark sites in Figure B.1-11. Analysis of the results suggest that millimeter-scale variance in surface deformation is seasonal and related to groundwater fluctuations. Two new monuments were installed at GDM-21 and GDM-22.

B.2. SEISMIC MONITORING

SEISMIC ACTIVITY IN THE UTAH FORGE STUDY AREA

Since the start of local seismic monitoring of the Utah FORGE area in November 2016, 597 earthquakes (-0.99 < M < 2.46) have been located in the region surrounding Utah FORGE (Figure B.2-1a), and of those 261 earthquakes (-0.92 < M < 2.46) have been located during the past year (Figure B.2-2). Seismic events located in the same areas identified in Phase 2 using the Utah Regional Seismic Catalog: primarily under the Mineral Mountains east of Utah FORGE and as scattered events to the northwest of Milford, Utah with a few events locating closer to Milford, Utah. Over the past project year, seismicity was restricted to under the Mineral Mountains with the majority of events locating on the eastern end (~ 4 km (2.5 miles) east of the Blundell power plant) of the swarm zone region first identified by Zandt et al. (1982).

The events on the eastern end of the swarm zone have characteristics of a new swarm and we initiated a study to better understand this seismic source zone (Mesimeri et al., 2020). Taking 75 earthquakes from the UUSS earthquake catalog and using matched-filter techniques, we constructed a catalog of over 1000 earthquakes comprising the Mineral Mountains swarm activity (-2.0 < M < 2.0) for the time period 2016 through 2019 (Figure B.2-3). Epicentral locations are well-constrained and place these quakes ~4 km (2.5 miles) east of the Blundell Power Plant. Hypocenters are not as well-constrained, because of the network geometry. Composite first-motion focal mechanisms of highly similar earthquakes are consistent with both east-west and north-south structures failing. During this three-year time period, we identify 15 periods of swarm-like activity that seem to be related to both fluid diffusion and aseismic processes. Despite hypocentral uncertainty, the fluids involved in these swarms have a deeper origin than what would be consistent with operations at the Blundell power plant, and we conclude these swarms are the result of the tectonic transport of fluid through the crust.

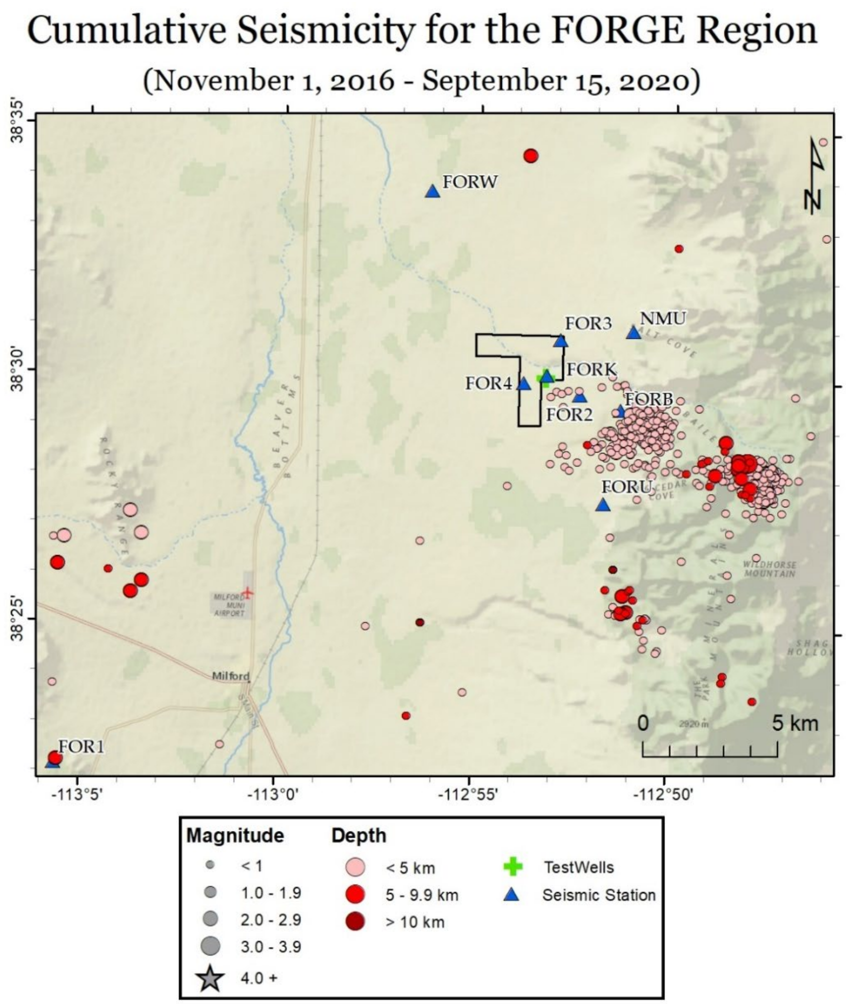

Figure B.2-1a *Map of seismic events located by UUSS since the start (November 2016) of local monitoring at the Utah FORGE site.*

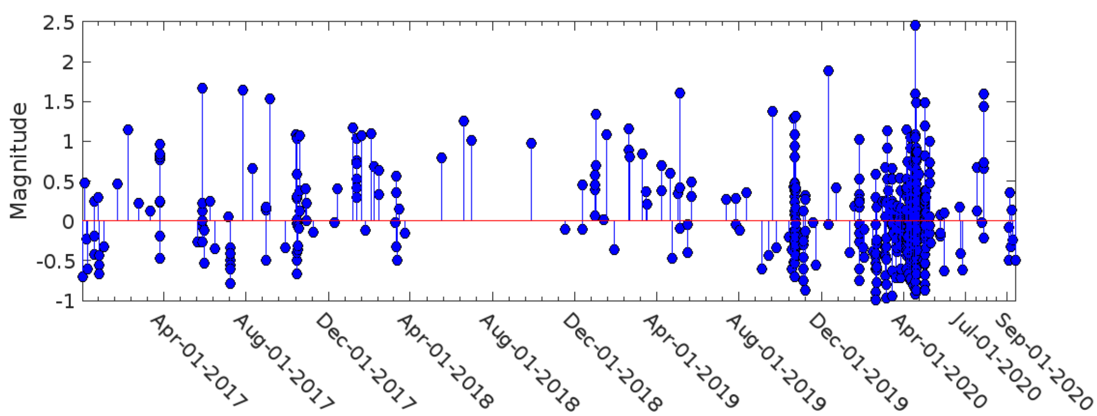

Figure B.2-1b. *Magnitude time history of seismic events shown in Figure B.2-1a.*

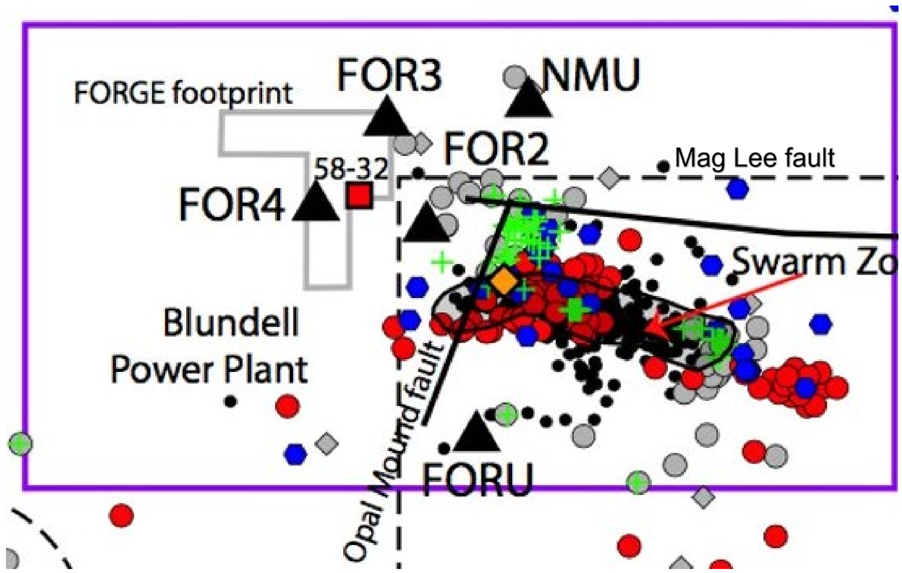

Figure B.2-1c. *Locations of microseismic events in the vicinity of the FORGE site since 1981. The grey polygon region defined as FORGE footprint. Symbols: grey circles: earthquakes from the UUSS catalog 1981–2016 relocated with an updated velocity model; red circles: earthquakes located after installation of the broadband network; blue hexagons: earthquakes detected with the Nodal array; grey diamonds: earthquakes from Olson (1976); black circles: earthquakes from Zandt et al. (1982); green crosses: earthquakes identified using subspace analysis.*

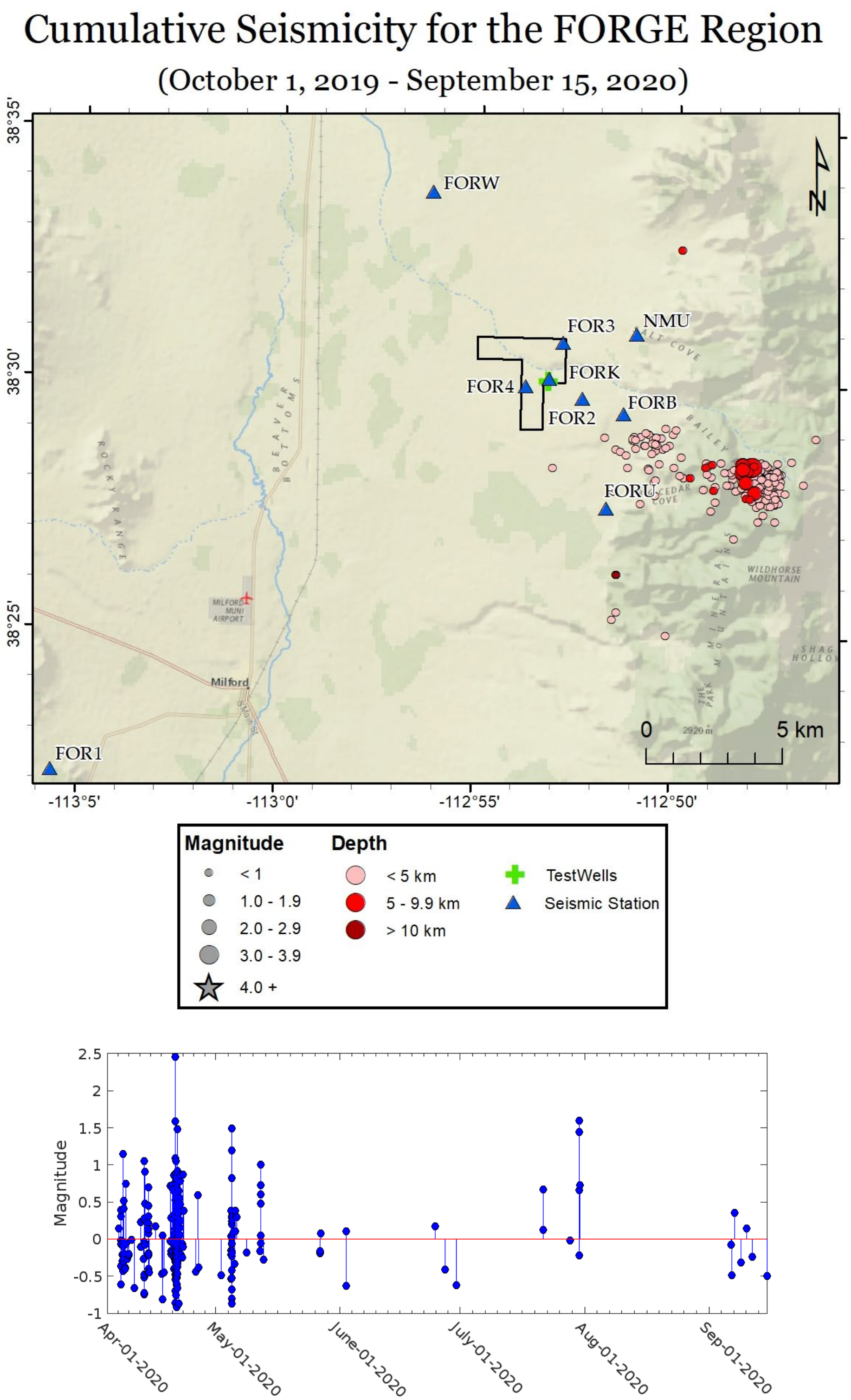

Figure B.2-2. *Map and magnitude time history of seismic events located by UUSS for the 2020 project year.*

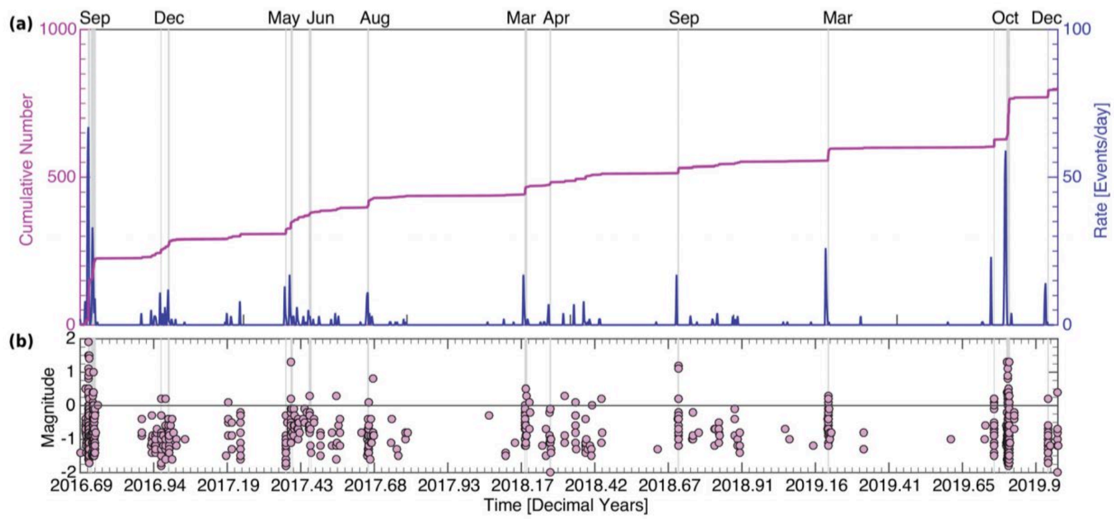

Figure B.2-3. *Temporal evolution of seismic activity identified with matched filter detection for earthquakes in the Zandt swarm zone east of the Blundell plant from Mesimeri et al. (submitted). (a) Cumulative number (purple), and daily rate (blue) of earthquakes vs time. (b) Magnitude –time history. Gray shaded areas identify 15 periods of elevated seismic activity.*

SEISMIC MONITORING

Seismic Network

One of the key efforts this year has been developing the plan for seismic monitoring at the Utah FORGE site. The SAT was organized to help provide expertise and advice in this endeavor. The SAT had representation from industry, academia, and the U. S. Geological Survey and expertise in geothermal, fluid disposal, and induced seismicity related to hydraulic stimulation, seismic instrumentation (both traditional seismometers and distributed acoustic sensors (DAS), as well as infrasound and more exotic sensors), seismic detection and discrimination related to nuclear treaty verification, and network seismology. During a one-day meeting at the University of Utah in November 2019, the SAT reviewed the existing data and plans for the injection well. With this information they developed a plan over the subsequent few weeks. The plan consisted of adding a deep monitoring well instrumented with DAS and available for geophone strings to complement existing wells 78-32 and 58-32. This was to be the primary network for monitoring reservoir development and growth.

A second network consisted of shallow borehole and surface stations for hazard monitoring. This network design includes two rings 3 and 8 km (1.9 and 5.0 miles) from well 58-32 (close to where the first injections will occur) (Figure B.1-6). The inner ring will help with detection levels and hypocenter control. The 8 km (5.0 mile) ring is needed for epicentral control and to track seismicity if there is migration away from the immediate injection site. The SAT also proposed additional instrumentation, such as surface DAS cables, and instrumenting the deeper wells with permanent high temperature geophones, and pressure sensors. This plan was presented to the STAT in January 2020. The initial plan was revised after consultation with the STAT and DOE and was finalized and approved in September 2020 as “Seismic Monitoring During Phase 3 Years 1 and 2” (FORGE, 2020). The shallow boreholes on the inner ring, BOR-1, BOR-2 and BOR-3, have been drilled and the sites prepared for adding the necessary electronics (Figure B.2-4). Sensors and telemetry will be installed before drilling starts at 16A(78)-32.

Figure B.2-4. *Site preparation for installation of electronics and tower for telemetry. Each barrel is 24 inches in diameter.*

Regarding the location of the new deep well, Rutledge et al. (2020) updated the modeling work originally performed by Schlumberger to estimate microseismic event minimum magnitude and location accuracy based on the location of wells 58-32 and 78-32 and three proposed locations for well 56-32. One of the main changes was updating the attenuation parameter to be consistent with detection levels at well 78-32 during the April 2019 stimulation. Based on this modeling work, the location for the deep monitor well originally proposed by the SAT is the preferred (Site 1, Figure B.2-5). These simulations can be re-evaluated once 16A(78)-32 is completed and tested, or if additional monitoring wells are contemplated.

Updated Velocity Model

To improve on seismic event locations and to help with estimating ground motions for the Utah FORGE site, additional effort has been undertaken to develop a detailed shallow velocity model for the region surrounding Utah FORGE. Using the data from the Nodal geophone experiment from December 2016 and the subset of geophones with 650 m (2133 ft) spacing, we expand on Markov-Chain Monte-Carlo (MCMC) inversion of spatial autocorrelation (SPAC) data (Zhang et al., 2019), and construct 61 one-dimensional shear wave velocity profiles across the immediate Utah FORGE footprint area (Zhang and Pankow, 2020). These profiles are stitched together to form a pseudo three-dimensional velocity model (Figure B.2-6). The velocity profile nearest to well 78-32 closely matches the shear-wave profile determined using the DAS data (Lellouch et al., 2020).

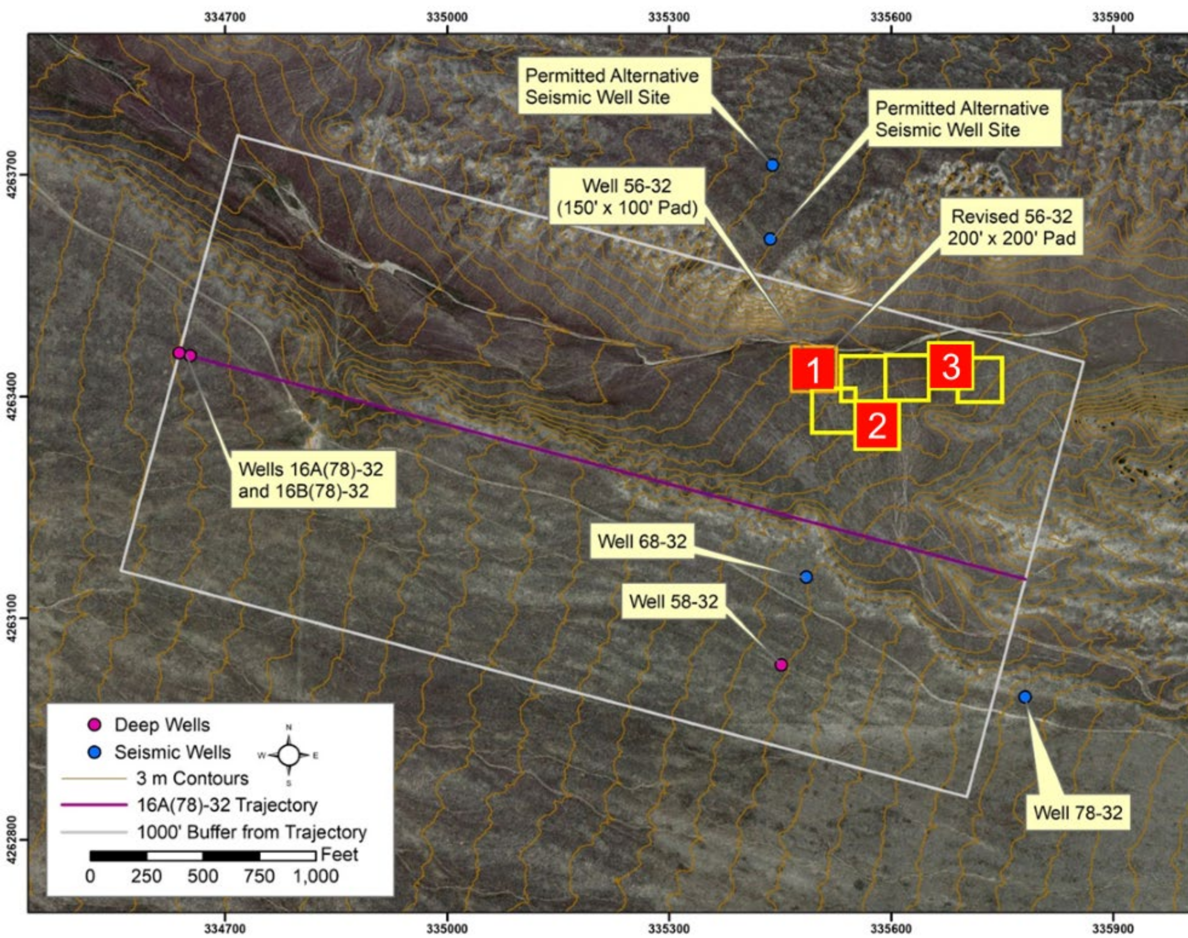

Figure B.2-5. *Plan view of Utah FORGE deep wells. The planned trajectory of the 16A(78)-32 well is shown purple. Wells 58-32 and 78-32 are the two existing deep seismic monitor wells. The yellow squares show possible 200 x 200 ft well pad sites for well 56-32 with suitable position, topography and permit clearance. Positions marked 1, 2 and 3 were considered in the modeling evaluation.*

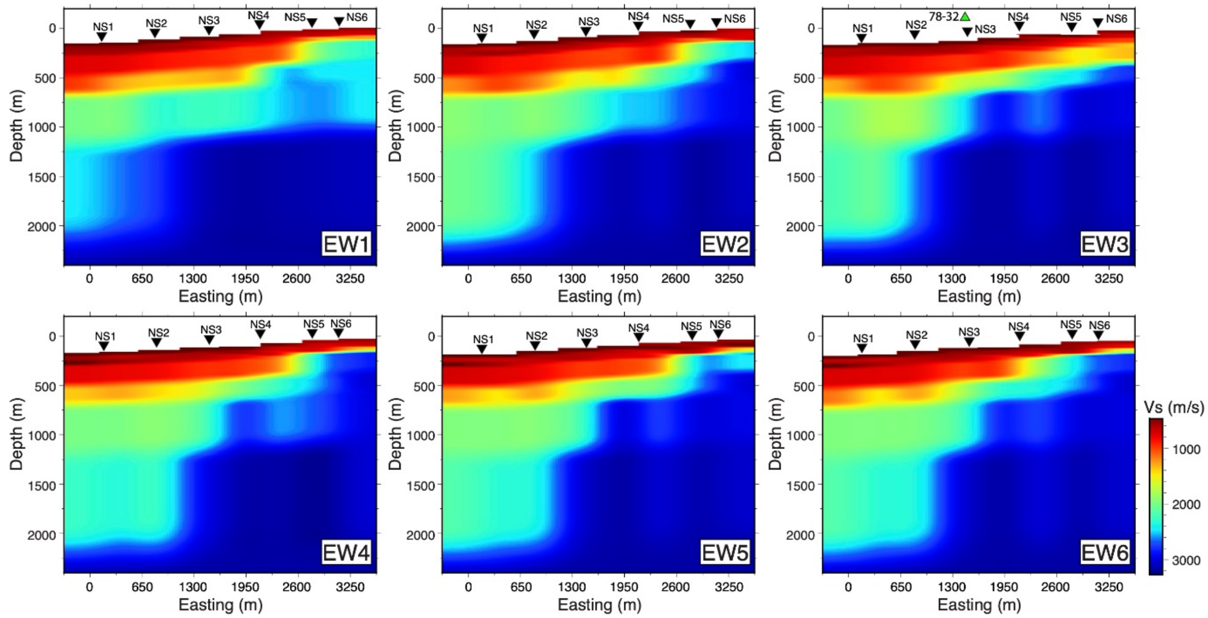

Figure B.2-6. *East-west shear wave velocity profiles from Zhang and Pankow (submitted). Profiles are ordered from south (EW1) to north (EW6) across the Utah FORGE footprint. The blocky nature is a function of smoothing between one-dimensional profiles.*

Overall, the image closely matches what was found in the three-dimensional seismic reflection profiles (Miller et al., 2019; Wannamaker et al., 2020). The granite alluvium interface dips gently to the west, the sediments form horizontal layers, and there is a depression on the granite alluvium interface beneath the Mag Lee Wash consistent with this being an erosional interface. Also like the reflection profile, there is no evidence across the granite alluvium interface suggesting the presence of a fault. This velocity model is being combined with the regional velocity model used in seismic event location from UUSS and Vp/Vs ratios determined from the DAS velocity models (Lellouch et al., 2020) to construct a three-dimensional velocity model that will be used to locate earthquakes in the Utah FORGE area.

New Detection Algorithm

Initial processing of the nodal data from the April 2019 stimulation experiment was limited by the seismic noise associated with activities at the 58-32 well pad. Given the potential that the Nodal data presents, we worked to develop a new seismic detection algorithm specific to high density geophone experiments with known source zones (close to a well in the case of injection or close to a mainshock in the case of an aftershock sequence) (Mesimeri and Pankow, 2020). This technique takes advantage of array processing of frequency domain data to detect seismic energy in a typical microseismic bandpass. In a subsequent step, this energy is back projected to locate the source. This second step greatly decreases the number of false detections, in that we require the detection to have coherent energy that can back-project to a source and identifies other seismic events outside the source zone of interest. Using this new detection algorithm, we identified 23 earthquakes (-1.71 < M < -0.52) that were also in the Schlumberger catalog and 18 new events (no magnitude determined) (Figure B.2-7).

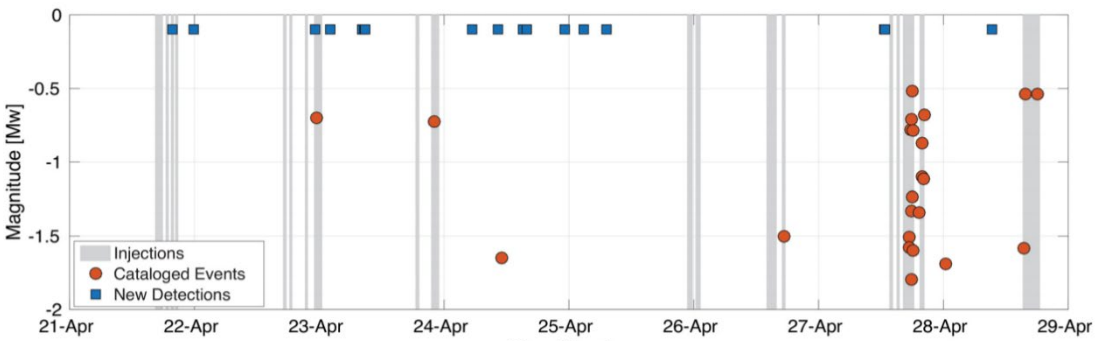

Figure B.2-7. *Seismic event detections during the April 2019 stimulation experiment found using new array processing techniques (Mesimeri and Pankow, submitted). Red circles, events in common with the Schlumberger catalog. Blue squares, new event detections—magnitudes that are not determined are plotted at M –0.1 for convenience and to emphasize the timing of events.*

INDUCED SEISMIC MITIGATION PLAN

An Induced Seismic Mitigation Plan (ISMP) was completed and submitted to DOE. Additionally, two reports, "Seismic Monitoring During Phase 3 Years 1 and 2" (FORGE, 2020) and "Review of Seismic Mitigation Strategies and Protocols" (Moore et al., 2020) based on the text from that ISMP were submitted to DOE. A revised ISMP following best practices and incorporating review comments is being finalized.

Data collected at Utah FORGE have primarily been used to update the ISMP in the following three ways: (1) establishing background ground motion levels; (2) confirming that mapped fault structures are not seismogenically active; and (3) updating the hazard calculated in the Utah FORGE Probabilistic Seismic Hazard Assessment (PSHA). First, using data collected at seismometers located in Milford and the Utah FORGE site (December 2017 through January 2018) and near the Blundell power plant (January 1 through May 2019), we see that ground motions are larger in Milford where there is more cultural noise and regular train traffic. These background ground motions in Milford are primarily at the minimum levels for felt ground motions from earthquakes. A few isolated measurements have larger ground motion that approach what might be expected for light damage, but if cultural in origin is likely too short in duration to produce damage. These data allow us to set the threshold ground motion above the minimum suggested in studies for felt earthquakes. The region near Utah FORGE and Blundell is mostly quiet with very low (< 0.5 mm/s) ambient ground motions.

During the time period of local seismic monitoring at Utah FORGE, seismic events have continued to locate in the same source regions identified in the regional catalog (Figure B.2-1).

The largest earthquake recorded during this time period is M < 2.5, located to the east of the Blundell power plant and M < 4.5 within 50 km (31 miles). The low magnitudes and rates are consistent with recurrence modeling performed in the PSHA, which predicts 1 M > 4 every 10 years, 1 M >5 every 100 years, and 1 M >6 every 1000 yrs. So, while possible, larger earthquakes in the area around Utah FORGE are low probability events. As previously discussed, we also investigated the Zandt swarm region and confirmed that the main source area is east of the Blundell power plant and Opal Mound Fault and south of the north dipping Mag Lee Fault (refer to Figure B.2-1 c) (Mesimeri et al., 2020). There is no evidence for earthquakes originating on either of these faults or the other mapped faults in the Milford basin.

The 2018 “Probabilistic Seismic Hazard Assessment for the FORGE Site” (PSHA) performed by Amec Foster Wheeler (Pankow, 2018) as part of Phase 2 was updated and a new 2020 PSHA (Pankow et al., 2020) was performed by Wood Environment and Infrastructure Inc (WEI) as part of the ISMP. Amec Foster Wheeler was acquired by Wood so both PSHA analyses were performed by the same group. The 2020 PSHA was updated to reassign the location of the Utah FORGE centroid towards the projected toe of 16A(78)-32 where stimulation will occur. The second main update was incorporating site specific velocity information (Vs30 and basin-depth parameters) from Zhang et al. (2019) and Zhang and Pankow (2020) to adjust the NGA-West 2 (Bozorgnia et al., 2014) ground motion models to the site conditions at each of the PSHA sites. The third update incorporated new research data on segments of the Wasatch Fault and Mag Lee Fault into the earthquake recurrence model of each fault. The effect of the fault changes was small. Wood also tested an updated earthquake catalog based on the 2018 National Seismic Hazard Map and updated UUSS catalogs (Arabasz et al., 2017). In the calculations, WEI identified an error in the 2018 PSHA calculations that was corrected in the new calculations. Overall, based on the above modifications and corrections, the 2020 PSHA results in a significantly reduced hazard compared to the 2018 PSHA.

B.3 UPDATED CONCEPTUAL GEOLOGICAL MODEL

The conceptual geologic model of the Utah FORGE site was updated and refined, incorporating results of newly acquired geoscientific data plus the understanding obtained from the drilling of wells 58-32, 68-32 and 78-32. The main Phase 3 year 1 updates and refinements are based on analysis of the magnetotelluric (MT) dataset, resolution of the reservoir stress regime from 2017-2019 stimulation testing and improvements to the DFN model and analysis.

The stratigraphy consists of two broad rock types, comprising layered basin fill sediments and crystalline basement rocks mostly made of Miocene granitoids. The contact between these rock types forms a gently undulating ramp, which dips 20-35° west and which likely represents a large-scale normal fault that has been rotated during extension predominantly ~8 Ma. The Opal Mound, Mag Lee and Mineral Mountains West Fault systems are the only other mappable structures (Figure B3.-1), but the measurable displacements are less than 15 m (49 ft). Anomalous heat flow comprises localized hydrothermal convection east of the Opal Mound fault and regional conduction (~70°C/km, well 58-32) west of the Opal Mound Fault. The modern regional stress regime is extensional, characterized by normal faulting and a maximum horizontal compressive stress oriented approximately N25°E.

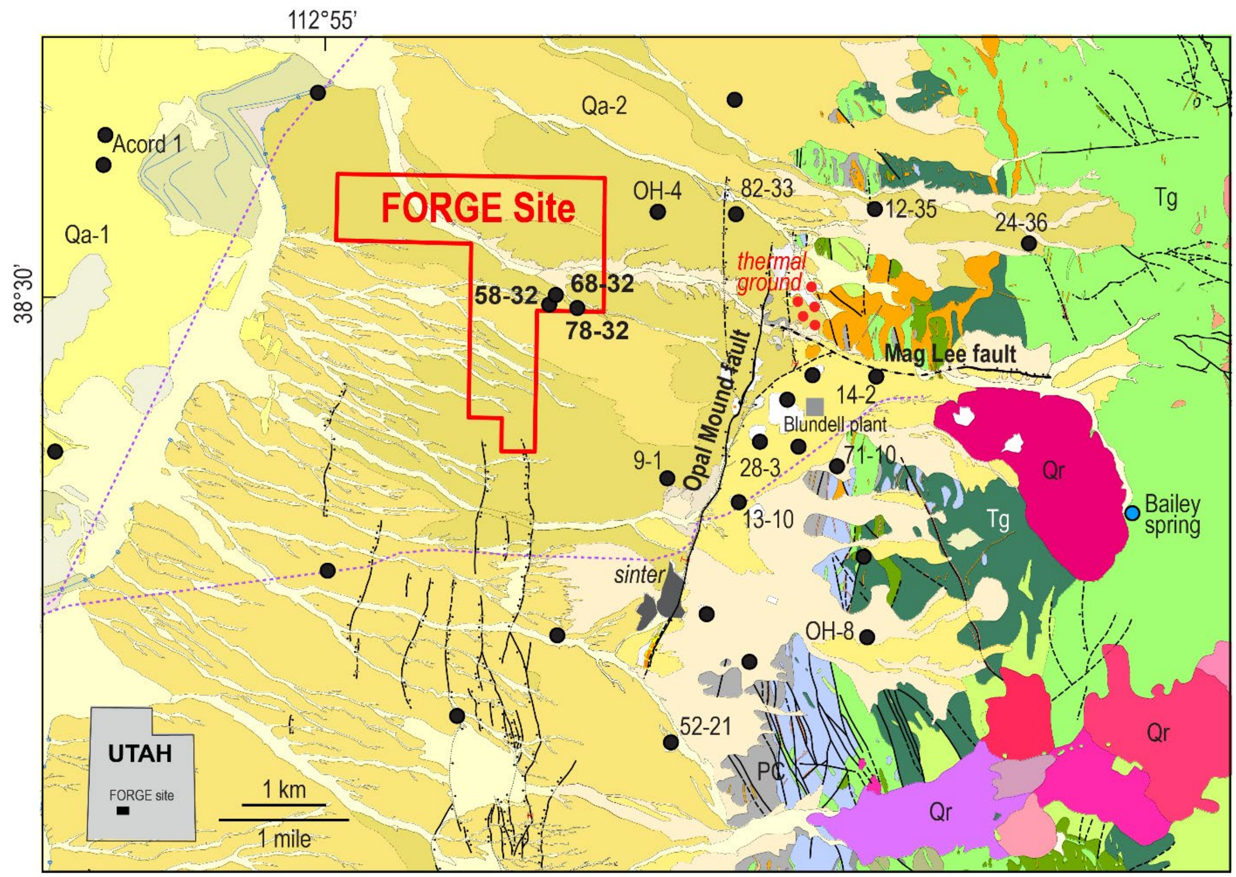

Figure B3-1. *Geologic map of the Utah FORGE area.*

The Utah FORGE EGS reservoir occupies a volume of 4.6 km^3 (1.1 mi^3) that is entirely hosted by hot (>175°C) crystalline granitoid, ranging from granite to diorite in composition. From an engineering and physical perspective, these rocks form a relatively homogeneous unit made of intergrown coarsely crystalline quartz and alumino-silicate minerals that have very low chemical reactivity and low solubility. The reservoir rock is endowed with a complex and relatively dense network of fractures having a wide range of orientations. The reservoir is very tight, with very low porosity and permeability, and there is no evidence of modern hydrothermal fluid. The only producible water is restricted to aquifers hosted in shallow basin-fill alluvium that overlie the EGS reservoir, and this water represents outflow from the Roosevelt Hot Springs system that lies >3 km (1.9 miles) to the east. That this water is abundant, non-potable, and of geothermal origin, fulfils a water resource requirement for future injection-production testing at the Utah FORGE site.

InSAR analysis indicates there has been no detectable ground movement at millimeter scale, and this contrasts with GPS survey campaigns which suggest that there is seasonal variation in ground surface deformation involving several millimeters of ground movement that possibly correlates with changes in groundwater level. The modeling of 3D seismic reflection and gravity data in Phase 2C confirmed the absence of stepped discontinuities associated with subvertical fault offsets crossing the basement contact beneath the Utah FORGE site to within 20-25 m (66-82 ft). From this limited offset coupled with interpreted age of the contact (~8 Na), natural seismic hazard has been reinterpreted and is deemed low under the Utah FORGE project area.

Utah FORGE MT data acquired in Phase 2C were merged with surrounding data taken in other campaigns. From these, a finite element inversion was used to generate a 3D understanding of the resistivity structure to >20 km (12.4 miles) depth. In the upper crust (<10 km (<6.2 miles) depth), strong N-S low-resistivity lineaments exist beneath the central Mineral Mountains, and they correlate with N-S steep fracture patterns mapped in the Mineral Mountains. One of these projects into the Roosevelt Hot Springs producing field. Zones coalesce with depth and merge into a larger single structure extending to the base of the crust. Relevant is that no similar conductive lineaments appear in the granitic basement west of the Opal Mound Fault, attesting to the integrity of the crystalline lithologies beneath the Utah FORGE site. A conductive body underlies the main Quaternary rhyolite flows centered along the crest of the Mineral Mountains (7-20 km (4.3-12.4 miles depth), and at > 15 km (9.3 miles) it begins to merge with a large-scale conductive structure trending ENE through the Cove Fort geothermal system. A significant low resistivity body occurs beneath the north-central Milford Valley to the west of the Utah FORGE site, and it appears to dip at a moderate angle to north. The former body is thought to represent a heat source for the Roosevelt Hot Springs geothermal system, and both of these features might represent large-scale heat sources for the Utah FORGE reservoir volume.

Minimum in-situ stress was reinterpreted from step rate and extended shut-in tests implemented during the stimulation of two zones in Well 58-32. For background, the lower zone (Zone 1) consists of 46 m (151 ft) of open hole at the toe of the well between 2248-2294 m (7375-7526 ft), whereas the upper zone (Zone 2) is cased and occurs between 2123-2126 m

6965-6975 ft). The inferred closure stresses of Zone 2 (17.2-21.5 MPa/km) are significantly higher than those of Zone 1 (15.2-18.3 MPa/km). The higher stress gradient in Zone 2 could be caused by the near-wellbore tortuosity, but there could also be natural variations in the stresses in the granitoid. Equivalent poro-elastic effects and the dilation and slippage of natural fractures appear to contribute to increases in closure stress with pumping volume. The natural fractures in the Utah FORGE reservoir likely played a role, and those participating in the hydraulic fracture initiation generated greater back stress (poro-elastic effect), increased the local total stress due to slippage and dilation, and contributed to higher closure stress in Zone 2 if they are connected to the wellbore and oblique to σ_{hmin}. Pump-in/flowback data and bottom hole temperatures were also used to interpret the in-situ stress measurements, and for Zone 2, the results are lower than those from step rate and extended shut-in tests. Stresses determined from temperatures for Zone 1, 2017, gives results that are similar to standard interpretations.

The sensitivity analysis for stimulation extents due to both DFN realization and regional stress uncertainty showed large variation due to both the S_{Hmin} gradient and the particular DFN realization. For example, the vertical stimulation extent increased approximately 50% by using the minimum value proposed for the S_{Hmin} gradient of 13.8 MPa/m vs the expected S_{Hmin} gradient of 17.0 MPa/m. Furthermore, the vertical stimulation extent is a critical value to know for planning the spacing between the injection well 16A(78)-32 and a future production well. Unlike the S_{Hmin} gradient, the uncertainty in the S_{Hmax} gradient does not seem to affect the vertical stimulation extent very much. As the particular DFN realization also seems to lead to highly variable stimulation extents, increased knowledge of the fracture intensity and orientations along the new well 16A(78)-32 will be important to predicting future stimulation effects.

B.4 R&D

In April 2020, the first solicitation for R&D funding was released by the university of Utah. The solicitation covered topics considered critical by the Science and Technology Analysis Team (STAT) and DOE for full EGS deployment (Table B.4-1).

Figure B.4-1 illustrates the proposal submittal and review process. This process was developed as a collaborative effort by the Technology, Analysis, Research and Management Committee (TARMaC), composed of Utah FORGE Co-Principal Investigators who sit on the FORGE Management Team, representatives of DOE, the Utah FORGE Project Administrator, and the University of Utah's Office of Sponsored Research.

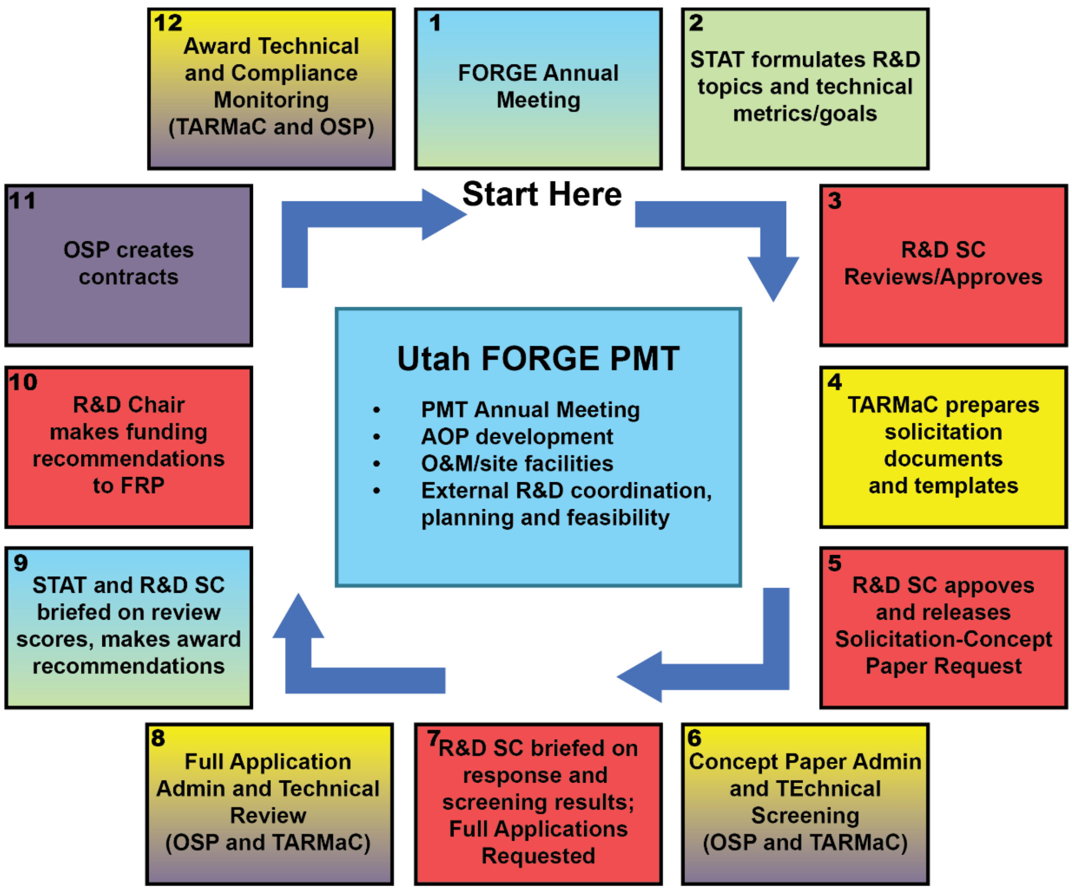

Figure B.4-1. *Sequence of activities required to formulate and prepare R&D solicitations and approve, review and award proposals. Details of the flow chart are described in the R&D Solicitation, Implementation and Management Plan on file with the DOE.*

Table B.4-1 summarizes the topics, number of concept papers received, funding available for each topic and estimated number of awards. Solicitation one made up to $46 million of DOE funds available for up to 19 proposals that will be awarded and managed by the University of Utah.

The response to this solicitation was extraordinary. One hundred sixty-four concept papers were submitted by domestic for-profit entities, individual U.S. citizens, educational institutions, federally funded research and development centers, unincorporated consortia and other groups (Table B.4-2). The Concept papers were reviewed for Conflicts of Interest prior to receiving a technical review by the TARMaC. The results of TARMaC reviews are summarized in Table B.4-2. Seventy of the R&D teams were encouraged to submit full proposals; sixty-three were received. Table B.4-2 shows the number of applicants by organization type that were encouraged to proceed with their applications.

Full applications will be reviewed in the first quarter of FY 2021 for their technical approach and technical innovation, applicability to the Utah FORGE site and infrastructure, and permitting and deployment requirements. The reviews will be conducted by external reviewers selected by the TARMaC (refer to Figure B.4-1). The STAT will consider the reviewer scores and comments, and provide recommendations for funding to the R&D Steering Committee, who will approve or reconsider the recommendations. Final approval of the awards will be made by the Federal Review Panel.

