

Oil & Natural Gas Technology

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Quarterly Report

October 2010 - December 2010

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 Utah Geological Survey's (UGS) Uinta Basin water project has now entered its final year. Project leaders expect at least one more quarter of data collection before interpretation and synthesis starts in the second half of Budget Period 3. The main research tasks are all on, or ahead of, schedule and should provide valuable insights into the water disposal issues facing the Uinta Basin.

Water chemistry data, sought to aid with the goals of Task 2, keep trickling in, with analyses received for over 1300 wells. These data will be invaluable as "ground truth" to aid in the mapping of aquifer salinity throughout the basin, scheduled to begin in the latter part of Budget Period 3. In addition, several oil and gas operators have donated digitized log data from nearly 680 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 in selected wells.

The Principal Investigator (PI) measured and described three outcrop sections through the saline zone within the upper Green River Formation. The locations highlighted the gradual disappearance of large saline nodules from the northern, deeper part of the lake, to the southern margin. The PI also described four additional cores containing all or part of the Birds Nest aquifer, including the P-2 core within a vital transitional zone between the eastern margin and the basin's depocenter.

The Task 4 team leader received water chemistry results from the fourth round (fall 2010) of water sampling in the eastern Uinta Basin. These results were compared to earlier data in order to evaluate potential seasonal changes. The fifth and final round of sampling will commence in the spring of 2011.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0: Project Management Plan

During the month of October, the PI wrote and submitted the project's eighth quarterly report for the period July through September 2010. 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

One of the most important steps in accomplishing the goals of Task 2 is to collect as many water chemistry analyses as possible from wells in the Uinta Basin. Through December 2010, the team has collected 2431 individual water analyses from 1374 different wells (figure 1). This information has been collected from a variety of sources including oil and gas operators (720 analyses), Utah Division of Oil, Gas, and Mining (DOGM) well files (290 analyses), UGS databases (1247 analyses), U.S. Geological Survey databases (104 analyses), and other publications (70 analyses).

For those areas where water chemistry data are lacking, work continues on determining the base of the moderately saline aquifer (BMSA) using geophysical logs. The Task 2 team leader has selected 264 wells spaced throughout the Uinta Basin for log interpretation. As of December 2010, the BMSA has been picked in 204 of the 264 wells (figure 2). To expedite this process, UGS has requested donations of the digital log files (LAS files) of these particular wells to aid in the picking of the BMSA. Through December 2010, UGS has received about 70% of the LAS files on the selected well list, and overall has obtained 677 digital log files

Table 1. Number of donated LAS files by company.

Company	# of LAS files
Questar	319
Newfield	100
Enduring	75
Anadarko	53
El Paso	24
EOG	17
Bill Barrett	16
Berry	15
Gasco	12
Rosewood	7
Wind River	6
FIML	6
Devon	5
Mustang Fuel	4
Whiting Petroleum	3
Forest	3
Flying J	2
Royale	2
Anschutz	1
Bayless	1
Pendragon	1
BT Operating	1
JW Operating	1
Elk Resources	1
McElvain	1
Summit Operating	1
Sub-total	677
Digitized by UGS	14
Purchased	60
Total	751

from 26 different companies (table 1; many companies donated more LAS files than requested). For the remaining 30% of selected wells, digital log files were either digitized in-house (14 wells) or purchased from a third party vendor (60 wells). The original plan was to digitize all necessary logs in-house, but this proved to be too time consuming and a waste of project funds.

