Oil & Natural Gas Technology

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Quarterly Report

October 2009 to December 2009

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

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Prepared for:
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EXECUTIVE SUMMARY

The Utah Geological Survey's (UGS) Uinta Basin water project has finished its fifth quarter of study (Budget Period 2; October to December 2009). Water chemistry data acquisition efforts have for the most part come to an end, with analyses received for over 1250 wells. These data will be invaluable as "ground truth" to aid in the mapping of aquifer salinity throughout the basin. In addition, several oil and gas operators have donated digitized log data from over 600 wells. These files will save large amounts of in-house digitizing time and provide the data needed to calculate the base of the moderately saline aquifer.

The UGS determined that the Birds Nest aquifer can be best characterized by the study of cores that cover all or part of the interval of interest. Of the 20 cores found, four were examined in the last quarter, one near the basin's depocenter and three farther to the southeast near the basin margin. Saline mineral crystals in the cores to the south were much smaller (1 inch to <¼ inch) than the large nodules (up to a foot in diameter) and beds seen in the core from the basin's center. The basin-center core also displayed three distinct zones of dissolution, each about 40 feet thick. It is currently uncertain whether these individual zones are hydrologically connected.

The project team has also completed the second round of water sampling and subsequent analyses from 17 sites on or near lands designated as having the highest oil shale development potential. These sites will be sampled bi-annually through spring 2011.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0: Project Management Plan

During the month of October, the Principal Investigator (PI) wrote and submitted the project's fourth quarterly report for the period July to September 2009. This report was subsequently sent via email to all interested parties and posted on the UGS project Web site.

Task 2.0: Moderately Saline Aquifer Study

The Task 2 team continued to request donations of as many digital geophysical log files (LAS files) as possible to expedite and aid in picking the base of the moderately saline aquifer. The Task 2 team leader, Paul Anderson, has made a list of 298 key wells spaced throughout the basin, and has focused on getting these specific LAS files. Through December 2009, UGS has received about 70% of the LAS files on the key well list, and has overall obtained 619 LAS files from 24 different companies (many companies donated more LAS files than requested) (figure 1, table 1). If the UGS had to purchase these digital files, which are vital to the success of this study, each file would cost about $250, meaning companies have donated roughly $150,000 to the project. The UGS would like to express our thanks to these companies for their generous data contributions. Using the donated LAS files, Anderson has started picking the base of the moderately saline aquifer, comparing the results with water chemistry data where available. To date, the boundary has been picked for 46 wells.

The Task 2 team also continues to search for specific water chemistry data for wells in the Uinta Basin. Through December 2009, the team has collected approximately 2100 individual water analyses from about 1250 different wells. Again, most of this data has been generously donated by several oil and gas companies.

Table 1. *Number of donated LAS files by company.*

Company	# of LAS files
Questar	319
Newfield	85
Enduring	73
Anadarko	41
Bill Barrett	15
Berry	15
EOG	15
El Paso	14
Wind River	6
Devon	5
Rosewood	5
Gasco	4
FIML	4
Mustang Fuel	3
Whiting Petroleum	3
Forest	2
Flying J	2
Royale	2
Pendragon	1
BT Operating	1
JW Operating	1
Elk Resources	1
McElvain	1
Summit Operating	1
Total	619