Table B.4-1. *Solicitation 1 R&D topics, funding levels and anticipated number of awards.*

Topic	Title	Number of Applicants	Potential Funding	Potential Number of Awards
1	Devices suitable for sectional (zonal) isolation along both cased and open-hole wellbores under geothermal conditions	21	$12,000,000	1 to 3
2	Estimation of stress parameters	25	$3,000,000	1 to 3
3	Field-scale characterization of reservoir stimulation and evolution over time, including thermal, hydrological, mechanical, and chemical (THMC) effects	50	$8,000,000	1 to 4
4	Stimulation and configuration of the well(s) at Utah FORGE	23	$12,000,000	1 to 3

5	Integrated Laboratory and Modeling studies of the interactions among THMC processes	45	$11,000,000	1 to 6

Table B.4-2. *Number of applicants encouraged to submit full proposals in each topic area.*

TOPIC	Domestic for-profit entity	Individual US citizen	Education Institution	DOE/NXSA FFRD Center	Other
1	5	1	2	1	0
2	2	0	5	4	1
3	6	1	4	9	0
4	3	0	5	2	0
5	2	0	10	6	1

B.5 OUTREACH AND COMMUNICATIONS

Outreach and communication activities were expanded during Phase 3 Year 1. The Outreach and Communications team was enlarged by the addition of a full-time communications specialist and a part-time student intern from the University of Utah's Department of Communications. Because of face-to-face limitations imposed by COVID 19, our outreach program made extensive use of electronic media, including the Utah FORGE website.

We utilized the website to provide updates about the progress of the Utah FORGE project, while offering resources and information to increase overall geothermal and EGS literacy. This included creating five new web pages (Modeling and Simulation Forum, Solicitation, Sample Curation, Education, and Data Dashboard), and developing seven new web features (Did You Know, Share a Scientific Paper, Partner Spotlight, Lectures/Podcasts, Word of the Week, Animations, Informational Timeline). Additionally, an inventory audit of the website was conducted.

Information about geothermal energy and the Utah FORGE project was provided through the establishment of an e-newsletter "*At the Core*", which is published quarterly. Two editions were produced and distributed. In tandem, a subscription list was cultivated for this and other news and announcements, with a current total of 276 subscribers.

One hundred twenty-seven social media announcements were posted on Facebook (60), Twitter (51) and LinkedIn (16). There are currently 251 followers across all three social media platforms (151 on Facebook, 51 Twitter, 49 LinkedIn).

Coverage of the Utah FORGE project and its progress was highlighted in the general mainstream media and in geothermal and other appropriate energy industry vertical outlets by creating a media kit, obtaining 13 media stories, providing background information to two general consumer publications, publishing and advertorial in the Beaver County Journal, creating and advertisement for the Beaver County Journal, and writing a piece for the Milford City Newsletter.

Research findings were presented at scientific conferences, including one presentation at the November 2019 NZ Geothermal Workshop, three presentations at the December 2019 AGU conference, seven presentations at the 2020 Stanford Geothermal Workshop, and three presentations at the Seismological Society of America conference. Four manuscripts were submitted to refereed journals for publication and two E-posters and a short video were submitted to the Geothermal Resources Council meeting. A virtual presentation was made in the American Rock Mechanics Association (ARMA) Endless Summer Series, and Dr. Joseph Moore participated in the ICDP workshop held at Cornell University in January 2020.

Utah FORGE personnel conducted two field trips for seven individuals to the Utah FORGE site.

A university-level lecture on conventional geothermal resources by Dr. Stuart Simmons was produced and promoted. A story board for a new fifth video was drafted, and a videographer was contracted to acquire and edit footage for the upcoming drilling campaign. The first podcast in the series *FORGEing Ahead with Geothermal Energy* was written, recorded and released. A webinar entitled *Geoscientific Overview of Utah FORGE* was produced, recorded and posted. In addition, four Modeling and Simulation Forums were hosted, and Seequent released a video showcasing Leapfrog's modeling capabilities featuring the Utah FORGE project.

Tools for visualizing Utah FORGE data have been developed and updated. A tool to examine Utah FORGE Stimulation Data is posted on the dedicated Utah FORGE Geothermal Data Repository archive page hosted by NREL. The interactive geologic map based in ArcGIS was updated with new features.

The FAQ sheets and a brochure were revised and updated. Kiosk panels describing geothermal energy and Utah FORGE were installed on Antelope Point road near the Utah FORGE site.

Feedback and input were obtained through implementation of a website user survey.

Elected officials and regulators were briefed about Utah FORGE through testimony presented by Joe Moore to the House of Representatives Science, Space and Technology committee, meetings with Beaver County and Milford City officials, and face to face meetings with over 60 stakeholders, including elected officials and citizens. Background information was supplied via email to U.S. Congress members and Utah State legislators.

STEM modules were presented and shared at ten events, including scheduled school visits, open houses, and STEM events. A prototype of a new STEM module showing how convection works using a thermochromatic display was developed. A team of undergraduate students from the University of Utah's Department of Chemical Engineering achieved an outstanding result at the November 2019 National American Institute of Chemical Engineers (AIChE) Competition, proudly taking 2nd place in the K-12 STEM Outreach Competition for a Peltier engine module.

In order to develop a program of K-12 education, an undergraduate intern and a PhD candidate from the College of Education, University of Utah were employed to draft a high school lesson plan on geothermal energy and other renewables. An advanced undergraduate level capstone class in the Department of Communications, University of Utah, with 15 students, was initiated in the fall 2020 semester under the instruction of Professor Sara K. Yeo, to develop and analyze public survey data of lay opinion, awareness and knowledge of geothermal energy.

C. SUMMARY OF LESSONS LEARNED IN PHASE 3 YEAR 1

The activities of Phase 3 Year 1 of the Utah FORGE project were primarily directed toward preparing the Utah FORGE site for the drilling of the first deep well 16A(78)-32, developing a seismic network for monitoring seismicity during drilling and stimulation activities, preparation and release of Solicitation 1, and expanding the Outreach and Communication program. The many lessons learned from these and other activities are described in the following sections.

DRILLING 16A(78)-32

Well 16A(78)-32 represents a major step-out in geothermal drilling and completion strategies. Unlike typical geothermal wells with relatively low deviations (30-40° from vertical) and measured depths of <10,000 ft, well 16A(78)-32 will be deviated at 65°, with an extended lateral of 4000 ft and a measured depth of nearly 11,000 ft. The well must be engineered to accommodate many cycles of heating and cooling, logging in the high temperature lateral, maintaining careful control over its trajectory and stimulating the granitoid behind casing.

The results of Phase 2 demonstrated the difficulties of drilling into the hot, hard, abrasive and low permeability granite of the FORGE reservoir. In Phase 2, drilling with tricone bits and nonoptimized drilling parameters resulted in low penetration rates averaging 10-13 ft/hr and a bit life of ~50 hours. PDC bits, which were expected to drill faster, yielded similar rates of penetration. Temperatures between 175° and 200°C (347° and 392° F) encountered during the 2019 stimulations in well 58-32 resulted in failures of the isolation tools, while the abrasive nature of the granite led to excessive wear of the downhole equipment.

The results of the Phase 2 drilling and stimulation programs were analyzed in Phase 3 Year 1 with the goal of implementing more effective and safer drilling techniques. The lessons learned from this analysis were incorporated into the bid specifications for well 16A(78)-32. Lessons learned from well 16A(78)-32 will be incorporated into the drilling of future wells.

Lessons Learned

1. Improvements in drilling performance should be possible by careful optimization of drilling parameters (torque, weight on bit, rotational speed and possibly vibrational measurements at the bit) based on Mechanical Specific Energy (MSE) calculations, automated control of the top drive, and control of other operational parameters

2. Without careful steering and oversight, bit walk can be significant in a nominally vertical hole. Inclination control is essential even in the vertical section of the well. A vertical rotary steerable system (mechanically operated) will be used to control the deviations in the vertical section.

3. PDC bits have the potential to increase the Rate of Penetration (ROP), which can have a significant effect on overall drilling costs by reducing the number of trips. PDC bits will

be tested with careful monitoring of at-bit parameters and guidance from MSE calculations and closer interaction with the directional contractor.

4. Bit and tool selection will be optimized by close coordination between drilling supervisors with extensive directional experience and engineering and insights from vendors.

5. Previous drilling operations in the abrasive granite caused significant wear and damage to down hole equipment, resulting in increased down time to replace worn equipment. TORKease, a blend of non-hydrocarbon lubricating agents was added “by feel” in well 58-32. During the drilling of well 16A(78)-32, engineered quantities of Lubra-Glide copolymer beads will be added to the mud system during the drilling to provide lubrication of the drill string, casing, and logging equipment. The controlled and monitored used of friction reducing compounds can potential reduce quantities of mud additives, mitigate wear of down hole equipment and improve drilling performance (e.g. reduce torque, increase Rate of Penetration).

6. Tool testing and development are critical for EGS development. Utah FORGE will encourage testing of novel tools and stimulation techniques developed through the R&D program, tool developers and service companies.

SEISMIC MONITORING NETWORK

Plans for a seismic monitoring network and protocols for mitigating induced seismicity during drilling and stimulation operations (Traffic Light System) were developed. The monitoring network will consist of 3 deep dedicated monitoring wells, 56-32 (7500 ft), 58-32 (7536 ft), and 78-32 (3200 ft) within 1000 ft of the trajectory of well 16A(78)-32, a moderate depth well FORK-68-32 (1000 ft)), and rings of shallow boreholes (100 ft deep) and surface sites at distances of 3 and 8 km (1.9 and 5.0 miles). Distributed Acoustic Sensing (DAS) fiber optic cables will be permanently deployed in wells 78-32 and 56-32. The permanent network will be augmented with temporary installations of downhole instruments and nodal geophone arrays. New modeling (Rutledge and others, 2020) was conducted to refine the location of the third deep seismic monitoring well (56-32).

Lessons Learned

1. Deep boreholes at or near reservoir depths allow low event detection levels but high borehole temperatures limit depth of emplacement and or operational life in the wells. New technologies are required for long-term seismic monitoring with high resolution instruments at temperatures exceeding 200°C. Attenuation in the granite is ~350 (Q value) as confirmed by the improved fit between models and observed seismic event magnitudes recorded by geophone string data.

2. The geophone string collocated in well 78-32 with a DAS string cemented in the casing annulus) was more sensitive than DAS (even after reprocessing) for detecting microseismicity.
3. With careful array processing the nodal geophones (located on the surface) can be used to detect seismic events below M -1.5.
4. There are recurring swarms of natural small (M < 0.5) earthquakes ~4 km (2.5 miles) east of the Blundell power plant located at depths between 2 and 6 km (1.2 and 3.7 miles) depths.
5. A revised Probabilistic Seismic Hazard Analysis (PSHA) significantly reduced the seismic hazard compared to the 2018 PSHA.
6. The models of Rutledge and others (2020) considered three locations for well 56-32; the initial position proposed by the Seismic Advisory Team (SAT), plus two positions further south and/or eastward. The initial position is best in terms of reducing the magnitudes of uncertainty and in reducing biases in location accuracy over the greatest length of well 16A(78)-32.
7. No standard Traffic Light Systems exists in the overall seismic community. Triggers for the system developed for Utah FORGE include: 1) the number of events within a specific time period; 2) magnitude of events; and 3) excessive lost circulation that cannot be readily controlled within a short time period.

SOLICITATION 1

Solicitation 1 was prepared and released to the public in April 2020. One hundred sixty-four concept papers were submitted on five topic areas. The concept papers were reviewed for technical innovation, compliance with solicitation requirements and possible Conflicts of Interest with the Technology, Analysis and Research Management Committee (TARMaC) members. Seventy R&D teams were encouraged by the TARMaC to submit full proposals; 63 were received.

Lessons Learned

1. There is significant interest from the scientific community and the oil and gas and geothermal service industries to participate in the development of EGS technologies.
2. InfoReady is a suitable platform for managing the submission and review of concept papers and proposals.
3. Even under expedited schedules, it took approximately 5 1/2 months from the time the solicitation was released to the time the TARMaC completed its report for submission to the Science and Technology Analysis Team (STAT) and R&D Steering Committee. Based on our experience, a full 6-6 1/2months should be allotted to this task.

ANALYSIS OF STRESS STATE

Data from the 58-32 well Distributed Fracture Injection Tests were reevaluated to assess earlier interpretations and improve the future collection of critical information.

1. Reevaluation of the interpretations of in-situ injection data are consistent with the earlier calculations of stress gradients.
2. Stress measurement protocols implemented on well 58-32 suggest that flowback may be a useful and expeditious technique. Flowback must start immediately after shut-in, and if it is incrementally staged, it should be done in small, short increments without changing choke size.
3. There is significant evidence that injection created detectable microseismic events.
4. There is evidence of an increase in the total residual stress between injection cycles that needs to be considered as a self-shadowing mechanism.

GEOLOGIC MODEL

The geologic model has been updated to include the results of Phase 3 Year 1. These results have been integrated into the Earth Model. The Earth Model is useful for planning drilling and stimulation activities and for research and full deployment of the Utah FORGE laboratory in Phase 3.

New seismic, gravity, hydrologic, InSAR, and GPS data have been collected. Changes in ground elevations at GPS stations, gravity measurements and water levels in two monitoring wells have been observed. interpretation of the magnetotelluric data has been refined.

Lessons Learned.

1. The Utah FORGE site continues to be quiet in terms of natural seismicity.
2. InSAR data show no evidence of ground deformation.
3. Changes in ground levels and gravity variations are interpreted to result from seasonal variations in precipitation and groundwater level.
4. MT data confirm that the EGS reservoir beneath the Utah FORGE site is entirely hosted by a hot dry granitoid; i.e., there is no evidence of electrically conductive regions that might be attributed to hydrothermal alteration or hot fluid.

ENVIRONMENTAL CONSTRAINTS AND RISKS

Assessment of the environmental and cultural impacts of the Utah FORGE project was initiated in Phase 1 and has continued through Phase 3 Year 1 – and is ongoing. During Phase 3 Year 1, archeological surveys were conducted at possible locations for seismic monitoring wells, and in areas where future infrastructure could be developed. No new cultural or environmental issues were identified in Phase 3 Year 1.

The Utah FORGE team is aware of the BLM requirement to limit activities on land suitable for hawk nesting to the period between April 1 and August 31. With careful planning, we have been able to adhere to these constraints by completing all construction and road work outside of the nesting season.

Lessons Learned

1. Cultural and environmental surveys require advance planning. All earthwork must be completed outside of the hawk nesting season. Time to complete the surveys must also be accounted for. It takes at least 3 months to conduct the surveys, prepare and submit reports to the regulatory agencies and allow for a 30-day comment period before permits for earthwork can be issued.

2. Operational and R&D requirements will change as the project evolves. In order to accommodate potential changes and ensure future flexibility: 1) all power drops have been oversized with additional capacity for monitoring activities and/or pumps; and 2) additional land parcels have been culturally cleared to provide contiguous blocks that include existing and likely future wells.

PARTNERSHIPS

New hog farm developments by Smithfield Foods continue to have a significant positive benefit to the Utah FORGE project. Beginning in late 2017, Smithfield Foods began expansion of their hog farming operations north of Milford. Smithfield Foods recently improved a section of Antelope Point Road, the main north-south road near Utah FORGE, drilled new water wells and permitted the electric distribution line route across the Utah FORGE site. Agreements are in place to purchase water from Smithfield Foods if needed.

Lessons Learned

1. Strong collaborative relationships with local stakeholders, including Smithfield Foods and Beaver County cannot be taken for granted. Maintaining these relationships requires active engagement by the Utah FORGE team.

OUTREACH AND COMMUNICATIONS

Ensuring public awareness at all levels continues to be an essential part of the Utah FORGE Outreach and Communications Program. Despite limited face-to-face contact because of COVID-19, Phase 3 Year 1 saw significant and innovative expansion of Utah FORGE Outreach and Communication activities. First and foremost, this included enlarging the team, by adding a full-time communications specialist and recruitment of two student interns with backgrounds in communications and K-12 education. The website at www.utahFORGE.com was refined with improved interactive tools and maps, links to technical publications, videos and the Geothermal Data Repository, and news on Utah FORGE activities and team members.

In addition to the Utah FORGE website, the public is being kept informed through Facebook, Twitter and LinkedIn, press releases, virtual and in-person presentations, permanent kiosks describing the importance of geothermal energy, industry interviews and articles, and the Utah FORGE e-newsletter *At the Core*. A "Capstone" class in the Department of Communication at the University of Utah has attracted 15 undergraduates who will conduct a survey of the public's knowledge of geothermal energy. A new PhD student, funded by Utah FORGE, will develop a curriculum for K-12.

Virtual presentations at scientific conferences around the world and publications in conference proceedings and journals keep the scientific community informed. The supporting data can be downloaded from the Geothermal Data Repository.

Lessons Learned

1. Outreach and Communication activities require a dedicated team of professional communicators.
2. E-newsletters, videos, and other electronic media are effective means of providing educational and informational material to the public, particularly during periods when in-person contact is limited.
3. Local stakeholder support of the Utah FORGE project has increased due to increased engagement with county, city and state representatives.
4. Various options for a Visitor Center were considered. Local stakeholder support for a conventional physical building is limited. However, some funds may be available from Utah government agencies, but no significant financial commitments are possible until a new governor and his energy team are in place.
5. Favorable viewer comments and metrics on social media suggest our communication and outreach efforts are having positive results and are increasing public awareness of geothermal energy.

D. CONCLUSIONS

The FORGE mission is to create a field laboratory where the community can test cutting-edge research and technology development focused on creating, sustaining and managing. This laboratory is intended to allow scientists and engineers to identify and advance replicable, commercial pathways to EGS implementation. Year 1 of Phase 3 has provided the opportunity to set this in motion, with planning and contracting vendors for the first extended reach well, known as well 16A(78)-32.

In addition to the facilities, infrastructure, and collaborative environment, Utah FORGE has started to provide and plan for a comprehensive network of instrumentation, data collection, and data dissemination to capture and share data and activities occurring at the site. This is reflected by activities on site (installation of seismic boreholes, building pads and roadwork for two wells) and activities offsite (issuing the first round of solicitations, stakeholder interaction, numerical modeling and data analysis)

The FORGE team, in cooperation with the STAT:

1. Solicited proposals for innovative technologies, fundamental research, operationally-oriented equipment, and methods for reservoir stimulation, monitoring and testing.
2. Developed critical infrastructure at the FORGE site where high-temperature tools, techniques, and equipment can be tested, along with novel stimulation and heat exchange techniques. Well 16A(78)-32 has been permitted and is expected to spud in late October 2020.
3. Shared data and lessons learned with the community in close to real-time on EGS advances, opportunities, and operational best practices.
4. Provided educational and research opportunities at all levels - from grade school to graduate programs, as well as to the general public, national and international specialists and laypersons.

All research and development activities at Utah FORGE focus on strengthening our understanding of the key mechanisms controlling EGS success – specifically, how to initiate, develop, control, and sustain multiple conductive and independent fracture networks in basement rock formations. This critical knowledge will be used to design and test methodologies for developing large-scale, economically viable and sustainable heat exchange systems.

PHASE 3 YEAR 1 ADVANCEMENTS

Phase 3 Year 1 in the Utah FORGE program has laid the foundations for upcoming research and for field, laboratory and numerical work. Injection testing has been revisited, revised seismic monitoring plans have been developed, and well planning has laid the technological and contractual groundwork for spudding well 16A(78)-32 in late October 2020. Numerical simulations have begun to history match legacy injection data. This now allows acceptance of a non-unique but reasonable and representative stochastic discrete fracture network so that stimulation design and simulations for hydraulic stimulation of well 16A(78)-32 can be undertaken. New geoscientific investigations have confirmed the conceptual geologic model that informs the earth model. This model is essential for planning the drilling and stimulation program. Our outreach program continues to expand geothermal awareness to the public, scientific community, and regulatory agencies. Noteworthy accomplishments are included in Table D-1.

Table D-1. *Key Accomplishments in Phase 3, Year 1: A High-Level Overview.*

Key Accomplishments	Impact
Drilling and Infrastructure	
Completed drilling plans for well 16A(78)-32. Drilling plan approved. State permitting completed.	Serves as injection well of injection /production well pair and as a platform for R&D research. First highly deviated long-reach geothermal well drilled in granite.
Prepared drilling plans for monitoring well 56-32.	Allows accurate determination of fracture locations. This well will contain DAS and geophones. It can also serve as a facility for trying out developing drilling technologies.
Completed and awarded bids to contractors for all aspects of drilling and completing well 16A(78)-32.	Competitive bidding undertaken to ensure timely and efficient drilling of this well.
Constructed pads for wells 16A(78)-32 and preliminary 56-32 and access road to the well 56-32 pad .	Supports drilling programs. After STAT approval of location of Well 56-32, the pad will be enlarged in the future for a larger drilling rig, based on the decision to drill a deeper well.
Completed plans for seismic monitoring network completed.	Allows detection of induced seismic events below M = 0 and will facilitate location of these events. This network will be essential, along with wells 56-32, 68-32, and 78-32 for locating – not just detecting – events and in particular for mapping future stimulations at the toe of well 16A(78)-32 along with research activity support.
Installation of BOR-1, BOR-2, BOR-3.	Provides monitoring capability during drilling and initial testing of 16A(78)-32. These are shallow, permanent monitoring wells that are part of the overall seismic monitoring network.

Completed electric distribution lines.	Provides opportunity for connecting electric power to the drill pads and facilities for Phase 3 operations and R&D activities.
Compiled microseismic monitoring data from 2016-2020.	Demonstrates low natural seismicity at the FORGE site.
Seismic Evaluations and Planning	
Updated PSHA.	Significantly lowered seismic hazard risk in comparison to an earlier PSHA.
Developed Seismic Mitigation Plan and Traffic Light System.	This will ensure operations are restricted, controlled or suspended depending on the level of microseismic activity (magnitude, number of occurrences) and certain drilling operations (uncontrolled lost circulation).
Analysis of microseismic data collected during well 58-32 stimulations.	Demonstrates adequacy of state-of-the-art and off-the-shelf microseismic monitoring tools; allows assessment of future monitoring requirements. Opportunities remain for improved interpretation and for higher temperature downhole equipment.
Reservoir Characterization	
Re-analysis of injection test data from well 58-32.	Confirms stress characteristics and ability to create, extend, dilate and/or reactivate fractures behind casing. Fine-tunes stress magnitude range. Identifies potential self-shadowing behavior. Confirms flowback as a viable method of stress prediction.
Analysis MT survey data.	Supports conclusion for a hot, dry granitoid; i.e., there is no evidence of conductive pathways that might be attributed to hydrothermal alteration or for hot aqueous pore fluid. Supports conclusion for absence of faults extending downward through the alluvium-granitoid contact beneath the FORGE site.
Repeated gravity measurements.	Provides baseline data for monitoring density changes in subsurface.
Other geodetic measurements.	Showed no surface deformation that can be correlated with site injection activities.
Numerical Simulations	
Refined conceptual model.	Confirms Phase 2C geologic model. Provides basis for reference numerical model.

Refined reference numerical reservoir model.	Informs the drilling and stimulation program in Phase 3, indicating anticipated temperature, pressure and stress values, according to acquired logging and other geophysical information.
Refined DFN models for sensitivity.	Discrete Fracture Network models are stochastically extended from FMI and outcrop measurements to form the basis of numerical simulations designed to history match previous injection data.
Dynamic reservoir modeling.	Demonstrates reasonable probability for propagating and sustaining interconnected fractures during Phase 3. Activities have included sensitivity evaluations of the DFN to reservoir properties to history match recorded pressures from Phase 2C. This forms the basis for a non-unique, but representative reservoir model that will be used in the upcoming year to design fractures for interconnecting the two extended reach wells. Demonstrates reasonable probability for propagating and sustaining interconnected fractures during Phase 3.
Management and Outreach Activities	
Release of the first solicitation for research proposals	Defines R&D needs based on STAT recommendations. Engages scientists and engineers from academic, national laboratory, geothermal and oil and gas communities.
Outreach and communications activities	Engages stakeholders including the local community, national and state regulators, elected and appointed officials, the general scientific and engineering communities worldwide, and educators and students (K to post-doctoral levels. Outreach and communications activities included an updated web site presence, extensive use of social media, and numerous publications and presentations.
Data Inventory update	A substantial amount of data was produced and shared on the Geothermal Data Repository (GDR) during Phase 3 Year 1, with a final total of 128,164 files.

PHASE 3 YEAR 2 PLANNED ACHIEVEMENTS

In Year 2 of Phase 3 Utah FORGE will drill the first of two directional wells into the target reservoir. After a brief hiatus to process acquired geoscientific information from this well, a stimulation campaign will be mobilized, and fracturing will be carried out at the toe of the well. In advance of that, the seismic network will be upgraded with an additional monitoring well

(well 56-32). Later in Phase 3, Year 3, the second of the extended reach wells (well 16B(78)-32) will be geosteered into the microseismic cloud enveloping the fractures created by stimulation at the toe of well 16A(78)-32. Two Wells of Opportunity (WOO-1, -2) will be drilled for technology testing in FY 2021 and FY 2022.

The steps to be accomplished in Phase 3, Year 2 include:

1. Make awards in five research topic areas for solicitations submitted in Phase 3, Year 1.
2. Implement research programs as appropriate.
3. Prepare for follow on solicitations while tracking progress of Year 1 Solicitation awards.
4. Drill well 56-32 so that the location, extent and direction of fracture growth during the stimulations of well 16A(78)-32 can be inferred from microseismic events and fiber optics.
5. Deploy nodal arrays and other seismic monitoring equipment at strategic intervals in the drilling program.
6. Drill, complete, test and secure well 16A(78)-32. Plans include an extended leakoff test, a diagnostic fracture injection test, two core runs, and multiple logging runs.
7. Engage with outside specialists to apply physics-based drilling techniques to reduce non-productive time and increase bit and drilling performance.
8. Evaluate and consolidate well stress, coring, drilling records, logging and other information associated with 16A(78)-32.
9. Incorporate these new data to refine geologic and numerical models. Develop numerical models to history match legacy injection pressure data from tests in well 58-32.
10. Using these history matched models, updated with new geoscientific information, design the stimulations at the toe of well 16A(78)-32.
11. When the stimulation design is completed and approved by a panel of specialists, re-enter well 16A(78)-32 and carry out the planned injection program intended to provide a near-toe connection between the drilled and the yet to be drilled extended reach wells.
12. Beginning in Phase 3 Year 2, facilitate Industry/R&D Performers to stimulate up-hole sections of the injection and production wells using different stimulation techniques. Potential techniques could include the use of proppant, cold water injection, propellant, abrasive slotting or CO_2 activated proppant.
13. Plan, design and contract services for drilling well 16B(78)-32, likely in the early part of FY 2022, and connect to the fracture networks from 16A(78)-32. The logging and casing program conducted in 16A(78)-32 will be repeated. Connections between the two deep wells will be confirmed by pressure transient testing, geophysical surveys, and tracer breakthrough. If communication is not adequate, 16B(78)-32 will be stimulated.

14. Conduct long-term circulation testing to establish the efficiency of the EGS system. Characterize the temperature, fracture volume, fracture interconnectivity, and heat sweep evolution of the system with time. Fracture growth, seismicity and pressures assessed using surface monitoring equipment, the seismic network, Distributed Temperature Sensors, geophysical measurements and downhole logs (e.g. Temperature-Pressure-Spinner logs) will validate model predictions. The effects of potential enhancement techniques such as repeated stimulations, changing fluid pressures and temperature will be determined.
15. Achieve step improvements in zonal isolation, reservoir characterization and geothermal science through research by external R&D Performers.
16. Optimize drilling rates through real-time Mechanical Specific Energy (MSE) analysis and physics-based drilling methods and publish results
17. Maintain and expand a vigorous outreach program and educational opportunities. Expand collaborations with international organizations.

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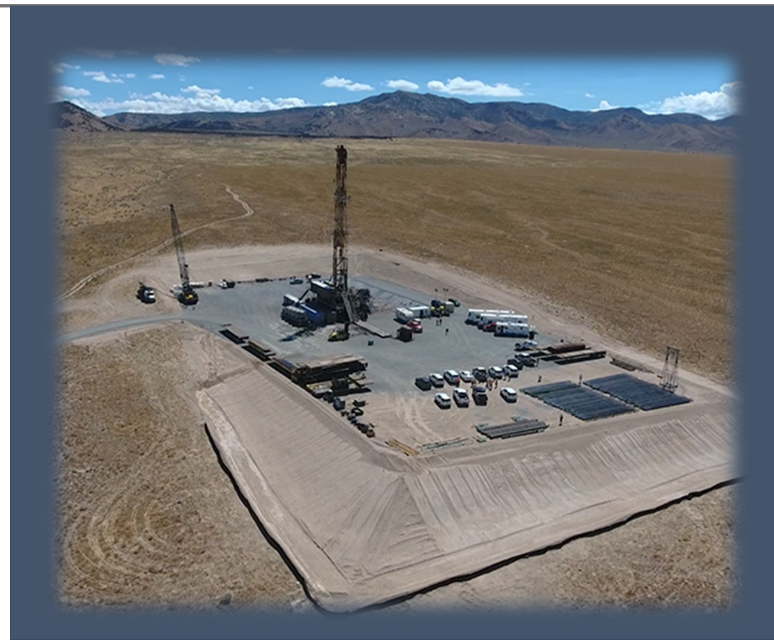


Phase 3 Year 1 Annual Report – Appendix

October 30, 2020
Revised December 28, 2020

UTAH FORGE
U.S. Department of Energy

E.A1. FORGE INFRASTRUCTURE ASSESSMENT

This section considers the infrastructure and budget required to support Utah FORGE operations and R&D activities. Both near-term and long-term activities are reviewed. We then consider budget changes required to support the infrastructure in Phase 3 Year 2. A summary of these changes in presented in Table E.A1-2

WELL 16A(78)-32

One of the major activities of Phase 3 Year 1 was developing a detailed drill plan for 16A(78)-32. The plan was approved by DOE and the State Engineer. The well will be drilled with a 65° tangent to a measured depth of 10938 ft and a true vertical depth of 8500 ft. The bottom hole temperature is anticipated to be approximately 228°C. The well design is shown in Figure 3.4.6-1**.**

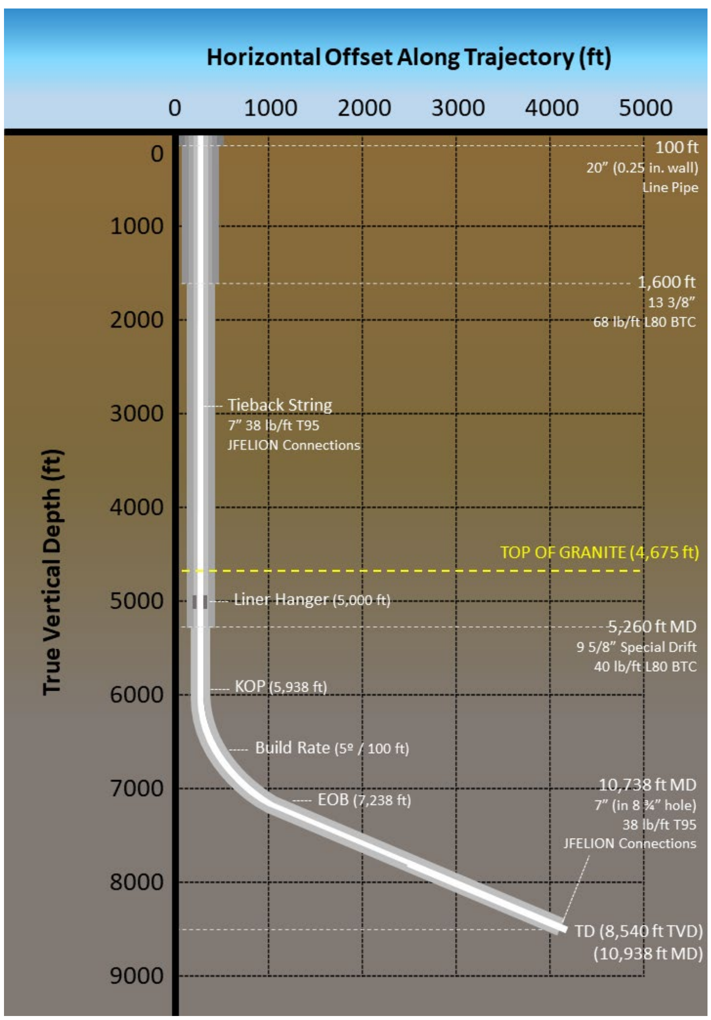


Figure 3.4.6-1. Casing diagram for well 16A(78)-32.

SEISMIC MONITORING NETWORK

A seismic monitoring network capable of detecting low magnitude induced and natural seismic events was designed (Figure E.A1-1). Three wells currently comprise the central portion of the network; wells 58-32, 68-32 and 78-32. BOR-1, BOR-2 and BOR-3, located on the 3 km (1.9 mile) ring were drilled at the end of FY 2020 and will be instrumented with broadbands seismometers by mid-October 2020 (QTR 1 FY 2021).

ROC 1 and ROC 2 and the strong motion sensor at Milford High School will be installed in early FY 2021. The remainder of the seismic monitoring network, BOR-4, BOR-5, BOR-6, and ROC-3 will be installed in mid to late FY 2021.

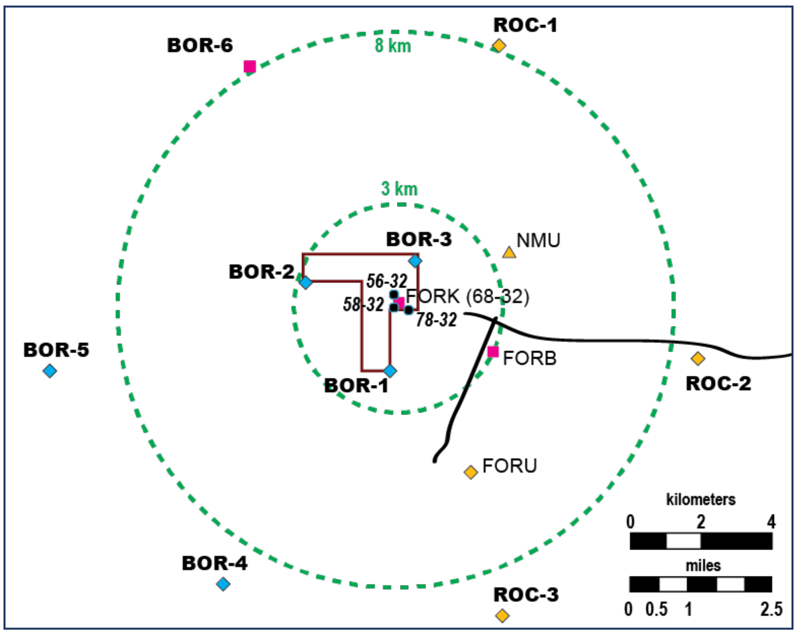


***Figure E.A1-1**. Final proposed seismic network. Seismic monitoring well 56-32 will be drilled in FY 2021. The trajectory of 16A(78)-32 will pass between wells 56-32 and FORK (68-32) from the west. Symbols: triangle = short period instrument; square = strong motion sensor; diamond = broadband instrument. Locations of proposed shallow boreholes are shown in blue and rock stations in gold. BOR-1, BOR-2 and BOR-3 were drilled in FY 2020 and will be instrumented in early FY 2021. Existing strong motion sensors are shown in magenta.*

WELL 56-32

Well 56-32 will be drilled in Mag Lee Wash north of the trajectory of well 16A(78)-32 in mid FY 2021. Figure E.A1-2 shows the existing location of the pad constructed for well 56-32 and locations recommended by the STAT. Potential pad locations in the wash to the south and east were culturally cleared to allow for flexibility in siting well 56-32 (Figure E.A1-3). In addition, the previously cleared area on the south side of the wash was extended to the east and north, providing a contiguous block of cleared ground between wells 56-32, 58-32 and 78-32. The newly cleared areas will provide a route for connecting the DAS cables in wells 78-32 and 56-32.

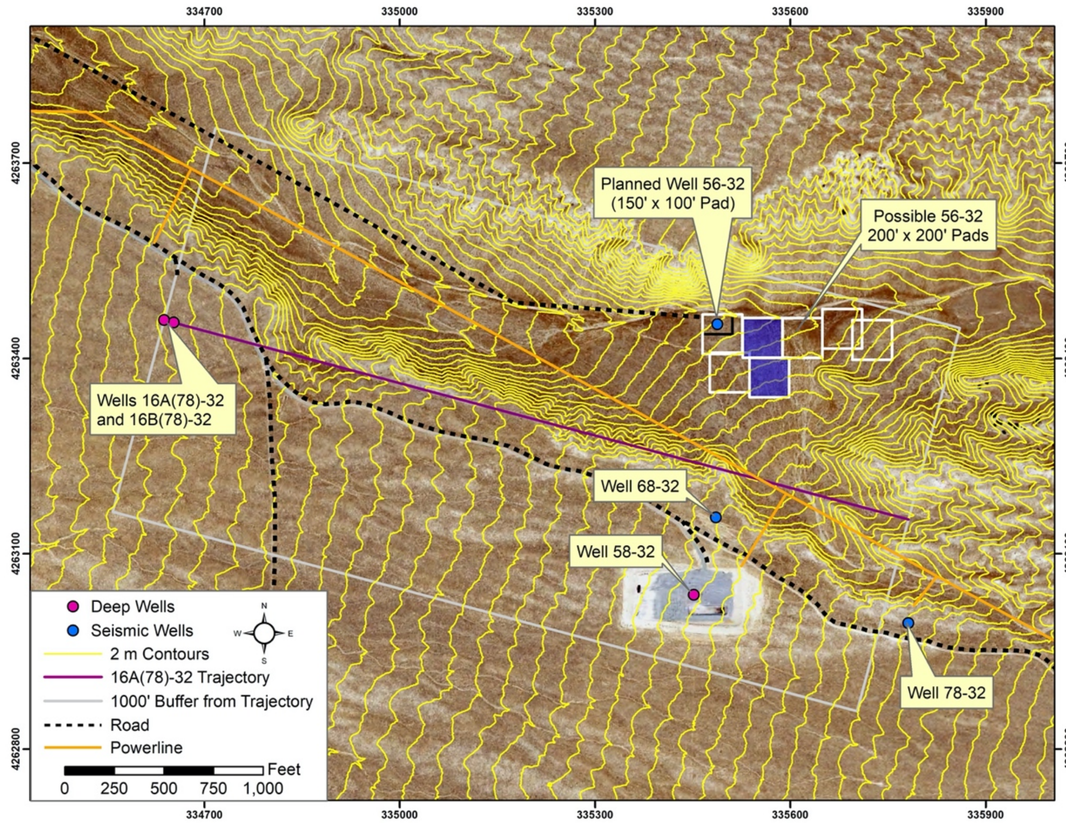


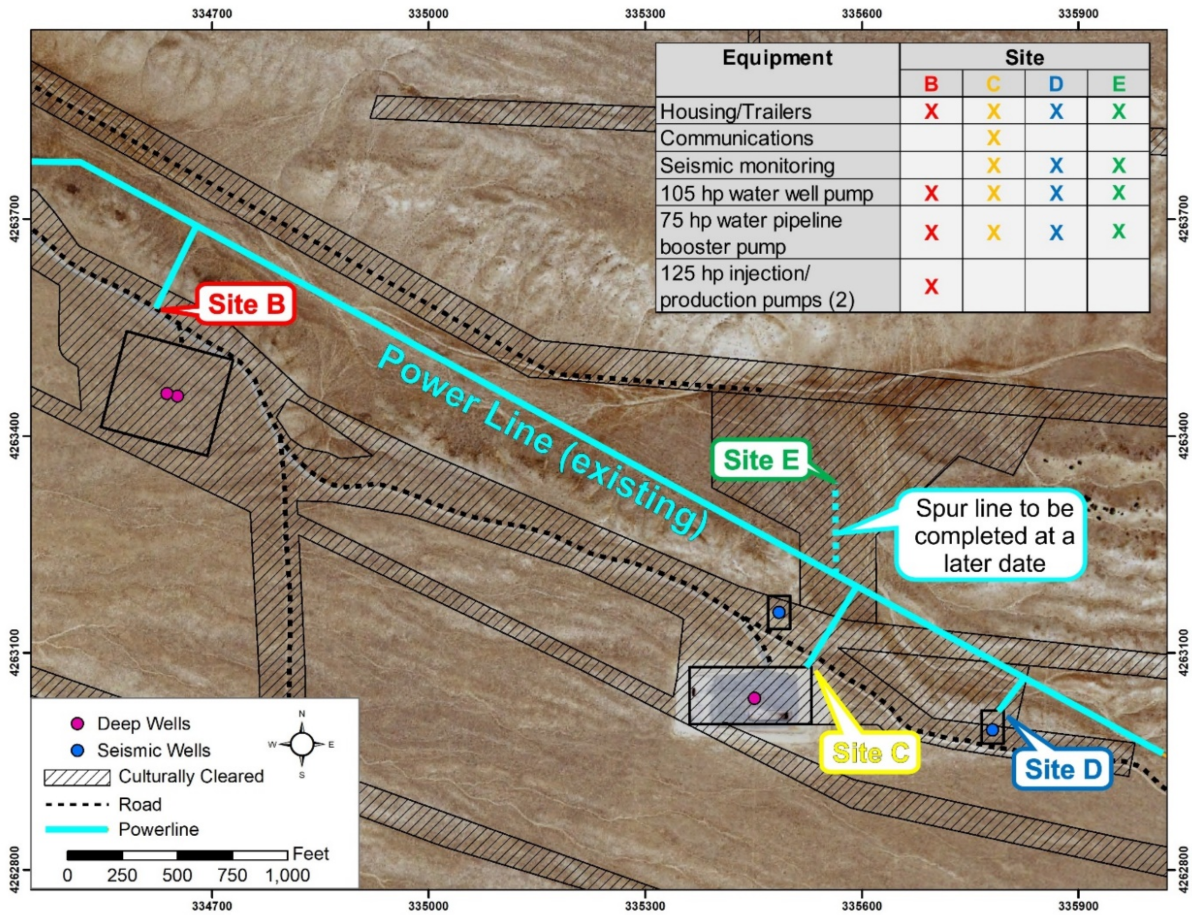
Figure E.A1-2. *Aerial view of the surface locations of FORGE wells. White squares are potential locations for well 56-32 north of 16A(78)-32. The squares are 200 ft on a side. The existing 56-32 well pad is located in the northwest corner of the western most square. Blue filled squares are locations recommended by the STAT for well 56-32. The yellow lines are 2 m (6.6 ft) contours.*

Figure E.A1-3. *Culturally cleared areas surrounding the deep wells.*

The original 56-32 pad measures 100 by 150 ft. It was designed for a truck-mounted drill rig suitable for drilling 5000 ft wells. This pad is too small for a typical “triple” drill rig capable of drilling to 7500 ft. Under the current STAT scenario, a new pad and extension of the access road will be required. The final location will be determined in early FY 2021.

ELECTRICAL UPGRADES

Spur lines from the main electric distribution line to locations near the pads for wells 16A(78)-32, 58-32 and 78-32 were constructed by Rocky Mountain Power (Figure E.A1-4). In FY 2021, the electrical connections from the ends of the spur lines to the pads will be installed. A new electrical spur line will be constructed to provide power to the 56-32 well pad. A contract for this line is in place with Rocky Mountain Power, pending easement approval from the land owner, the Utah School and Institutional Trust Lands Administration (SITLA). The new spur line is expected to be completed in the Spring of 2021. The electric lines have been engineered to provide power for present and future needs, including housing, large (125 hp) pumps for circulation testing, water wells, seismic monitoring, and communications.



Equipment	Site			
	B	C	D	E
Housing/Trailers	X	X	X	X
Communications		X		
Seismic monitoring		X	X	X
105 hp water well pump	X	X	X	X
75 hp water pipeline booster pump	X	X	X	X
125 hp injection/ production pumps (2)	X			

Figure E.A1-4*: Map showing the main electric distribution line and spur lines within the Utah FORGE site. The main electric distribution line traverses the site. Spur lines to pads for well 16A(78)-32 (sites B), 58-32 (site C) and 78-32 (site D) have been completed. The spur line to 56-32 (site E) will be completed in FY 2021. The black boxes around wellheads (pink and blue circles) are the approximate dimensions of the well pads.*

WELL OF OPPORTUNITY -1 (WOO-1)

Well of Opportunity-1 (WOO-1) is anticipated to be drilled in mid to late FY 2021. A second well will be planned if funding is available. The purpose of these wells is to provide opportunities for the community to test EGS technologies. Two meetings have been convened with the STAT, DOE and Utah FORGE to discuss well design requirements. These discussions will continue in FY 2021 and a location for the well will be selected. Possible infrastructure upgrades to be undertaken prior to drilling include road and drill pad construction, cultural surveying, power to the site, and connection to the communications system.

ROAD MAINTENANCE AND CONSTRUCTION

Currently the network of roads provides access to all of the sites within the FORGE project area.

During Phase 3 Year 2, Utah FORGE will continue to provide routine site maintenance. The majority of the work will consist of road grading, snow clearing and pad maintenance.

Beaver County has requested a one-time contribution of $150,000 to help pay for recently completed road improvements. We have budgeted $75,000 in Year 2 and will budget an additional $75,000 in Year 3.

CULTURAL SURVEYS

Figures E.A1-3 and E.A1-4 show areas that have been culturally cleared. The cleared areas provide flexibility for existing operations and R&D activities that may be conducted in the existing wells. Future activities including the drilling of WOO-1 and 2, and large-scale surveys may require new or expanded cultural clearances. Utah FORGE will initiate the process to clear additional land once we obtain a better understanding of R&D and WOO requirements.

FUTURE WATER NEEDS

Water wells may be required for stimulation activities, and subsequent circulation testing. Water rights for 250 acre-ft per year (81 million gallons/year) of non-consumptive use (Water Right 71-5429) and 50 acre-ft per year (16 million gallons/year) for consumptive use (Water Right 71-5430) have been acquired by the project. An additional 200 acre-ft of water has been offered by Smithfield Foods under a lease arrangement. Water can also be purchased from Milford. We will use water from Milford for drilling and testing wells 16A(78)-32 and 56-32.

