Oil & Natural Gas Technology

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Quarterly Report

April 2009 to June 2009

Water-related Issues Affecting Conventional Oil and Gas Recovery and Potential Oil-Shale Development in the Uinta Basin, Utah

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EXECUTIVE SUMMARY

The third quarter of our saline water project (April to June 2009) was dominated, much like the second quarter, by extensive data collection activities. We continued to contact several Uinta Basin oil and gas operators to ask for water quality information, digitized geophysical logs, and formation tops data. Most companies have responded favorably, generously offering large amounts of data as well as their support and advice. The efforts of the past several months have set an excellent foundation for further collaborations.

Work also continued setting up a comprehensive database to store, organize, and manipulate the collected data. Thus far, we have received water quality information from roughly 1150 wells and formation top information from about 3750 wells within the basin. For areas where water quality data are not available, we have developed improved methods for calculating salinity from geophysical logs, including a better technique for estimating equilibrium bottom hole temperature. These data collection efforts are expected to continue throughout the year, providing the necessary information for detailed mapping of the moderately saline aquifer within the Uinta Basin.

In addition to the regional aquifer study, we continued work on our more detailed investigation of the Birds Nest aquifer. As a first step, we completed two detailed geologic descriptions of core recovered from central Uintah County, both of which were drilled through the Birds Nest zone and into the underlying rich oil shale deposits. These descriptions will be used to correlate geophysical logs to core lithology for help in understanding lithologies in surrounding non-cored wells.

The analysis of the Utah State 1 core revealed no saline mineral dissolution, however, examination of the nearby Utah State 42-34 core revealed significant dissolution – it is the dissolution of saline minerals that creates the porosity and permeability needed for significant groundwater flow within the Birds Nest aquifer. These differing subsurface zones of dissolution seem to be controlled by cross-cutting gilsonite veins, complicating the aquifer's overall flow regime.

Work has also begun on sampling water from wells, springs, and creeks on lands with the highest oil shale development potential. The same sites will be sampled and analyzed bi-yearly throughout the course of the project.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0: Project Management Plan

During the month of April, the Principal Investigator (PI) wrote and submitted the project's second quarterly report for January to March 2009. This report was subsequently sent via email to all interested parties and posted on the Utah Geological Survey (UGS) project Web site.

Task 2.0: Moderately Saline Aquifer Study

During the spring, we continued to collect water quality analyses from Uinta Basin oil and gas operators. Through June 2009, we received water quality data from Anadarko Petroleum Corporation (124 wells in the Natural Buttes field), Enduring Resources (4 wells in central Uintah County), Newfield Petroleum (194 wells in the Monument Butte area), Bill Barrett Corp. (1 well near Nine Mile Canyon), and Questar E&P (164 wells in the Red Wash area). We also have information from 659 wells obtained from the U.S. Geological Survey (USGS); the Utah Division of Oil, Gas, and Mining (DOGM); and other governmental agencies (figure 1). We will continue to contact other operators to try to obtain as much water quality information as possible.

In order to relate a newly mapped base of the moderately saline aquifer to Uinta Basin stratigraphy, we also continue to collect formation top information. Through June 2009, we have received top information from Berry Petroleum (464 wells in the Brundage Canyon area), Enduring Resources (132 wells in central Uintah County), Newfield Petroleum (1842 wells in Monument Butte area), Gasco (4

wells in the Uteland Butte area), and Questar E&P (1315 wells in Red Wash area). Again, we will continue to communicate with operators to try to obtain as much data as possible. The formation top data will help us create three east-west and two north-south cross sections relating water quality to basin stratigraphy. Traces of these yet-to-be-made cross sections are plotted in figure 1.

An Access database has been created to store and organize all the collected data, as well as to facilitate its manipulation and retrieval. The database will be updated as new data are acquired from operators or generated by project researchers.

For those areas where we have not acquired water chemistry data, work has begun on refining techniques to determine the base of the moderately saline aquifer using geophysical logs. The resistivity of the formation water is used to estimate the total dissolved solids concentration of the water for the purpose of mapping the base of the moderately saline aquifer in the Uinta Basin, similar to methods used in Utah Department of Natural Resources Technical Publication 92. However, the resistivity of an aqueous solution is sensitive to the temperature of that solution. The principle author of Technical Publication 92 (Howells) changed the measured bottom-hole temperature to an equilibrium bottom-hole-temperature (EBHT) using a method based on data from wells throughout North America (Wallace and others, 1979). After extensive research, we have decided to use a method for calculating EBHT that is based on data from just the Uinta Basin (Chapman and others, 1984). Howells' method may have altered the EBHT by significant amounts, reducing the accuracy of the mapped interval, while a Uinta Basin-specific method should be considerably more accurate.