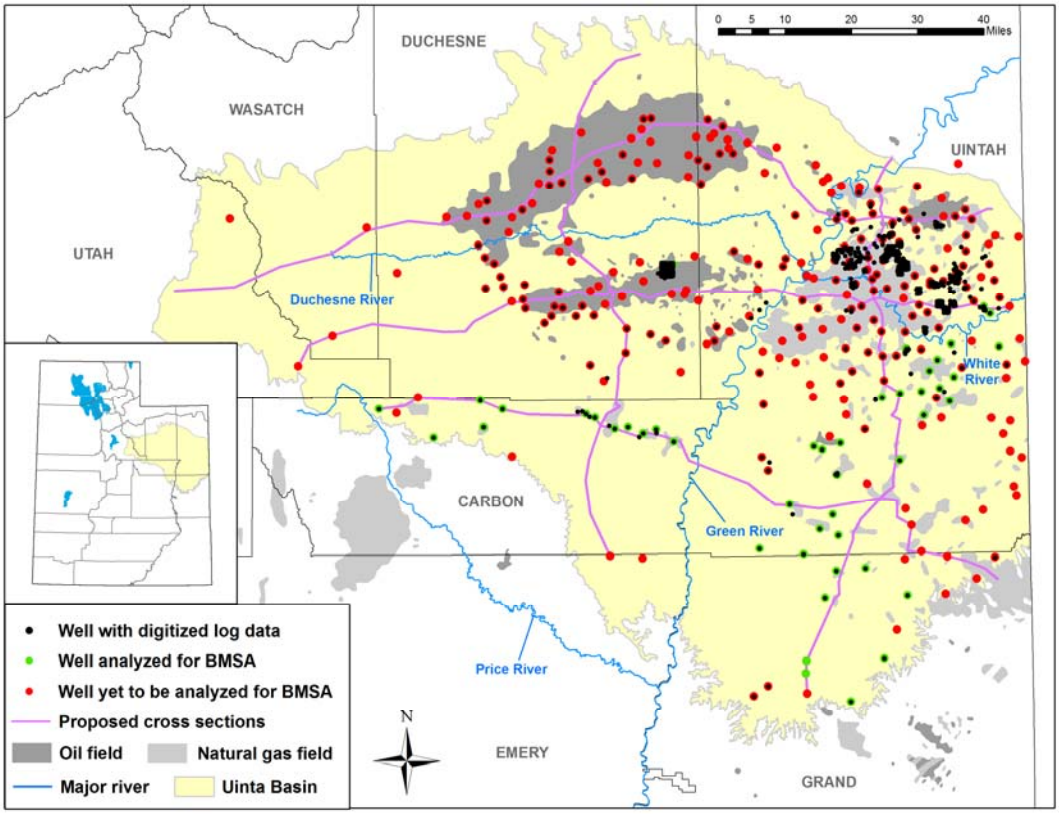

Figure 1. *Map of the Uinta Basin showing the location of wells with donated digitized geophysical logs and wells already and to-be evaluated for the base of the moderately saline aquifer (BMSA).*

Task 3.0: Geologic Examination of the Birds Nest Aquifer

Four additional cores were examined this quarter: Utah State 13X-2, Suicide Canyon 1, CRU-1, and Asphalt Wash 1 (figure 2). The Utah State 13X-2 well (T. 10 S., R. 21 E., sec. 2), located near Anadarko's Birds Nest saline water disposal wells in the basin's depocenter, penetrated the entire Birds Nest interval. The overall saline zone is 389 feet thick (1408-1797 ft), with dissolution of saline minerals occurring in three distinct zones: a 47-foot-thick upper zone (1525-1572 ft), a 42-foot-thick middle zone (1690-1732 ft), and 39-foot-thick lower zone (1758-1797 ft) (plate 1). It is currently unclear if these three zones are hydrologically connected; it seems possible that the lower two zones, which are only separated by 26 feet, are connected, but the upper zone, separated from the middle zone by 118 feet of impermeable oil shale, likely is a separate aquifer. Future core investigations should help determine the lateral continuity of these different dissolution zones. In addition, further research will try to determine whether water could travel vertically along a gilsonite/rock interface.

The Suicide Canyon 1 (T. 12 S., R. 23 E., sec. 36) and CRU-1 (T. 12 S., R. 24 E., sec. 3) wells are both located much farther south than the Utah State 13X-1 well, near the southern outcrop. Cores display a much thinner saline mineral interval and are composed of much smaller saline mineral crystals, probably due to their proximity to the basin margin. The saline zone in the Suicide Canyon 1 core is 114 feet thick (104-218 ft), with dissolution occurring primarily in a 27-foot interval between 168 and 195 feet. Similarly, the CRU-1 core captures a saline zone that is 135 feet thick (104-239 ft), with dissolution mostly occurring in a 51-foot interval between 167 and 218 feet. As more cores are described, the Task 3 team should be able to correlate these thinner intervals with the thicker saline sequences observed in the core closer to the basin's depocenter. The Asphalt Wash 1 (T. 11 S., R. 24 E., sec. 7) core only recovered the base of the saline mineral occurrence from 307 feet (the top of the recovered core) to 316 feet.