Testing of well 78-32 indicated that the aquifer at that site could produce 200 gpm. Two wells located in the vicinity of well 78-32 could supply the required water for circulation testing. We have considered several options for water storage. One solution is to use the existing sumps on the well 58-32 and 16A(78)-32 pads. Another is to purchase a frac lake. The temporary ponds are capable of storing up to 2 million gallons of water. Water produced near well 78-32 and stored in a frac lake or in the sump on the well 58-32 pad could be gravity fed to the injection well.

All electric drops have been oversized to accommodate both a 105 hp water well pump and a 75 hp booster pump, giving flexibility in the placement of a future groundwater well.

COMMUNICATION SYSTEM

A microwave radio link to bring high-speed internet to the Utah FORGE site has been installed by Utah Education and Telehealth Network (UETN). We are currently exploring options for telemetering data from within the Utah FORGE site to a central communications hub housed in the trailer on the 58-32 well pad and its integration with the Utah FORGE-Milford HS radio link. The communication link will be used to relay data from the seismic network and the continuous GPS station, and to facilitate R&D activities at the site for remote monitoring.

PROJECT OFFICE

To fulfill the request by the DOE to provide workspace for R&D researchers while on site, several alternatives for a project office have been explored. The project office was to be large enough to accommodate two groups of researchers simultaneously, with a conference room, office spaces, rest rooms, a small kitchen area and access to high-speed internet. It was anticipated the project office would be in full time use throughout Phase 3; however, R&D activities at the site are not expected to begin until Year 2 of Phase 3. Sufficient space will be available to accommodate visitors and other personnel in a rental unit that will be deployed for the duration of drilling and subsequent testing of 16A(78)-32.

Several attempts have been made to procure a permanent facility, but all have resulted in higher than anticipated costs. In addition to the structure itself, we considered costs for maintenance, furnishings, external supporting systems and security. Maintenance includes frequent cleaning, delivery of potable water, removal of sewage and/or household waste. Furnishings would be required to outfit a conference room, kitchenette, offices and communal work areas. The facility will require foundation/anchor; electrical; and plumbing (water delivery and either a septic system or lift systems and waste tankage) systems and high-speed internet. Security measures for times when the project office is not in use (the majority of the year) include cameras (and possibly a subscription service such as Ring or Nest), exterior lighting, and fencing.

We worked closely with the University of Utah Department of Planning, Design and Construction on the original design concept. During this process an architectural firm (VCBO) was contracted to design a double-wide mobile office space with input from EGI and DOE (Figure E.A1-5). A design-build bid for construction of the project office was issued; however, none of the bids were deemed cost effective. The lowest bid was ~$430,000, well in excess of what had been budgeted.

The second option explored (April 2020) was to rent a mobile office facility similar to those found at construction sites, rather than purchase one, for the duration of the project. A bid for a rental term of 5-years with an option to extend for 2 additional years was issued. The building requirements in this second bid were more flexible to allow for a more generic ‘off-the-shelf’ unit that we believed would be more readily available. There was little interest from potential bidders to provide a long-term rental unit, with only one firm submitting a bid. We believe this is largely due to the relatively remote location of the site, and the expense that would be incurred for repair and maintenance by the building supplier. The single vendor response was for $~353,000/5 years, or ~$443,000/7 years for the unit shown in Figure E.A1-6. This was deemed too expensive.

Other options that were subsequently explored include: premanufactured buildings with alternative construction methods; working with a manufactured home company to contact builders; and short-term rentals.

Several companies that produce premanufactured buildings with alternative construction methods were contacted. One such company, Ideabox, was unable to build to commercial code at the time (April 2020). A second company, MOD3 design, that fabricates buildings out of reclaimed shipping containers submitted a preliminary bid of $307,500 for the unit shown in Figure E.A1-7. Combined with other costs, this was deemed too expensive.

Working with a Clayton Homes representative out of Grand Junction Colorado, builders of manufactured homes were contacted regarding construction of a commercial project office. The Clayton Homes representative contacted four of the manufacturers they typically work with. None were interested in doing commercial work at that time (July 2020).

Working with the vendor that is supplying temporary housing/work space during the drilling of 16A(78)-32 (HB Rentals), a short-term rental of two units that can be tied together to create space for two working groups is currently being explored. The floor plans of the units are customizable and could include restrooms, a kitchenet and two open work areas. An example layout for the combined structures is shown in Figure E.A1-8. The short-term rental units would not require a foundation. External plumbing systems would be provided along with the units by HB Rentals. Preliminary figures from HB Rentals suggest that these units could be deployed on site for two months each year for around $25,000, or left on site year-round for roughly the same cost. There are several advantages to having a unit deployed as needed. Maintenance would be performed by HB Rentals when the unit is at their facility; no security measures may be needed if the unit is in frequent use; there would be no need to winterize the unit, or alternatively draw power in the colder months to keep the pipes from freezing.

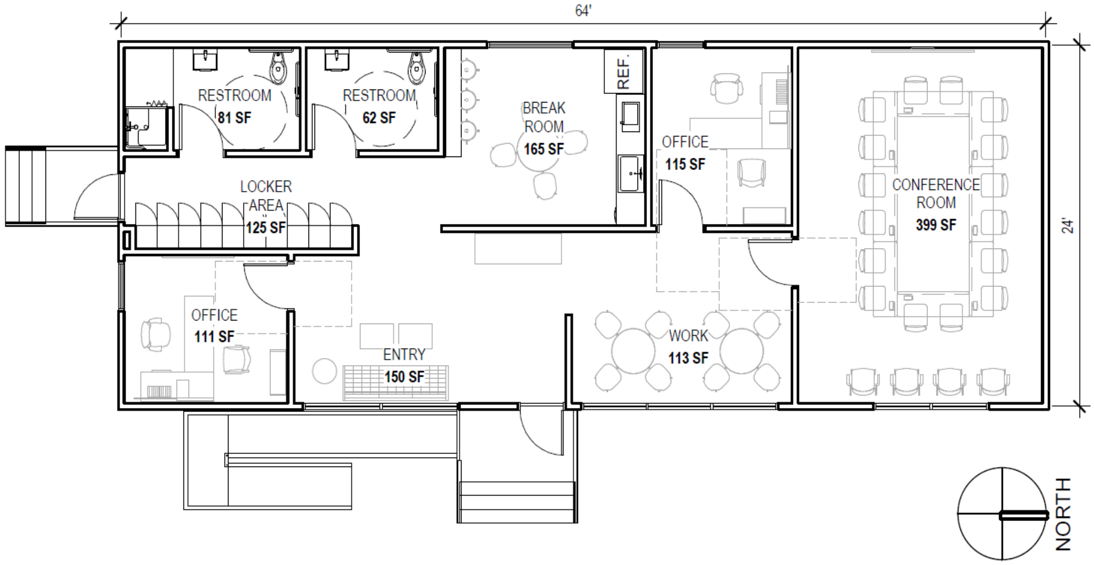


Figure E.A1-5: *Original design for the project office at the Utah FORGE site created by VCBO, contracted by University of Utah Department of Planning, Design and Construction, with input from EGI and DOE. This design was used in the first design-build bid for purchase.*

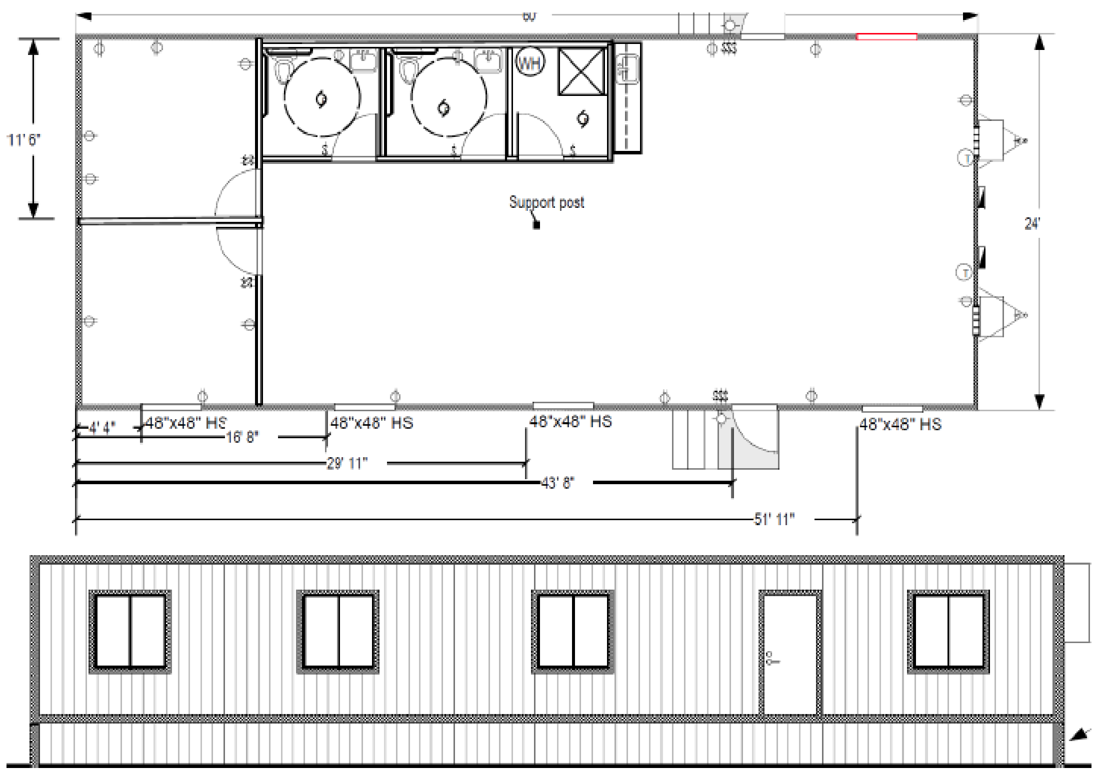


Figure E.A1-6: *Design submitted by the lone bidder in the second round of bidding for long-term rental of a project office.*

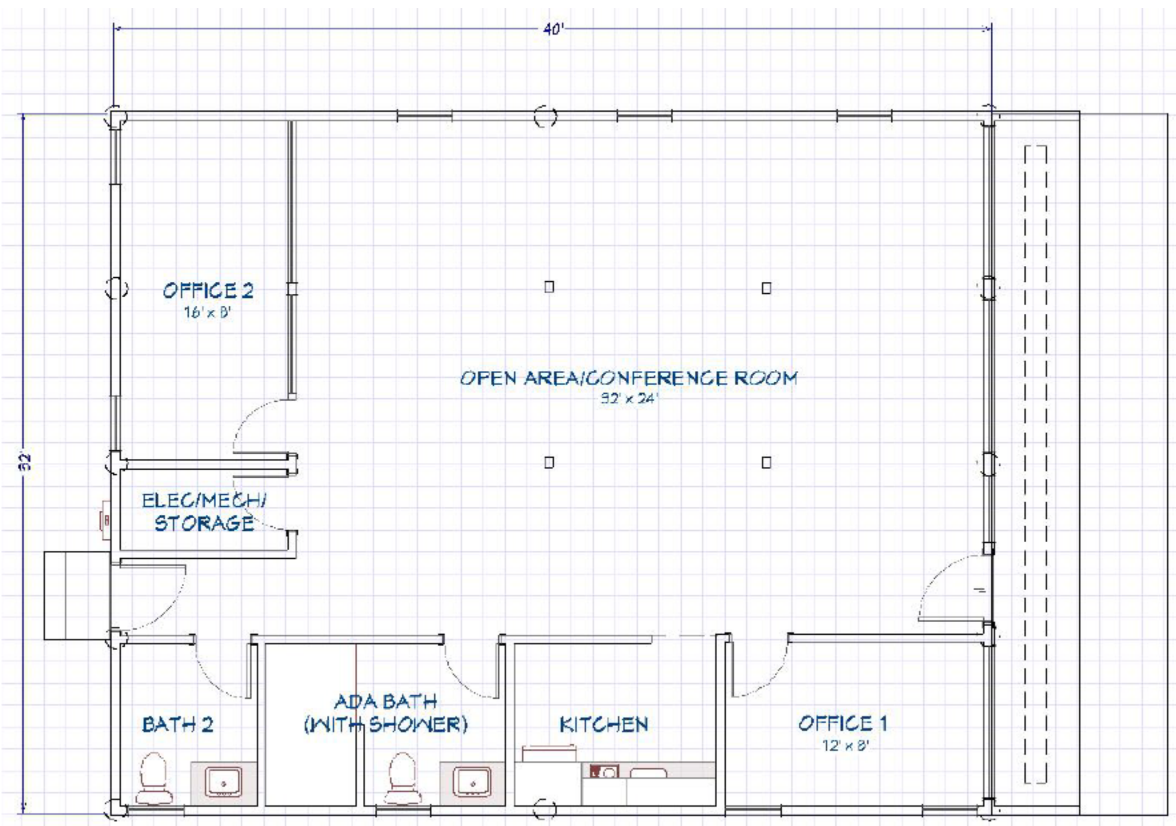


Figure E.A1-7*: Rendered image (top) and floorplan (bottom) of a project office constructed of reclaimed shipping containers from a bid submitted by MOD3 design.*

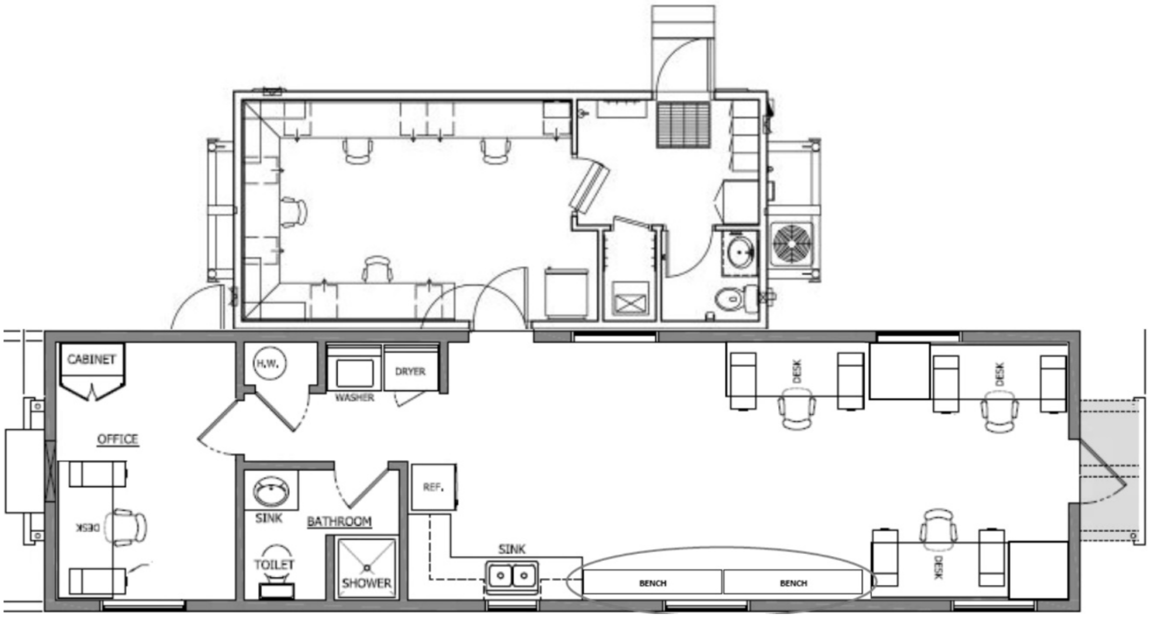


Figure E.A1-8. *Example floorplans of a bumper office (upper unit) and command center (lower unite) that have been joined together. Floor plans for these units are customizable.*

VISITOR CENTER

Increasing public awareness and acceptance of geothermal energy is a priority of Utah FORGE. In Phase 3 Year 1, multiple options for a Visitor Center were considered by the FORGE communications team and DOE. Table E.A1-1 presents the advantages and disadvantages of various approaches to a Visitors Center. We originally considered a physical building. While buildings have certain advantages, they are costly (refer to the section on the Project Office), and require funds for long term staffing, maintenance, and security. At the other end of the spectrum is a virtual Visitor Center. Such a center can be accessed from any location such as homes, libraries, state and county buildings, and museums with an internet connection.

The Governor's Office of Energy Development (OED) has been included in the discussion about a potential Visitor Center and has expressed some interest in possibly participating in its creation. Their vision for a Visitor Center highlights the many different forms of renewable energy in the state, including geothermal, EGS, wind, solar, hydro, and biogas. However, because a new governor is being elected in November 2020, further discussion about funding for and commitment to a Visitor Center cannot continue until after the new governor and legislative leadership has been inaugurated, budgetary priorities determined, and the energy leads announced.

Table E.A1-1. *Options for visitor center.*

Visitor Center Options					
Option	**Description**	**Advantages**	**Issues**	**Requirements**	**Costs**
Virtual	Website dedicated to the Beaver County renewable energy corridor. Information on the various sources, videos, animations illustrating processes, interactive games and quizzes for kids. Links to the page from participating organization's websites.	Most easily sustained following end of project. Allows for other partners to more seamlessly participate. Avoids need for permits, etc.	Requires third-party to build site. Commitment from partners to meet deadlines, provide content.	Selection of third-party website developer, cooperation of partners, project management, content generation, hosting, updating.	$150,000
Kiosk in Milford Park	Larger information panel discussing different types of energy in the area or just geothermal. Located in town for easy access by school groups, tourists, visitors. Refence back to participating group's / groups' website(s).	Ease of production, no-maintenance, most cost-efficient, located in existing tourist spot with option for brochure placement.	Cannot be udpated. City may not wish to keep following project.	Content, agreed-upon design, production, installation, possible permits from the city / county.	$7,500 - $10,000
Caboose in Milford Park	Convert existing Union Pacific caboose located in local Milford Park into a free-standing, staffed visitor center that highlights renewable energy corridor.	Offers a more in-depth, free-standing visitor center in an already existing, recognizable facility. Allows for greater partner participation. Provides physical location for students and potential tourists.	Gaining permission to rent, us or buy the caboose from the City of Milford. Making the required upgrades to be compliant with the ADA such as ramps, wider entry ways, egresses, etc. Hiring and training staff. Limited availability (e.g., winter). Ongoing upkeep. Questions around sustainability after the project.	Purchasing / renting the caboose. Possible electrical needs. Permits. Necessary construction to be ADA compliant, including ramps, enlarging doors. Hiring and training docent. Insurance.	$50,000-$150,000
Exhibit at Natural History Museum of Utah	A permanent exhibit focused on renewable energy in Utah housed at the Natural History Museum of Utah.	Provides a permanent home to the exhibit. Nearly 250,000 visitors annually.	Interest of the NHMU. Fitting in with their requirements, limited exhibit.	The NHMU deciding to include the topic in a display. From decision to implementation is a 1-1/2 to 2 year process	No hard costs.
Buy / Build Visitor Center	A free-standing visitor center, housing exhibits around Utah FORGE, geothermal energy, other renewable energy in the region.	Offers more in-depth, free-standing visitor center. Provides physical location of students and tourists.	Cost. Time line to build new / remodel existing structure. Staffing, maintenance, questions about ongoing sustainability. Lack of interest from partners / other stakeholders. Legal costs for commitment agreements.	Purchase an existing building or buy land on which to build a new structure. Must be ADA compliant, meet codes for waste removal, landscape, lighting, parking, restrooms. Must hire staff including docents, maintenance, janitorial and security. Must hire marketing staff. Legally-binding commitment agreements from partners. Development of economic sustainabilty plan.	$400,000 - $1,500,000

R&D SUPPORT

On-site support for R&D activities will be required in year 2 of Phase 3. During periods of drilling and testing, we anticipate the necessary support equipment and personnel will be on site to deploy downhole and surface instruments. On-site facilities could include drill rigs, cranes/boom trucks, storage facilities, and a Project Office. The Site Safety Manager and a Drill Site Manager will ensure all activities are conducted safe manner, will not cause damage to the infrastructure and wells and in accordance with permitted activities. Every attempt will be made to schedule R&D activities at times when costs can be minimized. However, we will work closely with the R&D teams to ensure their projects are completed in a timely manner. We have budgeted $456,070 in Phase 3 Year 2 to support the R&D projects but expect this amount to increase in future years as the projects mature and technologies and tools become ready to test.

DECOMMISSIONING

The original FORGE FOA states that the site will need to be decommissioned after five years of operation. Based on the current timing we expect that to be in 2024. Abandonment could vary from no cost to Utah FORGE if a geothermal developer takes over the project, to plugging the wells and bringing the pads and roads back to their original grade and condition. We currently have budgeted $1,000,000 for restoration and abandonment. As new pads and wells are drilled in future years, the budget will increase to accommodate the additional restoration costs.

BUDGET CONSIDERATIONS

Table E.A1-2 summarizes changes in the project budget for Phase 3 Year 2, compared to the budget proposed for Phase 3 Year 1. The most significant change is in the drilling of 16A(78)-32, which has decreased by slightly more than $2,000,000. This change reflects the downturn in the oil and gas industry and the availability of drill rigs and crews. As a result of this downturn, day rates and mobilization costs were significantly lower than several years ago when well 58-32 was drilled.

The pandemic has had both positive and negative effects on the budget. Travel has been significantly curtailed for FORGE and STAT members. However, the necessity of maintaining a safe working environment during the drilling of 16A(78)-32, while minimizing downtime resulting from sick workers, requires us to self-isolate and place greater reliance on contractors to provide routine support services. We have contracted for housing trailers, a staffed checkpoint station to ensure those who are sick are restricted from the site, removal of sewage and wastewater, a trailer in case someone develops symptoms, and power supplies for the camp. These full extent costs will be evaluated once the drilling is completed.

The final design and drill plan were modified from the original plan to accommodate the following equipment and activities:

- Slight changes in wellhead location after surveying and setting conductor pipe.
- Changes in service providers.
- Drilling permit obtained from State and alerts updated.
- Production hole changed from 8-1/2” to 8-3/4”
- 7-inch casing connections changed to JFELION

- 9-5/8” intermediate casing changed to 40 ib/ft special drift
- Days vs. Depth adjusted to 145 days
- COVID-19 precautions added
- Gyro surveys added
- VRSS for vertical hole added to keep inclination within two degrees of vertical
- MSE Training implemented
- All BHAs and bits modified
- Mud system modified per selected vendor.
- Wellheads selected, including the 7-inch.
- Cementing protocols modified for selected vendor.
- Bit selection refined on the fly.
- XLOT made non-optional per STAT
- Liner hanger procedure and tieback installation and wellhead installation refined with vendors.
- Added ghost reamer run before running casing.
- Stoplight system reworded per DOE request.

Table E.A1-2. Summary of budget changes from Phase 3 Year 1 to Phase 3 Year 2. Column 5 summarizes the reasons for these changes.

Budget Category	Subtotal	Variance (total by category)	Category	Reason for Variance
Faculty Salary		38,583	Personnel	
Phil Wannamaker	32,542			
Kris Pankow	6,041			Increased time
Other Salaries			Personnel	
Employee Benefits (Required if any salaries are indicated)		14,276	Fringe	Benefits for Phil W. and Kris P.
Faculty 37%	14,276			
Travel		-156,596	Travel	Reduced because of travel restrictions due to COVID-19
Consultants		-326,700	Contract	
STAT Team Compensation	-331,500			STAT members who do not charge
Greg Steiner (Pankow)	-40,000			Seismic engineering work not required
Guards	44,800			Required to monitor personnel entering site
Publishing/Page Charges		0	Other	
Repairs and Maintenance		0	Other	
Business Meals		-50,000	Other	Reduced because of travel restrictions due to COVID-19
Other Expenses		789,200		
Videos & Related Outreach Supplies	75,000		Other	Increased outreach activities
Decommission	655,000		Other	Additional costs to decommission wells and regrade
Pankow Seismic Expenses	-15,800		Other	
Roads/Gravel/Misc Rollins site work	75,000		Other	Contribution to Beaver County for road construction
Budget Items subject to F&A		**308,763**		
Items Excluded from F&A Calculation (MTDC)				
Equipment (over $5000 per asset)		14,860		
Visitor Center	150,000		Construction	Estimated additional cost for virtual Visitor Center
Project/Operations Office	-200,000		Construction	No R&D site activities in FY 2021
Pankow High Temp Geophones/Equipment	14,860		Equipment	Additional costs for BOR-1, BOR-2, BOR-3 geophones
Infrastructure-Fencing & other Rollins	50,000		Equipment	Required to maintain safe operations
Subcontracts > $25,000 & Drilling		-499,918		
Utah Geological Survey	20,238		Contract	Supplemental funding for UGS activities
GRG-Well Supervision	145,000		Contract	Supplemental funding for supervision and well design work
Red Resources	180,000		Contract	Supplemental funding for supervision and well design work
ITASCA/Oklahoma	150,000		Contract	Supplemental funding for modeling
Golder Associates	50,000		Contract	Supplemental funding for modeling
INL (Rob Podgorney)	-200,000		Contract	Change in personnel at INL (Podgorney)
Drilling	0			
Seismic Monitoring Wells	653,676		Contract-Drill	Best estimate based on AFE and increased depth from 5000-7500
Construction Equipment-Rollins	150,000		Contract-Drill	Improved equipment rental estimate
Production/Injection Pads (3)	189,885		Contract-Drill	Required for leveling 16A and sump and new 56 pad
Logging	16,349		Contract-Drill	Actual bid price
Deep Well Ph.3 YR1 Well #1	-2,071,876		Contract-Drill	Costs reduced due to slow oil and gas industry, AFE dropped
Other-Drill Site Supervision	150,000		Contract-Drill	For additional DSMs
Directional Tech (DH) & MWD Computer/Tech	66,810		Contract-Drill	Bid price
		-485,058		
TOTAL DIRECT COSTS		**-151,296**		
INDIRECT (F&A) COSTS (49%)		**151,294**	Indirect	
TOTAL BUDGET		**-2**		

E.A2 UPDATE SITE CHARACTERIZATION DATA INVENTORY

A substantial amount of data was produced and shared on the Geothermal Data Repository (GDR) during Phase 3 Year 1, with a final total of 128,164 files. Additionally, at the end of FY 2020 there had been 10,150 downloads of various Utah FORGE datasets from GDR.

The Utah FORGE website is now on line at: https://utahforge.com. This site contains information about the project, project news, solicitations, and data links which are found on the on the Data Dashboard.

A compilation of data that became available for download via GDR, during the Phase 3, 2020 FY, follows:

(1) High-Resolution DAS Microseismic Data from Well 78-32 (two separate submissions 11/13/2019 & 04/01/2002):

https://gdr.openei.org/submissions/1185 and https://gdr.openei.org/submissions/1207

127,676 segy files

(2) Utah FORGE: Phase 2C Topical Report (added 12/09/2019):

https://gdr.openei.org/submissions/1187

34 files

(3) Data for 3-D Model Development - Lithology, Temperature, Pressure, and Stress (added 03/13/2020): https://gdr.openei.org/submissions/1205

12 files

(4) Utah FORGE Well 16A(78)-32 Planned Trajectory Coordinates and Depths (added 03/24/2020): https://gdr.openei.org/submissions/1208

1 file

(5) 2019 ARMA Slide Presentation (added 03/24/2020):

https://gdr.openei.org/submissions/1209

1 file

(6) 58-32 Injection and Packer Performance, April 2019 (added 03/25/2020): https://gdr.openei.org/submissions/1210

1 File

(7) Utah FORGE Seismic Activity: April 2019 (added 04/24/2020):

https://gdr.openei.org/submissions/1215

1 file

(8) Report: Numerical Modeling of Microearthquake Monitoring

at the Utah FORGE Site, LANL (added 06/08/2020):

https://gdr.openei.org/submissions/1187

1 file

(9) Utah FORGE Well 16(78)-32 Planned Trajectory (added 04/29/2020):

https://gdr.openei.org/submissions/1216

1 file

(10) Discrete fracture network (DFN) data (added 06/24/2020):

https://gdr.openei.org/submissions/1222

154 files

(11) InSAR Study results: report and data (added 09/29/2020):

https://gdr.openei.org/submissions/1251

279 files

(12) Ground water monitoring data from wells WOW-2 and WOW-3 (added 09/30/2020):

https://gdr.openei.org/submissions/1252

1 file

(13) Microgravity and GPS data through time (added 10/7/2020).

https://gdr.openei.org/submissions/1256

1 file.

(14) Magnetotelluric (MT) data (added 10/7/2020).

https://gdr.openei.org/submissions/1255

3 files.

E.A3 UPDATED PERMITTING INVENTORY

A. Drilling permits were issued by the State Engineer for well 56-32 and the upper vertical portion of 16A(78)-32 in March 2020. The applications were retracted in June 2020 because of changes to the drilling plans.

B. A revised application to drill 16A(78)-32 was approved by the State Engineer in August 2020.

C. Permits for boreholes BOR-1, BOR-2, and BOR-3 were submitted and approved in September 2020.

D. An application for a Conditional Use Permit (CUP) from Beaver County was submitted to the Beaver County Planning and Zoning Commission in September 2020. The application included: 1) drilling of well 16A(78)-32; 2) to a MD of 11000 ft; 2) drilling of well 56-32 to 7500 ft; 3) drilling of Well of Opportunity-1 (WOO-1) to 7500 ft; 4) drilling of boreholes BOR-1, BOR-2, and BOR-3 (each to 100 ft); and temporary housing for drilling and drilling support crews. The Commission will formally approve the application in October 2020.

E. Additional land was culturally cleared near wells 58-32, 78-32 and 56-32 and approved by the State Institution and Trust Land Administration (SITLA) for Utah FORGE activities were of land were culturally cleared and approved for Utah FORGE use.

F. Permits for the electrical distribution line were obtained by Smithfield Foods. SITLA granted a Right of Way to Rocky Mountain Power.

E.A4 OPTIONAL TO PHASE 3 YR1 ANNUAL REPORT

Attachment 1 Statement of Project Objectives for Phase 3, Years 1 and 2
Frontier Observatory for Research in Geothermal Energy – Milford Site, Utah

A. Objectives

The ultimate objective of Utah FORGE (Recipient) is to demonstrate the viability of Enhanced Geothermal Systems (EGS) energy development. The project will create a controlled environment where EGS technologies and approaches can be developed, tested and optimized. The laboratory will function as a dedicated site for technical interaction and public education to support the widespread adoption of EGS as an energy source. The primary objectives of Years 1 and 2 of Phase 3 are to:

- Complete installation of a seismic monitoring system and all supporting infrastructure for the drilling and testing of a full-sized EGS well:
- Design, plan, drill and test the first full-sized EGS well at the site;
- Provide a well characterized, highly instrumented site to monitor reservoir creation from a scientific and hazard perspective;
- Solicit, competitively award, and track research and development (R&D) sub awards;
- Provide outreach that showcases to the public, stakeholders, and the energy industry that EGS technologies have the potential to contribute significantly to power generation in the future;
- Provide educational and research opportunities for students at all levels; and
- In collaboration with DOE, develop a comprehensive annual report summarizing activities, successes, and lessons learned at the Milford site.

B. Scope of Project

Phase 3 will involve full implementation of the Utah FORGE laboratory, including completion of all infrastructure required to support Phase 3 drilling, stimulation, flow testing, and reservoir analysis. In Phase 3, guided by earth and reservoir modeling, and technical advice from the Science and Technology Analysis Team (STAT), the Recipient will establish 2 or more wells to support competitively-solicited R&D projects designed to develop, test and evaluate new tools and techniques for EGS optimization. Key Phase 3 technical challenges that R&D projects are anticipated to address include:

- Test and prove multistage stimulation technologies that are effective and environmentally benign;
- Create and image a network of appropriate fluid conductivity pathways potentially interconnecting the wells and in collaboration with the STAT, awardees, and DOE, develop and document an understanding of how and why the pathways were created (based on observables) as well as a methodology for repeatability of this reservoir creation process;
- Circulate water through the stimulated fracture network for sufficient time to characterize heat exchange, and to undertake numerical simulations that predict and validate long term heat exchange potential (not focused on power production); and
- Test high-temperature logging and fracture imaging tools and equipment as well as novel stimulation and heat exchange techniques.

Well nomenclature used in this report:

Deep Well #1: currently referred to as 16A(78)-32
Deep Seismic Monitoring Well: currently referred to as 56-32
Pilot Well: currently referred to as WOO-1
BOR-1, BOR-2, and BOR-3: refers to shallow (~100 ft) boreholes on the 3 km (1.9 miles) ring of the seismic network

Milestone Chart

Utah FORGE milestones	FY 2020	FY2021				
		Q1	Q2	Q3	Q4	
3.1.0 Project Management						
3.1.1. Update Project Management Plan	✓	X				DELIVERABLE
3.1.1.1 Communications SOP	✓					DELIVERABLE
3.1.1.2 Liability / Indemnity Plan	✓	X				DELIVERABLE
3.1.2 Update Environmental Safety & Health Plan	✓	X				DELIVERABLE
3.1.3 Update Sample Handling and Core Curation Plan	✓	X				DELIVERABLE
3.1.4 Update Outreach and Communication Plan	✓	X				DELIVERABLE
3.1.5 Phase 3 Annual Topical Report	X				X	DELIVERABLE
3.2.0 R&D Management						
3.2.2 Technical Monitoring - review technical progress of R&D projects	n/a	X	X	X		
3.2.3 Financial Monitoring - review financial progress of R&D projects	n/a	X	X	X		
Draft Phase 3 R&D Solicitation 2			X			DELIVERABLE
3.3.0 Seismic Monitoring						
3.3.0 Archive Telemetered Data	✓				X	
3.3.0 Compile FORGE earthquake catalog	✓				X	
3.3.1 Convene Expert Seismology panel	✓					
3.3.1 Submit monitoring plan to DOE and STAT	✓					DELIVERABLE
3.3.2 Update ISMP and PHSA	✓		X			DELIVERABLE
3.4.0 Infrastructure Development						
3.4.2 Construct Drill Pad for Seismic Well and Deep Well	✓					
3.4.3 Establish Project Office	n/a					
3.4.4 Coordinate Establishment of Visitor Center – research funding options	✓					
3.4.6 Expert Drilling Panel	✓					
Go/No-GO #1 (Drilling Plans)	✓					DELIVERABLE
3.4.7 Drill Deep Well #1		X				
3.4.8 Drill Deep Seismic Well	n/a					
3.4.9 Conduct Aquifer Test	n/a					
3.5.0 Reservoir Modeling						
3.5.1 Modeling and Simulation Plan	✓					DELIVERABLE
3.5.2 Revise reference/native state models	✓					
3.5.3 Revise reference DFN	✓	X				
3.5.4 Simulate hydraulic stimulation options for Phase 3 Well 1			X			
3.5.5 Long-term THM simulations				X		
3.5.6 Convene Expert Stimulation Panel			X			
Go/No-GO #2 (Reservoir Testing Plans)		X				DELIVERABLE
3.6.0 Reservoir Testing Deep Well #1						
3.6.1.1 Reservoir Testing Deep Well #1			X			

3.6.1.2 Evaluate Geophysical Logs	n/a					
3.6.1.2 Evaluate Pressure-Time Data				X		
3.7.0 High-Resolution Data Acquisition and Analysis						
3.7.1 High-resolution Magnetotelluric Survey – complete analysis	✓					
3.7.2 Water Geochemistry of Phase 3 Wells - collect and analyze waters of Phase 3 wells	X	X			X	
3.7.3 Conduct InSAR Analysis - annual report	✓				X	
3.7.4 Perform 4D Gravity Surveys - annual report	✓				X	
3.7.5 Collect GPS Monitoring data - annual report	✓				X	
3.7.6 Geochemical Modeling of Water-Rock Interactions - report			X			
3.7.7 Analysis of Rock Samples	n/a				X	
3.7.8 Refine Phase 2C Conceptual Geologic Model	✓				X	
3.8.0 Data Sharing						
Establish online data archive for seismic data	✓					
3.9.0 Outreach and Communications						
3.9.0 Complete kiosk panels for Utah FORGE site	✓					
3.9.0 Appoint undergraduate intern from College of Education - U of U	✓					
3.9.0 Appoint undergraduate intern from Communications Dept. - U of U	✓					
3.9.0 Post interactive web-based tool created by NREL to represent stimulation effects	✓					
3.9.0 Undergrad chemical engineering students to complete one new geothermal energy demo module	X					
3.9.0 Formulate draft K-12 curriculum based on identified National and State level science standards	✓					
3.9.0 Publish 30-minute lecture/webinar on conventional geothermal resources w/downloadable slides	✓					
3.9.0 Publish 30-minute lecture/webinar on unconventional geothermal resources w/downloadable slides	X	X				
3.10.0 Permitting and Regulatory Compliance	✓				X	DELIVERABLE
Go/No-Go #3 (SOPO/Budget Y3-5				X		

C. Tasks to be Performed

Task 3.1.0 – Project Management

The Recipient shall execute the project in accordance with the approved Project Management Plan covering the entire project period. The Recipient shall manage and control project activities in accordance with their established processes and procedures to ensure tasks and subtasks are completed within schedule and budget by task/spend plan constraints defined by the Project Management Plan. This includes tracking and reporting progress and project risks to DOE and other stakeholders.

Subtask 3.1.1 – Update Project Management Plan
The Recipient shall revise the Project Management Plan (PMP). The PMP shall define the approach to management of the project and include information relative to project risk and risk mitigation strategies, an integrated project schedule (detailing the interdependencies of site operations and competitive R&D), milestones, funding and cost/spend plans, and decision point success criteria. The revised PMP shall be submitted within 30 days of the start of Phase 3. The DOE Project Officer shall have 20 calendar days from receipt of the PMP to review and provide comments to the Recipient. Within 15 calendar days after receipt of the DOE's comments, the Recipient shall submit a final Project Management Plan to the DOE Project Officer for review and approval.

The Recipient shall review, update and amend the PMP at key points in the project as required by DOE, notably at key Decision Points or upon schedule variances of more than 3 months and cost variances of more than 15%, which may require modifications to the agreement and constitutes a re-base lining of the project.

1. Planned Activities:

Update the PMP.

2. Actual Accomplishments:

The PMP was updated. The plan was submitted to DOE and approved.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Update the PMP to incorporate Phase 3 Year 2 milestones, budgets, risks and risk mitigation strategies and project schedule.

3.1.1.1 – The Recipient shall develop as appendices to the updated PMP standard operating procedures (SOPs) that define communication paths and protocols for all project participants during normal day-to-day project periods and during periods of active site operations (e.g., drilling, stimulation, and R&D testing). These SOPs will detail the communication paths between the various functions and entities of the Utah FORGE Team, the STAT, site support contractors, sub-recipients conducting competitively selected R&D, and the DOE Geothermal Technologies Office. The plan should include an updated organizational structure. In addition, the plan will define processes and communication channels to address potential project-related conflicts. Additionally, internal communications defined in this plan should be consistent and not conflict with communication protocols established during hazardous or emergency situations as defined in the updated ES&H Plan (subtask 3.1.2).

1. Planned Activities:

Define the SOP for communication paths and protocols for all project participants.

2. Actual Accomplishments:

A document describing SOP for communication paths and protocols was prepared. SOP were defined for normal, day-to-day operations and for periods of site activities. The plan was submitted to DOE and approved.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Update the SOP as necessary to reflect changes in project participants, communication paths and protocols.

3.1.1.2 – The Recipient shall develop a document outlining Liability / Indemnity established by the Team associated with operations at the Milford site. The Recipient shall develop an official procedure for reviewing, validating, and approving liabilities for all entities that will work on the Milford site, to be shared in the annual solicitations and process followed by the team prior to any physical work taking place at Milford. This "Procedure" should be outlined in the Liability and Indemnity Strategy and Process document as part of the PMP, or as a separate appendix to the PMP.

1. Planned Activities:

Develop official procedure for reviewing, validating, and approving liabilities for all entities that will work on the FORGE site

2. Actual Accomplishments:

A procedure for reviewing, validating and approving liabilities was developed. These proceedures are documented in the Liability and Indemnity Strategy and Process included as an attachment to the PMP. The plan was submitted to DOE and approved.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Update the proceedure as necessary.

Subtask 3.1.2 – Update Environmental, Safety and Health Plan

The Recipient shall revise the Environmental, Safety and Health (ES&H) Plan developed during earlier phases of the project. The plan shall identify and analyze hazards and risks to the safety of personnel and property as well as identify issues that could have an adverse environmental impact. The plan will include personnel responsible for on-site safety as well as procedures and protocols for hazards communication, emergency evacuation and response, and include ES&H training requirements for access to the FORGE site as well as protocols for all R&D sub-recipients, subcontractors, and other partners working on the Milford site. ES&H requirements shall flow down to subcontractors. Given the breadth of FORGE activities, the ES&H plan will serve as the foundation for additional planning needed to execute specific site activities. This will include directions for the development of activity specific plans, which will be required for all work conducted at the FORGE site.

1. Planned Activities:

Update the existing Environmental, Safety and Health Plan.

2. Actual Accomplishments:

The Environmental, Safety and Health Plan was updated. The plan was submitted to DOE and approved.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Update the Environmental, Safety and Health Plan as necessary.

Subtask 3.1.3 – Update Sample Handling and Core Curation Plan

The Recipient shall update the Sample Handling and Core Curation Plan developed during earlier phases of the project. The plan will be developed for any physical samples, including but not limited to core and cuttings obtained during FORGE drilling. This plan will provide details of on-site sample handling and analyses, long-term curation, the sample request approval process and protocols for sub-sampling and distribution of samples to individual investigators and how these processes will be integrated into the newly established front-end data portal or FORGE website. Additionally, the plan will describe sample inventory methodologies and the mechanism for interested parties to access records associated with the stored samples (via the FORGE Node of the GDR), including data and associated metadata acquired from various laboratory studies on these samples. In addition, the Recipient will ensure any accompanying material (thin sections, photos, analytical data, sample handling records, etc.) related to the core can be made available to facilitate scientific meetings to discuss results and future directions for sample studies and for subsequent sub-sampling of the core. The plan shall also address long-term housing of physical samples throughout the project lifetime and beyond (with no long-term costs to DOE beyond the project's period of performance permitted).

1. Planned Activities:

Update the Sample Handling and Core Curation Plan

2. Actual Accomplishments:

The Sample Handling and Core Curation Plan was updated. The plan was submitted to DOE and approved.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Update the Sample Handling and Core Curation Plan as necessary.

Subtask 3.1.4 – Update Outreach and Communication Plan

The Recipient shall update the Outreach and Communications Plan developed in earlier phases of the project to address communications, education, and outreach to outside stakeholders in Phase 3. The plan must include a clearly stated objective that summarizes the values and focus of FORGE Communications and Outreach efforts, and that also supports the overall goals of the FORGE initiative. The plan must include the planned innovative communication and outreach activities, with each activity to include a description, a target audience, the resources required to perform the activity, the timing of the activity, and that activity's unique goal or outcome mapped to the above-mentioned overall objective of FORGE Communications and Outreach efforts. The Project Management Plan should reflect two major Communications and Outreach milestones per quarter.

1. Planned Activities:

Update the Outreach and Communication Plan.

2. Actual Accomplishments:

The Outreach and Communication Plan was updated. The plan was submitted to DOE and approved.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Update the Outreach and Communication Plan.

Subtask 3.1.5 – Phase 3 Annual Topical Report

The Recipient will complete and submit a Topical Report summarizing the results of Phase 3 activities annually. The report will include a review of tasks performed over the preceding year and a summary of deliverables outlined in this SOPO. In addition, the Phase 3 Topical Report will include sections providing an updated Site Characterization Data Inventory, an updated Permitting Inventory, a Stakeholder Engagement Status report, and a list of Characterization data uploaded to the GDR. On an annual basis, in conjunction with the delivery of the Annual Topical Report, the FORGE Project will undergo a review of progress and performance in these areas:

- Site Infrastructure and Well Development
- Environmental, Safety & Health
- Cost and Schedule

- Project and Team Management

1. Planned Activities:

Prepare a Phase 3 Year 1 Annual Report**.**

2. Actual Accomplishments:

The Phase 3 Year 1 Annual Report was prepared and submitted to DOE.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Prepare a Phase 3 Year 2 Annual Report.

Task 3.2.0 – R&D Management

The Recipient shall provide R&D management in accordance with the *R&D Solicitation, Implementation and Management Plan for Utah FORGE* submitted to DOE as appendix A to the Phase 2C PMP. This Plan shall be updated throughout the life of the FORGE project, as necessary, to ensure lessons learned and best management practices are incorporated into the solicitation, selection, and execution of FORGE competitive R&D process. The Utah FORGE R&D management functions shall include technical (in collaboration with DOE) and financial monitoring as well as administrative and contractual oversight. Utah FORGE will ensure that effective web-based systems are in place for the issuance of solicitations, application submissions and to support all management functions of the FORGE R&D projects.

Subtask 3.2.1 – Science and Technology Analysis Team

The Recipient shall support the Science and Technology Analysis Team (STAT), composed of experts in the geosciences, engineering and drilling, that will provide technical guidance on research directions, identify specific research topics for R&D testing and evaluation, and ensure GTO goals and objectives are integrated into the FORGE mission throughout Phase 3. Coordination and involvement with and between the STAT, DOE and the Recipient shall be governed by the STAT Governance and By-laws established in Phase 2C. As deemed necessary, these documents will be updated to reflect any procedural or structural changes resulting from lessons learned.

1. Planned Activities:

Foster communication, coordination and involvement between the STAT, DOE, and FORGE to ensure GTO goals are consistent with the FORGE program.

2. Actual Accomplishments:

Significant efforts have been taken to ensure STAT and DOE involvement in all phases of the project. Communication with STAT members and DOE through regularly scheduled and topical meetings have promoted cooperation among the groups. Recommendations by the STAT and DOE have been incorporated into the project plans for drilling, seismic monitoring, modeling, outreach and communication, and R&D activities. Table 3.2.1-2 shows the schedule of regular monthly meetings involving the STAT, DOE, and FORGE. Table 3.2.1-1 summarizes Topical Meetings held during the year.

No changes were required to the STAT Governance documents and By-laws.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Forge will continue to seek involvement and recommendations from the STAT and DOE for technical recommendations on FORGE activities and R&D topics for Solication 2.

Table 3.2.1-1. Regulary sheduled monthly meetings. Participation is indicated by an X.