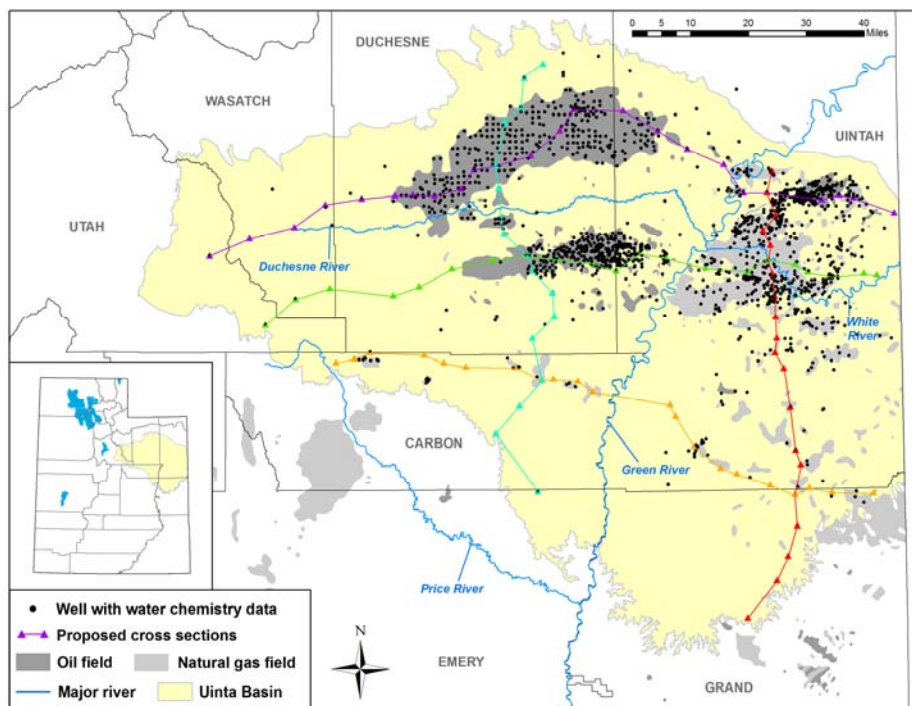


Figure 1. Location of wells in the Uinta Basin with available water chemistry data.

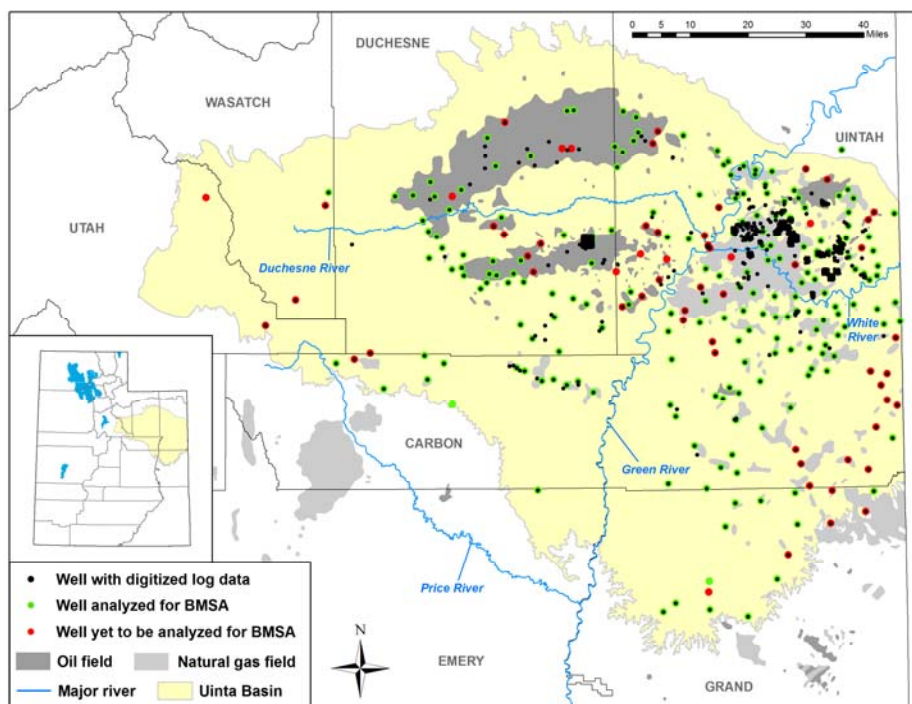


Figure 2. Location of wells in the Uinta Basin with donated digitized geophysical logs and wells already and yet-to-be evaluated for the base of the moderately saline aquifer.

In order to add a third dimension to the mapping effort, wells were selected for the construction of five regional cross sections, two north-south sections and three east-west sections (figure 1). These cross sections will highlight the general geology, water-bearing formations, formations that act as seals, and the level of the base of the moderately saline aquifer.

An Access database has been populated with all the incoming data, facilitating its manipulation and retrieval. The database will continue to be updated as new data are acquired from operators or generated by project researchers.