The Task 3 team leader is currently gathering all information related to the 20 wells with core that captured the Birds Nest aquifer, including geophysical well logs (both TIFF images and digital files), old lithologic logs, Fischer assays, water analyses, photographs, and any old corehole reports. This information will be posted to the project Web site in the next quarter.

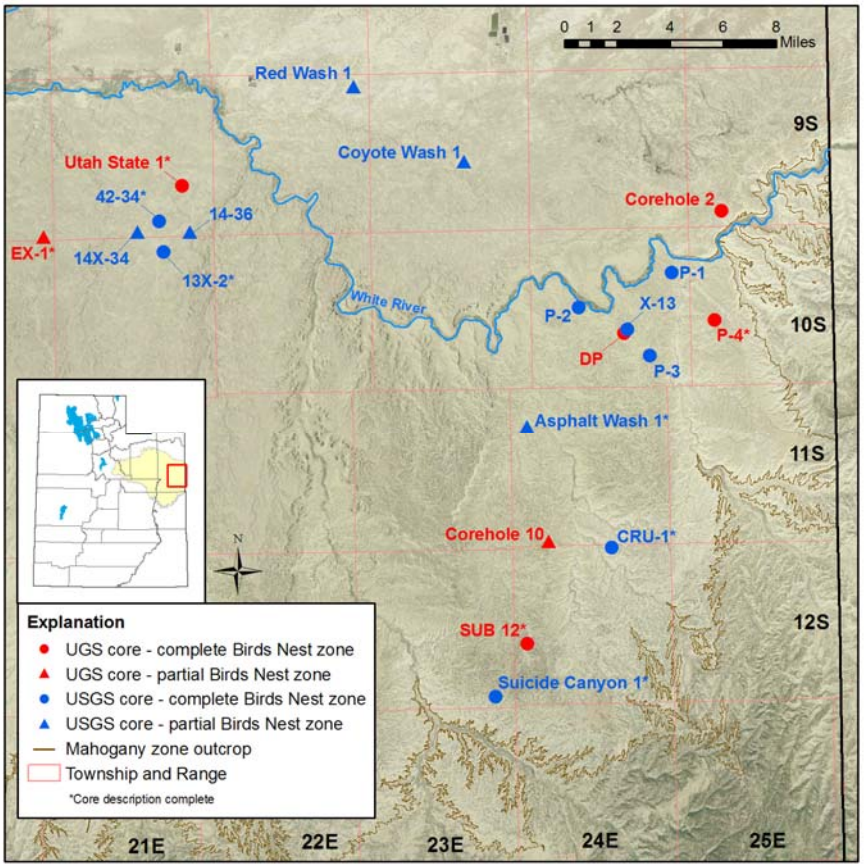

Figure 2. *Map showing the location of wells with core that captured all or part of the Birds Nest aquifer. The cores are housed either at the UGS Core Research Center in Salt Lake City, UT or at the USGS Core Research Center in Denver, CO.*

Task 4.0: Baseline Water Quality and Quantity GIS Database

During October 2009, 13 water samples were obtained from water wells and surface water sites in the Uinta Basin; 10 were from sites sampled during the summer and three were from new sites. Four sites sampled in the summer were not resampled in the fall due to access issues and time constraints. These sites will be sampled again in the spring of 2010. Table 2 provides a summary of each site including depth of sample in the well, summer and fall nitrate concentrations (NO_3), summer and fall total dissolved solid concentrations (TDS), and the formation from which the water was derived (if known). TDS values for the fall samples range from 400 to 2724 mg/L and nitrate concentrations range from less than 0.1 mg/L to 13.5 mg/L. The one well with nitrate concentrations exceeding the 10 mg/L EPA drinking water quality standard is located in an area adjacent to irrigated fields in the northwestern part of the study area (figure 3). Negligible seasonal variations for TDS concentrations exist, except in the "Seep Ridge" well; this variation is likely due to changing the sample location from near the edge of the flowing well's pond (summer) to a sample location closer to the flowing well itself (fall).