Meeting	STAT	DOE	FORGE	# per month
R&D SC	X	X	X	1
Monday Catch-Up		X	X	4
Tuesday Catch-UP		X	X	4
Wednesday TMT	X	X	X	1
Full Team Mtg	X	X	X	1
Drilling		X	X	4
Modeling		X	X	2
Outreach/Communication		X	X	1
Data Sharing		X	X	1
TOTAL				19

Table3.2.1-2. Topical Meetings.

Meeting	STAT	DOE	FORGE	When Held
Well 16A(78)-32 Planning	X	X	X	January 2020
Well 56-32 Planning	X	X	X	May, June 2020
Seismic Advisory Team		X	X	November 2019
Seismic Monitoring	X	X	X	January, May and June, 2020
Quarterly STAT Mtg	X	X	X	January, April 2020
ISMP Review	X	X	X	September 2020
Petrolern/Eavor	X	X	X	September 2020
DFIT Analysis	X		X	Numerous

WOO-1	**X**	**X**	**X**	**September 2020**
Proposal Reviews		**X**	**X**	**May, June 2020**

Subtask 3.2.2 – R&D Technical Monitoring
The Recipient shall maintain a Technology, Analysis and Research Management Committee (TARMaC) to provide technical management support for the external R&D research in collaboration with DOE. Management activities will include preparation of R&D solicitation topic areas, review of concept papers and full proposals, technical and financial review of R&D projects, and preparation of R&D contracts. These reviews will ensure the work is of high scientific merit, meets the goals of FORGE EGS development, is consistent with ongoing site activities and existing permits, and will do no harm to the FORGE site and wells. In collaboration with DOE technical liaisons, the TARMaC will support the development of a public-facing annual report summarizing technical successes and accomplishments of the Utah Team and those of the competitively selected R&D projects operating at FORGE over the previous year. The report will also present a forward looking projecings of major operational and R&D activities at the Utah site for the upcoming year.

1. Planned Activities:

Establish TARMaC, prepare and release Solicitation 1, review the Concept papers and identify those projects most appropriate for funding based on their potential impact to EGS development.

2. Actual Accomplishments:

Solicitation 1 was prepared and released to the public in April 2020. One hundred sixty four concept papers were submitted on five topical areas. The concept papers were reviewed for technical innovation, compliance with solicitation requirements and possible Conflicts of Interest with TARMac members. Seventy R&D teams were encouraged by the TARMaC to submit full proposals. Sixty-three were submitted. Statistics on the submissions are presented in the Phase 3 Year 1 Annual Report.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

The full proposals submitted under Solicitation 1 will be reviewed in October 2020 and the results will be reported to the STAT and the R&D Steering Committee in October and early November 2020. All projects will be evaluated for their technical quality, potential impact to EGS development, risk to the FORGE site and infrastructure, permitting requirements, and the extent of operational support that will be neeed. It is anticipated that Topics for Solicitation 2 will be reviewed by the STAT and FORGE team in the Spring of FY 2021. The TaRMAC will prepare Soliciatation 2 based on the suggested topics and release the solicitation in FY 2021.

Subtask 3.2.3 – R&D Financial Monitoring
The Recipient will be responsible for financial monitoring of all R&D subawards. This will include review of invoices against approved budgets and projected spend plans. Cost-share obligations will be reviewed, as necessary. The financial monitor(s) will interface as necessary with the TARMaC to ensure invoice costs are consistent with technical progress.

1. Planned Activities:

None.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

No R&D proposals were funded in Phase 3 Year 1.

4. Plans for Forthcoming Annual Cycle:

Contracts for R&D awards will be negociated in the first quarter of Year Two Phase 1. FORGE will conduct the contract negociations in concert with the University of Utah's Office of Sponsored Research and perform financial monitoring of the R&D awards.

Subtask 3.2.4 – R&D Field Support and Insurance
The Recipient will provide necessary field support and downhole tool insurance for the R&D projects as part of the ongoing operational support requirements of the FORGE project as outlined in the Liability and Indemnity Document/Strategy.

1. Planned Activities:

None.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

No R&D proposals were funded in Phase 3 Year 1.

4. Plans for Forthcoming Annual Cycle:

Site R&D activities are anticipated to begin in the Spring of Phase 3 Year 2. FORGE will begin working closely with the R&D teams shortly after the awards are made to ensure the proper field support, insurance, and other project needs (e.g. permitting) can be provided in a timely manner.

Task 3.3.0 – Seismic Monitoring

The Recipient will continue to collect seismicity data from surface and borehole seismometers throughout the lifetime of the project. Seismic instrumentation will be re-evaluated on an annual basis for efficacy in tracking seismicity and ensuring appropriate tracking of event magnitudes and ground shaking from a hazard and mitigation perspective. Data from the permanent network will be telemetered in near-real-time and made available to the public through the IRIS Data

Management Center. Data from temporary deployments (e.g. industry geophone strings, distributed acoustic sensors, and geophone arrays) will be archived in a timely fashion for access by the community. The results of existing data will be incorporated into the seismic catalog and the earth model. It will be used to update the Induced Seismicity Mitigation Plan (ISMP), including the Probabilistic Seismic Hazard Assessment (PSHA), on an annual basis or more frequently as required.

1. Planned Activities:

Continue collection and analysis of seismic data beneath and around the FORGE site. Based on the data, reevaluate the performance and efficacy of the seismic network. Provide the public with access to the seismic data.

2. Actual Accomplishments:

Since the start of local seismic monitoring of the FORGE area in Phase 1 in November 2016, 597 earthquakes ($-0.99 < M < 2.46$) have been located in the region surrounding FORGE (Figure 3.3-1). During the past year, 261 earthquakes ($-0.92 < M < 2.46$) have been located (Figure 3.3-2). Over the past project year, seismicity continued under the Mineral Mountains with the majority of events locating on the eastern end (~ 4 km (2.5 miles) east of the Blundell power plant) of the original Zandt swarm zone region.

Using matched-filter techniques, we constructed a catalog of over 1000 swarm earthquakes ($-2.0 < M < 2.0$) for the time period 2016 through 2019. Epicentral locations are well-constrained and place these quakes ~4 km (2.5 miles) east of the Blundell power plant as well. Composite first-motion focal mechanisms of highly similar earthquakes are consistent with both east-west and north-south structures failing. We identify 15 periods of swarm-like activity that appear to be related to fluid diffusion and aseismic processes with a deeper origin than what would be consistent with operations at the Blundell power plant. We conclude these swarms are the result of tectonic transport of fluid through the crust.

Going forward, further improvements in seismic event locations and estimation of ground motions for the FORGE site will be gained from a detailed shallow velocity model for the region surrounding FORGE. The model, derived using the data from the Nodal geophone experiment in December 2016 spans the alluvium and extends into the granite basement. A new seismic detection algorithm is developed and will be applied. The algorithm requires valid events to have coherent energy that back-projects to a source location.

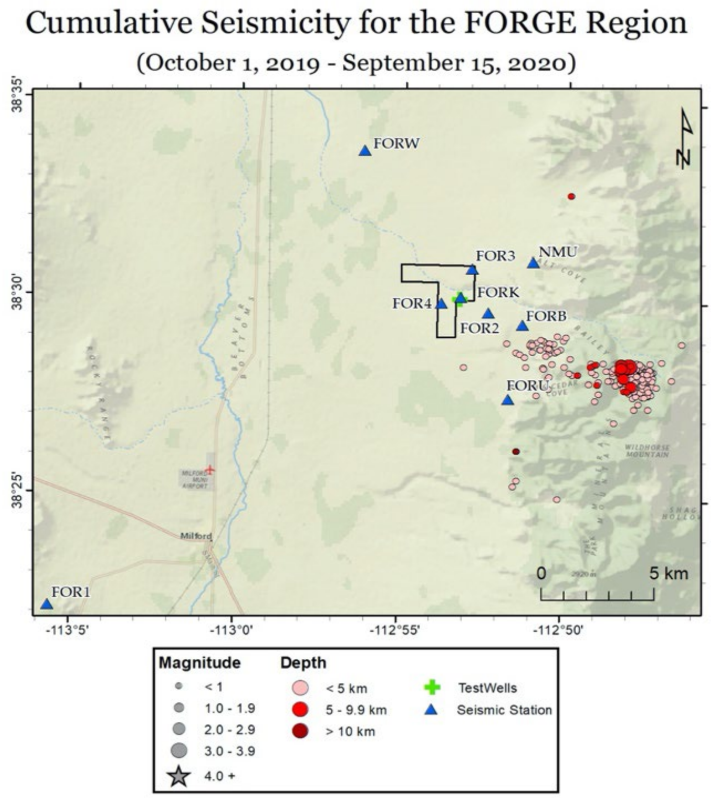


Figure 3.3-1. Summary of seismic activity since high resolution broadband instruments (triangles) were deployed on November 1, 2016 (start of Utah FORGE project).

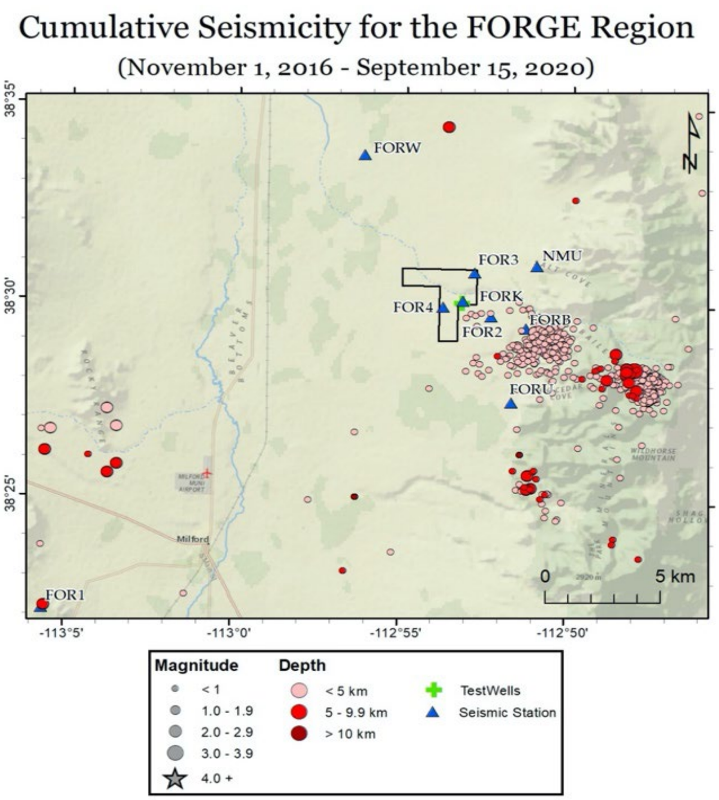


Figure 3.3-2. Summary of seismic activity over the past project year utilizing the same high resolution broadband instruments (triangles).

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Monitoring of natural seismicity in the Utah FORGE area will continue for the characterization of background tectonic levels and for informing the PSHA.

Subtask 3.3.1. – Convene Expert Seismology Panel

The Recipient will convene a panel of experts (Seismic Advisory Team or SAT) to provide input on the seismic monitoring program. Based on recommendations from the seismic expert panel and the STAT, the Recipient will prepare an update to the Seismic Monitoring Plan developed in Phase 2 and a plan for the drilling of a deep Seismic Well. The Seismic Monitoring Plan will be submitted to DOE for approval and the Seismic Drilling Plan will be submitted to both DOE and the Utah State Engineer for approval.

1. Planned Activities:

Convene the Seismic Advisory Team (SAT) and update the plan for the seismic monitoring network. Prepare a plan for seismic monitoring well 56-32. Submit both plans to DOE and the drilling plan to the State Engineer.

2. Actual Accomplishments:

a) Seismic Monitoring Plan. The SAT was convened on November 4, 2019, at the University of Utah. It had representation from industry, academia, and the U. S. Geological Survey and expertise in geothermal, fluid disposal, and fracking induced seismicity, seismic instrumentation (both traditional seismometers and distributed acoustic sensors (DAS)), as well as infrasound and more exotic sensors, seismic detection and discrimination related to nuclear treaty verification, and network seismology.

The SAT considered the infrastructure requirements for monitoring induced seismicity: 1) during deep borehole stimulation or injection to map and characterize the fracture systems created and activated for reservoir development; 2) during drilling operations for the purpose of detecting and identifying potential seismic hazards encountered and triggered by drilling fluid losses; 3) during active, post- and inter-injection operations to monitor and mitigate potential felt seismicity hazards; and 4) during post- and inter-injection periods and flow testing operations to continuously map and characterize the evolution of the r

Based on comments from the SAT, the STAT, and DOE, a Seismic Monitoring Plan (SMP) was prepared and submitted to DOE for approval. The plan included the drilling of new deep seismic well plus installation of two rings of shallow seismometers at 3 (1.9 miles) and 8 km (5.0 miles) radius from the seismic monitoring boreholes. Figure 3.3-3 illustrates the final proposed monitoring network. The new well to be drilled is labeled well 56-32 and lies north of the deeper eastward reaches of upcoming FORGE injection well 16A(78)-32 (refer to Figure 3.4.1-1).

A revised Seismic Monitoring Plan incorporating comments of the STAT and DOE was submitted to the DOE in August 2020 and approved.

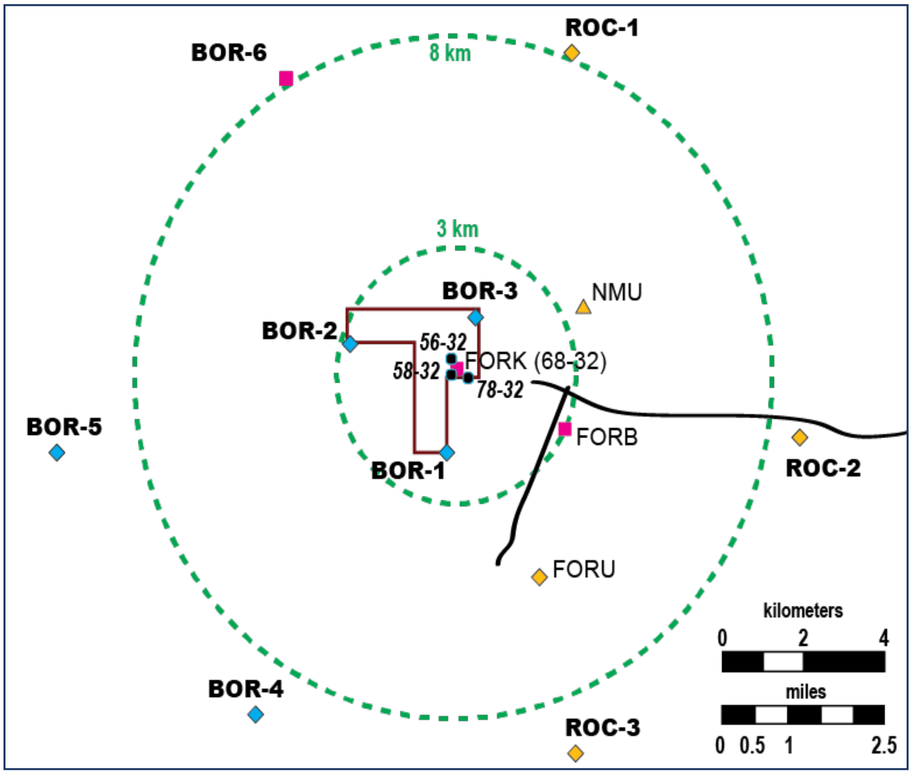


Figure 3.3-3. Final proposed seismic network. Seismic monitoring well 56-32 will be drilled in FY 2021. The trajectory of well 16A(78)-32 will pass between wells 56-32 and FORK (68-32) from the west *(refer to Figure 3.4.1-1). Symbols: triangle = short period instrument; square = strong motion sensor; diamond = broadband instrument. Locations of proposed shallow boreholes are shown in blue and rock stations in gold. Existing strong motion sensors are shown in magenta*.

b) Well 56-32 Drill Plan. A drilling plan was prepared for a new seismic monitoring well, (well 56-32). DOE originally requested we complete the well prior to the drilling of well 16A(78)-32. To accommodate this request, a site on culturally cleared land with access was required. A 5000 ft DAS cable, including Silixa's high resolution Constellation fiber and 4 single-mode fibers was purchased for deployment in the well. The cable has a temperature rating of 150°C. Only a small pad, 100 x 150 ft could be constructed on the cleared land. To accommodate these requirements, the well was programmed to reach a depth of 5000 ft.

The well design, depth, monitoring tools, location and requirement to drill well 56-32 before completing well 16A(78)-32 were subsequently modified to incorporate new requests by DOE and the STAT. The modified plan was to deepen well 56-32 to 7500 ft to reach a temperature of 200°C. The new plan would allow for seismic monitoring at reservoir depth and the ability to test high-temperature seismic monitoring instruments. New land was culturally cleared to allow for flexibility in siting the well and constructing a larger pad, which could accommodate a rig with a larger footprint and greater depth capabilities. The DAS cable was sold back to Silixa and a 7500 ft cable, containing a similar optic fiber configuration but suitable for temperatures up to 300°C, was purchased.

The optimal location for well 56-32 was reevaluated from the original calculations performed by Schlumberger for estimating microseismic event minimum magnitude and location accuracy based on the positions of existing wells 58-32 and 78-32. An important update was to the attenuation parameter for the granite basement to be consistent with detection levels at well 78-32 during the April 2019 stimulation. The existing position of planned well 56-32 was shown in the modeling to be close to optimal for seismic monitoring.

The drilling plan for the deepened 56-32 well was submitted to DOE and approved.

c) Shallow Seismic Boreholes. Three boreholes, BOR-1, BOR-2, and BOR-3, each approximately 100 ft deep, were drilled on the 3 km (1.9 mile) ring (see Figure 3.3-3). Broadband seismometers were ordered and will be deployed in the wells at depths of 80-100 ft.

3. Explanation of Variance:

The original DOE requirement to drill well 56-32 before 16A(78)-32 was recinded. After further consideration, DOE concluded well 56-32 should be drilled after 16A(78)-32 was completed. The STAT originally recommended drilling well 56-32 to the southeast of its original location, closer to the trajectory of well 16A(78)-32. At the time of this report no final decision or spud date has been received from the STAT or DOE. To accommodate new potential locations, additional land had to be culturally cleared.

4. Plans for Forthcoming Annual Cycle:

We will submit the revised drilling plan for well 56-32 to the State Engineer for approval. The three shallow boreholes will be instrumented with the broadband seismometers to complete the inner ring of instruments for monitoring events associated with the drilling of injection well 16A(78)-32. BOR-1, BOR-2 and BOR-3 will be operational by mid October 2020.

Subtask 3.3.2 – Update Induced Seismicity Mitigation Plan (ISMP)

The Recipient will update the ISMP at a minimum annually to incorporate the results of ongoing seismic investigations through the conclusion of the project. As an appendix to the ISMP, the Recipient will update the PSHA for the area surrounding the FORGE site annually, based on new data pertaining to ongoing field activities on the regional setting and structure, as related to seismic risk.

1. Planned Activities:

Update the ISMP, including the PSHA.

2. Actual Accomplishments:

The ISMP and PSHA were updated and the document submitted to DOE for review.

Seismicity data collected at FORGE have primarily been used to update the ISMP in the following three ways: (1) establishing background ground motion levels, (2) confirming mapped fault structures are not seismogenic; and (3) updating the hazard calculated in the PSHA. Ground motions are larger in Milford where there is more cultural noise and regular train traffic than at either the FORGE site of the Blundell power plant. The background

ground motions are at the minimum levels for felt ground motions from earthquakes. Larger ground motions are likely too short in duration to produce damage, which allows us to set the threshold ground motion above that suggested in studies for felt earthquakes. The region near FORGE and Blundell is quiet with very low (< 0.5 mm/s) ambient ground motions.

During the prior year of local seismic monitoring at FORGE, seismic events have continued to locate in the same source regions identified in the regional catalog (refer to Figure 3.3-1). The largest earthquake recorded during this time period is M < 2.5 located to the east of the Blundell power plant and M < 4.5 within 30 km (18.6 miles) to the south. The low magnitudes and rates are consistent with recurrence modeling performed in the PSHA - 1 M > 4 every 10 years, 1 M >5 every 100 years, and 1 M >6 every 1000 yrs. Thus, while possible, larger earthquakes in the area around FORGE are low probability events. Swarm events continue in the Zandt swarm area east of the power plant. There is no evidence of earthquakes on either the Opal Mound or Mag Lee faults.

A new 2020 PSHA was performed by Wood Environment and Infrastructure Inc (WEI), formerly Amec Foster Wheeler to update the 2018 PSHA. The location of the Utah FORGE centroid was reassigned towards the projected toe of well 16A(78)-32 where stimulation will occur. Site specific velocity information (Vs30 and basin-depth parameters) was incorporated to adjust the NGA-West 2 ground motion models to the site conditions at each of the PSHA sites. New research data on segments of the Wasatch fault and Mag Lee fault had only small effects on the earthquake recurrence model of each fault. WEI incorporated updated earthquake catalogs and corrected an error in the 2018 PSHA calculations. The modifications in the 2020 PSHA results in a significantly reduced seismic hazard compared to the 2018 PSHA.

3. Explanation of Variance:

Because of the need to work at home due to COVID 19, and the need to correct the previous analysis, WEI experienced delays in updating the PSHA. Substantial effort went into revising the ISMP to base it upon the best-practices document of Majer et al. (2016) subsequent to its initial creation following the protocols of Majer et al. (2012) as originally mandated.

4. Plans for Forthcoming Annual Cycle:

We will continue to address comments by DOE and the STAT as it relates to the ISMP. Newly acquired information from seismic monitoring and ongoing field activities will be provided to WEI, who will assess the need for updating the PSHA.

Task 3.4.0 – Infrastructure Development

The Recipient will establish and maintain all necessary infrastructure to support Phase 3 operations and R&D activities including but not limited to advanced technical monitoring capabilities, roads, power, water and office space.

Subtask 3.4.1 – Build Electric Distribution Line for Electric Power

The Recipient will complete contract negotiations with Rocky Mountain Power for an electrical distribution line. Rocky Mountain Power will schedule construction of the line.

1. Planned Activities:

Complete negotiations with Rocky Mountain Power and construct the electric distribution line and drop points to critical sites.

2. Actual Accomplishments:

Negotiations have been completed and the main electric distribution line has been constructed (Figure 3.4.1-1). The line extends across the FORGE site to the Smithfield Foods gas compression station to the east. Three additional spur lines have been installed connecting the main line to the 16A(78)-32, 58-32, and the 78-32 well pads.

Figure 3.4.1-1. Infrastructure map of the Utah FORGE site. The access road to 56-32 well pad follows the edge of the gully to the west.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

An additional spur line will be constructed from the main line to the north in order to provide power to seismic monitoring well 56-32. A contract for this additional line is in place with Rocky Mountain Power. Construction will begin following easement approval from the land owners, the Utah School & Institutional Trust Lands Administration (SITLA). The new spur line is expected to be completed in mid FY 2021.

Subtask 3.4.2 – Construct Drill Pads for the Deep Wells and Seismic Monitoring Well
The Recipient will construct drill pads for the deep wells and for at least one seismic well. All drill pads will be surveyed and graded with appropriate berms and road access. If necessary, a separate pad will be constructed for a groundwater supply well.

1. Planned Activities:

Construct drill pads for the pair of deep, deviated wells (16A(78)-32 and 16B(78)-32), deep seismic monitoring well 56-32, and shallow seismic boreholes (BOR-1, BOR-2, BOR-3).

2. Actual Accomplishments:

a) The drill pad, sump, and a short access spur road for the production/injection well pair 16A(78)-32 and 16B(78)-32 were completed (refer to Figure 3.4.1-1).

b) A 100 by 150 ft drill pad was constructed at the location of seismic monitoring well 56-32 proposed by the SAT. The pad can be accessed from Salt Cove road via a newly constructed ~5,000 ft long access road. The road follows the edge of Mag Lee wash to the west.

c) Drill pads for shallow seismic monitoring boreholes BOR-1, BOR-2, BOR-3 were constructed and the boreholes were drilled (refer to Figure 3.3.1-1 for location). The boreholes will be instrumented by mid October 2020.

3. Explanation of Variance:

The STAT and DOE concluded well 56-32 was not optimally located to monitor the stimulation of well 16A(78)-32 and that a location to the southeast or east was preferable.

4. Plans for Forthcoming Annual Cycle:

Construct a new drill pad for seismic monitoring well 56-32. To accommodate a larger drill rig with increased depth capacity, a larger pad will be required. Possible pad locations are under consideration by the STAT and DOE. Once a new pad location is recommended and approved, a new pad and road access will be built.

Subtask 3.4.3 – Establish Project Office
The Recipient will build a project office to serve as office space for researchers with sufficient space to accommodate simultaneous daily use for multiple teams.

1. Planned Activities:

Build a Project office.

2. Actual Accomplishments:

Bids were issued for both purchase and long-term rental of a project office; however, the bids received were deemed too costly. Utah FORGE has recommended use of a temporary project office during times when R&D work is being conducted at the site.

3. Explanation of Variance:

At the direction of DOE, plans to include a Project Office at the Utah FORGE site during the drilling of well 16A(78)-32 were canceled because no R&D-funded research will be conducted.

4. Plans for Forthcoming Annual Cycle:

Continue to evaluate options for project office space at the Utah FORGE site, including alternate construction methods (other than standard pre-fabricated mobile units) and short-term rentals on an as needed basis. The earliest R&D research at the site is not likely to begin prior to the 3rd quarter of Phase 3 Year 2. The needs of the funded R&D proposals will be reviewed by the Project Management Team, and based on this review, the required Project Office space will be provided.

Subtask 3.4.4 – Coordinate Establishment of Visitor Center

In Phase 3 Year 1, the Recipient will investigate leveraged funding opportunities from local, state and private entities and design alternatives for the establishment of a Visitor Center to highlight Utah FORGE and potentially other renewable energy projects in the region. Year 1 findings will be presented to DOE and reviewed against current FORGE budget priorities to determine if the Visitor Center can be established in Phase 3 year 2 or deferred to year 3.

1. Planned Activities:

Commence planning of the Visitor Center.

2. Actual Accomplishments:

A Visitor Center Master Interpretive Plan was developed. The plan outlined the required sequential steps needed to define a strategy for establishing the Visitor Center. It considered the goals, theme, and possible options for the construction and location of the Visitor Center. The plan serves as an initial guide for the decision-making process and ultimately, the completion of the subtask. A draft of the first step, refining the goals of the Visitor Center was prepared.

Potential partners including neighbors, local government, state government and the local business community were contacted to gauge their level of interest in participating in a Visitor Center and possible funding commitment. The results indicate that there is interest in some sort of Visitor Center, but a physical building does not have support. Funding support is also limited.

We analyzed the various options for a Visitor Center, developed a description of each option, weighed the advantages, potential issues and the requirements associated with the options. The estimated costs needed to complete a Visitor Center were also considered. The matrix can be seen in Table 3.4.4-1.

Table 3.4.-1. Analysis of various options for a Visitor Center.

Visitor Center Options					
Option	**Description**	**Advantages**	**Issues**	**Requirements**	**Costs**
Virtual	Website dedicated to the Beaver County renewable energy corridor. Information on the various sources, videos, animations illustrating processes, interactive games and quizzes for kids. Links to the page from participating organization's websites.	Most easily sustained following end of project. Allows for other partners to more seamlessly participate. Avoids need for permits, etc.	Requires third-party to build site. Commitment from partners to meet deadlines, provide content.	Selection of third-party website developer, cooperation of partners, project management, content generation, hosting, updating.	$150,000
Kiosk in Milford Park	Larger information panel discussing different types of energy in the area or just geothermal. Located in town for easy access by school groups, tourists, visitors. Refence back to participating group's / groups' website(s).	Ease of production, no-maintenance, most cost-efficient, located in existing tourist spot with option for brochure placement.	Cannot be udpated. City may not wish to keep following project.	Content, agreed-upon design, production, installation, possible permits from the city / county.	$7,500 - $10,000
Caboose in Milford Park	Convert existing Union Pacific caboose located in local Milford Park into a free-standing, staffed visitor center that highlights renewable energy corridor.	Offers a more in-depth, free-standing visitor center in an already existing, recognizable facility. Allows for greater partner participation. Provides physical location for students and potential tourists.	Gaining permission to rent, us or buy the caboose from the City of Milford. Making the required upgrades to be compliant with the ADA such as ramps, wider entry ways, egresses, etc. Hiring and training staff. Limited availability (e.g., winter). Ongoing upkeep. Questions around sustainability after the project.	Purchasing / renting the caboose. Possible electrical needs. Permits. Necessary construction to be ADA compliant, including ramps, enlarging doors. Hiring and training docent. Insurance.	$50,000-$150,000
Exhibit at Natural History Museum of Utah	A permanent exhibit focused on renewable energy in Utah housed at the Natural History Museum of Utah.	Provides a permanent home to the exhibit. Nearly 250,000 visitors annually.	Interest of the NHMU. Fitting in with their requirements, limited exhibit.	The NHMU deciding to include the topic in a display. From decision to implemenation is a 1-1/2 to 2 year process	No hard costs.
Buy / Build Visitor Center	A free-standing visitor center, housing exhibits around Utah FORGE, geothermal energy, other renewable energy in the region.	Offers more in-depth, free-standing visitor center. Provides physical location of students and tourists.	Cost. Time line to build new / remodel existing structure. Staffing, maintenance, questions about ongoing sustainability. Lack of interest from partners / other stakeholders. Legal costs for commitment agreements.	Purchase an existing building or buy land on which to build a new structure. Must be ADA compliant, meet codes for waste removal, landscape, lighting, parking, restrooms. Must hire staff including docents, maintenance, janitorial and security. Must hire marketing staff. Legally-binding commitment agreements from partners. Development of economic sustainabilty plan.	$400,000 - $1,500,000

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Findings will be presented to DOE and reviewed against current Utah FORGE budget priorities to determine if the Visitor Center can be established in Phase 3 year 2 or deferred to year 3.

Subtask 3.4.5 – Site Improvement and Maintenance

The Recipient will conduct site maintenance as needed. Roads will be graded and maintained to allow for year-round access to FORGE facilities.

1. Planned Activities:

Maintain existing infrastructure and expand infrastructure to meet the developing needs at the site.

2. Actual Accomplishments:

a) A microwave radio link to bring high-speed internet to the Utah FORGE site has been installed by Utah Education and Telehealth Network (UETN).

b) A contract is in place with a local electrician (A&F Electric) to install the electric infrastructure between the terminations of the spur lines installed by Rocky Mountain Power and the points of ultimate use within the Utah FORGE site.

c) Removal of accumulated tumble weeds from drill pads

d) The road that provides access to wells 16A(78)-32, 58-32, 68-32 and 78-32 also serves as an the access road to the new Smithfield Foods gas compressor station to the east. The road has been widened, graded, graveled and sculpted to optimize drainage. The cost for this has been shared by Smithfield Foods, Beaver County and Utah FORGE.

e) Replaced the deck on the cellar of well 58-32.

f) Replaced the liner in the sump of well 58-32.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

a) The installation of the electric infrastructure will be completed in three phases to accommodate developing infrastructure needs within the Utah FORGE site. Much of the work can be completed in the upcoming annual cycle.

b) Bring power to the communication mast and trailer in order to power the new internet link.

c) Maintain roads and pads and other infrastructure as needed

Subtask 3.4.6 – Convene Expert Drilling Panel (Deep Well #1)

The Recipient will convene a panel of experts to provide input to the drilling and logging of the Deep Well #1. Based on recommendations from the drilling expert panel and the STAT, the Recipient will prepare a plan for Deep Well #1. The plan will include the drilling, casing and cementing program, collection of drilling data, running of geophysical and image logs, and the collection of core, cuttings and water samples. The trajectory of Deep Well #1 will be based on numerical simulations, geologic characteristics of the FORGE site and wellbore stability considerations. The plan will be submitted to DOE, and the Utah State Engineer for review and approval.

1. Planned Activities:

Convene an expert drilling panel and prepare a drilling plan for 16A(78)-32 for approval by the STAT, DOE and the State Engineer.

2. Actual Accomplishments:

A detailed drill plan for 16A(78)-32 was prepared and approved by DOE and the State Engineer. The well will be drilled with a 65° tangent to a measured depth of 10938 and a true vertical depth of 8500 ft. The bottom hole temperature is anticipated to be approximately 228°C. The well design is shown in Figure 3.4.6-1**.**

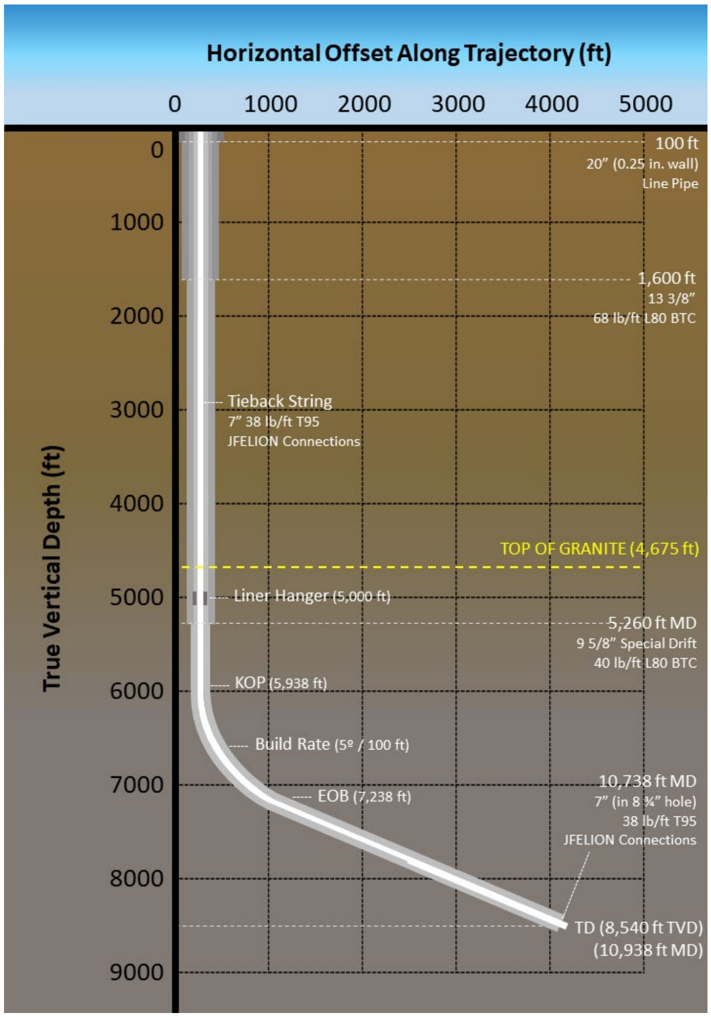


Figure 3.4.6-1. Casing diagram for well 16A(78)-32.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Task completed.

Go/No-Go Decision Point #1 – The Recipient shall provide DOE detailed plans including final cost estimates for the drilling of Deep Well #1. Drilling of Deep Well #1 will not commence until authorized through written approval by the Contracting Officer.

- Drilling was authorized by the Contracting Officer.

Subtask 3.4.7– Drill Deep Well #1
Based on input from subtask 3.4.6 and a Final DOE approved drilling plan, the Recipient will commence with preparing bids for sub-contracts and vendor services for the drilling of Deep Well #1. The Recipient will drill at least one deep well for R&D testing and evaluation.

1. Planned Activities:

Complete contracting for drilling Deep Well #1 (16A(78)-32) and drill well.

2. Actual Accomplishments:

Prior to October 1, 2020, bids for the majority of the services required for the drilling of 16A(78)-32 had been received and awarded.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Drilling of well 16A(78)-32 is scheduled to begin at the end of October 2020. The STAT and DOE will be kept informed of the drilling progress. They will receive daily drilling reports describing each day's activities. requent meetings will be held with the STAT and DOE to discuss the progress being made, issues and challenges, and any changes in the drilling plans.

Go/No-Go Decision Point #2 – The Recipient shall provide DOE detailed plans including: 1) final cost estimates for the drilling of a Seismic Monitoring Well; and 2) the Seismic Monitoring Plan. The drilling plan will be submitted to the State Engineer for approval. Drilling of the Seismic Well will not commence until authorized through written approval by the Contracting Officer.

Subtask 3.4.8 – Drill Seismic Monitoring Well
Based on input from subtask 3.3.1 and a final approved Seismic Monitoring Plan including the plan for drilling of a deep seismic well, the Recipient will commence with preparing bids for sub-contracts and vendor services for implementing the approved seismic monitoring network including the drilling of a deep seismic well. At least one seismic monitoring well will be drilled.

1. Planned Activities:

Contract vendors and drill seismic monitoring well 56-32.

2. Actual Accomplishments:

Based on input from the SAT, a plan for drilling well 56-32 was prepared and submitted to DOE and the State Engineer. A permit was issued. The permit was subsequently recinded and the well was redesigned to incorporate new recommendations by the STAT and DOE (refer to subtask 3.3.1). The updated well plan was submitted to DOE and approved.

3. Explanation of Variance:

At the request of DOE, drilling of well 56-32 was postponed and a new drilling plan was prepared.

4. Plans for Forthcoming Annual Cycle:

Once the DOE submits it recommendation for the location of the 56-32 well site, an application will be made to the State Engineer for a permit. A new well pad and road access will be constructed. Vendors will be contracted for drilling and drilling support services and well 56-32 will be drilled.

Subtask 3.4.9 – Convene Expert Drilling Panel (FORGE Pilot Wells)

The Recipient, in coordination with DOE and the STAT, will convene to provide input to the drilling of at least one Pilot Well for early-stage FORGE technology and methodology testing. Based on the input from this panel of experts, the Recipient will develop a Pilot Well Drilling Plan. The Pilot Well Drilling Plan will identify optimal location, depth and trajectory of the well based on the well configuration and instrumentation needs of the R&D community. The Plan will include the drilling, casing and cementing design, the collection of drilling data, geophysical and image logs, as well as the collection of core, cuttings and water samples, as determined necessary. The Test Pilot Well Plan will be submitted to DOE and the Utah State Engineer for approval.

1. Planned Activities:

Initiate conversations with the STAT and DOE to plan well WOO-1**.**

2. Actual Accomplishments:

Initial discussions were held with the STAT and DOE to consider the objectives, location, depth and drilling program for WOO-1. No concensous was reached. Possible uses for well WOO-1, including seismic monitoring and collecting core after stimulation of well 16A(78)-32 were considered.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Continue discussions with the STAT and DOE regarding the drilling of well WOO-1. Based on input from the STAT and DOE, a drilling plan for approval by DOE and the State Engineer will be prepared.

Go/No-Go Decision Point #3 – The Recipient shall provide DOE detailed plans including final cost estimates for the drilling of a minimum of one Pilot Well, Drilling of the Pilot Well will not commence until authorized through written approval by the Contracting Officer.

Subtask 3.4.10 – Drill FORGE Pilot Wells

The Recipient, based on input and approved plans from subtask 3.4.9, will prepare, permit, and drill at least one well for early-stage FORGE technology and methodology testing prior to or in lieu of testing in the FORGE Utah injection and production wells. This well will contribute to the overall goals and mission of the FORGE initiative by enabling higher-risk technology testing in lower-cost wells dedicated to early-stage testing.

1. Planned Activities:

None.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Permit well WOO-1, construct a drill pad and access road and drill WOO-1.

Subtask 3.4.11– Conduct Aquifer Test

The Recipient will, unless approved Pilot well design(s) preclude (see subtask 3.4.9), conduct an aquifer test in a minimum of one Pilot Well to determine the productivity of the aquifer and to further evaluate the potential of the aquifer to supply water for drilling and circulation testing. Samples of the water will be collected and analyzed. The data will be used to monitor changes in groundwater chemistry during Phase 3.

1. Planned Activities:

Conduct an aquifer test of well 56-32 during drilling.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

Drilling of well 56-32 did not occur as expected.

4. Plans for Forthcoming Annual Cycle:

If possible, conduct an aquifer test of wells 56-32 or WOO-1 during drilling.

Task 3.5.0 – Reservoir Modeling

The Recipient shall update and maintain the reference numerical reservoir model created during Phase 2C. The model, based on the updated earth model, will use both discrete fracture network (DFN) and continuum methods to inform the Phase 3 drilling and stimulation program, as well as serve as a tool to share numerical modeling data. The reference models will utilize existing and newly acquired FORGE data. The Recipient will utilize the reference models to conduct: 1) analyses of efficacy of stimulation techniques, including thermal and mechanical stimulation and hydro-shearing; 2) predict changes in permeability resulting from the stimulations; and 3) expand development of the existing earth model to better understand and characterize the behavior of the fracture networks away from the borehole.

Subtask 3.5.1 – Modeling and Simulation Plan
The Recipient will prepare a Modeling and Simulation Plan that details, documents, and schedules modeling and simulation activities to be performed in Years 1 and 2 of Phase 3.

1. Planned Activities:

Prepare a modeling and simulation plan to guide the modeling team's activities for the first two-years of Phase 3.

2. Actual Accomplishments:

The modeling and simulation plan was completed, and used to guide the FY20 efforts.

3. Explanation of Variance.:

None.

4. Plans for Forthcoming Annual Cycle:

We will update the plan to cover Years 2 and 3 of Phase 3. This update will be informed by planned activities at the site, and also the actual work completed in Year 1 with respect to the planned work.

Subtask 3.5.2 – Revision of reference/native state models
The Recipient will update the reference numerical reservoir model annually, or at relevant intervals, based on the updates to the reference earth model. The reference models will utilize existing and new data developed from the testing of deep wells and other characterization activities in the vicinity of the FORGE project area to inform the drilling and stimulation program. The Recipient will assess the reference model sensitivity to variations in stress directions and magnitudes, reservoir material property values, and geologic structure.

1. Planned Activities:

Plan and prepare a suite of native state models that examine the potential variation and range in the stress directions and magnitudes.

2. Actual Accomplishments:

Three new native state model domains were developed that encompass a significantly larger volume than was used for Phase 2 studies. The new domains are based on the final plans for Well 16A(78)-32. S_{H_max} directions of N10E, N25E, and N40E were evaluated, along with 3 potential magnitudes for S_{H_max} and 2 for S_{H_min}. A total of 18 native state simulation cases were considered. These have all been completed and are shown in Figure 3.5.2-1.

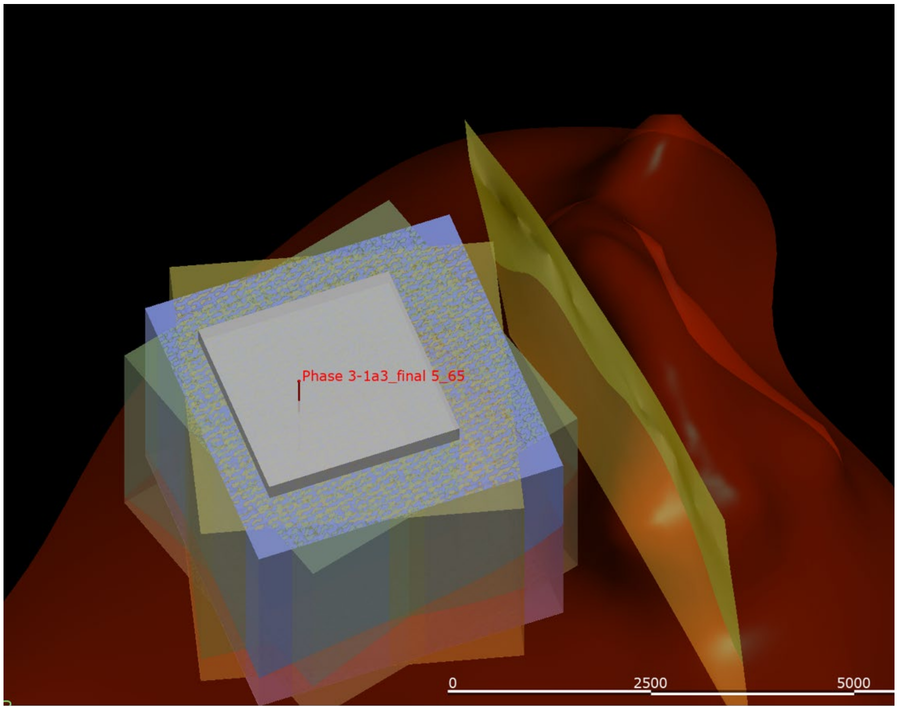


Figure 3.5.2-1. The figure shows the Phase 2 model domains in dark gray, with the three Phase 3 domains shown in tan and blue colors.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Refine the native state models based on the results of Year 2 characterization efforts and well drilling.

Subtask 3.5.3 – Revision of reference DFN

The Recipient will update the reference DFN annually, or at relevant intervals, based on updates to the reference earth model. The reference DFN will utilize existing and new data developed from the testing of deep wells and other characterization activities in the vicinity of the FORGE project area. The reference DFN will be shared with the community via the FORGE website or GDR, and will be provided to the R&D sub-recipients focused on therm- hydro- mechanical- chemical- (THMC) modeling.

1. Planned Activities.

Update the reference DFN to include the increased fracture density near the granite/sediment contact.

2. Actual Accomplishments.

The DFN was updated, and included an increase in the fracture density in the upper 200-300 m (656 -984 ft) of granite. We also evaluated the stress sensitivity of the DFN to potential stimulation treatments using the same stress cases as discussed in Subtask 3.5.2. An image of the revised DFN upscaled onto the native state model domain is shown below.