Task 3.0: Geologic Examination of the Birds Nest Aquifer

In November 2010, the PI measured and described three of four planned stratigraphic sections through the Birds Nest aquifer to help quantify and characterize the disappearance of large saline nodules between Evacuation Creek and the southern margin of the basin (figure 3). The northernmost outcrops of the Birds Nest aquifer occur near Evacuation Creek and the White River and display abundant large saline mineral nodules in a continuous section about 50-75 feet thick directly below the Horse Bench Sandstone (figure 4, section to be measured in spring 2011). The first section measured this fall was near the old town site of Watson, also along Evacuation Creek, but farther to the south. This section contains only three isolated beds of large saline nodules, each roughly 2-3 feet thick, within a zone of small disseminated saline crystals and fracture fill measuring about 125 feet thick (figure 5). The second section was measured within Long Draw Canyon, southwest of the Watson section. The Long Draw section measured 78 feet of abundant saline minerals deposited in the form of small crystals and fracture fill, but revealed no large saline mineral nodules (figure 6). These observations, despite lacking access to the upper ~40 feet of the saline zone, match closely the saline deposits displayed in the nearby CRU-1 core. The southernmost outcrop location, near Bitter Creek, displays roughly 111 feet of significant saline mineral deposition in the form of small disseminated crystals and fracture fill, but again no large saline nodule cavities were observed at this location (figure 7). The Bitter Creek section, despite lacking access to the lower ~30 feet of the saline zone, closely matches the saline minerals displayed in the nearby SUB 12 and Suicide Canyon 1 cores. These measured sections reveal the gradual transition from abundant large saline mineral nodules near the northern side of Township 10 South (closer to the basin depocenter) to zero large saline mineral nodules in Township 12 South (nearer the basin margin) (figure 3). This is the same pattern observed in geophysical logs in the area (and to the west), where the signature on bulk density logs representing large saline nodules slowly disappears to the south.

In addition to the measured sections, four additional cores were described: P-2, 42-34 (re-described after being slabbled by Anadarko), Corehole 10, and the newly found Corehole 9. Corehole 10 and Corehole 9 only recovered the base of the saline zone, while P-2 and 42-34 recovered the entire zone. The P-2 core is in a strategic location between outcrops along Evacuation Creek, where the saline zone is roughly 135 feet thick and topped by the ~20-foot-thick Horse Bench Sandstone, and cores in the basin's depocenter, where the saline zone is almost 400 feet thick with no record of the Horse Bench (figure 3). The saline zone recovered by the P-2 core is about 130 feet thick, while the Horse Bench Sandstone is only about two feet thick. Sandy sediments of the Horse Bench are thought to represent a freshwater influx from the east, creating a localized freshening of the lake and shutting off saline mineral deposition on the eastern side of the basin. The P-2 core is most likely near the western extent of this localized event.