Table 2. *Overview of water sampling sites.*

Well ID	Depth (ft)	Level (ft)	NO_3 (mg/L) Summer 2009	NO_3 (mg/L) Fall 2009	TDS (mg/L) Summer 2009	TDS (mg/L) Fall 2009	Formation
Park-USGS	193+	flowing	<0.1	<0.1	796	854	Green River
Big Pack	6900	flowing	<0.1	<0.1	1298	1308	Wasatch
Willow – dom.	711	flowing	<0.1	<0.1	936	956	Green River?
Willow Creek	surface	surface	<0.1	<0.1	562	648	Alluvial
Sulfur Spring	spring	flowing	<0.1	<0.1	578	584	Green River?
Evacuation Cr.	surface	surface	<0.1	<0.1	2832	2724	Alluvial
4-star	172	70	12.6	13.5	1260	1280	Alluvial
Kings[1]	?	67?	9.5	--	2114	--	?
Windmill	1382+?	flowing?	<0.1	<0.1	2394	2236	Green River?
Target[2]	53	23	10.0	--	1442	--	Alluvial
R&N	60 & 80	23 & 49	7.7	7.7	1016	978	Alluvial
Batty[2]	83	28	18.8	--	1908	--	Alluvial
Seep Ridge	>2510	flowing	<0.1	<0.1	3056	1462	Green River
PR Spring[2]	spring	flowing	0.4	--	420	--	Green River?
South camp	98	61	--	5.8	--	1204	Green River?
White River	surface	surface	--	<0.1	--	400	Alluvial
White/Green R.	surface	surface	--	<0.1	--	412	Alluvial

[1]No access to site in fall 2009 due to weather conditions
[2]Not sampled in fall 2009 due to time constraints