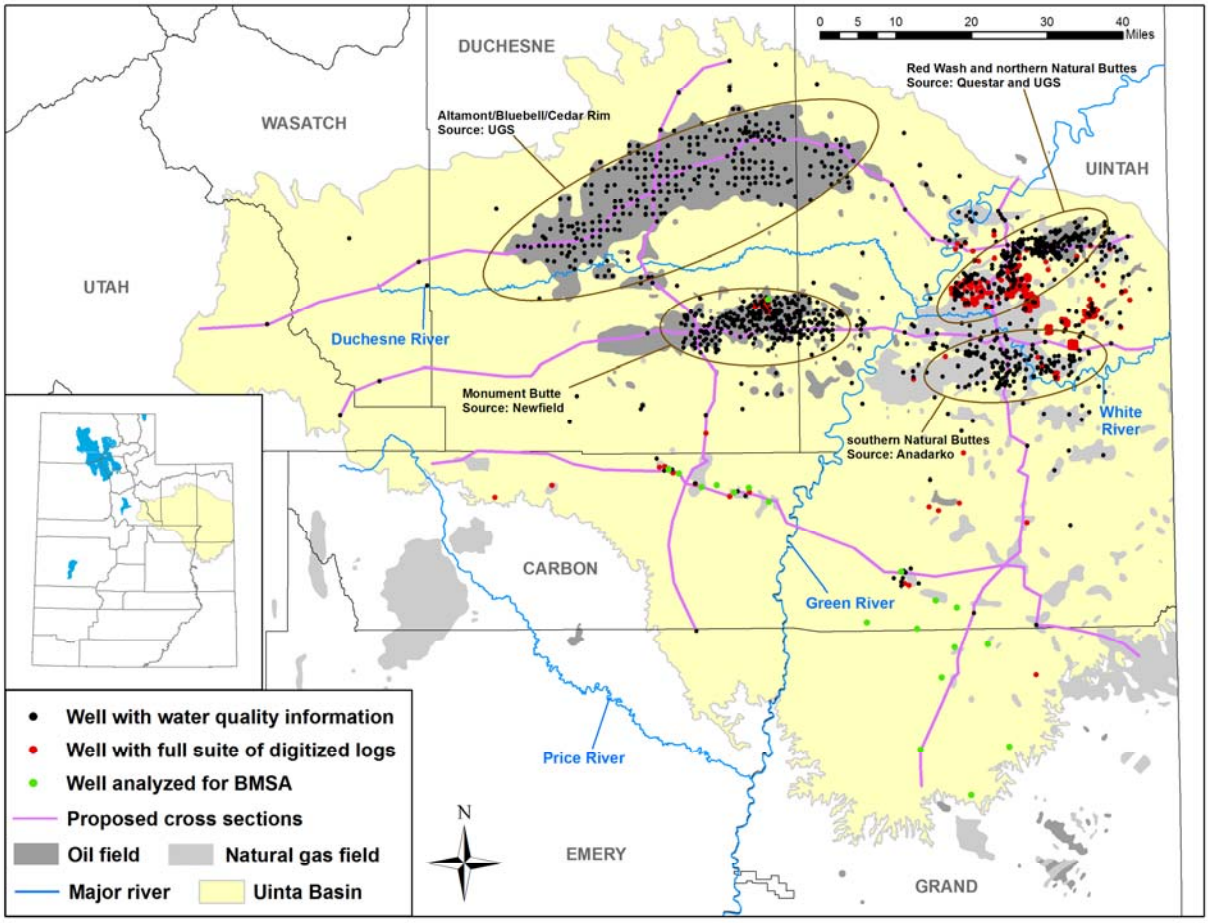

Figure 1. *Map of the Uinta Basin showing the location and source of wells with water quality information, wells with a full suite of digitized geophysical logs, and wells evaluated for the base of the moderately saline aquifer (BMSA).*

In addition, to speed our interpretation of well logs and help facilitate picking the base of the moderately saline aquifer, we have requested digitized log files (LAS files) from oil and gas operators. Through June 2009, we received LAS files from Questar E&P (297 wells), Enduring Resources (66 wells), Royale Energy (2 wells), Wind River Resources (4 wells), Summit Operating Co. (1 well), Mustang Fuel (3 wells), OSO Oil & Gas (1 well), Rosewood Resources (1 well), Anadarko Petroleum (2 wells), Bill Barrett (13 wells), and Blue Tip Operating (1 well) (figure 1). For logs where LAS files are not available (especially older wells), we began the very time consuming task of digitizing the logs in-house. To date we have completed a full suite of logs for 4 wells.