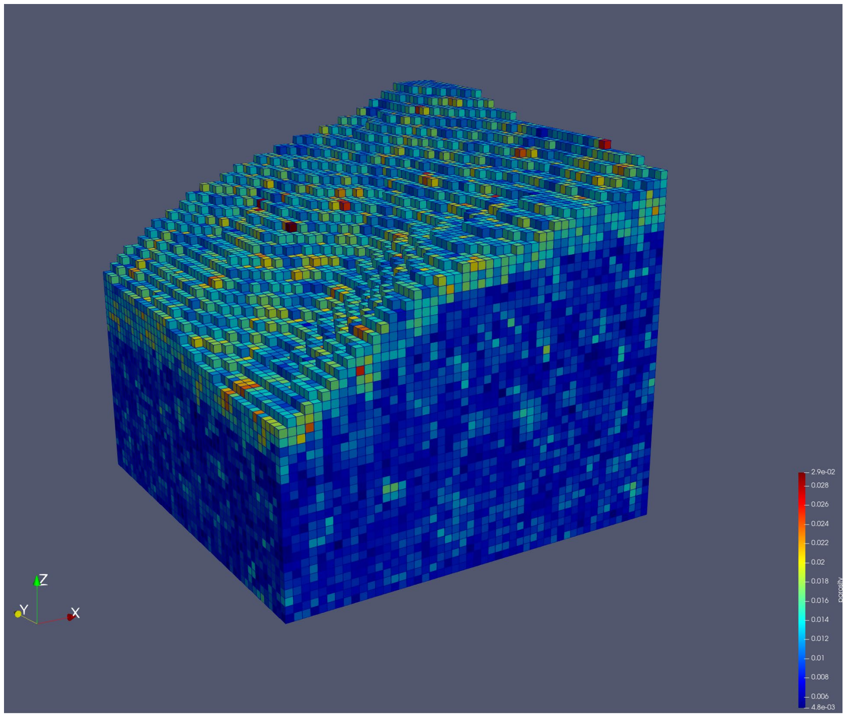


Figure 3.5.3-1. Revised DFN upscaled onto the native state model domain.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Refine the reference DFN as soon as new well data are available.

Subtask 3.5.4 – Simulate hydraulic stimulation options for Phase 3 well 1

The recipient will conduct numerical simulations to evaluate stimulation options, and plan stimulation treatment spacing, pumping rates/durations, and fluid viscosities. The Recipient will coordinate with the STAT for technical advice on proposed stimulation options.

1. Planned Activities:

None were planned. This is an FY21 activity, with limited work focused on calibrating numerical models of well 58-32 testing.

2. Actual Accomplishments:

Commerical DFN-based (Discrete Fracture Network) simulators have been used to work towards history matching pressure signatures from the injection programs conducted in well 58-32 in 2017 and 2019. The predicted pressure chronologies are beng compared with measured pressure-time data (history matching). Once these injection histories can be matched, the appropriate non-unique reservoir model can be used to simulate upcoming stimulation events at the toe of well 16A(78)-32. Key learnings are the need for full 3D evaluation of the tests, and the importance of the DFN in and around the well bore, as well as stress boundary conditions. Full calibration has not been achieved, but the controlling physics have been identified. An example of an XSite simulation is shown below.

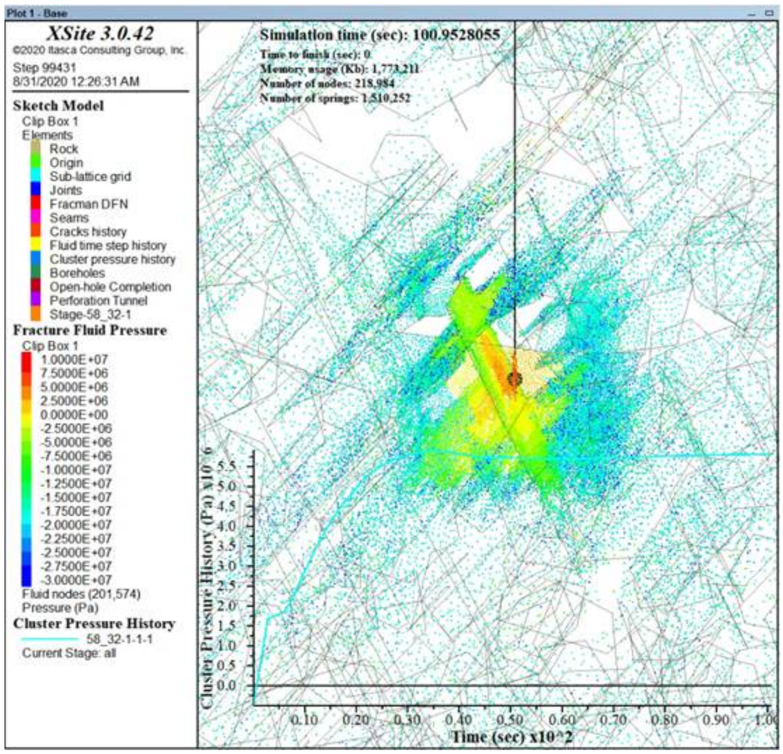


Figure 3.5.4-1. Example of XSite simulation.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Use XSite models to assist in the preparation of a final plan for the initial stimulation of well 16A(78)-32.

Subtask 3.5.5 – Long-term THM simulations

The Recipient will perform long-term (5-10 operational years) simulations to predict how the reservoir responds over time to production, and will include additional mechanical feedbacks such as thermal stimulation and chemical evolution with solution/dissolution. The Recipient will coordinate with the STAT for technical advice on long term stimulations and R&D sub-recipients focused on THMC modeling if feasible.

1. **Planned Activities:**

None were planned. This is an FY21 activity.

2. Actual Accomplishments:

We have used FY20 to prepare for this task by preparing revised native state models, developing well hydraulics capabilities and coupling them with the reservoir simulator, and preparing preliminary native state and reactive geochemical simulations. An example output from the reactive geochemistry simulations of batched fluids (no transport) is shown in Figure 3.5.5-1.

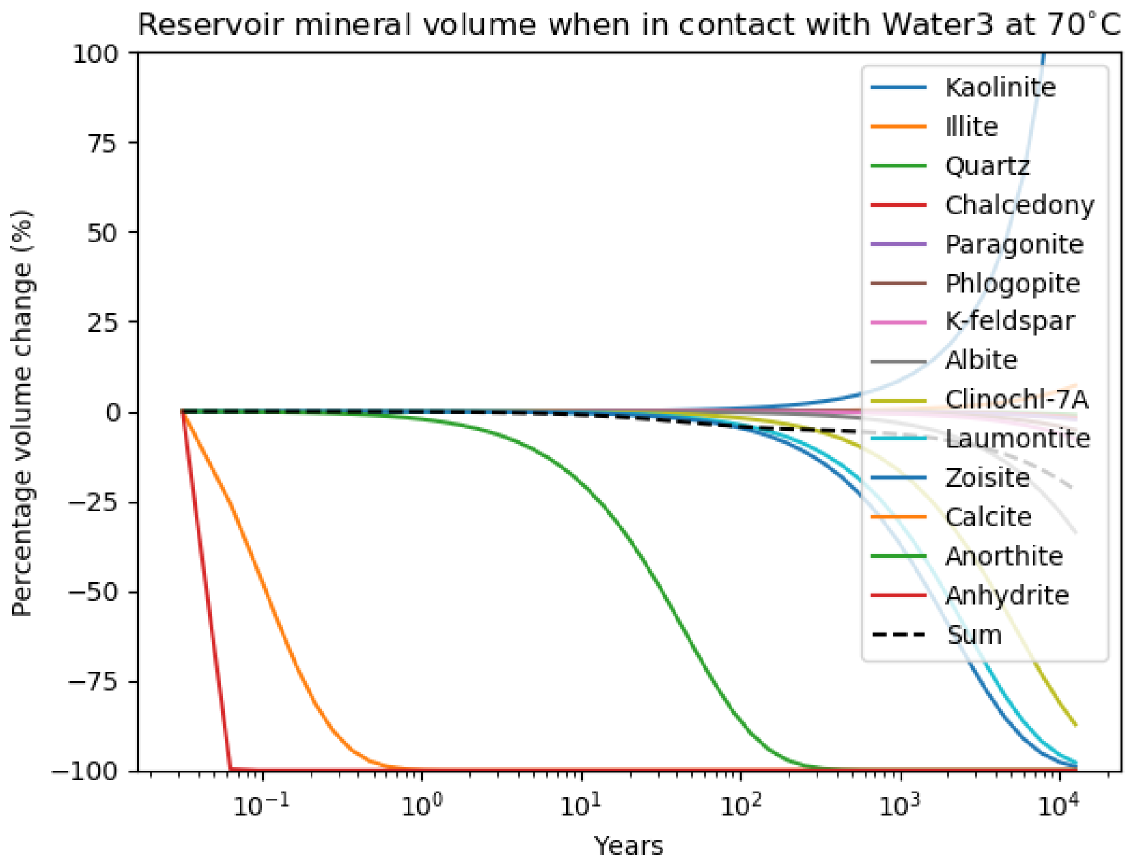


Figure 3.5.5-1. Example output from the reactive geochemistry simulations of batched fluids (no transport).

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Continue evaluation of water-rock interactions.

Subtask 3.5.6 – Convene Expert Stimulation Panel

The Recipient, supported by modeling efforts in Task 3.5, will convene a panel of experts to provide input to the stimulation of Deep Well #1. Based on the input from the expert panel and the STAT, the Recipient will develop a Stimulation Test plan. The Plan will be submitted to DOE for review and approval.

1. Planned Activities:

None were planned. This is an FY21 activity.

2. Actual Accomplishments:

We have begun to discuss potential invitees, a preliminary list for discussion purposes only is:

- Carl Montgomery – NSI
- George King – Viking
- Mark McClure – McClure
- Jack Norbeck – may be conflict of interest
- Kevin England – retired SLB
- Leen Weijers – Liberty
- Dave Cramer – ConocoPhillips
- Ali Daneshy – Daneshy Consultants
- Kumar Ramurthy – Halliburton
- Monty Besseler

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Form the Panel and gather input and advice.

Go/No-Go Decision Point #4 - The Recipient shall provide DOE a detailed Stimulation Test plan including final cost estimates for reservoir testing. These tests will be based on the results of Reservoir Modeling from Task 3.5.0 presented to DOE. Reservoir Testing of Deep Well #1 will not commence until authorized through written approval by the Contracting Officer.

Task 3.6.0 – Reservoir Testing

In order to evaluate the potential effectiveness and sustainability of the FORGE reservoir, injection tests will be conducted in Deep Well #1 in conjunction with high-resolution numerical modeling and monitoring performed by both the Recipient team and R&D sub-recipients. The results will be used to inform the stimulation program that will lead to creation of the reservoir.

Subtask 3.6.1 – Reservoir Testing of Deep Well #1

The Recipient will conduct reservoir testing in the deep well drilled in subtask 3.4.7.

3.6.1.1 –Based on the approved stimulation plan from subtask 3.5.6, the Recipient will commence with testing of Deep Well #1. The plan will be submitted to DOE for review. Stimulations will initially be conducted at the heel and toe of Deep Well #1 to further evaluate the reservoir's characteristics and provide information necessary for completing the stimulation program in the deep wells. Critical elements of the plan will include:

1. Conducting Diagnostic Fracture Injection Tests (DFIT) in the heel and barefoot section of the well.
2. Stimulation of one or two additional zones within the cased portion of the well.
3. Monitoring the direction and extent of the fractures created.
4. Running geophysical and FMI/UBI logs prior to cementing the production casing.
5. Running FMI/UBI logs again after each stimulation.

1. Planned Activities:

None.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Test well 16A(78)-32 following the approvied drilling and stimulation plan.

3.6.1.2 – The geophysical and image logs will be evaluated to assess reservoir conditions, and fracture orientations at the deep well site. The results will be compared to data from well 58-32.

1. Planned Activities:

None.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Run geophysical and image logs in 16A(78)-32. The image logs will be evaluated to determine fracture orientations and abundances and compared to fracture characteristics determined from 58-32. The geophysical logs will be analyzed for rock property data.

3.6.1.3 – Pressure-time data collected during the stimulations will be analyzed to evaluate stress magnitudes, fracture propagation, and permeability.

1. Planned Activities:

None.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Analyze pressure-time data to evaluate fracture characterisitcs.

Task 3.7.0 – High-resolution Data Acquisition and Analysis

The Recipient will enhance current FORGE reservoir characterization through collection and analysis of new high-resolution geological, geophysical and geochemical data, ongoing monitoring activities, and evaluation of downhole logs and rock samples. The Recipient will make these comprehensive data sets available to the public via the FORGE website/GDR, and will ensure the appropriate curation and management of this data for related FORGE R&D solicitations.

Subtask 3.7.1 – High Resolution Magnetotelluric (MT) Survey

The Recipient will analyze newly acquired high-quality tensor MT data over the FORGE project area. The data will be analyzed through three-dimensional (3D) inversion to: 1) delineate fault and fracture zones in crystalline basement rocks; and 2) provide a baseline resistivity structure for evaluating temporal changes in the structure following well stimulation(s). Multiple starting models will be considered, including smooth 1D models from integrated impedance and externally constrained models of alluvial thickness over the project area. The MT data will be made publicly available to those who wish to derive their own resistivity models.

1. Planned Activities:

Compute a 3D finite element inversion model of the MT resistivity based on data acquired from 122 MT sites at the close of Phase 2C using an in-house developed FE algorithm. Invert the combined FORGE-SubTER-PFA data set to provide superior data aperture for imaging to depth.

2. Actual Accomplishments:

Utah FORGE magnetotelluric data acquired in Phase 2C (GDR link) were merged with regional data, covering a total of 470 sites. From these, a finite element inversion was used to generate a 3D understanding of the resistivity structure to >20 km depth.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

The end of fiscal year 2020 coincides with the close of the Utah FORGE site characterization using MT. No formally supported activities are to continue beyond September 30, 2020. As the interpretation is joint with the data set of the neighboring SubTER project (it self mostly expended), a minor effort will continue into FY2021 under its support. We will continue to fine-tune the finite element model through additional exploration of the effect of the Kern River pipeline. We will compare the resistivity structure below the Mineral Mountains and the Utah FORGE project area with natural seismicity in the area being monitored by Dr. Kristine Pankow and her post-doctoral researcher Dr. Maria Mesimeri.

Subtask 3.7.2 – Water Geochemistry
The Recipient will analyze water samples from wells drilled during Phase 3 for major and minor species (e.g. pH, Cl, HCO_3, SO4, Li, Na, K, Ca, Mg, B, SiO_2. As, Sb), stable isotopes and dissolved noble gases. Where appropriate, chemical aqueous geothermometers will be applied to interpret subsurface temperatures and to evaluate hydrothermal fluid inputs. The results will be integrated with existing geochemical and hydrological data across the Utah FORGE site.

1. Planned Activites:

Collect and analyze water samples obtained during aquifer testing of well 56-32, and the sampling of new groundwater wells near the Utah FORGE site. Interpret results and integrate findings to refine understanding of the controls and causes of spatial variability.

2. Actual Activities:

Ten water samples were collected from groundwater wells around the Utah FORGE site in September, and analytical results are expected by December 2020. Continuous water level data from wells WOW2 and WOW3 collected from October 1 to September 30, 2020 were uploaded to GDR: https://gdr.openei.org/submissions/1252

3. Explanation of variance

No new wells were drilled in Year 1 of Phase 3. Consequently, efforts were focused on the collection of water samples and hydrologic data from the region surrounding the Utah FORGE site.

4. Plans for Forthcoming Annual Cycle:

Chemical analyses of the samples collected should be completed in the first quarter of FY 2021. These data will be analyzed to determine the extent of chemical variability of the fluids, trends over time, possible causes of any observed variations and their significance. Samples of geothermal waters, aquifer test samples, stimulation fluids and/or groundwaters will be collected and analyzed as opportunities arise. Monitoring of WOW2 and WOW3 will continue.

Subtask 3.7.3 – Conduct InSAR Analysis
The Recipient will obtain and interpret InSAR interferograms to assess ground deformation and to complement continuous GPS monitoring. Additional scenes will be acquired from several satellite missions as available. The new scenes will be compared with previous scenes in interferometrically compatible combinations. The InSAR results will be evaluated to estimate ground deformation. Hydromechanical modeling in a poroelastic medium will be conducted. The InSAR data will be analyzed and interpreted, and the results registered ("geo-coded") and integrated into the earth model.

1. Planned Activities:

Obtain and interpret InSAR interferograms to assess ground deformation and to complement continuous GPS monitoring. Additional scenes will be acquired from several satellite missions as available. The new scenes will be compared with previous scenes in interferometrically compatible combinations. The InSAR results will be evaluated to estimate ground deformation. Since the rate of subsidence at the Utah FORGE site is expected to be low, a careful analysis using many SAR images acquired over several years was required to quantify any deformation at the level of several millimeters per year.

2. Actual Accomplishments:

The SAR data from early January 2019 (20190131) through August 2020 (2020814) consists of SAR images acquired by TerraSAR-X and TanDEM-X satellite missions operated by the German Space Agency (DLR). Many interferometric pairs were calculated but no deformation has been detected.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Analyze additional InSAR data acquired by the TerraSAR-X satellite mission operated by the German Space Agency (DLR), and analyze InSAR data from the SENTINEL satellite mission operated by the European Space Agency (ESA). These data sets cover the Utah FORGE site from late 2016 through the present. Additional scenes will be acquired every 6 or 12 days through at least 2023. For the data acquired by the SENTINEL missions, we will use the Interferometric synthetic aperture radar Scientific Computing Environment (ISCE) that is being developed by colleagues at NASA's Jet Propulsion Laboratory. After analyzing each interferometric pair individually, we will analyze multiple interferograms as time series using MintPy in order to model and remove atmospheric effects. We will also compare the time series of displacement derived from InSAR with those estimated from GPS data at nearby stations to assess seasonal variation.

Subtask 3.7.4 – 4D Gravity Survey

The Recipient will conduct repeat gravity surveys for the purpose of monitoring surface elevations during the creation and growth of the Utah FORGE reservoir in Phase 3. The 4D gravity surveys will be combined with changes in the groundwater elevation to assess possible elevation changes measured by GPS benchmarks and InSAR data.

1. Planned Activities:

Complete campaign gravity loops of the Utah FORGE stations on all geophysical deformation monuments four times in 2020.

2. Actual Accomplishments:

Three campaigns consisting of five trips down to the Utah FORGE site were completed.

3. Explanation of Variance:

Degrading weather conditions affected the November 2019 survey. In 2020, COVID19 pandemic safety guidelines prevented fieldwork for the first half of the year.

4. Plans for Forthcoming Annual Cycle:

Repeat gravity loops on all monuments four times at regularly spaced intervals to improve understanding of seasonal variations in the gravity field. Future data collection will incorporate groundwater level changes thanks to a new monument located near a groundwater monitoring well. The addition of continuous GPS stations will assist analysis of new gravity data and analysis of correlations regarding seasonal ground deformation.

Subtask 3.7.5 – GPS Monitoring

The Recipient will conduct repeat measurements at the GPS stations and two survey base monument stations established in Phase 2C to determine if ground motion has occurred as a results of ground water drawdown or stimulation.

1. Planned Activities:

Perform GPS campaign monitoring at a semi-regular interval, assess the need for additional GPS monuments, and investigate the potential connection between groundwater and surface deformation.

2. Actual Accomplishments:

Implemented four survey campaigns in November 2019, December 2019, March 2020 and September 2020. Analysis of the results suggest that millimeter-scale variance in surface deformation is seasonal and related to groundwater fluctuations. Two new monuments were installed, one next to WOW2, which is monitored for groundwater levels, and another to make up for space required for a new drill pad.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Reoccupy GPS monuments in quarterly intervals and report results. Install two continuous monitoring GPS units including solar power and equipment enclosures in the Utah FORGE project area.

Subtask 3.7.6 – Geochemical Modeling of Water-Rock Interactions

The Recipient will conduct numerical simulations to assess the effects of water-rock interactions as the injected fluids circulate through the granitic reservoir. The simulations will consider a variety of fluid temperatures and compositions based on chemical analyses of the local ground waters.

1. Planned Activities:

Building on Geochemist's Workbench batch models, a simple 2-D flow through model is to be developed and processed to assess the water-rock interaction effects of mineral dissolution-precipitation. Produced fluid chemistry data from Roosevelt Hot Springs wells will be analyzed as an analogue to EGS-type heat transfer between the injection and production sector.

2. Actual Accomplishments:

A simple 2-D flow through model was developed for the tightly coupled multiphysics solver from INL called MOOSE in order to assess the water-rock interaction effects of mineral dissolution-precipitation in the Utah FORGE reservoir. The simulation involves pumping cold fluid into a thin hot confined aquifer and determining the resulting geochemical changes.

The Roosevelt Hot Springs production fluid chemistry was analyzed for water-rock interaction affects, in particular EGS-type heat transfer, leading to a manuscript entitled "The chemical and physical evolution of the Roosevelt Hot Springs, Utah, USA, hydrothermal system in response to >30 years of geothermal production: Interpretation of native state hydrothermal conditions, production-injection induced effects, and evidence for EGS-type heat exchange" submitted to Geosphere, which is in review.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Advance the 2-D flow through modeling activities with more sophisticated scenarios of fracture-controlled fluid flow in granitic rock

Subtask 3.7.7 – Analysis of Rock Samples

3.7.7.1 – The Recipient will examine cutting samples from newly drilled wells to determine the lithologies encountered in the reservoir, the distribution of primary and secondary minerals and evidence of structural disruption. The core samples will be photographed and fracture distributions, orientations, and mineral fillings will be documented.

1. Planned Activities:

Analyze cuttings and core from wells 56-32 and 16A(78)-32.

2. Actual Accomplishments:

None.

3. Explanation of Variance:

There were no wells drilled in this time period and therefore no new samples to analyze.

4. Plans for Forthcoming Annual Cycle:

Analyze and document the characteristics of rock samples (core and cuttings) from wells 16A(78)-32, 56-32 and the WOO-1 well that are to be drilled in the upcoming annual cycle.

3.7.7.2 – The Recipient will provide samples of the cores and cuttings to R&D sub-recipients as defined in the updated Sample Handling and Core Curation Plan (subtask 3.1.3).

1. Planned Activities:

Create content on the Utah FORGE web site to detail what samples are available for research activities, including a web portal with a sample request form.

2. Actual Accomplishments:

The samples available for study are outlined on the Utah FORGE site (https://utahforge.com/laboratory/sample-curation/) along with a sample request form (https://utahforge.com/laboratory/sample-curation-page/) where R&D sub-recipients and the geothermal community at large may request rock samples (and fluid samples when they become available) for research.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Curate rock samples (core and cuttings) from upcoming wells (16A(78)-32, 56-32 and the WOO-1 well) and make these rock samples available to appropriate researchers.

Subtask 3.7.8 – Refine the Phase 2C Conceptual Geologic Model

The Recipient will update the geologic model, incorporating newly acquired geological, geophysical, geochemical, groundwater, thermal and seismic data. Attention will be paid to developing 3D distributions of critical reservoir parameters that will influence plans for new wells and stimulation activities. Relevant data from competitive R&D projects will be incorporated as available and as is beneficial to the project.

1. Planned Activities:

Update and refine the geologic model, incorporating results of newly acquired geoscientific data. Attention will be paid to developing 3D distributions of critical reservoir parameters that influence plans for new wells and stimulation activities.

2. Actual Accomplishments:

The conceptual geologic model of the Utah FORGE site was updated and refined, incorporating results of newly acquired geoscientific data plus the understanding obtained from the drilling of wells 58-32, 68-32 and 78-32. The main Phase 3 Year 1 updates and refinements are based on analysis of the MT dataset, resolution of the reservoir stress regime from the 2019 stimulation testing, and insights gained from modeling and simulation activities.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Update and refine the geologic model, incorporating results of newly acquired geoscientific data. Attention will be paid to developing 3D distributions of critical reservoir parameters that influence plans for new wells and stimulation activities.

Task 3.8.0 – Data Sharing

Data collected during Phase 3 will be incorporated by the Recipient into an updated Site Characterization Inventory and all new data, including site characterization and monitoring data, will be uploaded to the GDR quarterly. Data will be curated according to GTO standards using appropriate content models and will be curated into subsets of data catalogues relevant to the annual FORGE R&D solicitations to be advertised as such on the GDR and/or FORGE website to ensure streamlined access for recipients.

1. Planned Activities:

Submit new data and reports to GDR. Update the Utah FORGE geoscientific webmap to include new and updated data layers, additional functionality and new user interface.

2. Actual Accomplishments:

New data collected during FY 2020 was submitted to GDR and can be found in the Phase 3 Year 1 Annual Report. The ArcGIS interactive Utah FORGE webmap was updated with current data. The webmap can be accessed through the Utah FORGE website.

3. Explanation of Variance:

None.

4. Plans for Forthcoming Annual Cycle:

Upload new data to GDR as it becomes available.

Task 3.9.0 – Outreach and Communications

The Recipient shall conduct local, regional and national education and public outreach activities in accordance with the updated, DOE-approved Outreach and Communications Plan (subtask 3.1.4). The Recipient will employ a spectrum of innovative methods including public meetings, classroom visits, site tours, videos and web-based media to increase geothermal science and technology literacy amongst key stakeholder groups. Educational outreach describing the FORGE site and FORGE activities shall target the general public, K-12 teachers, and students and faculty within the higher education system. The Recipient shall specifically design Outreach and Communication efforts to broaden the public's understanding of FORGE, the fundamentals and benefits of EGS, and the importance of EGS and geothermal energy as a renewable base-load energy source.

1. Planned Activities:

Utilize website to provide updates about the progress of the Utah FORGE project, while offering resources and information to increase overall geothermal and EGS literacy. Provide regular information about geothermal energy and the Utah FORGE project through an e-newsletter. Highlight announcements and information through social media. Gain coverage of the Utah FORGE project and its progress in the general mainstream media, and geothermal and other appropriate energy industry vertical outlets. Present research and findings at scientific conferences and seminars, as well as introduce geothermal energy, EGS technologies, and Utah FORGE. Provide field trips to the site in Milford, Utah. Produce videos, video lectures, webinars, and podcasts to provide general education and updates about the project. Create interactive visual tools to illustrate various aspects of geothermal energy and EGS technologies. Create a series of materials that quickly and easily describe and explain geothermal energy and Utah FORGE. Obtain feedback and input through surveys. Brief elected officials, government agencies and regulators. Build and grow the catalogue of STEM modules/projects. Develop a program of teaching the teachers at all levels of education and instruction on geothermal technologies, including employment of an intern and a graduate student research assistant. Run yearly Capstone advanced-level undergraduate course in the Department of Communications. Hire a part-time student intern from the Department of Communications, and hire a full-time communications specialist to coordinate and manage the communications and outreach activities.

2. Actual Accomplishments:

Utilized the website to provide updates about the progress of the Utah FORGE project, while offering resources and information to increase overall geothermal and EGS literacy. This included, creating five new web pages (Modeling and Simulation Forum, Solicitation, Core Curation, Education, and Data Dashboard), and developing seven new web features (Did You Know, Share a Scientific Paper, Partner Spotlight, Lectures/Podcasts, Word of the Week, Animations, Informational Timeline). Additionally, an inventory audit of the website was conducted.

Provided regular information about geothermal energy and the Utah FORGE project through the establishment of an e-newsletter called *At the Core*, which is published quarterly. Two editions were produced and distributed. In tandem, a subscription list was cultivated for this and other news and announcements, with a current total of 276 subscribers.

Highlighted announcements and information through social media. This included, posting 127 social media announcements on Facebook (60), Twitter (51) and LinkedIn (16). There is a total of 251 current followers (151 on Facebook, 51 Twitter, 49 LinkedIn).

Gained coverage of the Utah FORGE project and its progress in the general mainstream media, and geothermal and other appropriate energy industry vertical outlets by creating a media kit, obtaining 13 media stories, providing background information to 2 general consumer publications, publishing and advertorial for the Beaver County Journal, creating and advertisement for the Beaver County Journal, and writing a piece for the Milford City Newsletter.

Presented research and findings at scientific conferences, including 1 presentation at the November 2019 NZ Geothermal Workshop, 3 presentations at the December 2019 AGU conference, 7 presentations at the 2020 Stanford Geothermal Workshop, and 3 presentations at the Seismological Society of America conference. Four manuscripts were submitted to refereed journals for publication and 1 E-poster was submitted for the Geothermal Resources

Council meeting. A virtual presentation was made in the ARMA Endless Summer Series, and Joe Moore participated in the ICDP workshop held at Cornell University in January 2020.

Provided two field trips and led seven individuals around the Utah FORGE site

A university-level lecture on conventional geothermal resources by Stuart Simmons was produced and promoted. A story board for a new fifth video was drafted, and a videographer was contracted to acquire and edit footage for the upcoming drilling campaign. The first podcast in the series *FORGEing Ahead with Geothermal Energy* was written, recorded and released. A webinar entitled Geoscientific Overview of Utah FORGE was produced, recorded and posted. In addition, 4 Modeling and Simulation Forums were promoted and facilitated, and Seequent released a video showcasing Leapfrog's modeling capabilities featuring the Utah FORGE project.

Facilitated the development of an interactive visualization of Utah FORGE Stimulation Data posted on the dedicated Utah FORGE GDR archive page hosted by NREL. Updated and added extra features to the interactive geologic map based in ArcGIS.

FAQ sheets and a brochure were revised and updated. Kiosk panels of geothermal energy and Utah FORGE were installed on Antelope Point road near the Utah FORGE site.

Feedback and input were obtained through implementation of a website user survey.

Elected officials and regulators were briefed about Utah FORGE through testimony presented by Joe Moore to the House of Representatives Science, Space and Technology committee, meetings with Beaver County and Milford officials, and face to face meetings with over 60 stakeholders, including elected officials and citizens. Background information was supplied via email to U.S. Congress members and Utah State legislators.

STEM modules were presented and shared at 10 events, including scheduled school visits, open houses, and STEM events. A prototype of a new STEM module showing how convection works using a thermochromatic display was developed. A team of undergraduate students from the University of Utah's Department of Chemical Engineering achieved an outstanding result at the November 2019 National American Institute of Chemical Engineers (AIChE) Competition, proudly taking 2^{nd} place in the K-12 STEM Outreach Competition for a Peltier engine module.

To develop a program of K-12 education, an undergraduate intern and a PhD candidate from the College of Education, University of Utah were employed to draft a high school lesson plan for geothermal energy and other renewables.

An advanced undergraduate level capstone class in the Department of Communications, University of Utah, with 15 students, started in the fall 2020 semester under the instruction of Professor Sara K. Yeo, to develop and analyze public survey data of lay opinion, awareness and knowledge of geothermal energy.

Enlarged the Outreach and Communications team with the hiring of a full-time communications specialist and the hiring of a part-time student intern from the Department of Communications, University of Utah.

Six of eight milestones were achieved, including the installation of roadside kiosk panels for Utah FORGE site, the appointment of an undergraduate student intern from the College of Education (University of Utah), the appointment of an undergraduate student intern from the Department of Communication (University of Utah), designed and planned one new STEM geothermal energy module, formulated a draft lesson plan on geothermal energy at a high school level, and published a university-level lecture on conventional geothermal resources.

3. Explanation of Variance:

The COVID-19 pandemic and subsequent restrictions ended in-person outreach, caused conferences to be cancelled or postponed, and prevented students from the College of Engineering from gathering to continue work on modules. The preparation of the ad hoc Geoscientific Overview webinar took up time required to develop the unconventional geothermal resources lecture, which is postponed until the first quarter of FY 2021.

4. Plans for Forthcoming Annual Cycle:

Continue to grow the Utah FORGE audience and increase geothermal literacy by expanding Utah FORGE's presence in the Beaver County community, advancing K-12 curriculum, adding "special sections" to the e-newsletter, employing stakeholder surveys, continuing media relations, and generating on-line lectures, videos, podcasts, posters, and brochures.

Task 3.10.0 – Permitting and Regulatory Compliance

The Recipient will ensure that all permits for Phase 3 activities required for drilling, surface disturbances, infrastructure installation, and aquifer testing will be identified and obtained. Permitting and regulatory approval documents will be submitted to DOE for review to ensure National Environmental Policy Act (NEPA) requirements are met and continued consistency with the Milford FORGE Environmental Assessment's (EA) Finding of No Significant Impact (FONSI).

1. Planned Activities:

Communicate with regulatory authorities and land owners to explain Utah FORGE project objectives and obtain all necessary permits and approvals for Utah FORGE site activities.

2. Actual Accomplishments:

Discussions were held with the appropriate agencies to obtain permits and approvals for Utah FORGE site work. These discussions were held with Utah School and Institutional Trust Lands Administration (SITLA) (February 2020), the State Engineer, Beaver County Commissioners (September 2020), and Beaver County Planning and Zoning Commission (September 2020). These meetings focused on a overview of the Utah FORGE project and future Utah FORGE infrastructure and well drilling plans.

Drilling applications were created and submitted for well 56-32 and the upper vertical portion of well 16A(78)-32 in March 2020 and for seismic monitoring boreholes BOR-1, BOR-2, and BOR-3. Applications for wells 56-32 and 16A(78)-32 were retracted in June 2020 because of changes to the drilling plans. A revised application to drill well 16A(78)-32 was submitted and approved in August 2020.

Permits for boreholes BOR-1, BOR-2, and BOR-3 were submitted and approved in September 2020.

An application for a Conditional Use Permit (CUP) from Beaver County was submitted to the Beaver County Panning and Zoning Commission in September 2020. The application included: 1) drilling of well 16A(78)-32; 2) to a MD of 11000 ft; 2) drilling of well 56-32 to 7500 ft; 3) drilling of WOO-1 to 7500 ft; 4) drilling of boreholes BOR-1, BOR-2, and BOR-3 (each to 100 ft); and temporary housing for drilling and drilling support crews. The Commission will formally approve the application in October 2020.

3. Explanation of Variance:

Drilling applications were withdrawn because of significant changes in the drilling plans of wells 56-32 and 16A(78)-32.

4. Plans for Forthcoming Annual Cycle:

Prepare and submit a revised drilling application for well 56-32.

Go/No-Go Decision Point #5 - The Recipient shall provide DOE detailed Statement of Project Objectives and Budget for years 3-5 as well as a presentation of Phase 1-2 results. Budget Period 5/Year 3-4 and Budget Period 6/Year 5 efforts shall not commence until authorized through the Continuation Application process as outlined in the Special Terms and Conditions.

Task 3.11.1 – Years 3 - 5 Project Management

The Recipient shall execute the project in accordance with the approved Project Management Plan covering the entire project period. The Recipient shall manage and control project activities in accordance with their established processes and procedures to ensure tasks and subtasks are completed within schedule and budget by task/spend plan constraints defined by the Project Management Plan. This includes tracking and reporting progress and project risks to DOE and other stakeholders.

Task 3.11.2 –Drill 2nd Deep Well

The Recipient will drill the second deep well for R&D testing and evaluation. A panel of experts will be convened to provide input to the drilling, logging and stimulation plan. Based on input from the panel, the Recipient will prepare a detailed drilling plan for Deep Well #2. The plan will be submitted to DOE and to the Utah State Engineer for approval. The trajectory of Deep Well #2 will be based on numerical simulations, geologic characteristics of the FORGE site and wellbore stability considerations. The plan will include the drilling, casing, and cementing program, collection of drilling data, running of geophysical and image logs, and the collection of core, cuttings and water samples.

Task 3.11.3 – Circulation Testing and Analysis

The Recipient will circulate water between the injection and production wells and monitor temperature, flow rate and pressure at the well heads. The results of the circulation testing will be analyzed to evaluate the characteristics of the reservoir. Microseismic and geophysical monitoring will continue

Task 3.11.4 – R&D Support

The Recipient shall provide management and support of R&D activities in accordance with the *R&D Solicitation, Implementation and Management Plan for Utah FORGE*. This Plan shall be updated throughout the life of the FORGE project, as necessary, to ensure lessons learned and best management practices are incorporated into the solicitation, selection, and execution of FORGE competitive R&D process. The Utah FORGE R&D management functions shall include technical (in collaboration with DOE) and financial monitoring as well as administrative and contractual oversight. The Utah FORGE team shall provide operational support for R&D testing as necessary.

Task 3.11.5 – Year 5 Complete Reservoir Testing and Analysis

The Recipient shall complete circulation testing, monitoring and analysis of the data. A final report will be prepared. All data will be archived on the GDR.

Task 3.12.0 – Decommissioning

At the conclusion of the project, the wells will be plugged and abandoned and the pads will be regraded to match the original contours as requested by the land owners.

D. Deliverables Phase 3, Year 1 and 2

Periodic, topical, and final reports shall be submitted in accordance with the attached "Federal Assistance Reporting Checklist" and its corresponding instructions. In addition, the following deliverables are also to be submitted:

Task 3.1.1 – Updated PMP, including SOP appendices (subtask 3.1.1.1) and Indemnification Strategy and Process (subtask 3.1.1.2)
Subtask 3.1.2 – Updated Environmental, Safety and Health Plan
Subtask 3.1.3 – Updated Sample Handling and Core Curation Plan
Subtask 3.1.4 – Updated Outreach and Communication Plan
Subtask 3.1.5 – Annual Phase 3 Topical Report(s)
Task 3.2.0 – Draft of the Phase 3 annual R&D Solicitation
Subtask 3.2.2 – Draft input for Annual Success Document
Subtask 3.3.1 – Updated Seismic Monitoring Plan
Subtask 3.3.2 – An updated Induced Seismicity Mitigation Plan (ISMP) with an updated Probabilistic Seismic Hazard Analysis (PSHA) as appendix
Subtask 3.4.6 – DeepWell #1 Drilling Plan
Subtask 3.4.9 – FORGE Pilot Well Drilling Plan
Subtask 3.5.1 – Modeling and Simulation Plan
Subtask 3.5.6 – Stimulation Test Plan

Task 3.10 – Permitting and Regulatory Compliance Documents

E. Meetings and Project Briefings

Detailed briefings will be prepared for presentation to the DOE Project Officer's facility located in Pittsburgh, PA or Morgantown, WV, or at an alternate site designated by the Project Officer. The briefings shall explain the plans, progress and results of the technical effort at the completion of each budget period and on an annual basis at a minimum.

Attachments to Appendix Section 4

Annual Research Performance Progress Report

Subtask 3.7.1. High Resolution Magnetotelluric (MT) Survey

Task Goal: Current Utah FORGE reservoir characterization will be enhanced through new high-resolution data collection and analysis. High-quality, tensor MT data including the vertical magnetic field and utilizing ultra-remote referencing have been acquired at 122 sites over the FORGE project area near the close of Phase 2C. FORGE MT data coverage is displayed in topographic form in Figure 3.7.1-1 and in smaller-scale geological map form in Figure 3.7.1-2. The data set abuts existing MT coverage of the DOE/GTO-supported EGI SubTER project over the Mineral Mountains and Roosevelt Hot Springs (RHS) to the east plus scattered State of Utah and Play Fairway Analysis MT sites. The results are used to: 1), Delineate the densities of faults and fractures in crystalline basement rocks so that they can be compared to independent data acquired from drilling, geologic field mapping, seismic reflection and gravity surveys and to properties in the Mineral Range; 2), illuminate potential heat sources for the FORGE area and perhaps adjacent RHS; and 3), Derive baseline 3D resistivity structure for possible MT monitoring of temporal changes in resistivity structure following well stimulation. The last purpose aims to quantify the total volume of stimulated reservoir rock and assist in locating possible fluid connections and flow paths through the fracture mesh later in FORGE Phase 3. It was decided that near-optimal and practical MT site spacing was of order 0.5 km at the surface over the immediate FORGE area for fracturing target zones at depths of 2-3 km.

1. Planned Activities:

A 3D finite element model inversion model of the MT electrical resistivity was to be computed from the 122 MT sites acquired at the close of Phase 2C using our in-house developed FE algorithm described by Kordy et al (2016a,b). This algorithm's development was supported by DOE/GTO contract DE-EE002750 to Wannamaker and has been used in various Play Fairway Analysis (PFA) and related studies (e.g., Wannamaker et al., 2019, 2020). The intention is to invert the combined FORGE-SubTER-PFA data set (470 sites altogether) to provide superior data aperture for imaging to depth. A consideration in modeling the MT data set is presence of the metallic Kern River pipeline traversing from NNE to SSW through the project area between RHS and the FORGE site, which was to be explicitly included in the finite element mesh. In addition, this is the largest data set and mesh computed by our research group to date, so we expect to gain more experience with challenges to practical run times or internal array headroom.

2. Actual Accomplishments:

The acquired MT data set from contractor Quantec Geoscience Inc. was merged with the broader MT set in the region including the adjacent SubTER and Play Fairway Analysis responses for a total of 470 sites. Two example soundings appear in Figure 3.7.1-3 which straddle FORGE well 58-32 by 1-2 km each side E-W. Use of an ultra-remote MT reference in western Nevada helped improve midband data quality in places where cultural and geothermal field noise was strong. Most soundings were given ~15 hours of recording that ran over-night. Good data quality at most sites was obtained in the period range 0.005 to 850 s, which should cover the depth interval ~200 m to 50 km.

A finite element mesh for inversion imaging has been constructed which accommodates all MT data in the region and is plotted in Figure 3.7.1-4. The FE mesh consists of 162(x=north) by 166(y=east) by 60(z=down) cells with 15 layers of air. Project area elevations for the finite element mesh nodes are from the SRTM resource and the outmost FE surface elevations are fixed to 1500 m. The mesh is deformed vertically to mimic the topography at the air-earth interface. It also is deformed in the E-W direction such that the FE cells representing the pipeline can mimic its path. In addition, to be precise, the mesh x-axis is oriented N020 so that the pipeline aligns directly up the page in the vicinity or FORGE and RHS. The smallest cell widths in the center of the MT data coverage are 200 m, except across the Kern River pipeline (see below), while the thinnest cells at the surface are 30 m growing by 15% per element with depth. Apart from a two-element rim around the mesh edge and the fixed air resistivity, all elements are inversion parameters for a total of 1126224. Air is assigned a fixed resistivity at 10^{18} Ωm, while the earth starting resistivity is 40 Ωm. The inversion period range is 0.0133 to 500 s. Error floors are applied to the real and imaginary parts of the complex impedance elements Zij of 5%(|Zxy-Zyx|/2) and to the tipper elements of 0.04 at each frequency. The inversion is parallelized to run on a linux workstation with 36 cores and 1.5 TB RAM.

The Kern River pipeline is represented by a 4x4 line of elements each 12.5 m wide for a total pipeline width of 50 m. In this fashion, the pipeline is narrowed and does not require any side-stepping to represent pipe meanders along its path as is necessary with finite difference modeling codes; the finite element flexibility should be much more favorable for accurate current flow. The finite element approach also allows a higher contrast between pipe and earth host, and reduces the effect of finite cell width. The pipeline is buried in the mesh at a nominal depth of 50 m and inverted MT stations do not lie closer than 500 m to the pipe. We examined several starting guesses for pipeline resistivity. Published property accounts suggest an equivalent resistivity of 0.0182 ohm-m within the 50 m wide pipe representation to preserve conductivity-area product of the 0.5” thick, 42” diameter carbon steel pipe. Aeromagnetic surveying centered on the Mineral Mountains to the east in the SubTER project indicated that the pipe had negligible magnetic permeability. However, inversion experience over time suggests that the pipe acted as though discontinuous in its electrical conduction along its length, with electrical interruptions at kinks in its orientation. These variations only appear to affect earth structure within 1-2 km of the pipe in the several inversion runs we tried. This matter deserves further investigation.

A model fitting the data well using the low starting pipe resistivity is shown in Figures 3.7.1-5 through 3.7.1-10. A final nRMS misfit in the impedance data of 1.28 is achieved from a starting value of 21.8 for the preferred resistivity model shown here. To start, strong N-S low-resistivity lineaments are visible in the central Mineral Mountains in the upper few km (Figures 3.7.1-5 and 3.7.1-6). These curious features are correlated with N-S steep preferred fracture patterns mapped in the Mineral Mountains (Bartley, 2019) under the FORGE project. Zones coalesce with depth and extend to beyond 5 km, upon which they merge into a larger single structure extending to base of the crust as discussed next. No such conductive lineaments appear in the granitic basement west of the Opal Mound Fault, however, attesting to the integrity of the crystalline lithologies beneath FORGE project area.

At greater depths (7.5-22.3 km) (Figures 3.7.1-7 to 3.7.1-9), a conductive body under the main Quaternary rhyolite flows centered along the crest of the Mineral Mountains (Figure 3.7.1-2) may be remnant from the magma chamber feeding that igneous event (Nielson et al., 1986). It may not be magma per se, but simply a residual structural zone hosting magma passage and now containing high temperature fluids in a fracture network. The merged MT data set has the aperture to resolve this high-angle low resistivity zone as traversing the entire vertical extent of the crust from a deep quasi-tabular layer likely representing ponded melts and fluids near Moho levels up through a fracture zone connecting into the RHS producing system. Below 15 km and toward the northeast this conductive structure begins to merge with a large-scale conductive structure trending ENE through the Cove Fort geothermal system. This semi-regional structure is in an appropriate location to represent the Cove Fort transverse structural zone (Rowley, 2013) which trends oblique to the current E-W extension direction and thus is prone to dilatency.

Significant low resistivity bodies in the middle crust also are seen below the northern Cove Fort-Dog Valley areas to the northeast, below Twin Peaks to the northwest, and below northern Milford Valley to the west. These all generally are locations of enhanced ^{3}He in water samples recovered from deep water wells or springs (S. Simmons, 2020, pers. comm.). The one under northern Milford Valley in particular is newly recognized in the FORGE MT study and appears to dip at a moderate angle from the base of the valley sediments at the latitude of the FORGE project area northward to the deep crust beneath the northernmost tip of the valley before running out of data aperture (Figure 3.7.1-10). This is an independent structure from the high-angle conductor under the central Mineral Mountains, which may explain why high 3He values are seen in groundwater well waters of the central Milford Valley that cannot represent outflow from the Roosevelt Hot Springs hydrothermal system.

Further structural and thermal insights from the MT model are apparent in E-W section views across the Mineral Mountains (Figures 3.7.1-11 and 3.7.1-12). In Figure 3.7.1-11 through the RHS and Mineral Mountains, a high-angle low-resistivity structure originating in the lower crust rises with a strand projecting directly into the RHS producing area. This strand is suggested to represent the fractured feed zone for produced fluids there and would explain their magmatic characteristics. It corresponds to the elongate N-S structure seen in plan view most clearly in Figure 3.7.1-7. The broad low resistivity below 20 km is taken to represent magmatic ponding and fluid release that contribute to the ultimate geothermal fluid source. The crustal-scale, high-angle conductive zone also is suggested to represent the convective zone that heats not only RHS fluids but also the FORGE granitic rocks through lateral heat conduction. The added aperture to the west by including the FORGE MT data was crucial in resolving this deeper structure to a better extent than for previous quarterly reports. In Figure 3.7.1-12 to the north, the Mineral Mountains high-angle conductor turns eastward and merges with a larger structure associated with the Cove Fort transverse zone mentioned previously. The pipelike conductor beneath northern Milford Valley dipping to the north-northwest also is well visible in this northerly cross section. We supplied a model volume to FORGE colleague Dr. Rob Podgorney of INL for incorporation into the overall FORGE earth model using the Leapfrog platform.