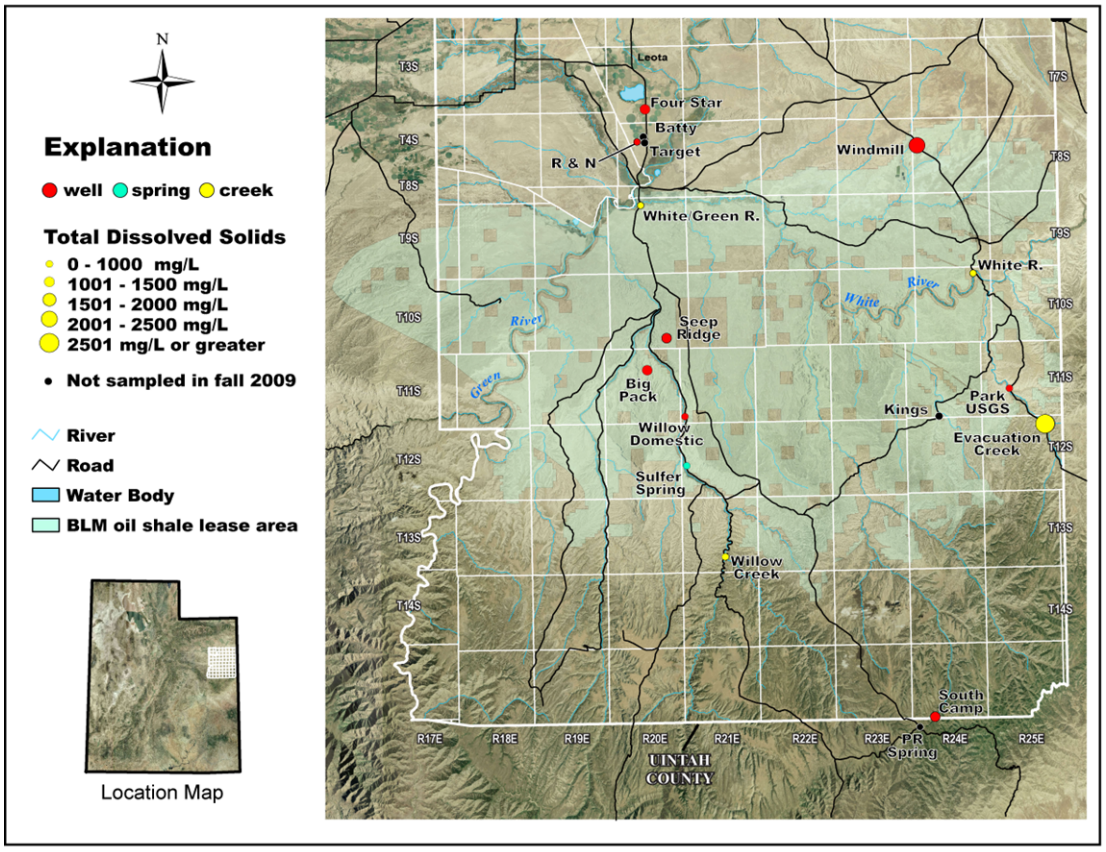

Figure 3. *Map of fall 2009 sampling sites related to Task 4.*

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 hosted a Year 1 Review meeting in Vernal, Utah in the beginning of October. Roughly 30 individuals from local oil and gas companies, government agencies, and academia attended the meeting. After a brief introduction by the PI, each Task Leader presented the work accomplished in the last year, and what they hope to accomplish in the final two years of the project. The meeting was well received and many individuals provided excellent feedback and encouragement. The presentations for each task have been posted to the UGS project Web site.
- Also in October, the PI presented a talk at the 29th Oil Shale Symposium held at the Colorado School of Mines. The talk focused on how saline water disposal into the Birds Nest aquifer might affect potential oil shale development. This presentation has also been posted to the project Web site.
- Also in October, the PI and members of the U.S. EPA Region 8 disposal well permitting team met at the U.S. Geological Survey's (USGS) Core Research Center to study Birds Nest aquifer core and discuss permitting issues. The meeting was very successful and provided the permitting team with the background information helpful for evaluating Birds Nest disposal well permits. The meeting also addressed questions on how best to monitor and protect surrounding fresh water resources. The EPA is in charge of responsible disposal permitting and is a major customer of this research effort. The PI looks forward to continuing this important partnership as the project moves forward.
- An abstract about the project submitted to the 2010 American Association of Petroleum Geologists Annual Meeting was accepted. The research team will present a poster in the Environmental Remediation and Hydrogeological Characterization session scheduled for the afternoon of April 12, 2010. The poster will detail the progress made on each part of the project.
- The project Web site (http://geology.utah.gov/emp/UBwater_study) was updated with new quarterly reports, newly submitted abstracts, and recent presentations.

CONCLUSION

With the project nearing its halfway point, the study is on schedule to achieve the goals of understanding the aquifers in the Uinta Basin to help facilitate safe and efficient saline water disposal. The Task 2 team has collected hundreds of down-hole water chemistry analyses and hundreds of digitized log files to aid in picking the base of the moderately saline aquifer; the Task 3 team has described nine cores containing the Birds Nest aquifer; and the Task 4 team has collected and analyzed a second set of water samples from 17 sites in central Uintah County as part of a biannual sampling plan to develop baseline water quality in the area. The project is scheduled for several more months of data collection and analysis before the final interpretation and synthesis can start in year three.

COST STATUS

Water chemistry analyses for all samples collected during the summer and fall were billed in November and December of this quarter. The larger-than-budgeted expenses for October and December were the result of significant personnel time on the project, making up for underbudget months from this past summer (figure 4). As displayed in figure 5, the cumulative budget through the end of December 2009 is very close (90%) to projected billing.