With the initial data acquisition phase well underway, work commenced on picking the base of the moderately saline aquifer in wells. We started in the southern portion of the basin and will systematically move to the north. Thus far, we have picked the boundary in 19 wells (figure 1).

Task 3.0: Geologic Examination of the Birds Nest Aquifer

The first core we described containing the Birds Nest aquifer (Utah State 1 well) showed no nahcolite dissolution and thus no large scale porosity and permeability (figure 2). In June, we traveled to the USGS Core Research Center in Denver, CO, to evaluate and describe core from a second well (Utah State 42-34) near Anadarko's saline water disposal site into the Birds Nest, south of the above mentioned well (figure 3). As expected, the nahcolite in this core displayed extensive dissolution (figure 2), including entirely empty zones measuring 0.5 to 1.5 feet (dissolved nahcolite nodules). These empty spaces provide the massive porosity of the "zone of lost circulation" described by drillers and thus confirming the dissolution zonality of the Birds Nest aquifer. This zonality seems to be controlled by large northwest-trending gilsonite veins, creating channels of dissolution and groundwater flow (figure 3). To test this theory further, we plan to examine several more cores drilled through the Birds Nest aquifer and gauge the amount of saline mineral dissolution. Also, we plan to examine old drilling reports and caliper log traces to see if a zone of lost circulation was encountered while drilling through the Birds Nest interval. The caliper log seems to be one of the log traces that might be useful in determining the degree of saline mineral dissolution.

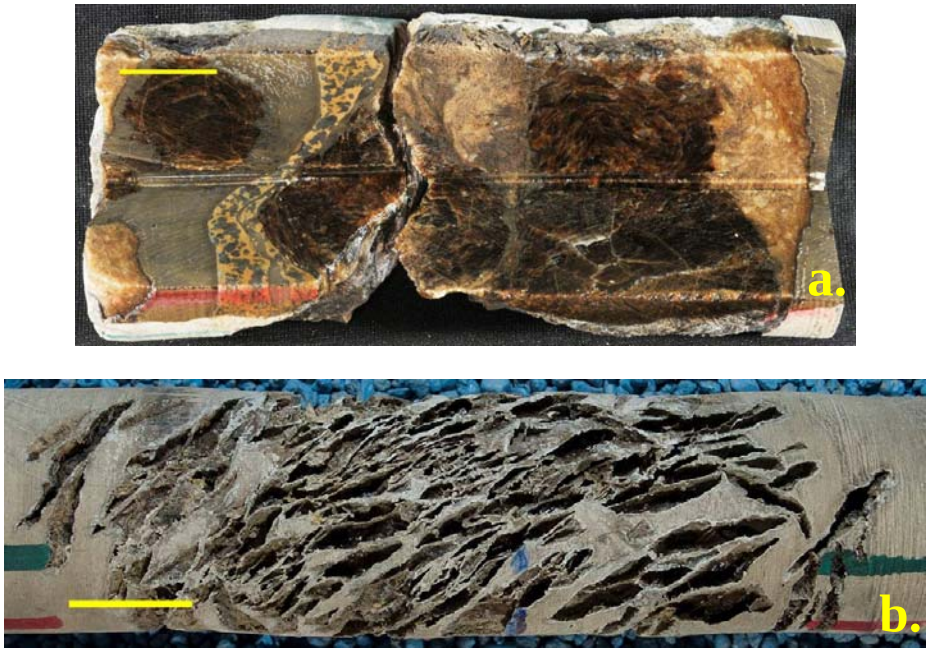

Figure 2. *a. Nahcolite nodules within the Utah State 1 core displaying no dissolution (depth – 1825.6 ft) (yellow bar equals one inch). b. Dissolution of nacholite in the Utah State 42-34 core (depth – 1795.0 ft).*