3. **Explanation of Variance**: No variance from plans.

4. **Plans for Next Quarter**

The end of fiscal year 2020 coincides with the close of the FORGE site characterization using MT. No formally supported activities are to continue beyond September 30, 2020. As the interpretation is joint with the data set of the neighboring SubTER project (it self mostly expended), a minor effort will continue into FY2021 under its support. We will continue to fine-tune the finite element model through additional exploration of the effect of the Kern River pipeline. We will compare the resistivity structure below the Mineral Mountains and FORGE project area with natural seismicity in the area being monitored by Dr. Kristine Pankow and her post-doctoral researcher Dr. Maria Mesimeri.

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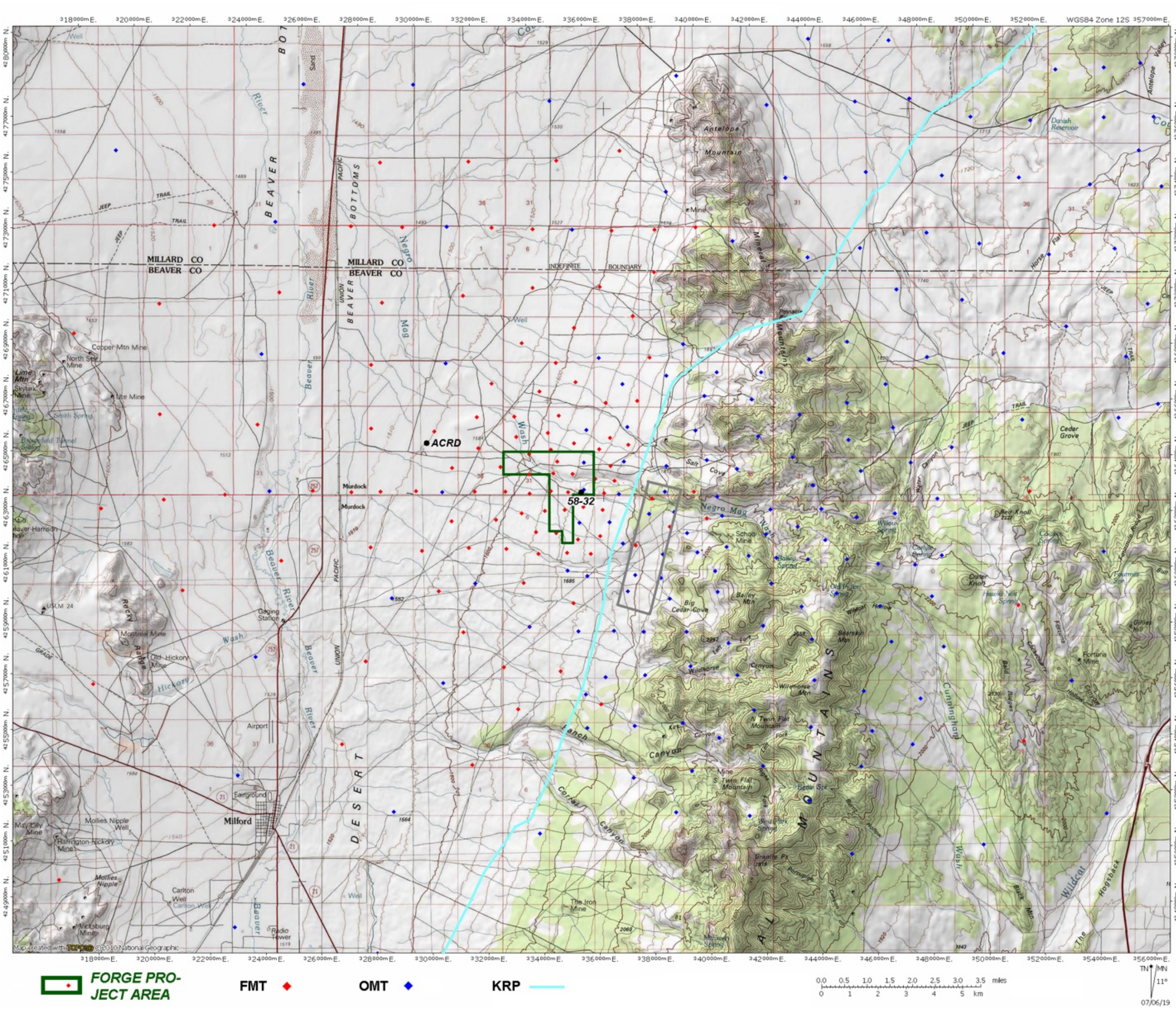

Figure 3.7.1-1. MT site topographic survey map of the Utah-FORGE project area showing prior other (blue, OMT) and new FORGE station coverage (red, FMT). Cyan trend running NNE-SSW through the project area is the Kern River pipeline (KRP). FORGE property boundary shown as dark green right polygon, and Acord-1 (ACRD) and FORGE test drill site (58-32) wells are marked as black circles. Dark grey rectangle shows approximate production area of the Roosevelt Hot Springs (RHS) producing geothermal system.

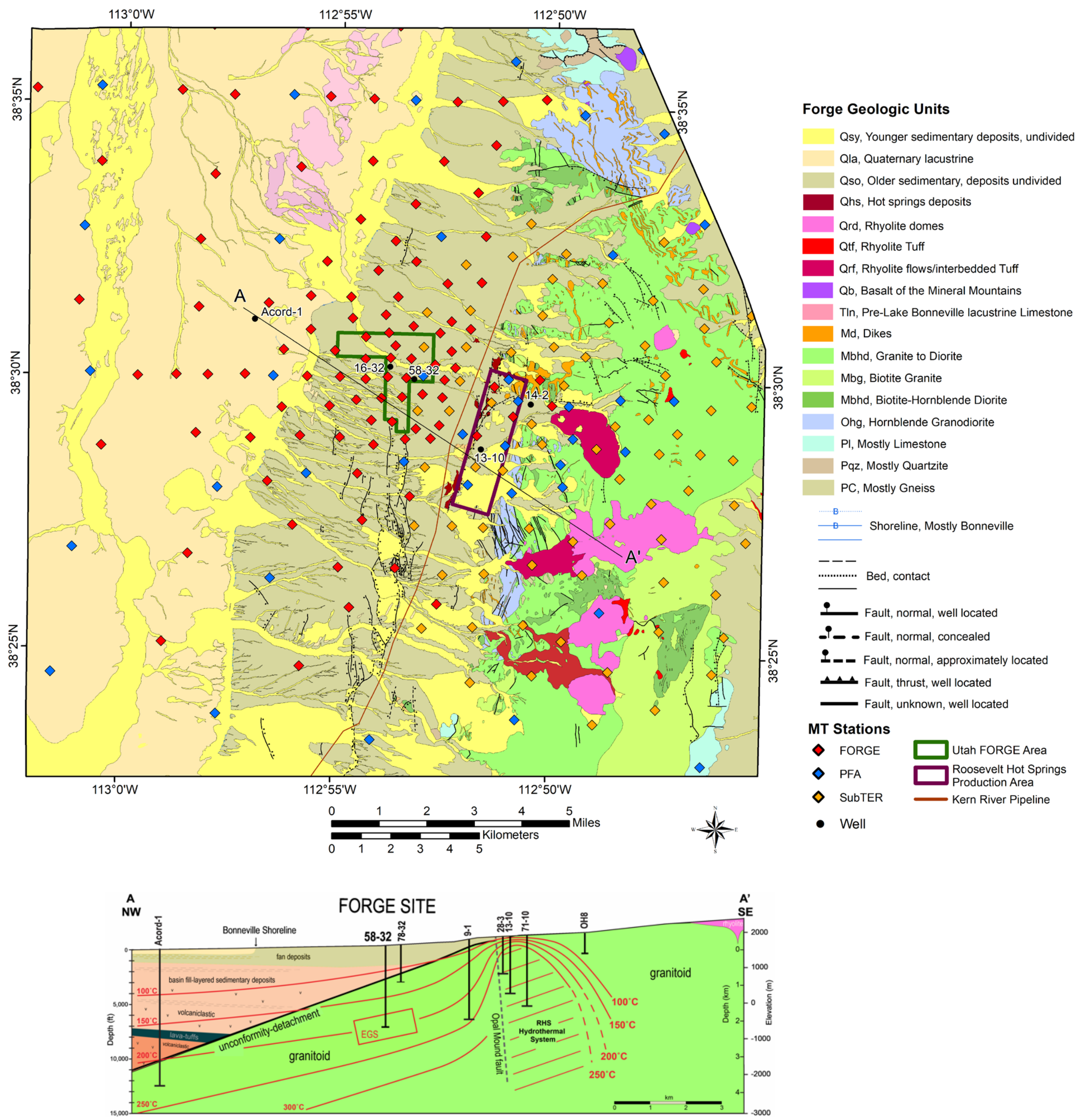

Figure 3.7.1-2. Upper: Smaller-scale, MT site geological map of the Utah-FORGE project area showing former Play Fairway Analysis and State of Utah sites (blue), recent SubTER sites (orange) and new FORGE station coverage (red); Lower: Geological-thermal cross section along line A-A' in part a), modified from Allis et al (2019) and Kirby et al (2019). Plutonic units are undifferentiated in the section view.

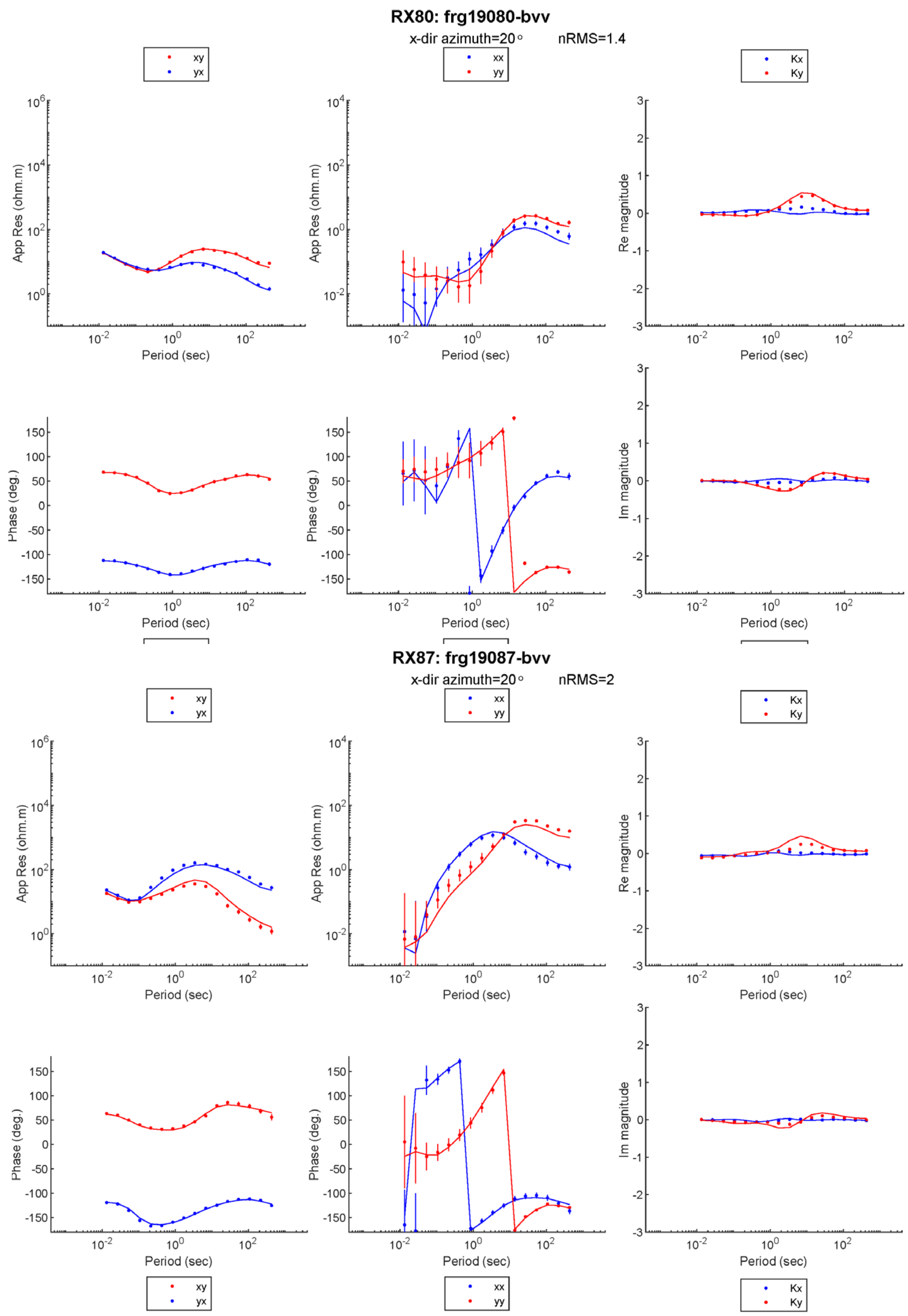

Figure 3.7.1-3. Two example sounding curves from the recently completed FORGE MT survey that straddle well 58-32 by 1-2 km. Upper site (FRG19080) is from the central portion of the project area, while lower site (FRG19087) is from the eastern portion of the project area. Solid curves denoted computed response of 3D inversion model fit to the observations. Fits are considered to be good overall.

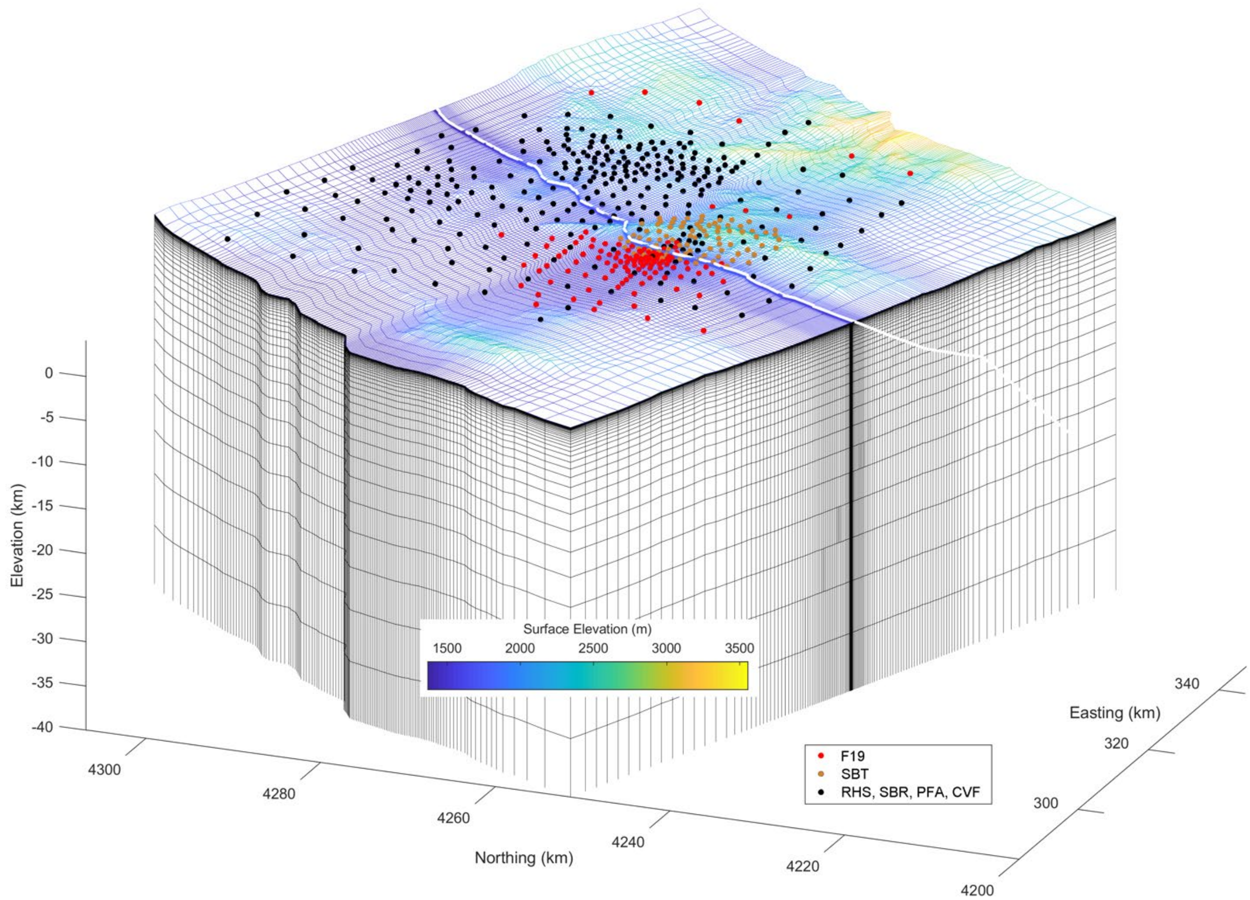

Figure 3.7.1-4. Wireframe view of surface of deformed hexahedral finite mesh for 3D inversion of FORGE+SubTER+ PFA MT data. White meandering lineation is element representation of Kern River pipeline. Horizontal units are NAD84 UTM Zone 12S.

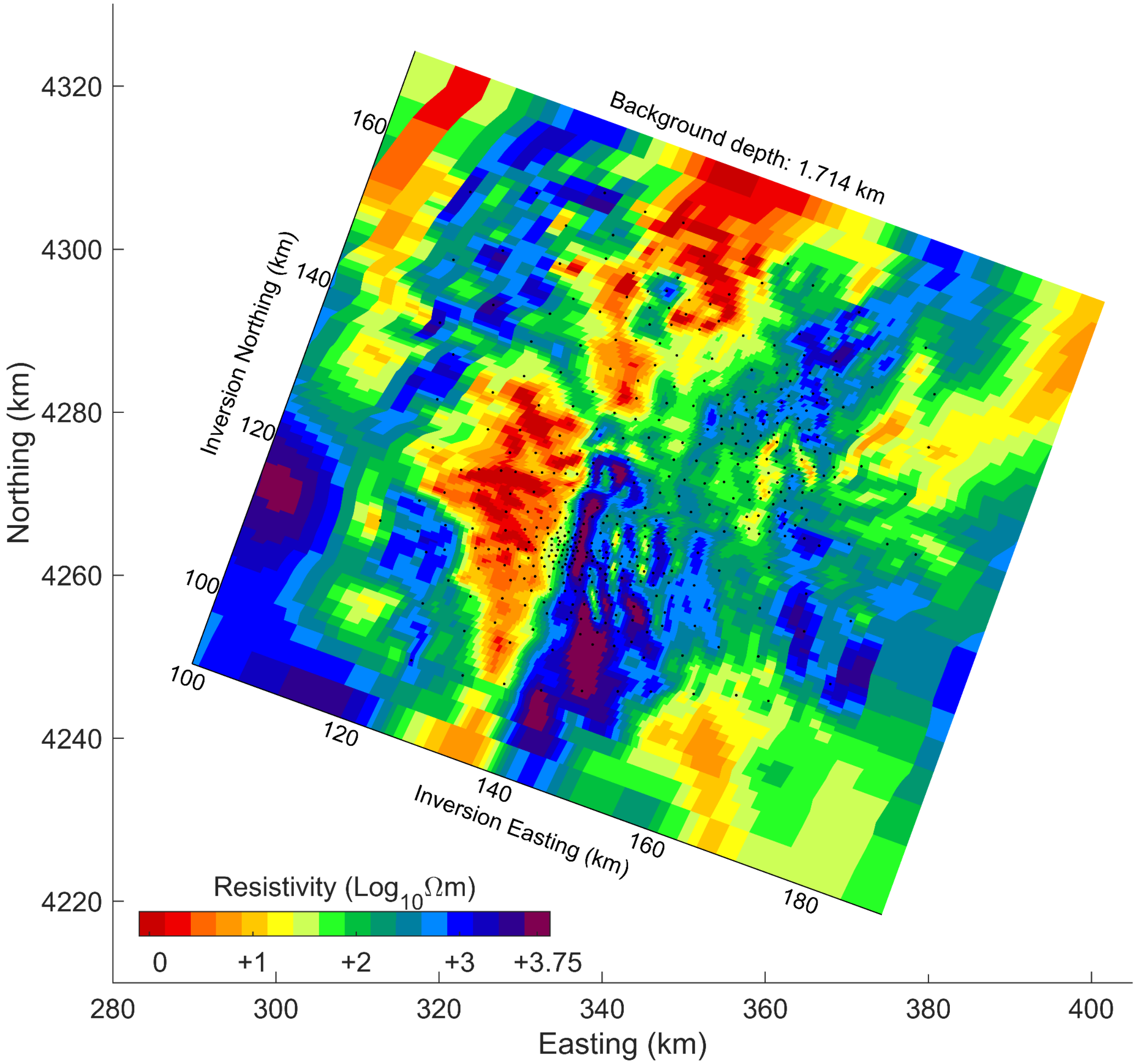

Figure 3.7.1-5. Plan view of 3D resistivity inversion model through the FORGE-SubTER- PFA MT data set at an average depth of 1714 m (accounting for mesh deformation due to elevation. Mesh is tilted to true north is up. A Mineral Mountains area of interest at UTM Northing 4265 km and Easting 340 km centers on low-resistivity lineations in the middle Mineral Mountains trending north-south, the westerly of which projects in the RHS producing area.

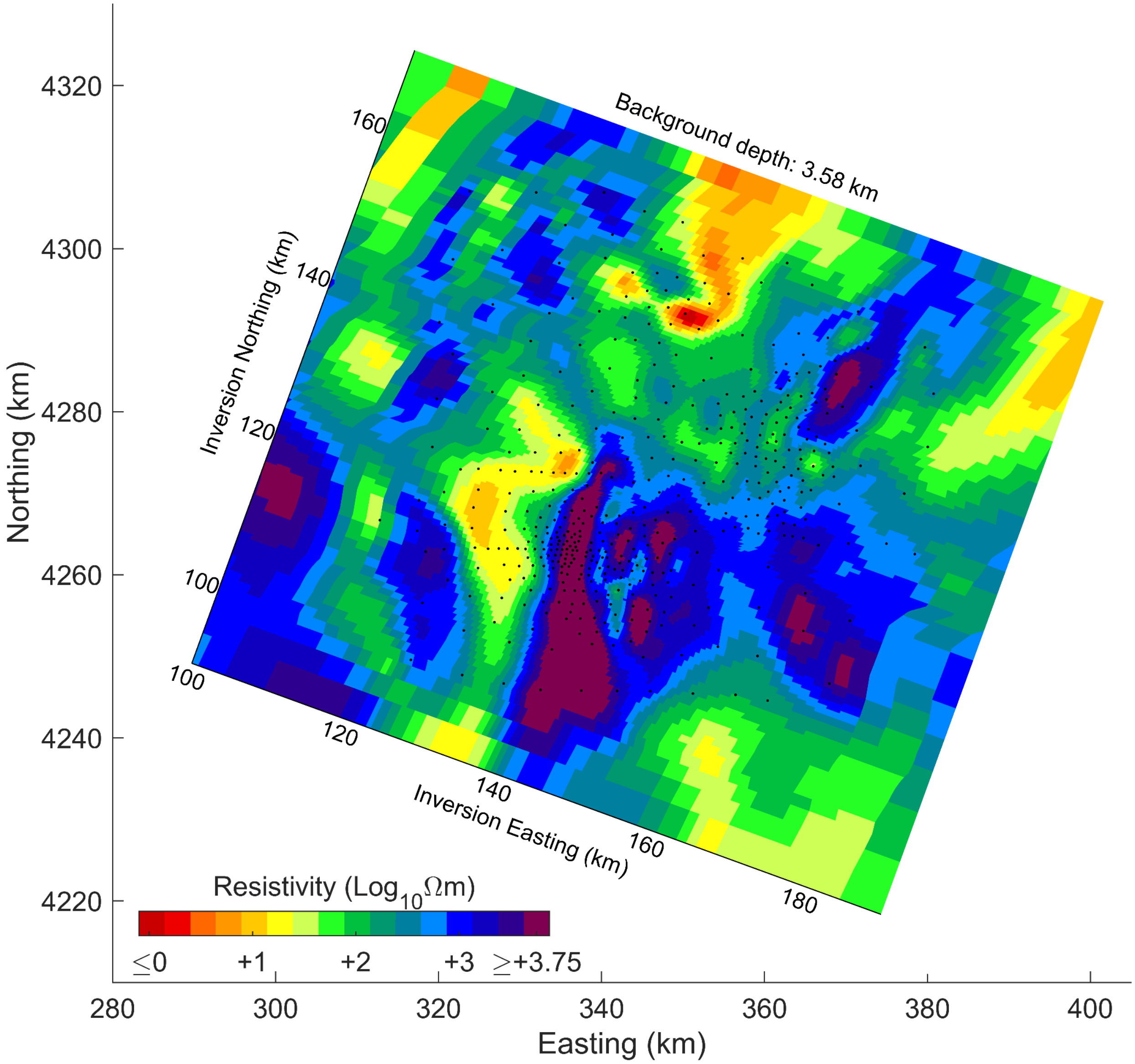

Figure 3.7.1-6. Plan view of 3D resistivity inversion model through the FORGE-SubTER-PFA MT data set at an average depth of 3580 m. Low resistivity lineaments in the middle Mineral Mountains persist to depth.

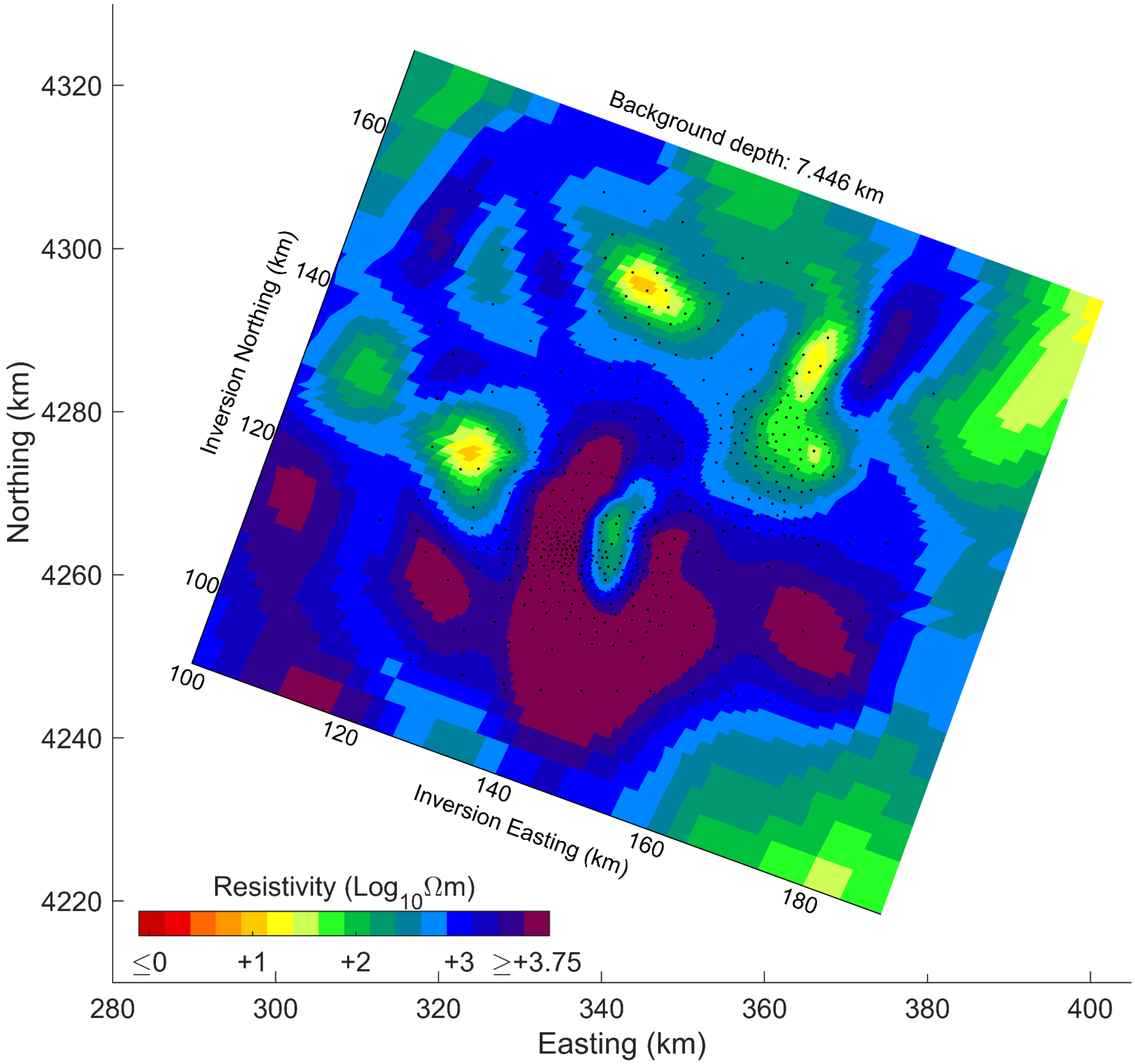

Figure 3.7.1-7. Plan view of 3D resistivity inversion model through the FORGE-SubTER-PFA MT data set at an average depth of 7446 m. Low resistivity lineaments in the middle Mineral Mountains have converged to a single low-resistivity feature. Conductor under northern Milford Valley has become distinct but can be followed shallowing upward to the south to the base of the valley sediments.

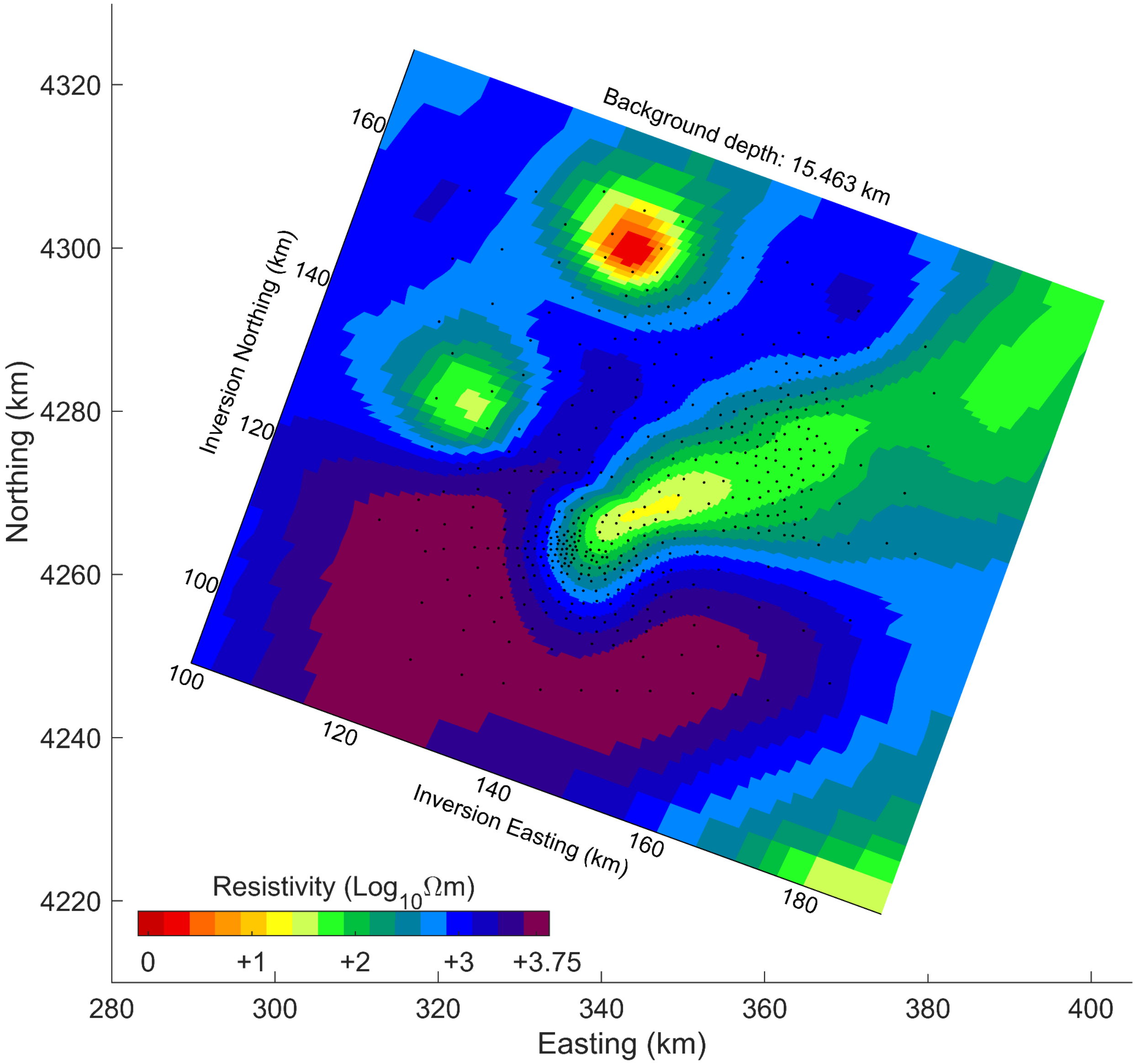
Background depth: 15.463 km
Inversion Northing (km)
Inversion Easting (km)
160
140
120
100
100
120
140
160
180
Northing (km)
4320
4300
4280
4260
4240
4220
Easting (km)
280
300
320
340
360
380
400
Resistivity (Log10Ωm)
0
+1
+2
+3
+3.75

Figure 3.7.1-8. Plan view of 3D resistivity inversion model through the FORGE-SubTER-PFA MT data set at an average depth of 15.46 km. Low resistivity structure below the middle Mineral Mountains appears to merge eastward with the Cove Fort transverse zone.

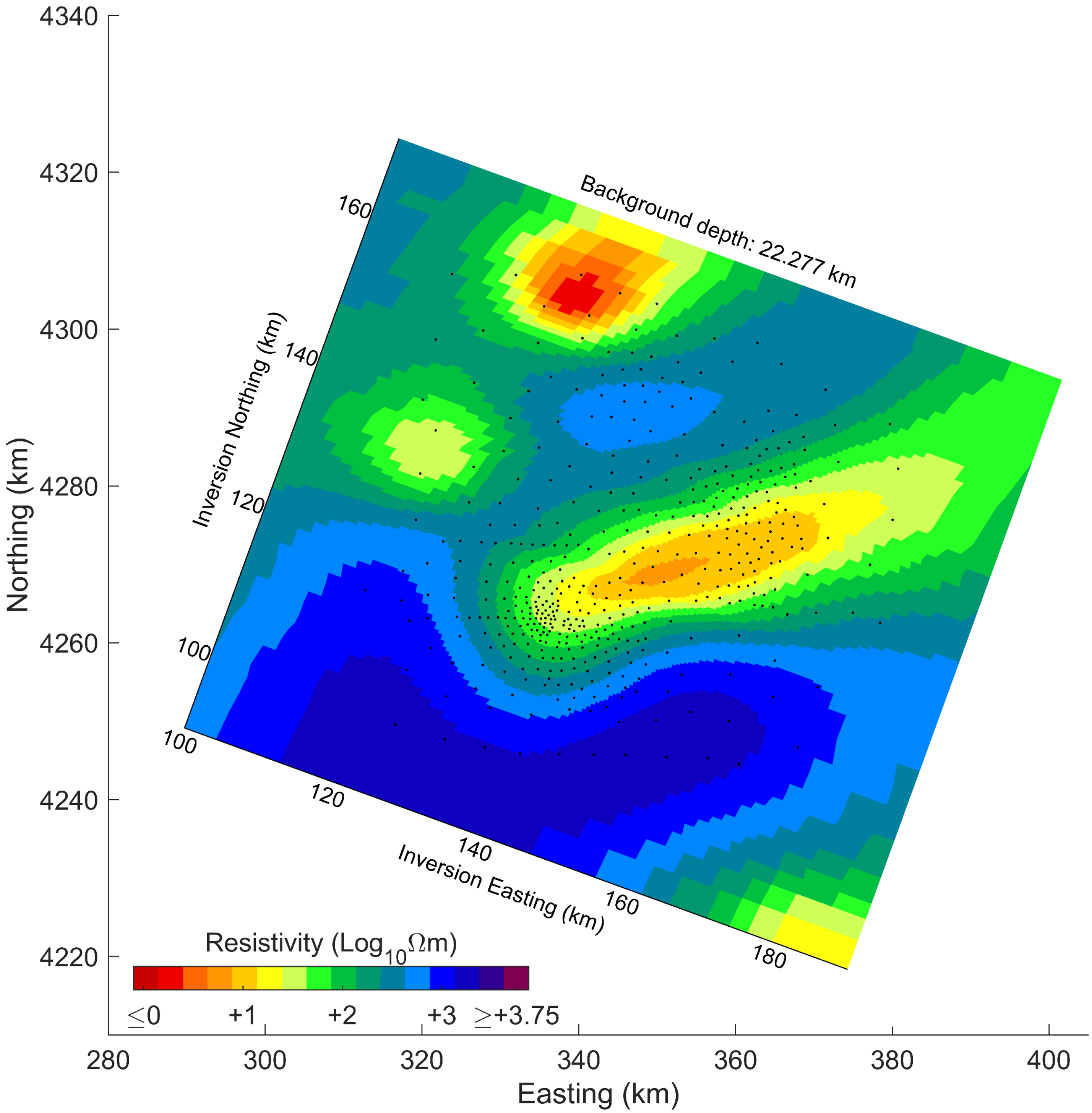

Figure 3.7.1-9. Plan view of 3D resistivity inversion model through the FORGE-SubTER-PFA MT data set at an average depth of 22.28 km. Merger of low resistivity structure below the middle Mineral Mountains eastward with the Cove Fort transverse zone appears complete.

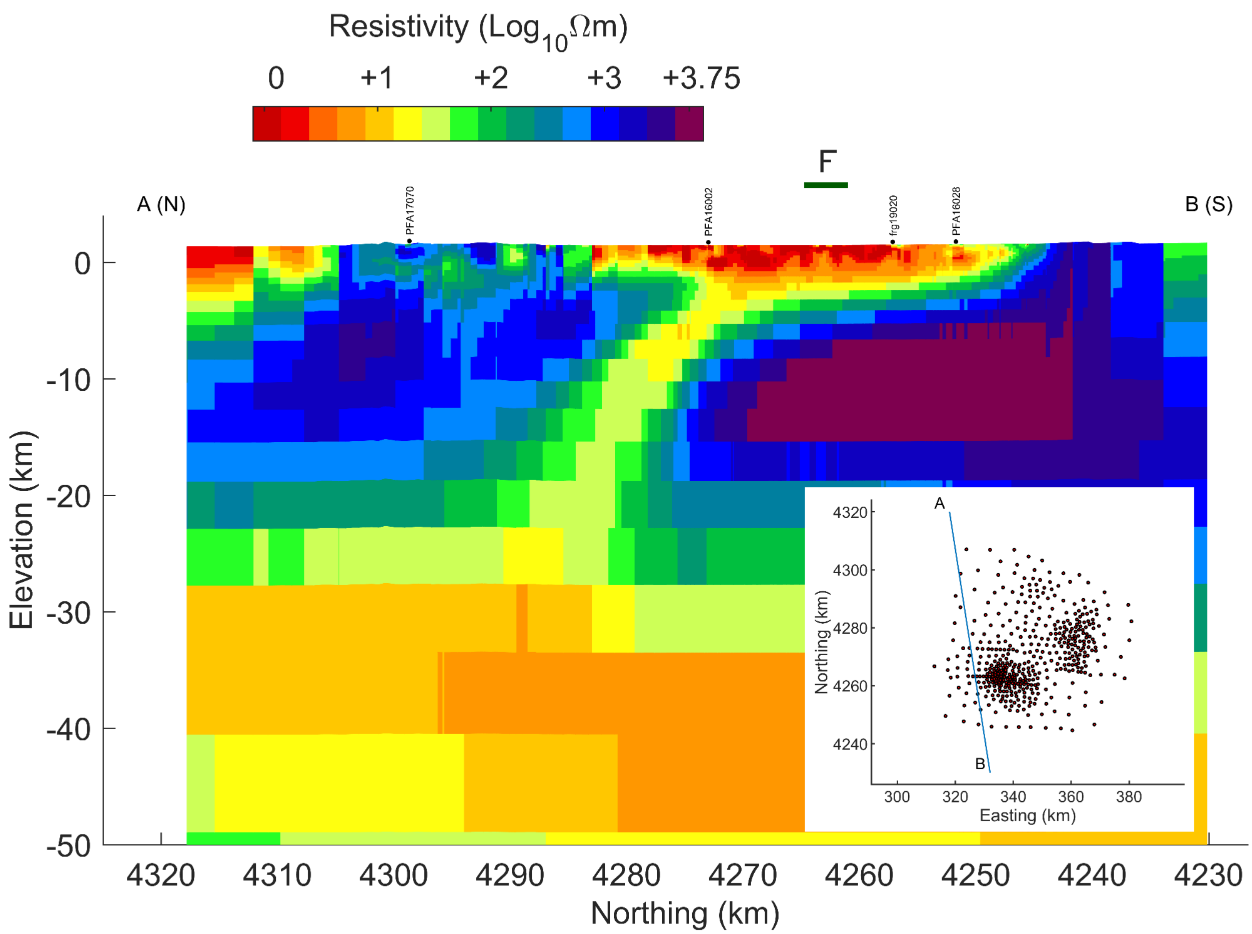

Figure 3.7.1-10. Section view through FORGE-SubTER resistivity model along Milford Valley from south to north. Projection of the FORGE project area westward onto the section line is denoted with horizontal green bar and label F.

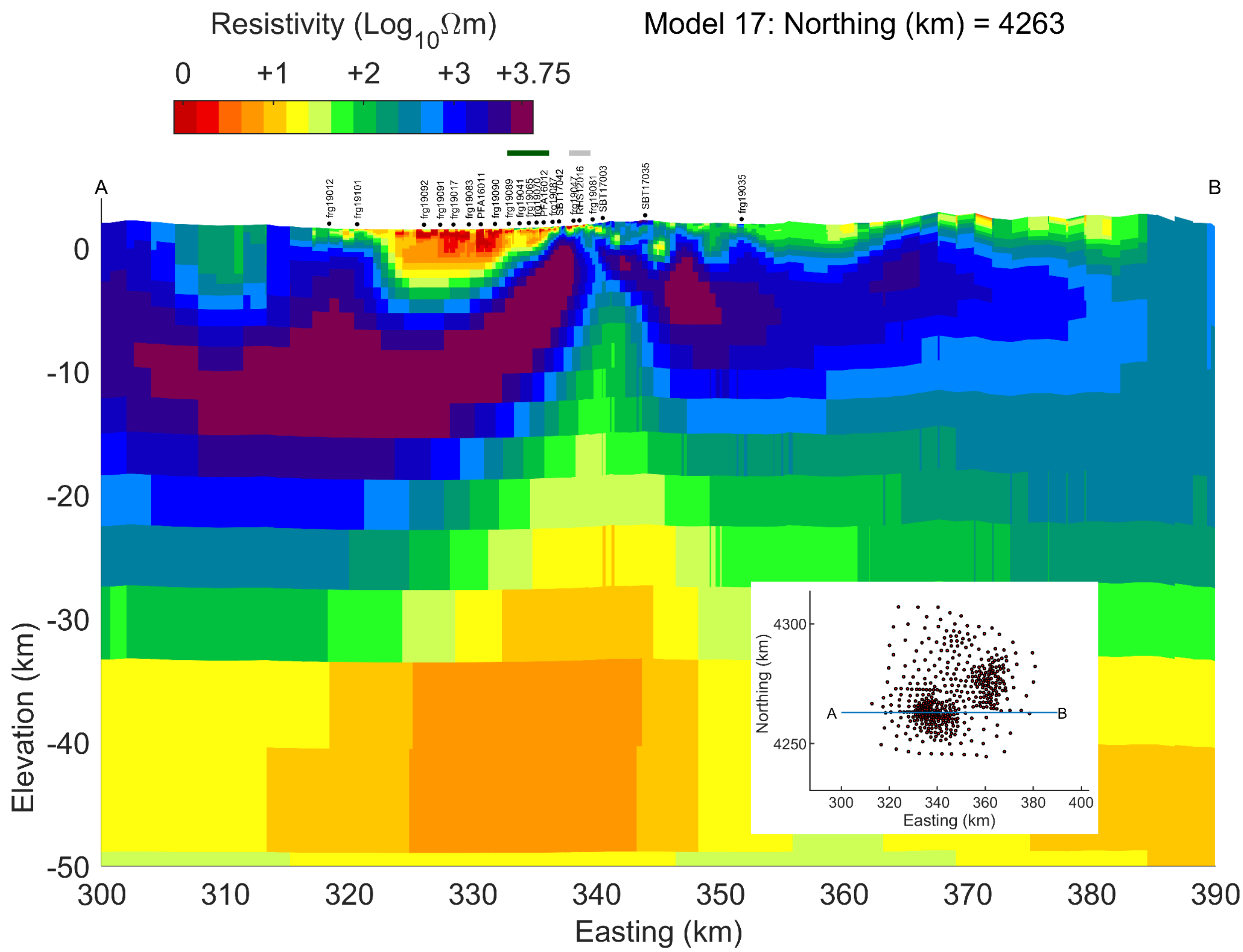

Figure 3.7.1-11. Section view through FORGE-SubTER resistivity model across the FORGE project area (dark green bar), Roosevelt Hot Springs (RHS) producing area (grey bar) and central Mineral Mountains.