Table 3. *Project costing profile for Budget Period 2 (first quarter).*

	Oct 2009		Nov 2009		Dec 2009	
	Plan	Actual	Plan	Actual	Plan	Actual
UGS-personnel	$8,112	$18,919	$10,859	$8,837	$9,217	$15,605
Travel Expenses[1]	$2,431	$1,387	$1,136	$762		
Water Chemistry[2]			$4,237	$7,169		$4,880
Miscellaneous[3]		$203				
SUBTOTALS	$10,543	$20,509	$16,232	$16,769	$9,217	$20,485
UGS OVERHEAD (32.40%)	$3,416	$6,645	$5,259	$5,433	$2,986	$6,637
SUBCONTRACTS						
P. Anderson[4]	$6,777	$7,280	$6,777	$0	$6,777	$12,080
GRAND TOTALS	$20,735	$34,433	$28,269	$22,202	$18,981	$39,202

[1]October – trip to the Uinta Basin for water sampling, trip to Vernal for Year 1 review meeting, trip to Denver for 29th Oil Shale Symposium and core work at USGS; November – additional travel billing for October trips to Vernal
[2]Billing for water chemical analysis for both summer and fall samples
[3]October – field supplies, room rental and refreshments for Year 1 review meeting held in Vernal
[4]December billing includes November