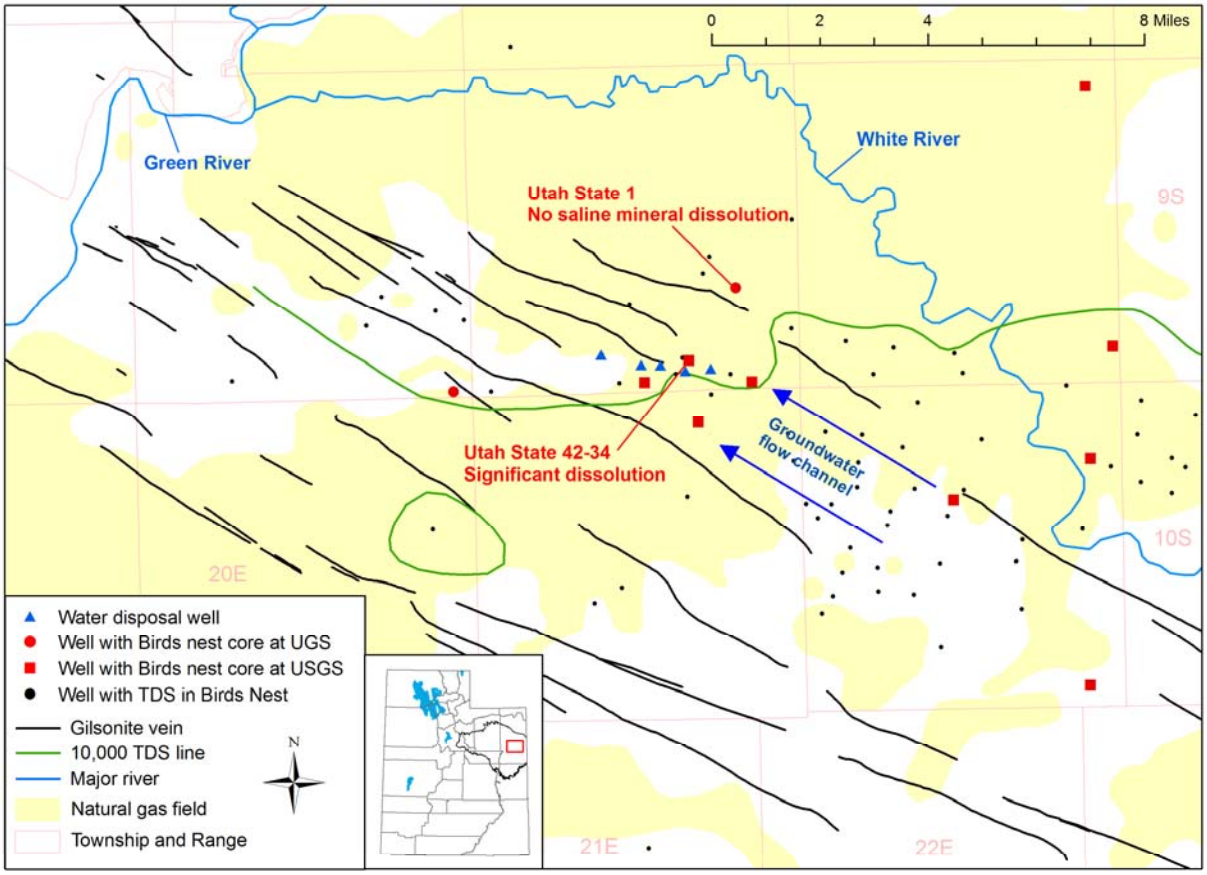

Figure 3. *Map showing location of described cores and their relationship to gilsonite veins.*

Task 4.0: Baseline Water Quality and Quantity GIS Database

In April 2009, the Task 4 leader arranged a 2-day field reconnaissance trip with local U.S. Bureau of Land Management (BLM) and Utah DOGM staff familiar with the study area to determine if sites/wells proposed in the Quality Assurance Project Plan could be sampled. Based on this reconnaissance, we discovered that many of the wells originally selected for water sampling no longer exist; they are either plugged former water wells for oil/gas sites, abandoned wells that have not been updated in the Utah Division of Water Rights' database, or private wells that are no longer being used. In addition, some of the originally selected wells, including monitoring wells around the Deseret Power Plant, would not provide accurate representations of the ground-water conditions. Furthermore, another seven wells owned by the Utah Division of Wildlife Resources, Ouray National Wildlife Refuge, the BLM, USGS, and the Utah State and Institutional Trust Land Administration are no longer functioning water wells. This information has reduced the number of potential sampling sites from 50 down to approximately 20 (figure 4). Since our sample set was reduced by half, we are proposing to change our original sampling plan of collecting water once per year to sampling twice a year (spring and fall 2009, spring and fall 2010, and spring 2011).