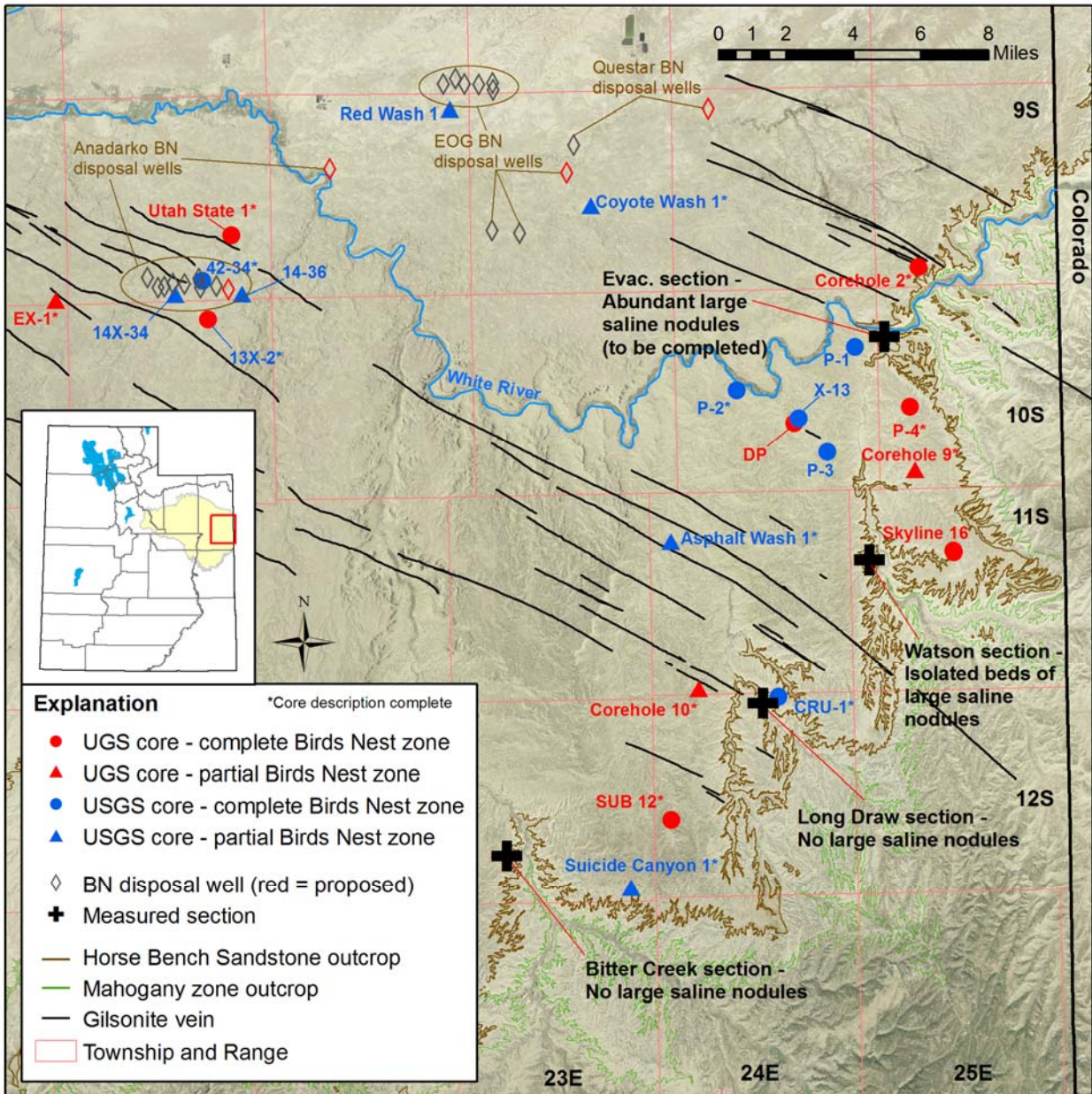


Figure 3. Location of 22 wells in Uintah County with core that captured all or part of the Birds Nest aquifer. Also plotted are the locations of four measured sections (Evac. section is yet to be completed) and Birds Nest saline water disposal wells.

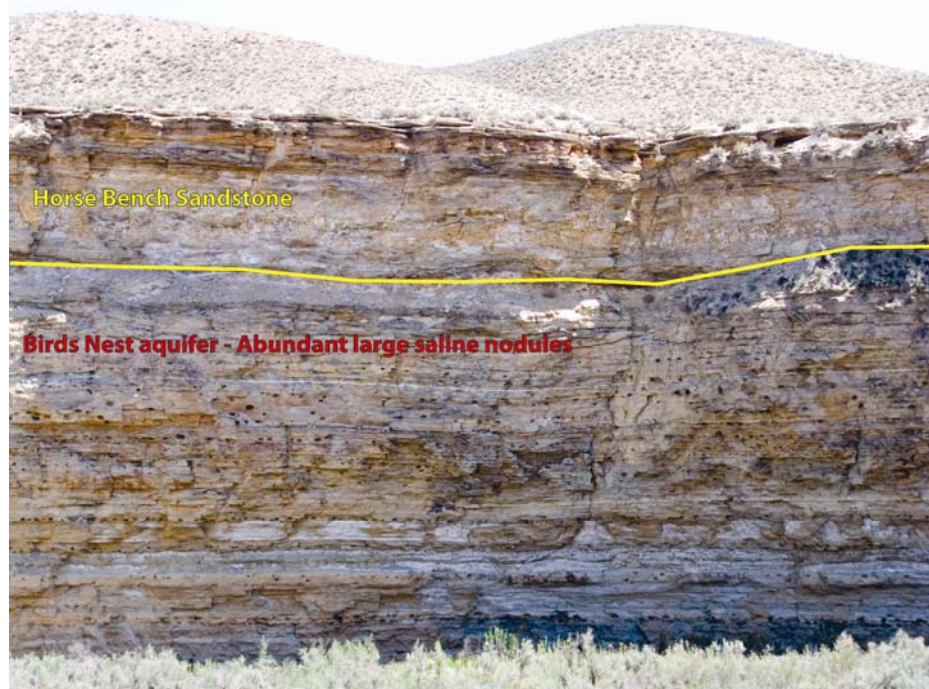


Figure 4. Saline zone outcrop along Evacuation Creek displaying abundant large saline mineral nodules.