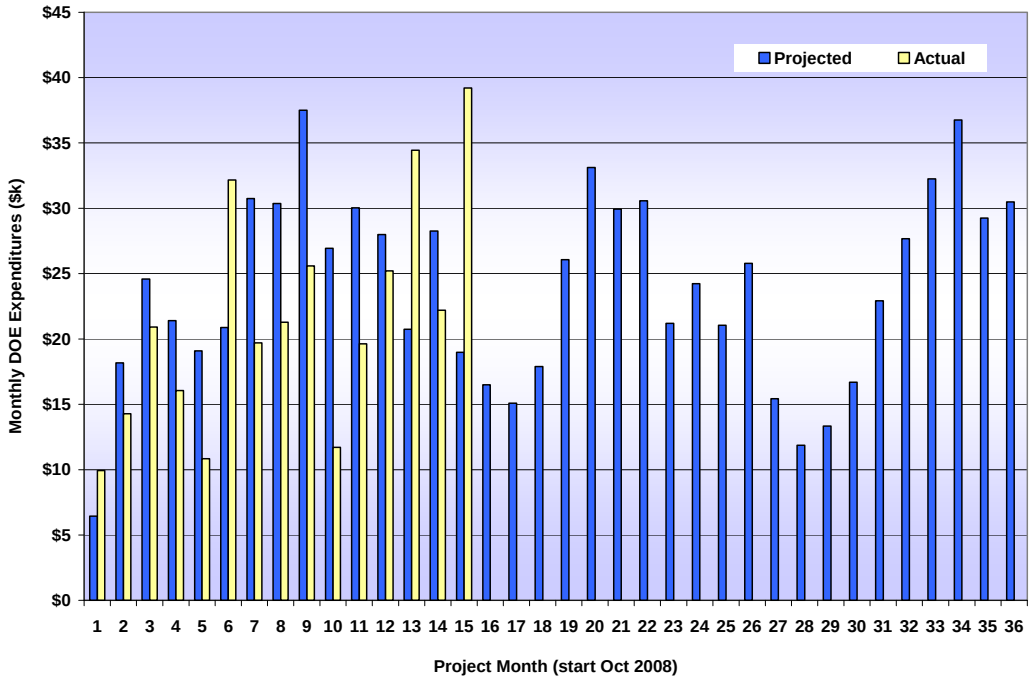

Figure 4. *Project costing profile.*

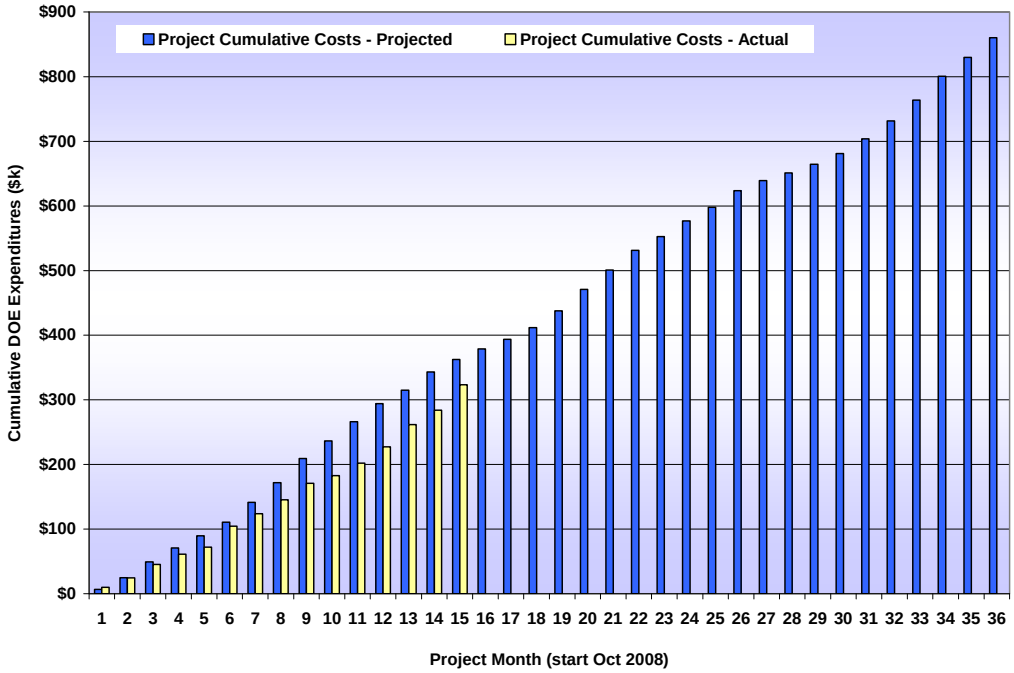

Figure 5. *Project cumulative costs.*

MILESTONE STATUS

Table 4. *Milestone log for Budget Period 2.*

	Title	Description	Related task or subtask	Completion Date	Update/comments
Milestone 2.1	Water chemistry data collection (part 2)	Collect the remaining required 1 well per township, adding additional data to areas of interest	Subtask 2.1	9/30/2010	Currently have chemistry data from ~1250 wells; currently analyzing well logs in areas where no chemistry data exists (46 of 298 wells completed)
Milestone 2.2	Create Birds Nest aquifer well database	Create a database with all collected data	Subtask 3.4	9/30/2010	Evaluated Birds Nest in 9 of 20 cores; started Birds Nest well database, initially focusing on wells with core

ACCOMPLISHMENTS

- Hosted Year-1 review meeting in Vernal, Utah
- Presented at the 29th Oil Shale Symposium in Golden, CO
- Examined and described four Birds Nest cores housed at USGS
- Completed fall 2009 water sampling and analysis from sites in Uintah County

PROBLEMS OR DELAYS

The Task 2 Leader has identified 298 wells in which geophysical logs will be used to determine the base of the moderately saline aquifer. Of these 298 wells, digital log files have been obtained or created from 206 wells, leaving 92 wells without complete digital LAS files. Our original proposal indicated that UGS would digitize needed geophysical logs in-house, but digitizing a full suite of logs has proven to be a very time-consuming task. Project leaders are currently exploring alternatives to in-house digitizing, including purchasing the digital files from a third party vendor.

PRODUCTS AND TECHNOLOGY TRANSFER ACTIVITIES

- Completed fourth quarterly report
    - July 2009 to September 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
- Uinta Basin Oil and Gas Collaborative Group meeting - Vernal, UT – convened October 8, 2009
    - This is a group of state and federal officials and Uinta Basin oil and gas operators that meets quarterly to discuss latest activities in the basin
    - Members of the research team attended the meeting and networked about the project
- Hosted Year-1 review meeting in Vernal, UT – convened October 8, 2009
    - Each Task Leader presented an overview of Year-1 accomplishments
    - Displayed maps, posters, and Birds Nest core
    - Attended by ~30 people from industry, government, and academia
    - Presentations are available on the UGS project Web site
- Oral presentation - 29th Oil Shale Symposium, Colorado School of Mines – October 19-21, 2009
    - The PI gave a presentation discussing how saline water disposal into the Birds Nest aquifer could affect potential oil shale development
    - Presentation is available on the UGS project Web site
- Met with researchers from U.S. EPA Region 8 to discuss Birds Nest aquifer and water disposal permitting issues
- Abstract – AAPG Annual Meeting – New Orleans, LA – April 11-14, 2010
    - An abstract was submitted and accepted to the 2010 AAPG Annual Meeting detailing progress made on all aspects of the project
    - The poster presentation will be part of the Environmental Remediation and Hydrogeological Characterization session scheduled for the afternoon of April 12, 2010
    - The abstract is available on the UGS project Web site