Despite the trouble locating appropriate wells/sampling sites, in June we collected samples from four water wells, one spring, and one creek (figure 4). Each of these samples was submitted to the Utah Division of Epidemiology and Laboratory Services and will be analyzed for pH, specific conductance, temperature, dissolved oxygen, general chemistry, dissolved metals, nutrients, total organic carbon, and volatile organic compounds. The remaining samples (~15) will be collected during July and August.

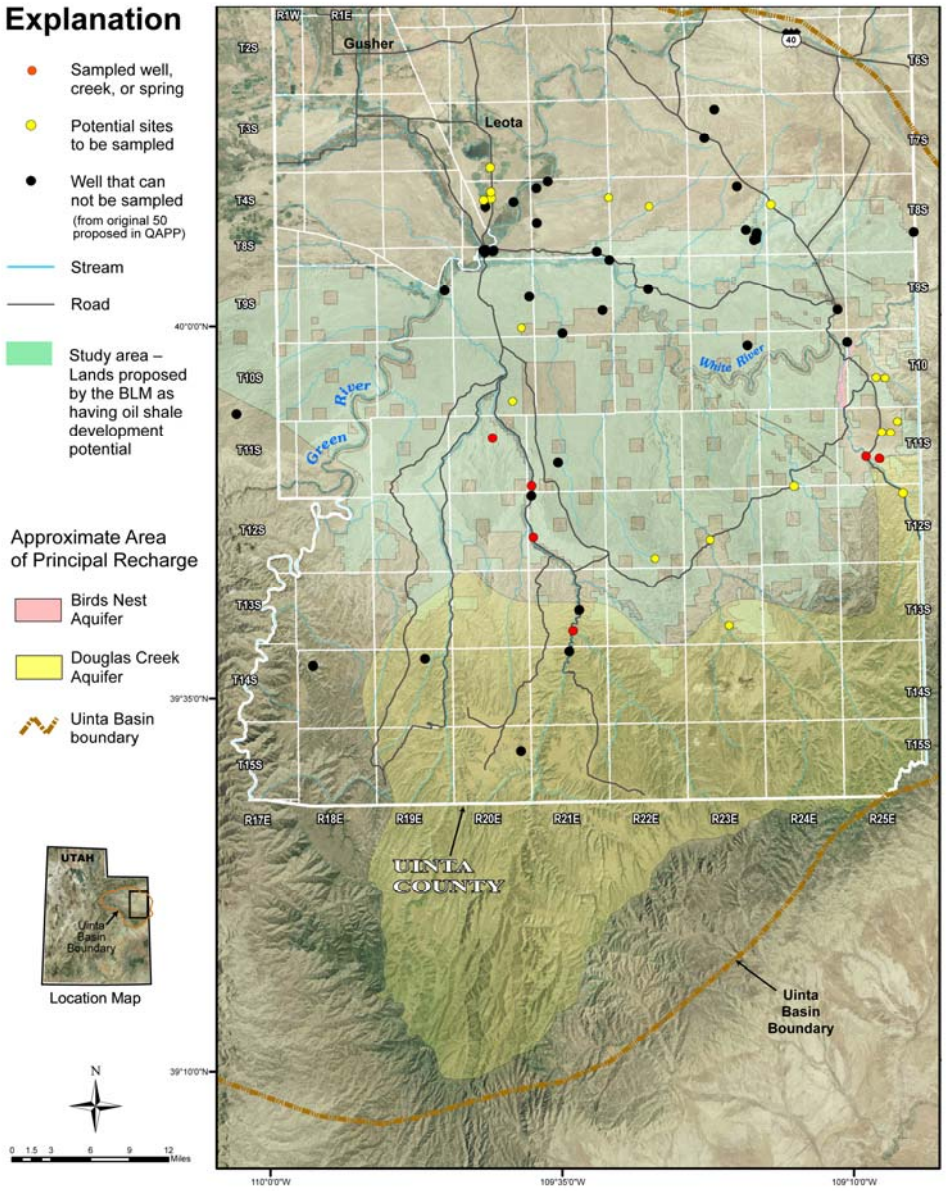

Figure 4. *Map of sampling sites related to Task 4.*

Task 5.0: Integration of Analysis of Produced Water from Simulated In-situ Oil Shale Extraction Technologies

This task is scheduled for Budget Period 3.