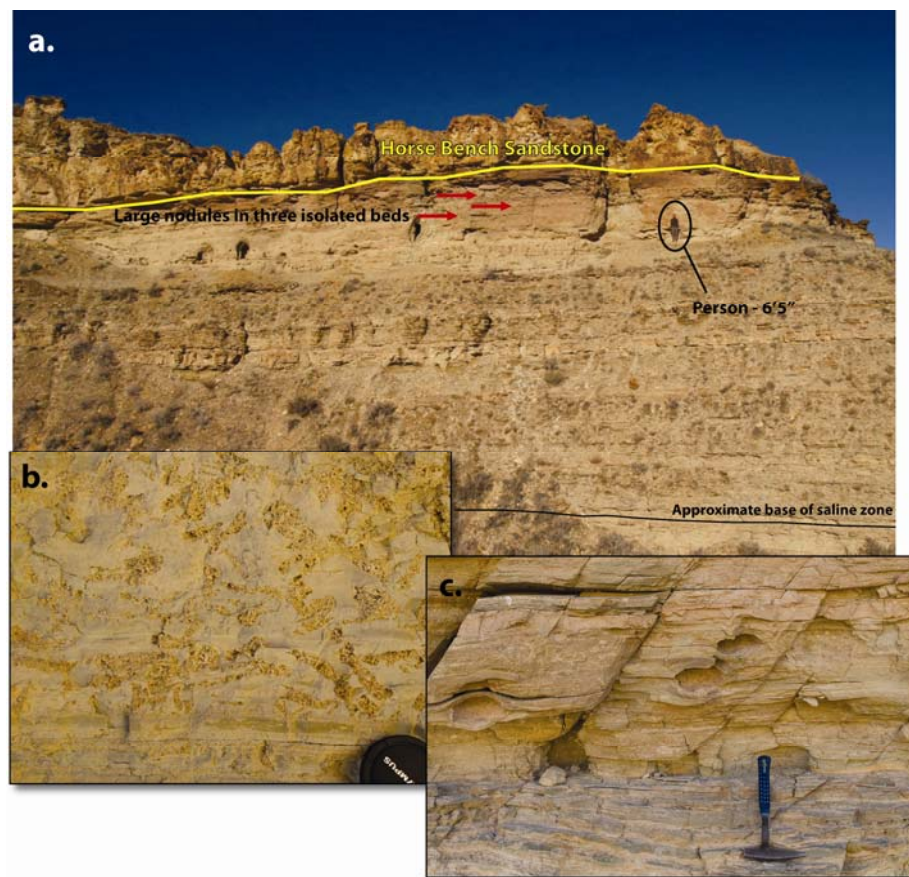


Figure 5. a. Saline-zone outcrop near Watson displaying large saline mineral nodules in three isolated beds below the Horse Bench Sandstone (red arrows). b. Close-up of small saline mineral crystals. c. Close-up of one large saline nodule layer, notice high-angle fractures.



Figure 6. *Saline-zone outcrop within Long Draw Canyon, no large saline mineral nodules.*



Figure 7. *Small saline mineral crystals displayed in outcrop near Bitter Creek.*

Task 4.0: Baseline Water Quality and Quantity GIS Database

During fall 2010, 20 water samples were collected from water wells and surface-water sites in the Uinta Basin field area (figure 8). All samples are repeats from previously sampled sites in 2009 and spring 2010, while two sites that were unavailable in spring 2010, R&N and Windmill, were accessible during the autumn sampling season. Total-dissolved-solids concentrations for all samples ranged from 378 to 2632 mg/L and nitrate concentrations ranged from <0.1 to 12.7 mg/L (table 2, figure 9 and 10). None of the samples had detectable volatile organic compounds. Fourteen samples were analyzed for boron concentration (table 2); most of these (12 of 14) had levels of boron above the detection level but below the maximum contaminant level (not a primary drinking water standard, but a surface water quality standard based on the Utah Division of Water Quality's criterion for a maximum boron concentration of 0.75 mg/L for Class 4 "Beneficial Use Designation" for the Green River emptying into Flaming Gorge). Figure 11 shows boron concentrations for different seasons sampled from 2009 to 2010. For all graphs, points that plot on the x-axis have concentrations below the detection level.