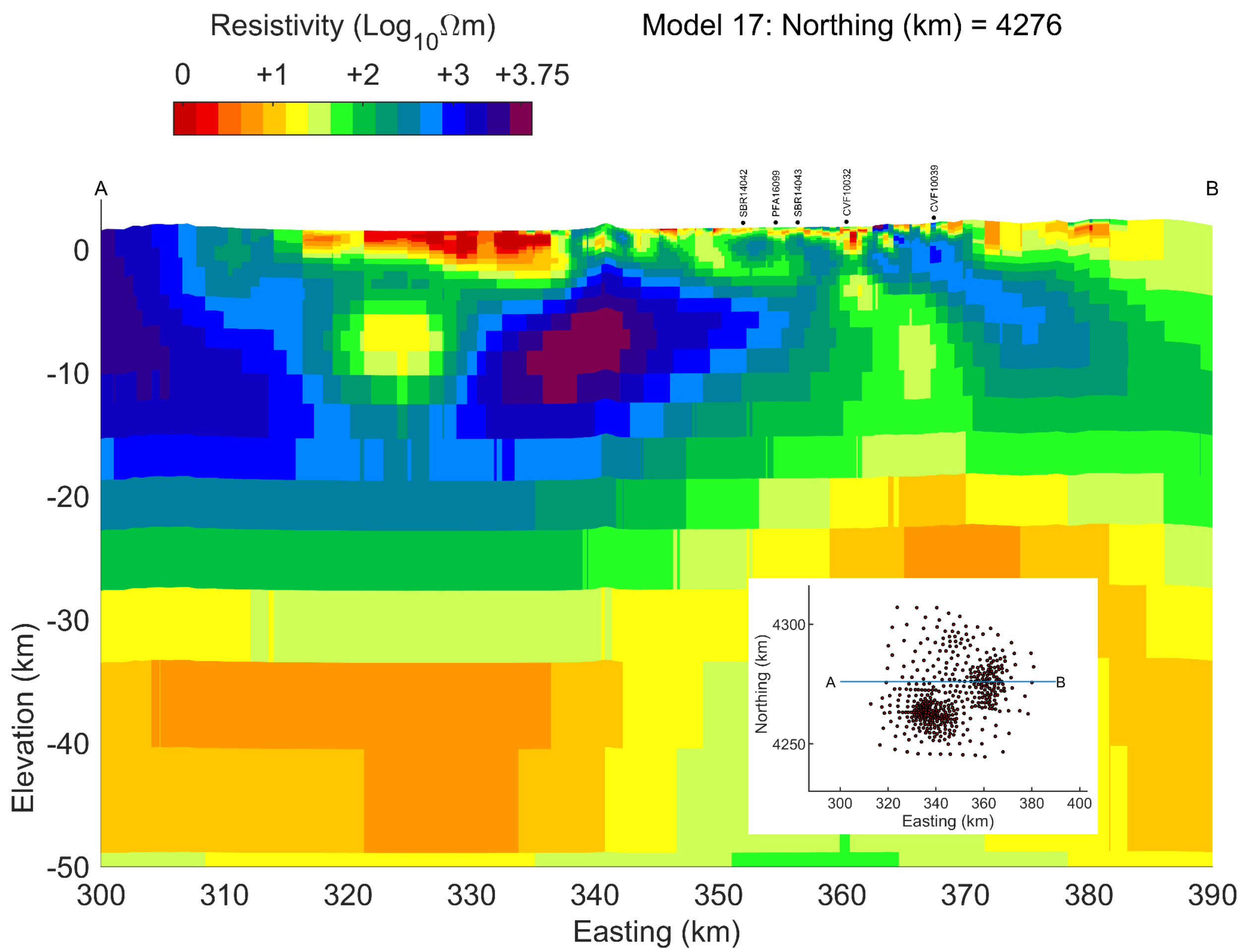

Figure 3.7.1-12. Section view through FORGE-SubTER resistivity model across northern Milford Valley and northern Mineral Mountains. The Mineral Mountains deep crustal conductor is moving eastward to join the Cove Fort transverse zone. The compact northern Milford Valley conductor dips at a moderate angle to the north.

Subtask 3.7.2 – Water Geochemistry
The Recipient will analyze water samples from wells drilled during Phase 3 for major and minor species (e.g. pH, Cl, HCO_3, SO4, Li, Na, K, Ca, Mg, B, SiO_2. As, Sb), stable isotopes and dissolved noble gases. Where appropriate, chemical aqueous geothermometers will be applied to interpret subsurface temperatures and to evaluate hydrothermal fluid inputs. The results will be integrated with existing geochemical and hydrological data across the FORGE site.

Planned Activities: Collect and analyze water samples Sample of discharge during aquifer testing and sampling of new wells near the FORGE site. Contribute to an improved understanding of the groundwater characteristics and reservoir fluid geochemistry on and near the FORGE site. We will interpret the data from the groundwater samples, and collect and analyze as appropriate

Actual Accomplishments: Ten groundwater samples from wells near the FORGE site and across Milford Valley were collected. (Figures 1). The goal of this sampling was to collect a consistent dataset that includes analyses of standard major ion, trace constituents, metal isotopes of Sr and B, stable isotopes of C, H, and O, and dissolved He concentrations. These data will be used to better define the characteristics of the local aquifer, surrounding the Utah FORGE site and provide further constraints on the regional setting of the geothermal resource.

Samples for major ion, trace constituents, and stable isotopes of C, H, and O were submitted to the Brigham Young Geochemical Laboratory. Samples for metal isotopes were submitted to the University of Utah Metal Isotope Laboratory and those for dissolved He were submitted to University of Utah Dissolved Gas Laboratory.

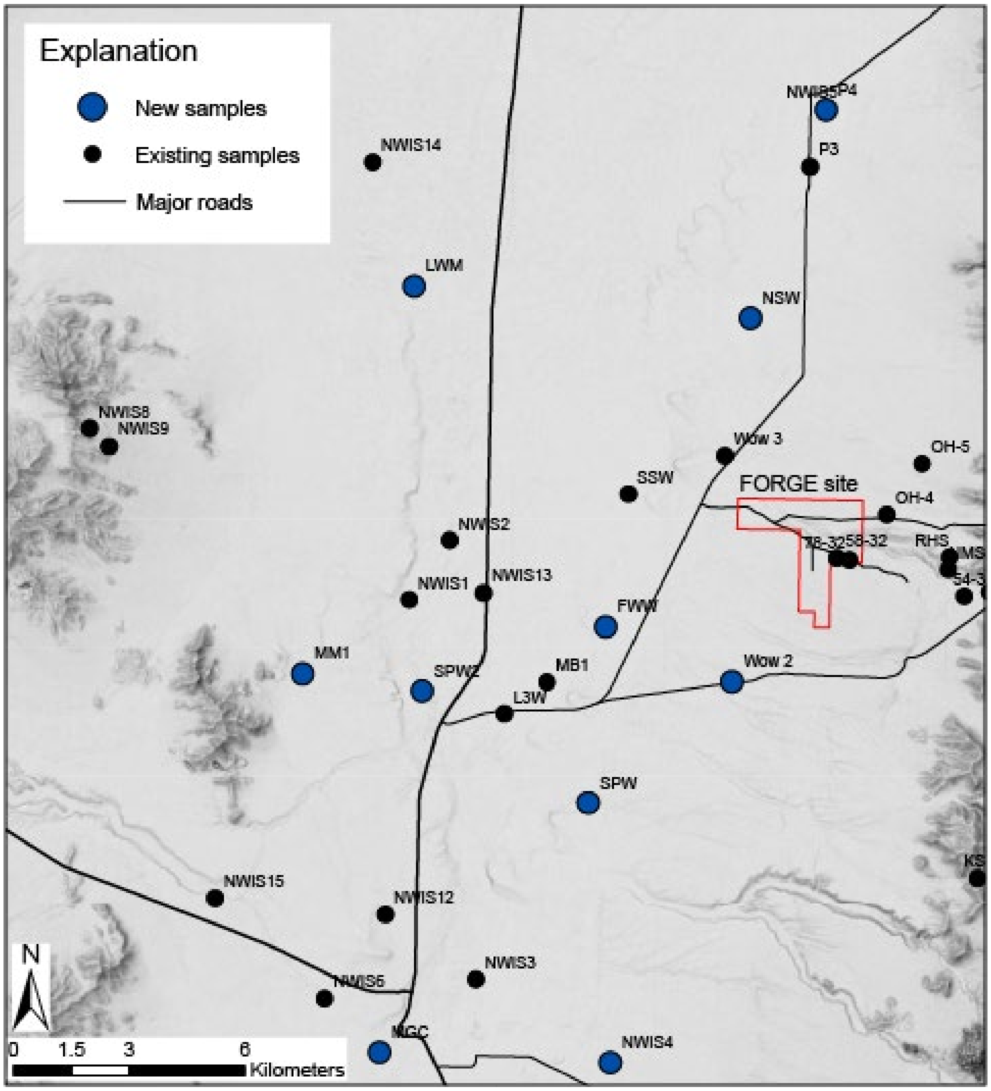

Figure 1. *Location map of new geochemical samples. Sample sites were chosen based on access, preexisting geochemical and dissolved gas data, and location.*

Existing hydrologic data was updated based on continuous water level data from wells WOW2 and WOW3, collected thru September 2020 (Figures 1 and 2). Both of these wells are existing monitoring wells constructed in the early 1980’s. These sites were chosen for long term monitoring based on proximity to the Utah FORGE site and an existing long-term record of water levels collected annually by the USGS since 1976. These sites are located several kilometers to the west and south of the FORGE site (Figure 1). Water levels at both sites have been recorded continuously since February of 2019. Downhole transducers installed in WOW2 and WOW3 record water levels every hour. Field water levels and data are downloaded quarterly. Transducer data is adjusted for barometric change using data from a barometric logger located at the WOW3 site. These data are then cleaned and checked for consistency.

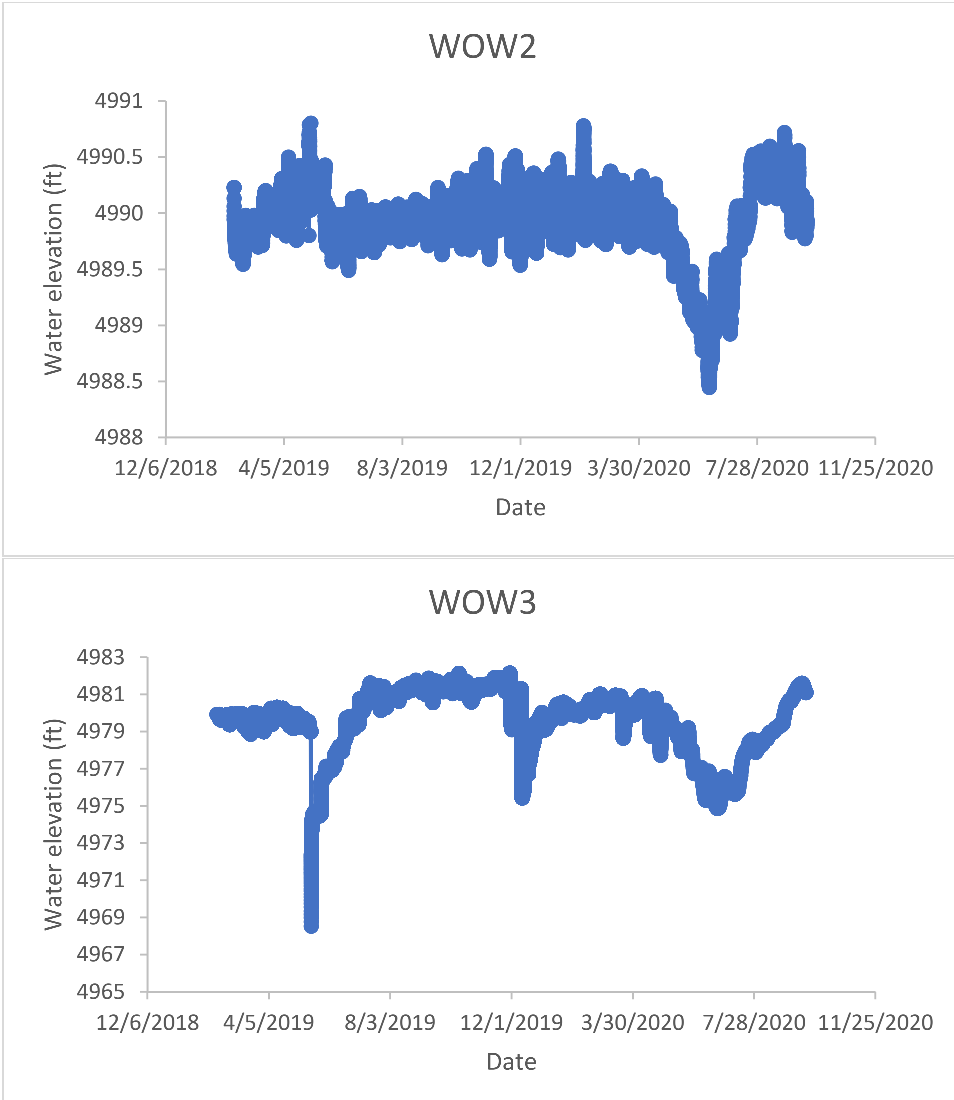

Figure 2. Continuous water levels for the WOW2 and WOW3 monitoring sites.

These wells show significant differences in water level variations. The water level at WOW2 is relatively stable through time although a single decline and recovery of just over 1 foot is recorded during the summer of 2020. In contrast, the water level at WOW3 fluctuates just over one foot over time intervals of less than a week. Based on available well logs and the conceptual setting discussed in Kirby and others (2019) it is likely that the WOW3 well is completed in fine grained silts and clays typical of a confined aquifer setting and WOW2 is completed in unconsolidated sands and gravels typical of unconfined aquifer setting. Variability at WOW3 is likely driven by the confined nature of aquifer, proximity to pumping supply wells located at the NSW and SSW well sites (Figure 1) and extensive powerline and water line construction near the site. We suggest the stable water level at WOW2 is the result of the unconfined nature of the aquifer and great distance to pumping wells at this site. Similar aquifer responses are typical for unconfined and confined aquifer settings (Domenico and Schwarz, 1997).

Explanation of Variance: No new wells were drilled in Year 1 of Phase 3. Consequently, efforts were focused on the collection of water samples and hydrologic data from the region surrounding the FORGE site.

Plans for Forthcoming Annual Cycle: Chemical analyses of the samples collected should be completed in the first quarter of FY 2021. The data will be analyzed to determine the extent of chemical variability of the fluids, trends over time, possible causes of any observed variations and their significance. Samples of geothermal waters, aquifer test samples, stimulation fluids and/or groundwaters will be collected and analyzed as opportunities arise. Monitorig of WOW2 and WOW3 will continue. The results will be made available through GDR.

References

Domenico, P.A., Schwartz, F.W., and others, 1997, Physical and chemical hydrogeology: 528 p.

Kirby, S.M., Simmons, S., Inkenbrandt, P.C., and Smith, S., 2019, Groundwater hydrogeology and geochemistry of the Utah FORGE site and vicinity, *in* Allis, R., and Moore, J.N., editors, Geothermal characteristics of the Roosevelt Hot Springs system and adjacent FORGE EGS site, Milford, Utah: Utah Geological Survey Miscellaneous Publication 169-E, 21 p., https://doi.org/10.34191/MP-169-E.

Progress Report to FORGE

For ENERGY & GEOSCIENCE INSTITUTE (EGI) AT UNIVERSITY OF UTAH

AnnualReportTask3_7_3_20200908.docx

Annual Report for FORGE Task 3.7.3
covering the period from 1 September 2019– August 30, 2020

Kurt L. Feigl and Sam Batzli

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Submitted September 2020 (revised Oct. 2)

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SUBTASK 3.7.3 – CONDUCT INSAR ANALYSIS (FEIGL & BATZLI)

This subtask aimed to quantify deformation at the Utah FORGE site using Interferometric Synthetic Aperture Radar (InSAR).

1. Planned Activities

The Recipient will obtain and interpret InSAR interferograms to assess ground deformation and to complement continuous GPS monitoring. Additional scenes will be acquired from several satellite missions as available. The new scenes will be compared with previous scenes in interferometrically compatible combinations. The InSAR results will be evaluated to estimate ground deformation. Since the rate of subsidence at the FORGE site in Utah is expected to be low, a careful analysis using many SAR images acquired over several years was required to quantify any deformation at the level of several millimeters per year.

2. Actual accomplishments

In this year, we have analyzed the SAR data from early January 2019 (20190131) through August 2020 (2020814). This data set consists of SAR images acquired by TerraSAR-X and TanDEM-X satellite missions operated by the German Space Agency (DLR). DLR charges a fee of 200 EUR for one scene as the cost of fulfilling user requests (COFUR) under the "general science" category. The images acquired on individual dates are listed in Table 1.

As described previously [*Reinisch et al.*, 2018b; *Reinisch et al.*, 2020], the InSAR data products are registered ("geo-coded") to a digital elevation model (DEM) in cartographic (Universal Transverse Mercator Zone 12) coordinates to within ~10 m. We have produced geo-coded interferograms for pairs of SAR images that correlate successfully. To produce the interferograms, we analyze the SAR data at UW-Madison using the GMT5SAR suite of open-source software [*Sandwell et al.*, 2011].

We have calculated many different interferometric pairs. Several examples are shown in Figure 1 in terms of wrapped phase. In these individual pairs, we do not observe any deformation that is obviously associated with the deep well 58-32. No deformation is expected. The crenulated patterns are probably the result of atmospheric effects that are partially correlated with topography. The wide-scale patterns are probably the result of unmodeled orbital effects in the satellite trajectories.

To improve the precision of the deformation measurement, we have formed a stack with a subset of pairs, listed in the file named **TSX_T30_forge_pairs.txt**. For each pixel in the stack, we have a time series of pair-wise measurements of unwrapped range change in meters. We have calculated the mean rate of range change and its standard error for each pixel in the stack, with at least 6 good pair-wise measurements.

Figure 3 shows the mean rate of range change in map view. Figure 4 shows the standard error of the mean rate of range change. Figure 5 shows the mean rate for those pixels that have rates that are significantly different from zero with 95% confidence. To make this plot, we calculate the so-called "Z-score" as the mean rate normalized by its standard error. Using the standard error of the estimated rates, we can test the null hypothesis of no deformation. Using a Student's T-test, if the null hypothesis fails to be rejected with 95% confidence, then the mean rate is not shown in Figure 5.

Regarding the area within a kilometer of deep well 58-32 in the stack of radar images spanning from December 2018 through August 2020, we do not see any deformation with a mean rate of range increase (downward motion) greater than 3 mm/year. In other words, Accordingly, we infer that any processes at work below ground are not causing measurable deformation at the Earth's surface.

The geocoded data products have been delivered to the prime contractor in a CSV file format that can be imported into LeapFrog. These files have been uploaded into the shared data repository at the following URL:

https://collab.openei.org/29/insar/task3-7-3-annual-report-2020september

The contents of this file are listed in Table 2

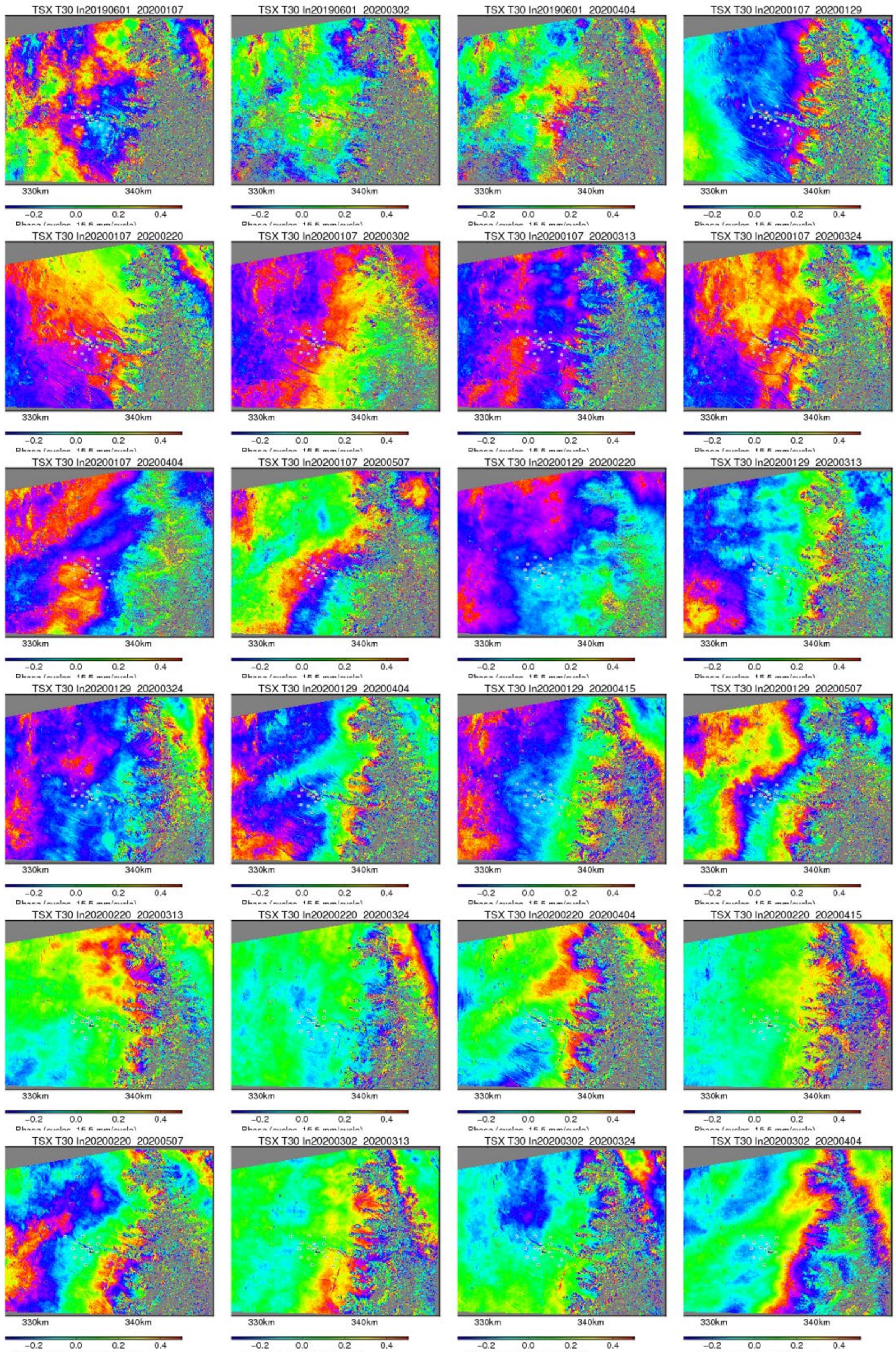
The data products are also archived at UW-Madison.

```
$ grep forge /s21/insar/TSX/TSX_OrderList.txt | cut -c 1-78 | sort -un
```

#date	site	sat	track	swath	frame	orbit	ascdes	status	source
20161108	forge	TDX	T30	strip_004	nan	35404	A	D	dlrdlr
20181115	forge	TDX	T30	strip_004R	nan	46593	A	D	dlrdlr
20190131	forge	TSX	T30	strip_004R	nan	47762	A	D	dlrdlr
20190211	forge	TSX	T30	strip_004R	nan	47929	A	D	dlrdlr
20190222	forge	TSX	T30	strip_004R	nan	48096	A	D	dlrdlr
20190418	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**48931**	**A**	**D**	**dlrdlr**
20190510	forge	TSX	T30	strip_004R	nan	49265	A	D	dlrdlr
20190601	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**49599**	**A**	**D**	**dlrdlr**
20190623	forge	TSX	T30	strip_004R	nan	nan	A	C	dlrdlr
20190715	forge	TSX	T30	strip_004R	nan	nan	A	C	dlrdlr
20200107	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**52939**	**A**	**D**	**dlrdlr**
20200129	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**53273**	**A**	**D**	**dlrdlr**
20200220	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**53607**	**A**	**D**	**dlrdlr**
20200302	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**53774**	**A**	**D**	**dlrdlr**
20200313	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**53941**	**A**	**D**	**dlrdlr**
20200324	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**54108**	**A**	**D**	**dlrdlr**
20200404	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**54275**	**A**	**D**	**dlrdlr**
20200415	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**54442**	**A**	**D**	**dlrdlr**
20200426	forge	TSX	T30	strip_004R	nan	54609	A	D	dlrdlr
20200507	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**54776**	**A**	**D**	**dlrdlr**
20200518	forge	TSX	T30	strip_004R	nan	54943	A	D	dlrdlr
20200529	forge	TSX	T30	strip_004R	nan	55110	A	D	dlrdlr
20200609	forge	TSX	T30	strip_004R	nan	55277	A	D	dlrdlr
20200620	forge	TSX	T30	strip_004R	nan	55444	A	D	dlrdlr
20200701	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**55611**	**A**	**D**	**dlrdlr**
20200712	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**55778**	**A**	**D**	**dlrdlr**
20200723	forge	TSX	T30	strip_004R	nan	55945	A	D	dlrdlr
20200803	**forge**	**TSX**	**T30**	**strip_004R**	**nan**	**56112**	**A**	**D**	**dlrdlr**
20200814	forge	TSX	T30	strip_004R	nan	56279	A	D	dlrdlr
20200825	forge	TSX	T30	strip_004R	nan		A	P	dlrdlr
20200905	forge	TSX	T30	strip_004R	nan		A	P	dlrdlr
20200916	forge	TSX	T30	strip_004R	nan		A	P	dlrdlr
20200927	forge	TSX	T30	strip_004R	nan		A	P	dlrdlr
20201008	forge	TSX	T30	strip_004R	nan		A	P	dlrdlr
20201019	forge	TSX	T30	strip_004R	nan		A	P	dlrdlr
20201030	forge	TSX	T30	strip_004R	nan		A	P	dlrdlr

Table 1. List of SAR acquisitions from TerraSAR-X and TanDEM-X radar satellite missions showing date (YearMonthDate) and orbit number. The status flags are defined as follows: "D" represents a scene that has been delivered. "P" denotes a scene that is planned for acquisition in the future. All of these acquisitions follow Track 30 in an ***asc****ending orbital pass that crosses the equatorial plane from south to north. Scenes listed in bold contribute to interferometric pairs shown in subsequent figures.*

Figure 1. (Next page). Example interferograms showing wrapped phase change in map view. One colored fringe of phase change represents a range change of 15.5 mm. Time intervals are given as YYYYMMDD. Coordinates are Easting and Northing in kilometers using the Universal Transverse Mercator (UTM) cartographic projection, Zone 12.


TSX T30 In20190601_20200107
TSX T30 In20190601_20200302
TSX T30 In20190601_20200404
TSX T30 In20200107_20200129
TSX T30 In20200107_20200220
TSX T30 In20200107_20200302
TSX T30 In20200107_20200313
TSX T30 In20200107_20200324
TSX T30 In20200107_20200404
TSX T30 In20200107_20200507
TSX T30 In20200129_20200220
TSX T30 In20200129_20200313
TSX T30 In20200129_20200324
TSX T30 In20200129_20200404
TSX T30 In20200129_20200415
TSX T30 In20200129_20200507
TSX T30 In20200220_20200313
TSX T30 In20200220_20200324
TSX T30 In20200220_20200404
TSX T30 In20200220_20200415
TSX T30 In20200220_20200507
TSX T30 In20200302_20200313
TSX T30 In20200302_20200324
TSX T30 In20200302_20200404
330km
340km
-0.2
0.0
0.2
0.4

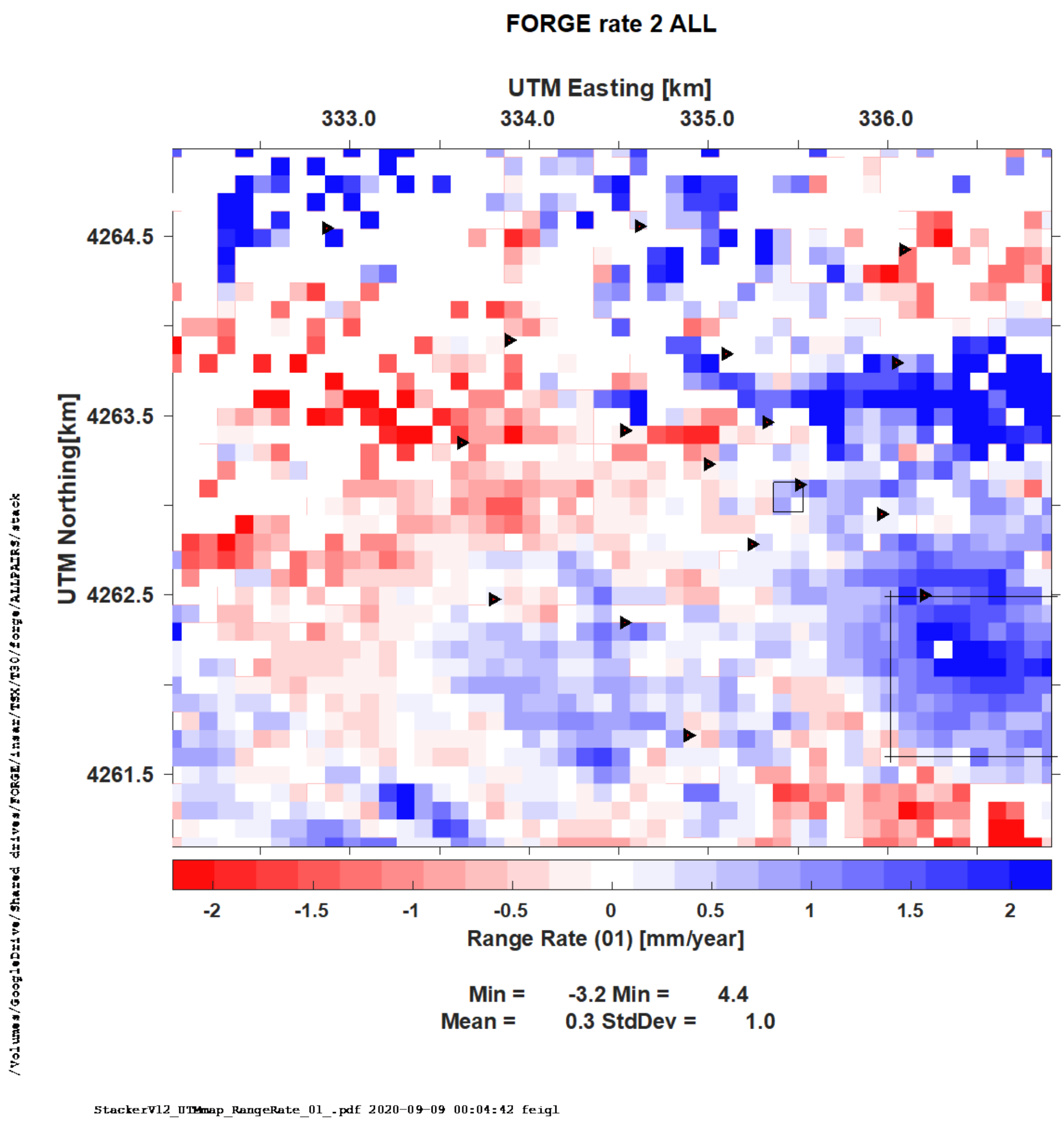


Figure 2. Mean rate of range change in mm/year for stack of interferograms. Coordinates are UTM (zone 12) easting and northing in km. The small black box denotes location of deep well 58-32. The large black box outlines the area considered as stable. Black triangles denote GPS stations.

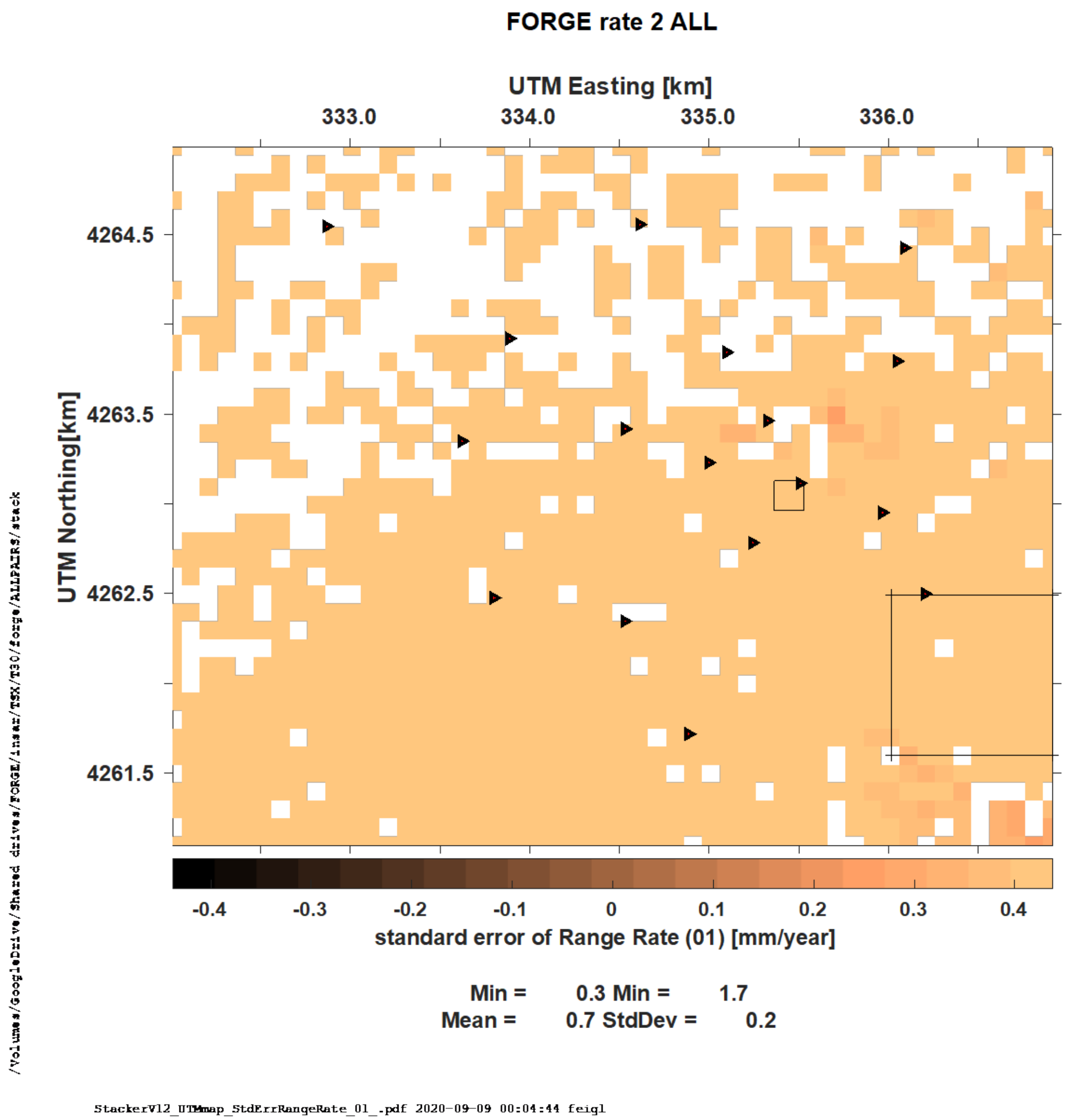


Figure 3. Standard error of mean rate of range change in mm/year for stack of interferograms. Plotting conventions as in previous figure.

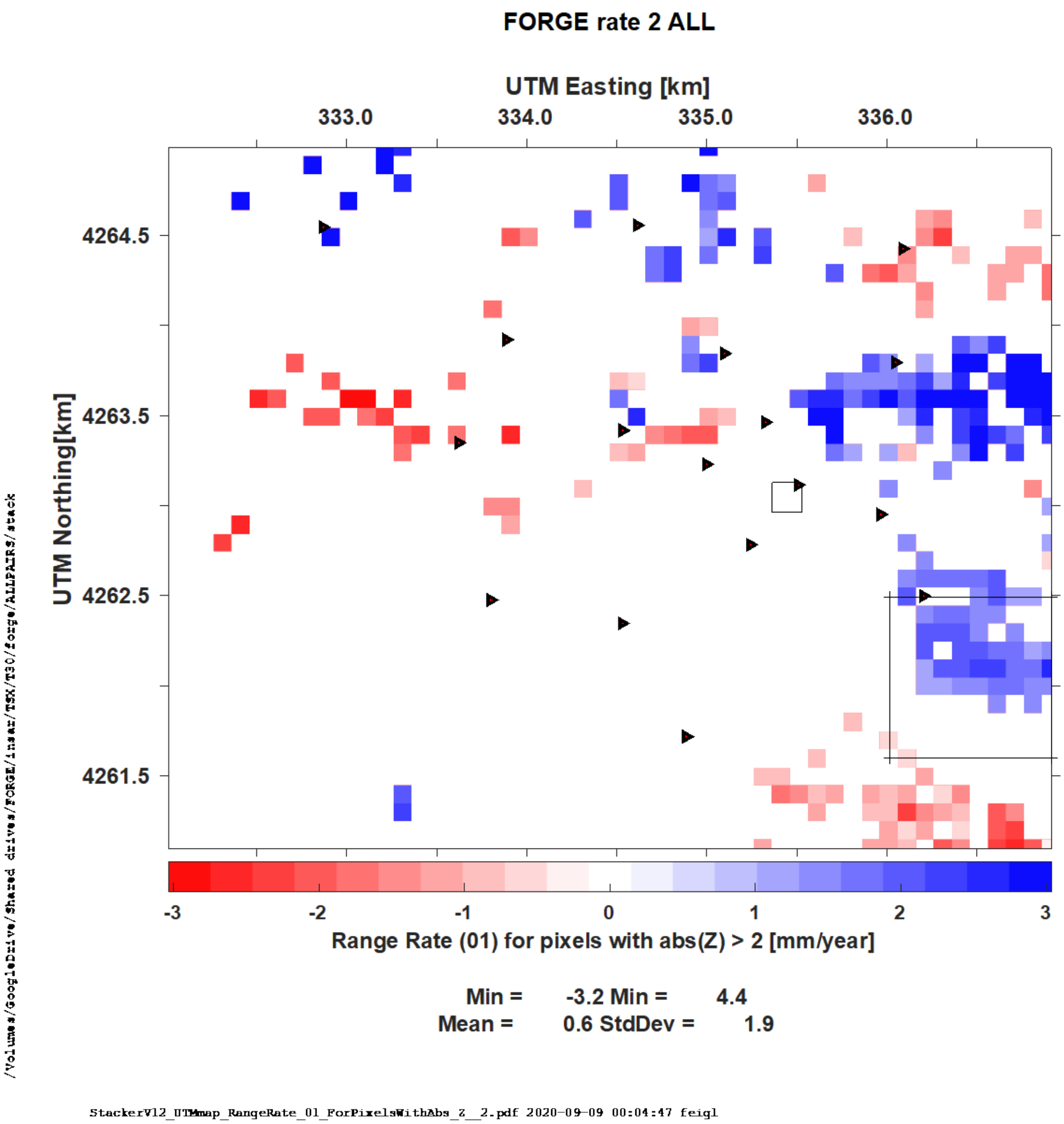


Figure 4. Mean rate of range change in mm/year for stack of interferograms, showing only pixels with rates that are significantly different from zero with 95% confidence. Increasing range denotes motion away from the satellite, e.g., downward motion or subsidence. Coordinates are UTM (zone 12) easting and northing in kilometers. The small black box denotes location of deep well 58-32. The large black box outlines the area taken as reference. Black triangles denote GPS stations.

File Name	Contents
0README.xlsx	This file
avg_range_mperyr_utm.csv	Mean rate of range change in CSV format (UTM Easting in meters, UTM Northing in meters, standard error of mean rate in m/year)
avg_range_mperyr_utm.grd	Mean rate of range change in NetCDF format
drhomaskd_utm.tgz	Compressed tar file containing masked range change for each pair in NetCDF format. Made with following commands. ls intf/In*/drhomaskd_utm.grd >! drhomaskd_utm.lst; tar -czvf drhomaskd_utm.tgz `cat drhomaskd_utm.lst`
ModeledPDFs.zip	Zipped archive containing PDF files showing maps of modeled values of range change for each pair. Made with the following command. zip -r -X ModeledPDFs.zip StackerV12*Modeled*.pdf
ObservedPDFs.zip	Zipped archive containing PDF files showing maps of observed values of range change for each pair. Made with the following command. zip -r -X ObservedPDFs.zip StackerV12*Observed*.pdf
phasefilt_utm.tgz	Compressed tar file containing masked range change for each pair in NetCDF format. Made with following command. ls intf/In*/phasefilt_utm.grd >! phasefilt_utm.lst; tar -czvf phasefilt_utm.tgz `cat phasefilt_utm.lst`
preproc.tgz	Compressed tar file containing metadata; made with following command. tar -czvf preproc.tgz preproc/*.LED preproc/*.PRM
ResidualPDFs.zip	Zipped archive containing PDF files showing maps of residual values of range change for each pair. Made with the following command. zip -r -X ResidualPDFs.zip StackerV12*Residual*.pdf
sig_range_mperyr_utm.csv	Standard error of mean rate in CSV format (UTM Easting in meters, UTM Northing in meters, rate in m/year)
sig_range_mperyr_utm.grd	Standard error of mean rate in NetCDF format
StackerV12_UTMmap_RangeRate_01_.pdf	Map of mean rate of range change for full area
StackerV12_UTMmap_RangeRate_01_ForPixelsWithAbs_Z__2.pdf	Map of mean rate of range change for full area for pixels with abs(Zscore) > 2
StackerV12_UTMmap_StdErrRangeRate_01_.pdf	Map of standard error of mean rate of range change for full area
StackerV12.zip	Zipped archive containing Matlab source code to perform time series analysis.
StackerV12report.pdf	Report generated by Matlab script StackerV12.pdf.
TSX_T30_forge_pairs.txt	List of grid file names for each pair
unit_vectors.txt	Vector pointing from target on ground to sensor aboard satellite.

Table 2. List of files on Data Foundry in folder named https://collab.openei.org/29/insar/task3-7-3-annual-report-2020september

3. Explanation of Variance:

During this year, the activities in this subtask took place according to plan.

4. Plans for Next Year:

In the year, we plan to analyze additional InSAR data acquired by the TerraSAR-X satellite mission operated by the German Space Agency (DLR).

We will also analyze InSAR data from the SENTINEL satellite mission operated by the European Space Agency (ESA). These data sets cover the FORGE site from late 2016 through the present. Additional scenes will be acquired every 6 or 12 days through at least 2023. Data from ESA from are available free of charge. For the data acquired by the SENTINEL missions, we will use the Interferometric synthetic aperture radar Scientific Computing Environment (ISCE) that is being developed by colleagues at NASA's Jet Propulsion Laboratory [*ISCE*, 2020].

After analyzing each interferometric pair individually, we will analyze multiple interferograms as time series, using the "temporal adjustment" approach to reduce sets of interferograms spanning irregular *intervals* of time to a series of range change values at arbitrary *points* in time (epochs) [*Feigl et al.*, 2000; *Berardino et al.*, 2002; *Schmidt and Bürgmann*, 2003; *Reinisch et al.*, 2016; *Reinisch et al.*, 2017; *Reinisch et al.*, 2018b]. To perform time-series analysis, we plan to use MintPy [*Yunjun et al.*, 2019]. Applying this approach to the Utah FORGE site should be straightforward. It will allow us to model and remove atmospheric effects using weather models from the European Center for Medium-range Weather Forecasts (EWMWF).

We will also compare the time series of displacement derived from InSAR with those estimated from GPS data at nearby stations. This effort will help address the issue of seasonal signature.

Acknowledgments:

Interferograms were created using GMT-SAR processing software [*Sandwell et al.*, 2011]. Several figures were created using the Generic Mapping Tools [*Wessel et al.*, 2013]. We gratefully acknowledge support from the Weeks family to the Department of Geoscience at the University of Wisconsin-Madison. Synthetic Aperture Radar data from the TerraSAR-X and the TanDEM-X satellite missions operated by the German Space Agency (DLR) were used under the terms and conditions of Research Project RES1236.

Software is available publicly on GitHub for the General Inversion of Phase Technique (GIPhT) [*Feigl et al.*, 2019], the PoroTomo project [*Reinisch and Feigl*, 2018], and the UW Madison HTCondor InSAR Workflow [*Reinisch et al.*, 2018a].

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FORGE Annual Report for 2020

Subtask 3.7.4 4D Gravity Survey

1. **Planned Activities for the year:** Complete campaign gravity loops of the FORGE stations on all geophysical deformation monuments four times in 2020.

2. **Actual Accomplishments:** Three campaigns consisting of five trips down to the Utah FORGE site were completed.

3. **Explanation of Variance:** Degrading weather conditions affected the November 2019 survey. In 2020, COVID19 pandemic safety guidelines prevented fieldwork for the first half of the year.

4. **Plans for Forthcoming Annual Cycle:** Repeat loop of gravity station measurements on all monuments 4 times annually to continue the monitoring campaign. Full analysis of gravity data is currently hindered by an incomplete dataset due primarily to a coverage gap spanning May-November 2019 and infrequent intervals in 2020 due to the COVID19 pandemic. Continuation of repeat measurements for 2021 should give a better picture of seasonal variations in the gravity field. Future data collection will more easily incorporate groundwater level changes thanks to a new monument located near a groundwater monitoring well. The planned addition of continuous GPS stations will also assist in further analyzing gravity data to better understand its relationship with ground deformation.