Task 6.0: Technology Transfer

The UGS presented a poster at the American Association of Petroleum Geologists (AAPG) annual meeting held in Denver, CO, on June 9 in the Groundwater and Site Remediation session. The poster was well attended and participants provided excellent feedback and related their interest in the project. The UGS also staffed an exhibit booth were a poster panel detailing the project was on display.

An oral presentation was also made at the Geological Society of America – Rocky Mountain Section (GSA-RMS) meeting held in Orem, UT, on May 13 in the Economic Resources of the Rocky Mountains session. This presentation focused on work related to mapping individual oil shale horizons, along with

their richness, throughout the Uinta Basin. This research will help define how water disposal into the Birds Nest aquifer might impact a potential oil shale industry.

In June, the PI submitted an abstract to the 29th Oil Shale symposium, scheduled for October 19-21, 2009 at the Colorado School of Mines in Golden, CO. The abstract talks about new discoveries related to the Birds Nest aquifer and how disposal might impact future oil shale development.

The project Web site (http://geology.utah.gov/emp/UBwater_study) was updated with new quarterly reports, newly submitted abstracts, and our poster presentation from AAPG.

CONCLUSION

During this quarter we continued our data gathering activities, including contacting several oil and gas operators and setting up databases to organize incoming information. Initial efforts have been very successful and dialogues will continue until we have collected as much data as possible. Acquiring digitized log traces from operators is especially important since in-house log digitization is one of the most time consuming tasks.

Initial studies related to the Birds Nest aquifer are proving that much is still unknown about this potential disposal zone. Work will continue on defining differing areas of dissolution and how these areas could affect future saline water disposal and possible oil shale development.

We had to revise our groundwater sampling plan related to Task 4; we will be collecting and analyzing samples from fewer water wells, but will increase our sampling frequency to twice a year. This should still give a useful baseline of water conditions in central Uintah County.

COST STATUS

The delay of fieldwork to look at the Birds Nest aquifer in outcrop from spring 2009 to fall 2009 resulted in three months of under budget billing (in both personnel time and travel). This time and money will be spent in the next several months. Also, water sampling field work, which was scheduled for April and May, will mostly take place in July and August.

Table 1. Project costing profile for Budget Period 1 (third quarter).

	Apl 2009		May 2009		Jun 2009	
	Plan	Actual	Plan	Actual	Plan	Actual
UGS-personnel	$12,438	$8,279	$15,011	$9,732	$17,928	$8,434
Travel Expenses[1]	$4,644	$148	$1,782	$271	$4,256	$3,779
Water Chemistry						
Miscellaneous[2]		$37				$233
SUBTOTALS	$17,082	$8,464	$16,793	$10,002	$22,184	$12,446
UGS OVERHEAD (32.40%)	$5,535	$2,742	$5,441	$3,241	$7,188	$4,032
SUBCONTRACTS						
P. Anderson	$8,132	$8,500	$8,132	$8,040	$8132	$9,110
GRAND TOTALS	$30,749	$19,706	$30,366	$21,283	$37,504	$25,588

[1]April and May travel – trips to the Uinta Basin for water sampling recon; June travel – trips to Denver for AAPG and trips to the Uinta Basin for water sampling