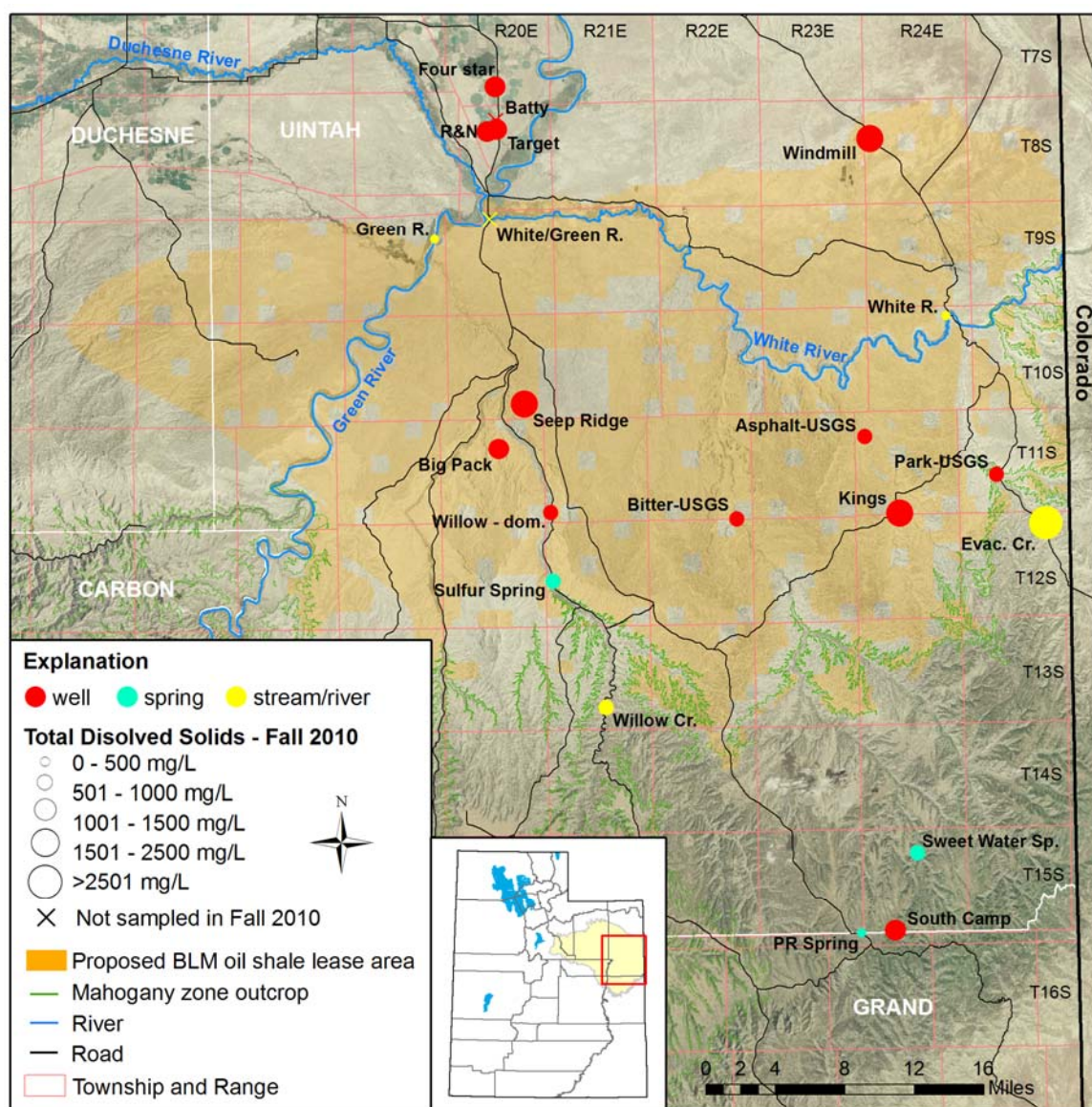


Figure 8. Sampling sites related to Task 4, with TDS data from fall 2010 samples.