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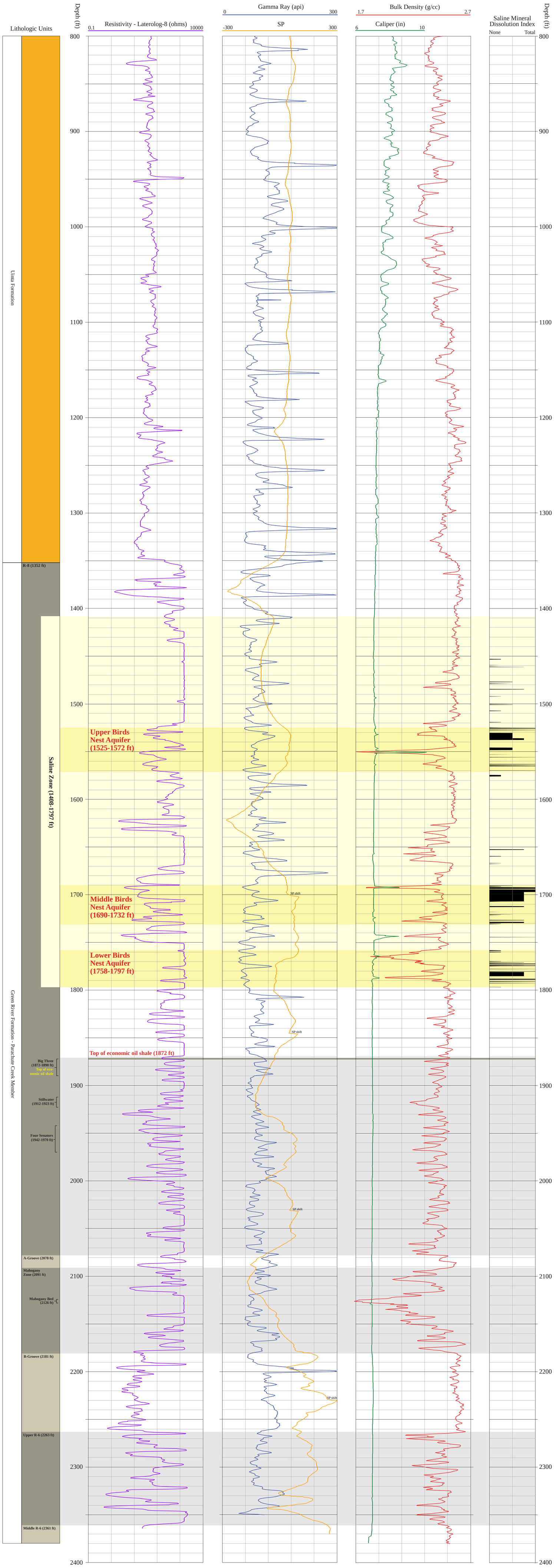
Plate 1

Michael D. Vanden Berg
Utah Geological Survey
January 14, 2010

Well name: Utah State 13X-2

Operator: Tosco Corp.
Location: T10S, R21E, Sec. 2
UTM E 625912, UTM N 4425960
Ground elevation: 5064 ft
Year drilled: 1977
Cored interval: 120 - 2191 ft (whole core - 3.5 in)
Core examined: 1289 - 1818 ft
Core housed at the USGS Core Research Center



Core Log Key

- Calcareous/siliciclastic mudstone - slightly dolomitic in places
- Siltstone / sandstone - bitumen stained in places
- Nahcolite bed ($NaHCO_3$)
- Abundant fractures filled with shortite [$Na_2ca_2(CO_3)_3$]
- Nahcolite nodule
- Small shortite/nahcolite crystals
- Bitumen
- Near-vertical fracture

Core Log