[2]April and June – field supplies; June – AAPG poster lamination

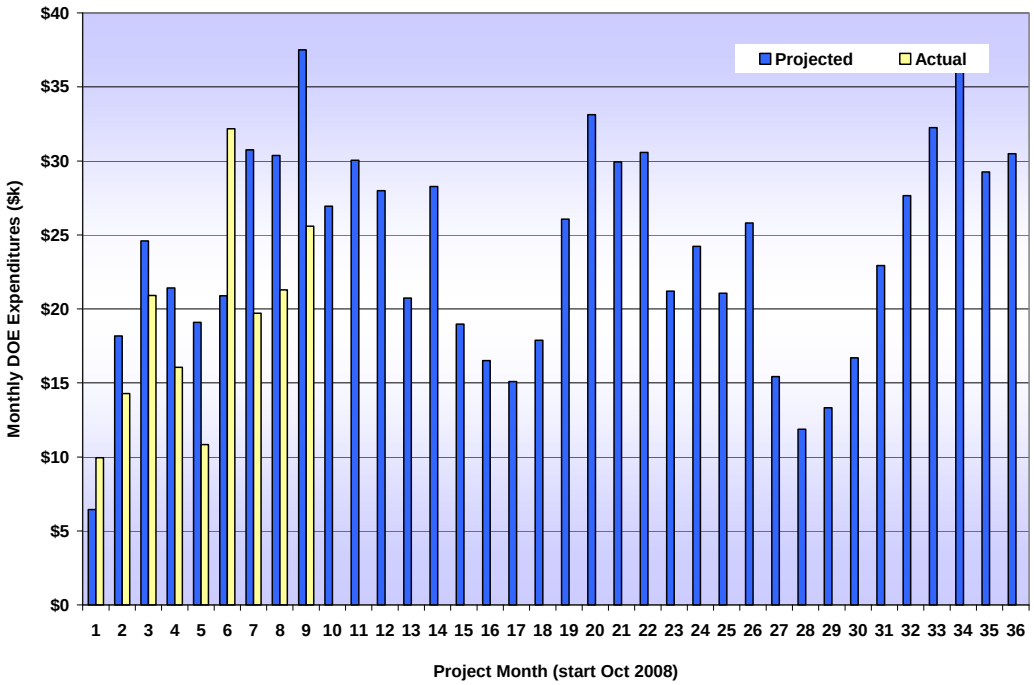

Figure 5. *Project costing profile.*

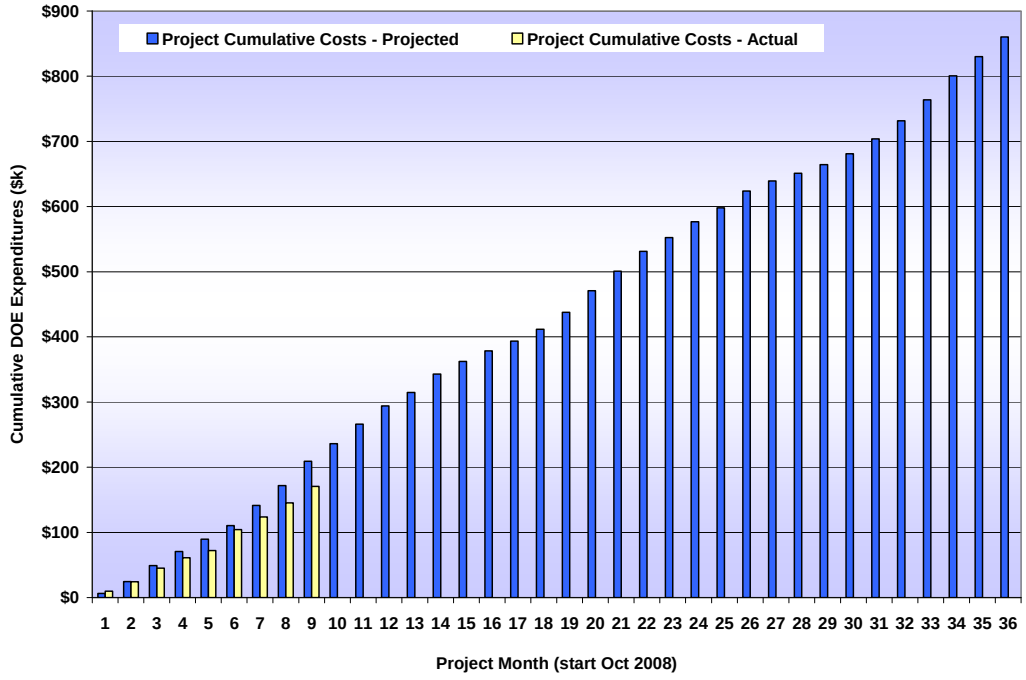

Figure 6. *Project cumulative costs.*

MILESTONE STATUS

Table 2. Milestone log for Budget Period 1.