Table 2. Overview of water sampling sites.

Well ID	Depth (ft)	Level (ft)	NO ₃ (mg/L)				TDS (mg/L)				Boron (µg/L)				Formation
			Summer 2009	Fall 2009	Spring 2010	Fall 2010	Summer 2009	Fall 2009	Spring 2010	Fall 2010	Summer 2009	Fall 2009	Spring 2010	Fall 2010	
Park-USGS	193+	flowing	<0.1	<0.1	<0.1	<0.1	796	854	786	782	442	414	398	na	Green River
Big Pack	6900	flowing	<0.1	<0.1	<0.1	<0.1	1298	1308	1320	1246	2760	3010	3170	3180	Wasatch
Willow – dom.	711	flowing	<0.1	<0.1	<0.1	<0.1	936	956	924	888	321	294	295	na	Green River?
Willow Creek	surface	surface	<0.1	<0.1	0.1	<0.1	562	648	506	592	na	74	41	na	Alluvial
Sulfur Spring	spring	flowing	<0.1	<0.1	<0.1	<0.1	578	584	586	572	159	135	133	na	Green River?
Evacuation Cr.	surface	surface	<0.1	<0.1	<0.1	<0.1	2832	2724	2708	2632	236	182	145	151	Alluvial
4-star	172	70	12.6	13.5	12.7	12.7	1260	1280	1332	1232	576	672	653	315	Alluvial
Kings ¹	?	67?	9.5	--	8.2	8.3	2114	--	1988	1886	5620	--	6020	5790	?
Windmill ⁴	1382+?	flowing?	<0.1	<0.1	--	<0.1	2394	2236	--	2106	3030	na	--	2410	Green River?
Target ²	53	23	10.0	--	8.5	9.4	1442	--	1496	1446	324	--	315	280	Alluvial
R&N ⁵	60 & 80	23 & 49	7.7	7.7	--	7.6	1016	978	--	1058	na	399	--	471	Alluvial
Batty ^{2,6}	83	28	18.8	--	--	--	1908	--	--	--	482	--	--	--	Alluvial
Seep Ridge	>2510	flowing	<0.1	<0.1	<0.1	<0.1	3056	1462	1486	1516	2510	1750	1360	na	Green River
PR Spring ¹	spring	flowing	0.4	--	0.6	0.3	420	--	356	378	<30	--	<30	<30	Green River?
South camp ³	98	61	--	5.8	<0.1	<0.1	--	1204	1352	1172	--	32	<30	<30	Green River?
White River ³	surface	surface	--	<0.1	<0.1	<0.1	--	400	300	400	--	99	37	na	Alluvial
White/Green R. ^{3,7}	surface	surface	--	<0.1	--	--	--	412	--	--	--	165	--	--	Alluvial
Green River ⁸	surface	surface	--	--	<0.1	<0.1	--	--	172	410	--	--	89	122	Alluvial
Sweet Water Spr. ⁸	spring	flowing	--	--	0.6	0.6	--	--	994	996	--	--	34	41	?
Bitter Cr–USGS ⁸	1497	?	--	--	<0.1	<0.1	--	--	950	886	--	--	253	123	Green River
Asphalt 1–USGS ⁸	2650	?	--	--	<0.1	<0.1	--	--	1012	958	--	--	202	203	Green River