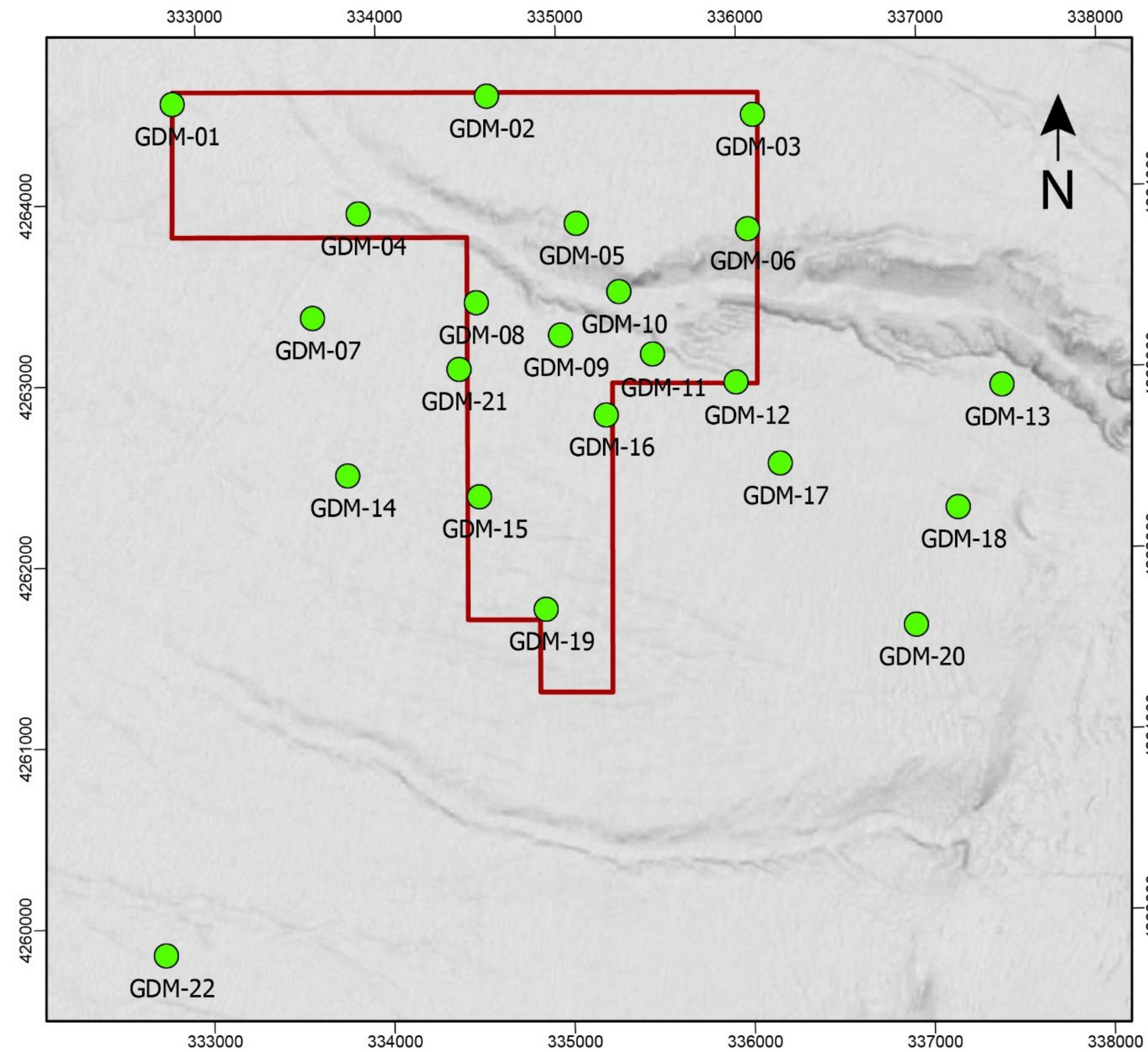

Figure 3.7.4-1. Map of FORGE 4D gravity station locations for 2020. Newly established gravity stations on deformation benchmarks of GDM-21, GDM-22 denoted.

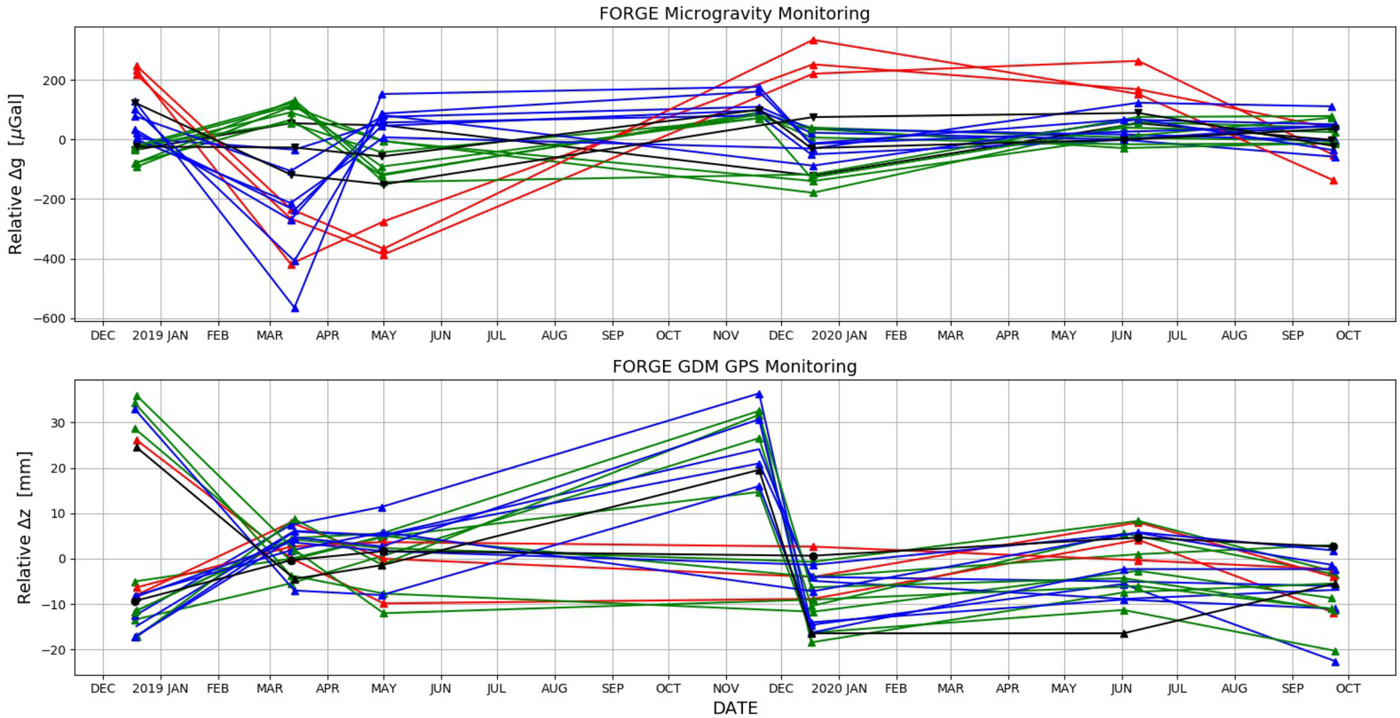

Figure 3.7.4-2. Plot of FORGE 4D gravity station trends from December 2018 to September 2020. Top panel shows the gravity changes in microGals, bottom panel shows elevation changes in millimeters. Assigned colors display preliminary groupings based on signal trends. GDM-21, GDM-22 not shown.

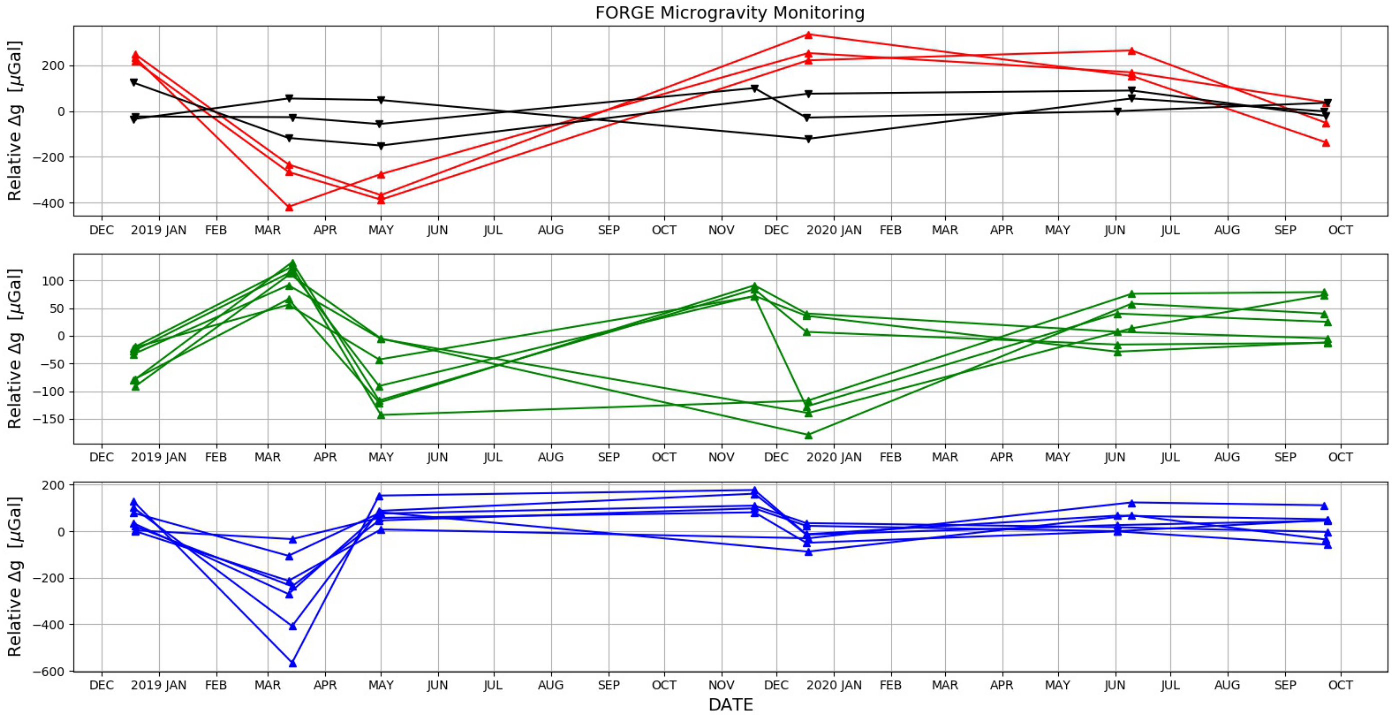

Figure 3.7.4-3. Plot of FORGE 4D gravity station trends from December 2018 to September 2020 shown in 3 panels based on preliminary groupings. GDM-21, GDM-22 not shown.

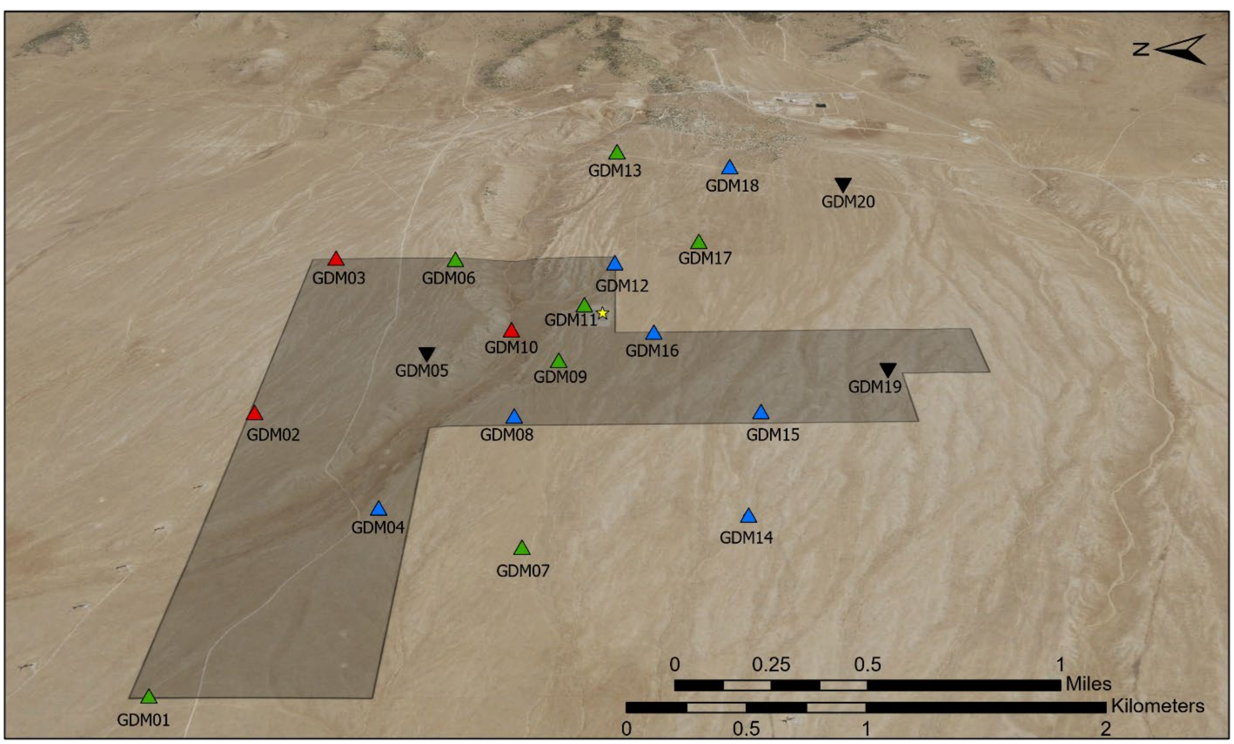

Figure 3.7.4-4. Map of FORGE 4D gravity stations. Symbology coloring based on preliminary groupings using signal trends (see Figures 3.7.4-2 and 3.7.4-3). GDM-21, GDM-22 not shown.

2020 Annual Report for the Utah Geological Survey tasks by Ben Erickson

Subtask 3.7.5 GPS Monitoring Network

Planned Activities: Perform GPS campaign monitoring at a quarterly interval. Explore the installation of additional GPS monuments. Investigate the potential connection between groundwater and basin filled valley surface deformation.

Actual Accomplishments:

Monitoring Campaign 3

In the fall of 2019 Campaign 3 was performed on November 19 using ATV and truck transport between monitoring stations. Stations GDM-B1, GDM-B2, GDM-01, GDM-02, and GDM-07 were started the night prior to the rest of the Campaign, due to the high change documented in Monitoring Campaign 2 for those stations. Another overnight occupation was planned for three additional stations, but due to significant inclement weather, the overnight occupation was not performed. During Station GDM-B1 equipment retrieval, it was discovered the power supply cable connection was detached and that the receiver recorded under five hours of data as a result. No other significant issues occurred during this occupation.

The results of Monitoring Campaign 3 are summarized in Figure 1. When comparing to the Initial Monitoring Campaign B in March, there is an overall inflation throughout the FORGE site. Unlike Monitoring Campaign 2, the FORGE site shows an average vertical inflation of 24.5 mm, with a maximum of 31.6 mm and a minimum 14.9 mm, all exceeding the calculated GNSS errors for both occupations. Due to lack of long-term, seasonal data for the area, including groundwater levels and the nearby Blundell Geothermal Plant production and injection wells influence, and that no FORGE project well testing occurred during the time period between Monitoring Campaigns 2 and 3, we theorize the ground inflation is related to natural effects in the area, such as from groundwater changes. However, as further occupations add to the dataset of ground monitoring data, seasonal and other natural effects should be more discernable in developing a more accurate conclusion related to the ground deformation observed in the GNSS data. The Monitoring Campaign Initial B to 3 horizontal vectors show a general movement trend to the east/southeast. The Monitoring Campaign 2 to 3 horizontal vectors show a general movement trend to the southwest with a magnitude less than between Monitoring Campaign Initial B to 3.

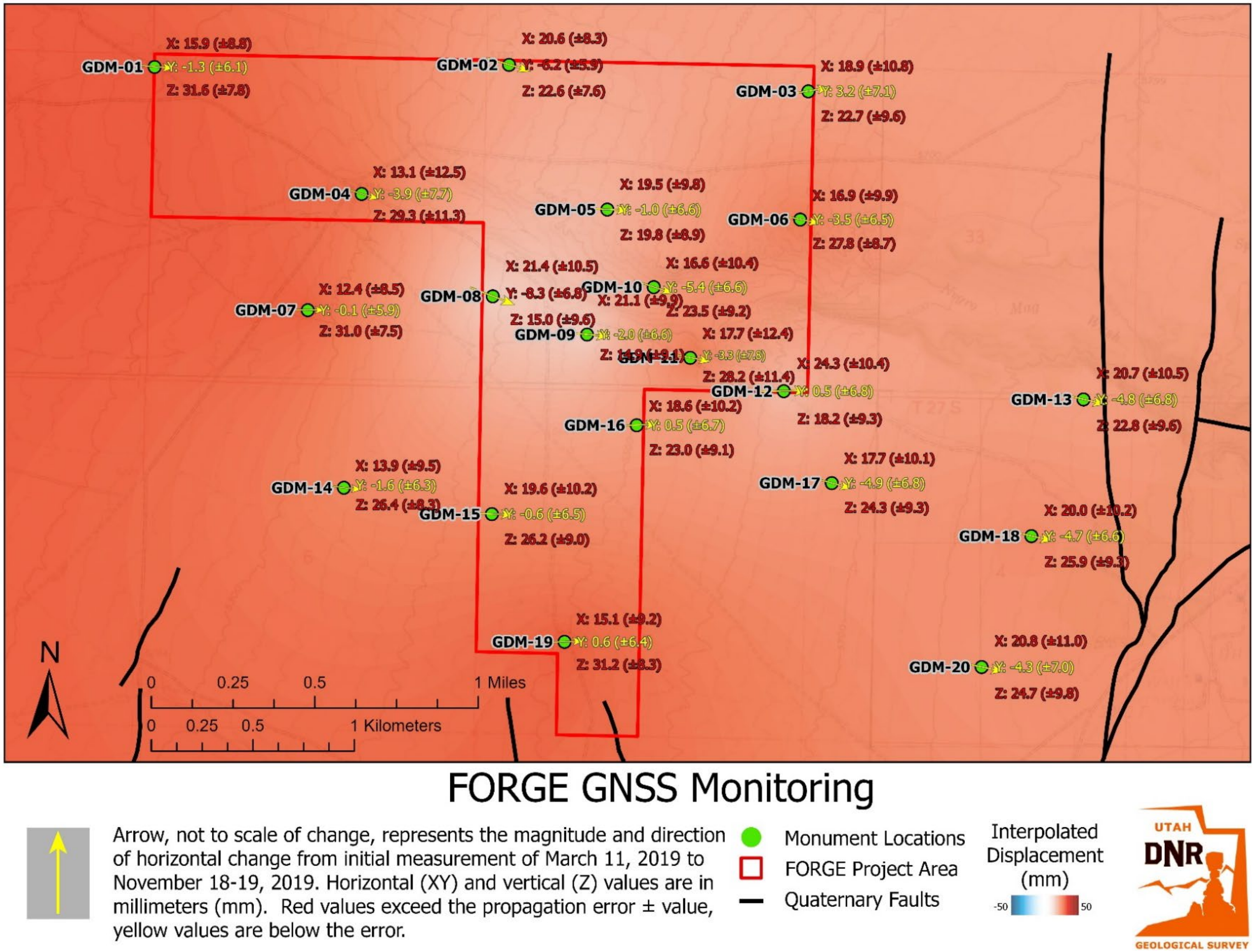

Figure 1: Vector map and displacement interpolation of monument movements measured between Monitoring Campaigns Initial B and 3. Displacement surface interpolation range is ±50 mm, located to lower right of figure.

Monitoring Campaign 4

Monitoring Campaign 4 was performed on December 16, using ATV and truck transport between monitoring stations. There was snow on the ground at station GDM-B1 and was not accessible by truck, 3-foot high snow drifts prevented access. However, the lightweight ATV was nimble enough to traverse the snow and was used to setup and take down station GDM-B1. As was done for Monitoring Campaign 3, stations GDM-B1, GDM-B2, GDM-01, GDM-02, and GDM-07 were started the night prior to the rest of the campaign. Additionally, stations GDM-04, GDM-11, and GDM-18 were started at the end of the campaign and allowed to record throughout the night. Stations GDM-01 and GDM-04 had a battery issue and only recorded 10 hours, acquiring additional batteries is being considered. No other significant issues occurred during this occupation.

The results of Monitoring Campaign 4 when comparing to the Initial Monitoring Campaign B in March 2019 (Figure 2), there is an overall reduction or ground deflation throughout the FORGE site. Unlike Monitoring Campaign 3, the FORGE site shows an average vertical deflation of -7.4 mm, with a maximum of -16.7 mm, and a minimum inflation 2.9 mm. The resulting reversal to what was observed in Monitoring Campaign 3, provides further evidence of the dynamic behavior of the area. The time of year further suggests the influence of groundwater in the area, as it appears groundwater transience is lowest in the winter months. However, without a measurable groundwater monitoring well in the area, we can only rely on what is observed in similar basins and assume similar mechanisms are at work. We also found a study (Ji and Herring, 2012) where groundwater deformation was recorded using GPS measurements within a basin over the course of a year. The results of the study showed similar horizontal and vertical change as the groundwater deformed the ground surface throughout the year. This provides further confidence in our results and we are hopeful in future results as we are approaching a year of measurements. In addition to this study, we refined our calculated error statistics with the inclusion of propagation of errors (Harvard, 2007). We included a brief explanation of this calculation in the Monitoring Network GNSS Analysis Methods section within this report. As a result, all error measurements have been recalculated and all maps updated. The resulting recalculation showed minor changes in the maps, but we will maintain this statistical analysis going forward.

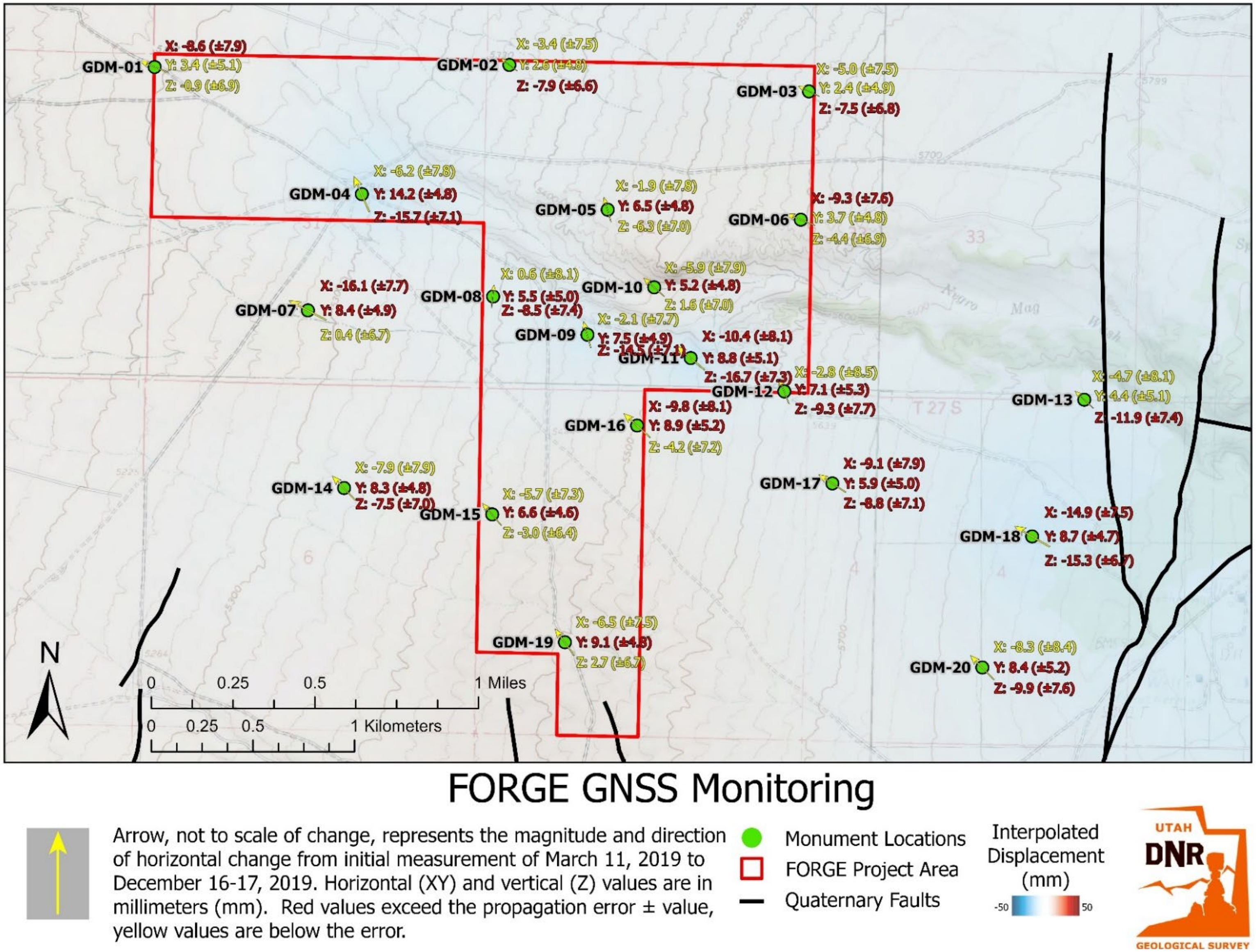

Figure 2: Vector map and displacement interpolation of monument movements measured between Monitoring Campaigns Initial B and 4. Displacement surface interpolation range is ±50 mm.

Monitoring Campaign 5

In spring of 2020 a new pad was installed in proximity of GDM-08. During Campaign 5 on June 2, a review of GPS station GDM-08 was performed and was found to be intact, however concerns over the proximity of the adjacent new drill pad were raised over gravity measurements. A new monument was installed in similar fashion as the 20 previous installations, with a three-person crew of Christian Hardwick, Will Hurlbut, and Ben Erickson. A trailered, power auger was used to drill the three-foot deep hole and a demolition hammer was used to drive the monument rod into the ground, using the same methods implemented previously, for the monument installations. An additional new monument was installed near regional water well WOW2, on the southern end of the FORGE Project area, approximately 2.8 km southwest of GDM-19, near the Blundell Geothermal access road using the same installation methods. Monitoring Campaign 5, starting June 1, 2020, was performed using ATV and truck transport between monitoring stations.

As was performed for previous monitoring campaigns, stations GDM-B1, GDM-B2, GDM-04, GDM-08, and GDM-09 were started the night prior to the rest of the campaign. Station GDM-08 had battery issues and only recorded 1.5 hours. Additionally, stations GDM-11, GDM-12, and GDM-21 were started at the end of the campaign and allowed to record through the night. When processing the data, it was discovered that the GDM-B1 height was incorrectly entered, as 1.175 m, where the correct value of 1.755 m was not. When comparing to the Initial Monitoring Campaign B in March 2019, there is little change, unlike Campaign 2 of June 2019, occupied at the same time of year, where an inflation was detected on the western end of the study area. The largest change is a deflation at GDM-12 of 15.0 mm with the overall trend of negative values in the area. GDM-01 shows the highest inflation value of 10.6 mm, but the overall area shows little ground deformation to within estimated uncertainties of 5-6 mm.

The figure below shows the results of Campaign 5 (June 2, 2020) compared with Initial Campaign B (March 11. 2019). Additional analysis was done to better represent the change in measurements. Surface interpolation was performed on the vertical displacement values between the measurements. Colors grading to dark red highlight the areas of positive change or inflation of the area. Colors grading to dark blue highlight areas of negative change or deflation of the area. Displacement graphs were also added to accommodate the updated map scale to include GDM-22 location. The graphs plot the measured displacement for each GDM station and the distribution of X, Y, and Z changes. These graphs include the maximum GPS error range determined through the calculations between the two campaigns.

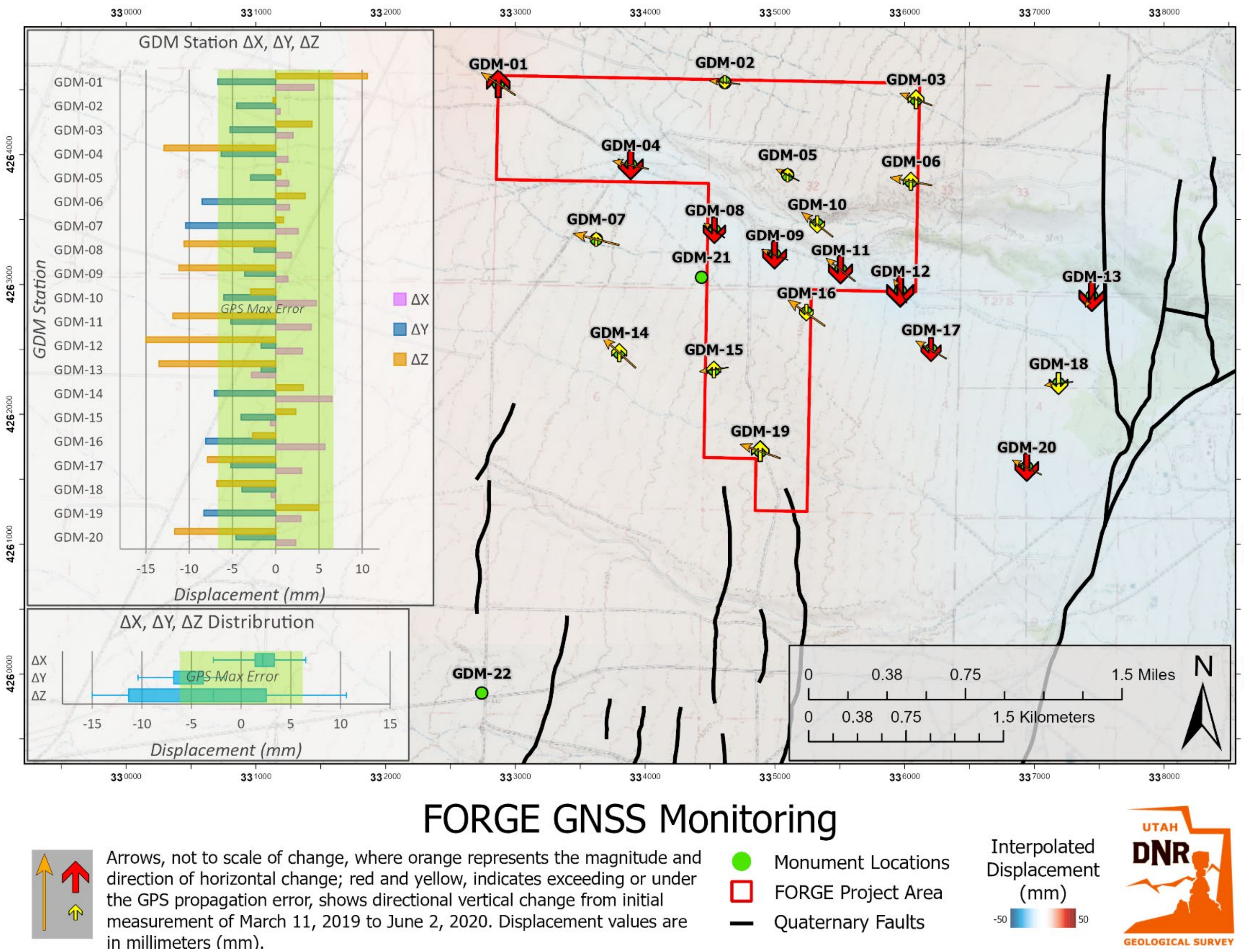

Figure 3: Vector map and vertical displacement interpolation of monument movements measured between Monitoring Campaigns Initial B (March 11, 2019) and 5 (June 2, 2020). Displacement surface interpolation range is ±50 mm.

Monitoring Campaign 6

In September 2020 monitoring Campaign 6 was performed with an ATV and a truck, similar to earlier campaigns. GDM-B2 was set up and configured first, followed by GDM-B1. After the two bases were started there was enough time in the day to begin measuring other monuments. GDM-22, GDM-18, GDM-13, GDM-12, GDM-09, and GDM-04 were completed where GDM-20, GDM-11, and GDM-01 were left overnight for their measurements. The remaining monuments were measured the following day with sporadic rain hampering the campaign in the late afternoon. GDM-03, GDM-10, and GDM-08 were left for overnight measurements. No issues were encountered when retrieving GDM-B1 and GDM-B2.

The results of Campaign 6 compared to March 2019 (Figure 4), shows an overall negative displacement in the area. There is larger downward trend along Mag Lee Wash south ridge with GDM-04 measuring the highest negative displacement, with GDM-09, GDM-12, and GDM-13 forming a trend along the south ridge.

Comparing the deformation between Campaigns 5 and 6 (Figure 5) show similar results as compared to the initial campaign, but the more negative values are measured north of Mag Lee Wash with an inflation in the southeast of the area.

In addition to these GPS results, a comparison between the cumulative monthly precipitation at the Milford Municipal Airport (Figure 6), approximately 8.5 miles (13.7 km) southwest from the FORGE project area was plotted for comparison. Averaged monthly well elevation measurements of WOW2 and WOW3 was also compared with the displacement results (Figure 7). The monthly cumulative precipitation plot shows displacement correlation with increase of precipitation, with an apparent delay in correlation. Similarly, for the well elevation, correlation is seen with well WOW3, which is located west of the FORGE project area. Further measurements are needed to confirm correlations, however, there is apparent influence in water precipitation and groundwater with displacement measurements.

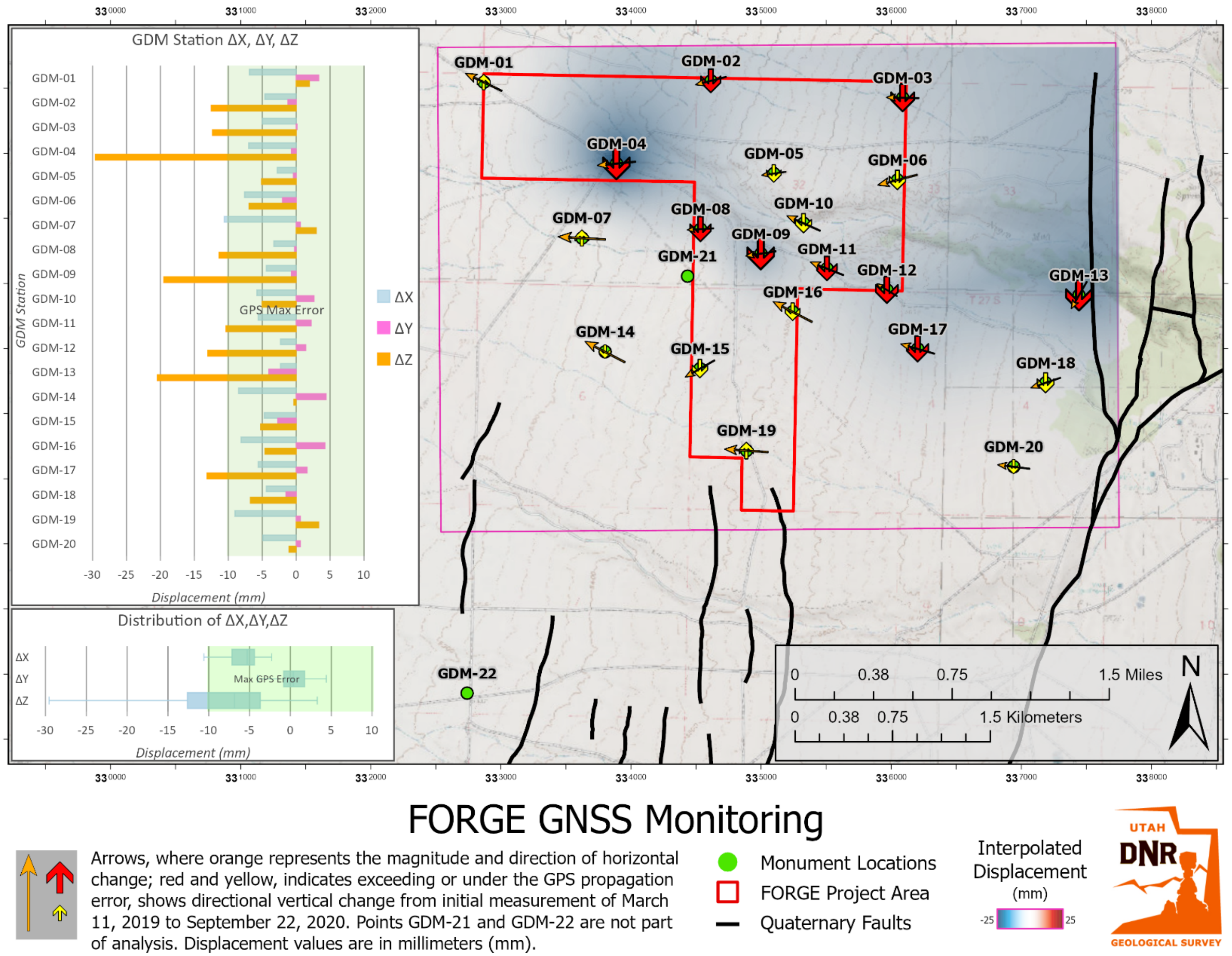

Figure 4: Vector map and vertical displacement interpolation of monument movements measured between Monitoring Campaigns Initial B (March 11, 2019) and 6 (September 21, 2020). Displacement surface interpolation range is ±25 mm.

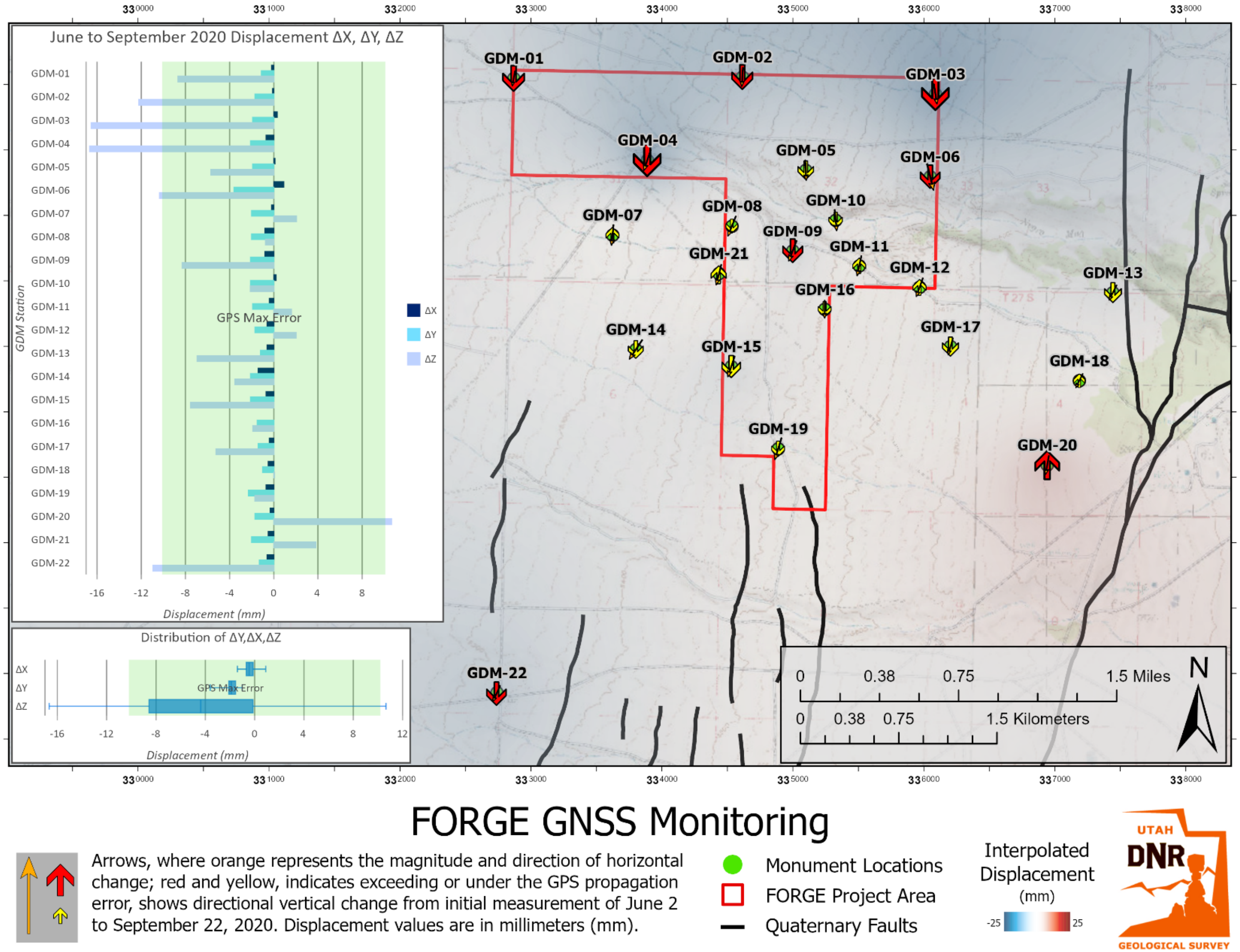

Figure 5: Vector map and vertical displacement interpolation of monument movements measured between Monitoring Campaigns 5 (June 2, 2020) and 6 (September 21, 2020). Displacement surface interpolation range is ±25 mm.

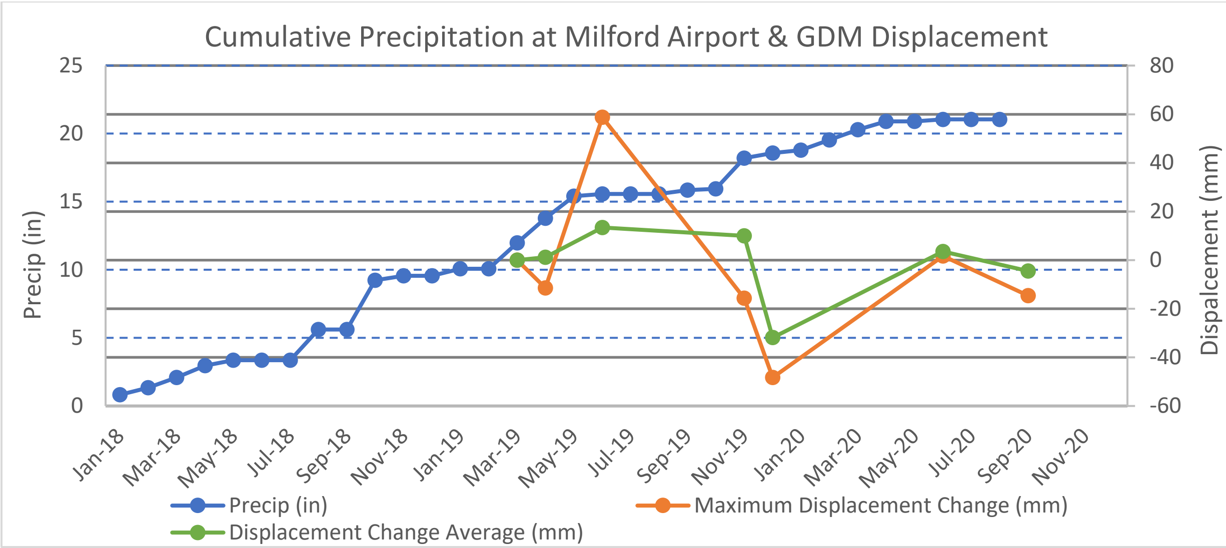

Figure 6: Graph comparing the cumulative precipitation at the Milford Municipal Airport to the displacement maximum change and average change from campaign to campaign.

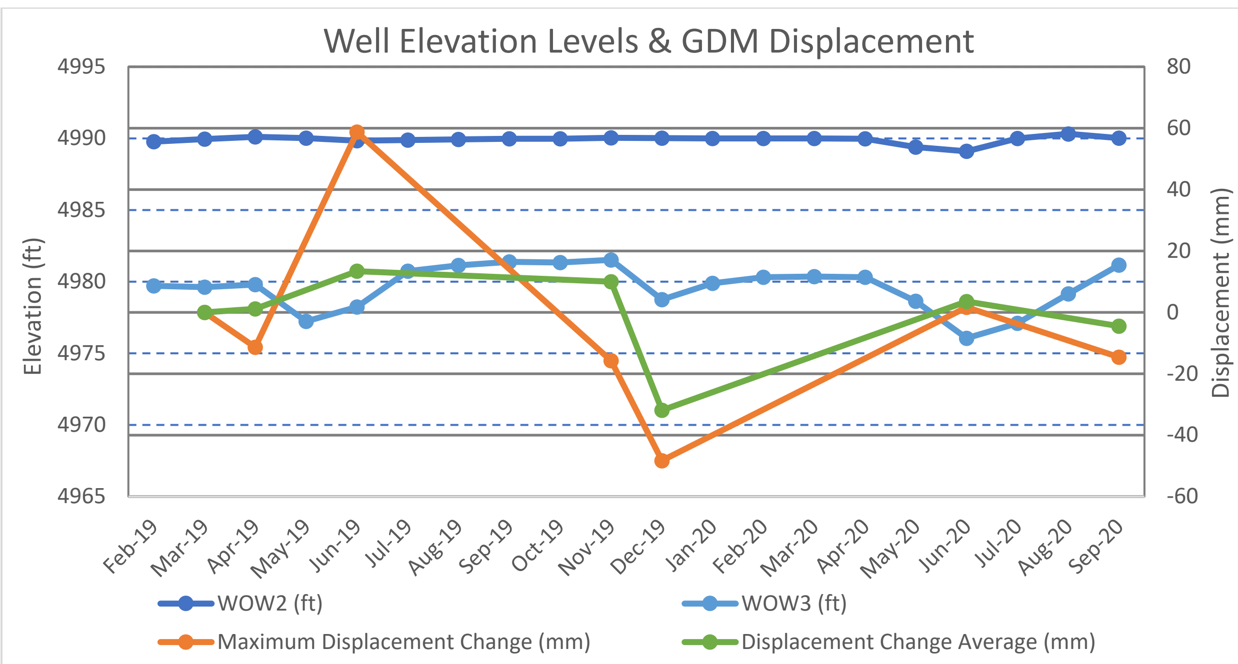

Figure 7: Graph comparing well elevations of WOW2 and WOW3 to the displacement maximum change and average change from campaign to campaign.

Explanation of Variance: No issues were encountered.

Plans for Forthcoming Annual Cycle: Reoccupy GPS monuments in quarterly intervals and report results. Install two continuous monitoring GPS units including solar power and equipment enclosures in the FORGE project area.