	Title	Description	Related task or subtask	Completion Date	Update/comments
Milestone 1.1	Water chemistry data collection (part 1)	Collect at least half of the required 1 well per township	Subtask 2.1	9/30/2009	Data collection is in progress; currently have data from 1146 wells, still communicating with several operators to get more data, began analyzing well logs in areas where no chemistry data exists
Milestone 1.2	Evaluation of the Birds Nest in core and outcrop	Examine the Birds Nest in core and find at least five outcrop exposures to describe	Subtask 3.2, 3.3	6/30/2009	Evaluated Utah State 1 and Utah State 42-34 cores, plan to look at more core in Oct 2009, plan to look at outcrop in fall 2009
Milestone 1.3	Completion of the Quality Assurance Project Plan	Locate 50 sites suitable for water chemistry analyses	Subtask 4.2	12/15/2008	Completed, water sampling has commenced

ACCOMPLISHMENTS

- We completed a detailed description of the Utah State 42-34 core.
    - Detailed lithologic description of the Birds Nest aquifer and underlying rich oil shale deposits.
- We had an excellent poster presentation at AAPG in June. We received lots of positive feedback and established many new contacts.
- We revised our groundwater sampling program for Task 4 based on 2-day reconnaissance fieldtrip.

PROBLEMS OR DELAYS

We have decided to focus our efforts this spring on describing the Birds Nest aquifer in core, both at the UGS and USGS Core Research Centers. This will push back planned fieldwork to look at the Birds Nest aquifer in outcrop until fall 2009.

In the spring of 2009, the Task 4 leader arranged a 2-day field reconnaissance trip with local U.S. BLM and Utah DOGM staff familiar with the study area to determine if sites/wells proposed in the Quality Assurance Project Plan could be sampled. Based on this reconnaissance, we discovered that many of the wells we originally selected for sampling no longer exist; they are either plugged former water wells for oil/gas sites, abandoned wells that have not been updated in the Utah Division of Water Rights' database, or private wells that are no longer being used. In addition, some of the originally selected wells, including monitoring wells around the Deseret Power Plant, would not provide accurate representations of the ground-water conditions. Furthermore, another seven wells owned by the Utah Division of Wildlife Resources, Ouray National Wildlife, BLM, the USGS, and SITLA are no longer in use and are not functioning water wells. This information has reduced the number of potential sampling sites from 50 down to 20. Since our sample set was reduced by half, we are proposing to change our

original plan of sampling each well once per year to sampling twice a year (spring and fall 2009, spring and fall 2010, and spring 2011).

PRODUCTS AND TECHNOLOGY TRANSFER ACTIVITIES

- Completed second quarterly report
  - January 2009 to March 2009 – available on the UGS project Web site
- Updated project Web site
  - Posted various reports, abstracts, and presentations
  - http://geology.utah.gov/emp/UBwater_study
- Poster Presentation – AAPG annual meeting – Denver, CO – June 7-10, 2009
  - The PI presented a poster at the AAPG 2009 annual meeting which detailed the project objectives, with particular emphasis on the Birds Nest aquifer and its relationship to oil and gas development.
  - The poster is available on the UGS project Web site
- AAPG annual meeting exhibit booth – Denver, CO – June 7-10, 2009
  - A poster panel detailing the overall project goals and objectives was on display at the UGS exhibit booth during the AAPG conference.
- Oral Presentation – GSA-RMS – Orem, UT – May 11-13, 2009
  - We presented a talk at the GSA-RMS conference which detailed work related to mapping specific oil shale horizons within the Uinta Basin, Utah.
  - The abstract is available on the UGS project Web site.
- Abstract – Ground Water Protection Council – Salt Lake City, UT – September 13-17, 2009
  - An abstract was submitted and accepted (as a poster presentation) to the Water/Energy Sustainability Symposium at the Ground Water Protection Council's annual forum. The abstract details the project objectives, with particular emphasis on the Birds Nest aquifer and its relationship to oil and gas development.
  - The abstract is available on the UGS project Web site.
- Abstract – 29th Oil Shale Symposium – Golden, CO – October 19-21, 2009
  - An abstract was submitted to the 29th Oil Shale Symposium located at the Colorado School of Mines, Golden, CO. The abstract presents recent research about the Birds Nest aquifer and its potential relationship to oil shale development. We are waiting to hear if it was accepted.
  - The abstract is available on the UGS project Web site.
- Helped organize an oil shale and tar sand field trip to the Uinta Basin – May 5-6, 2009
  - Participants included energy/water researchers at the University of Utah as well as natural resources faculty of the University's law school.
  - Discussed the Birds Nest aquifer and its relationship to unconventional resource development.
  - Examined the Birds Nest aquifer in outcrop.

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