¹No access to site in fall 2009 due to weather conditions

²Not sampled in fall 2009 due to time constraints

³New sites sampled in fall 2009

⁴Well not operational in spring 2010

⁵Unable to sample in spring 2010

⁶Well no longer in use starting spring 2010

⁷Not sampled in spring or fall 2010

⁸New sites sampled in spring 2010

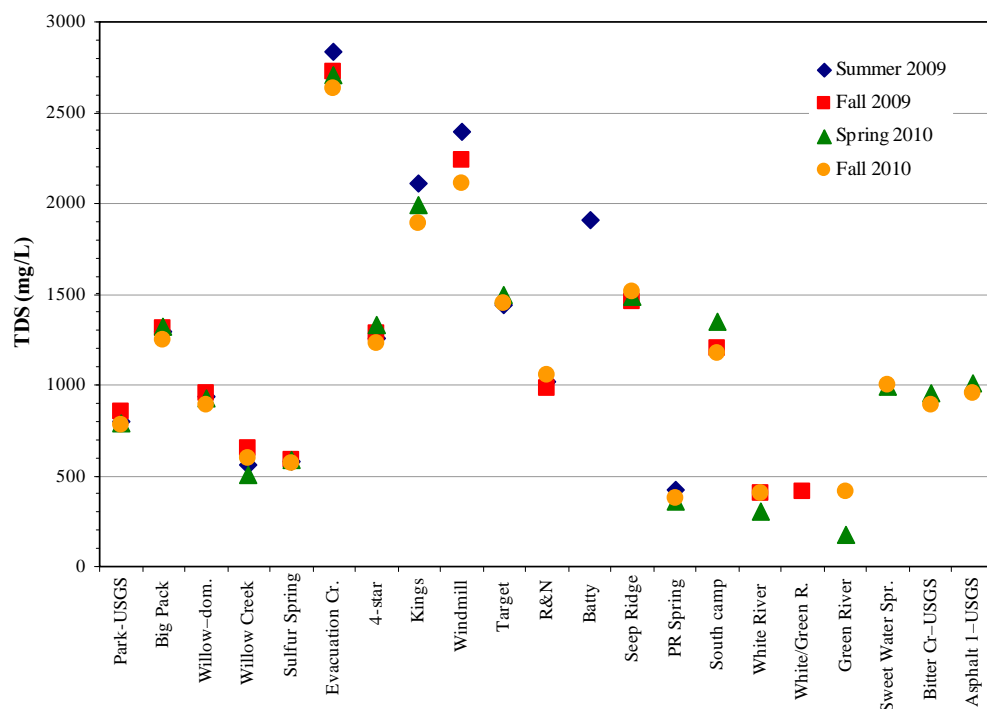


Figure 9. Total dissolved solids concentrations from sites sampled as part of Task 4.

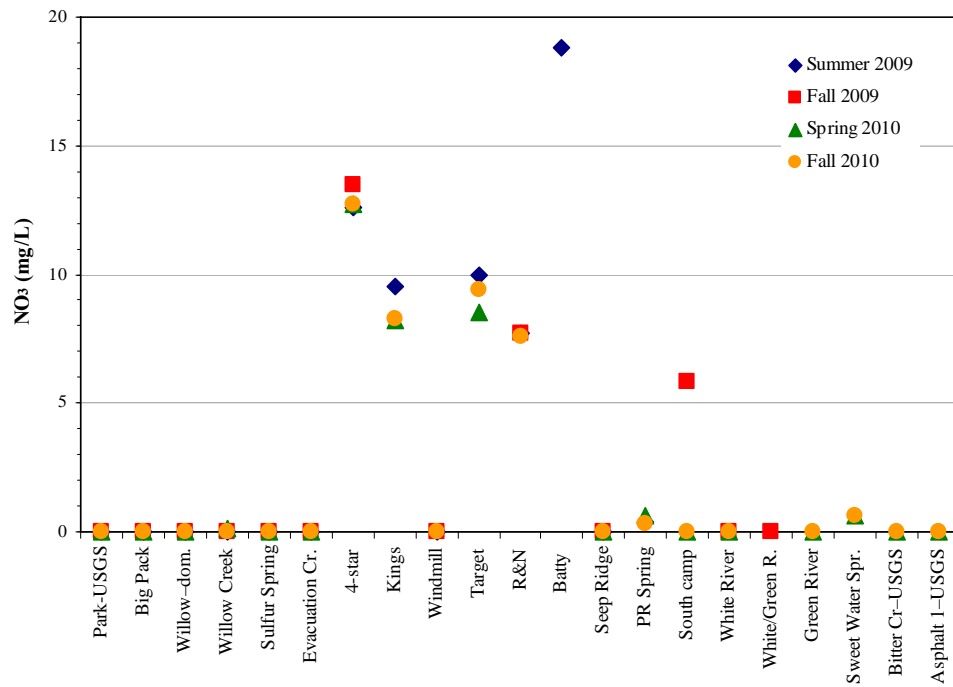


Figure 10. Nitrate concentrations from sites sampled as part of Task 4.

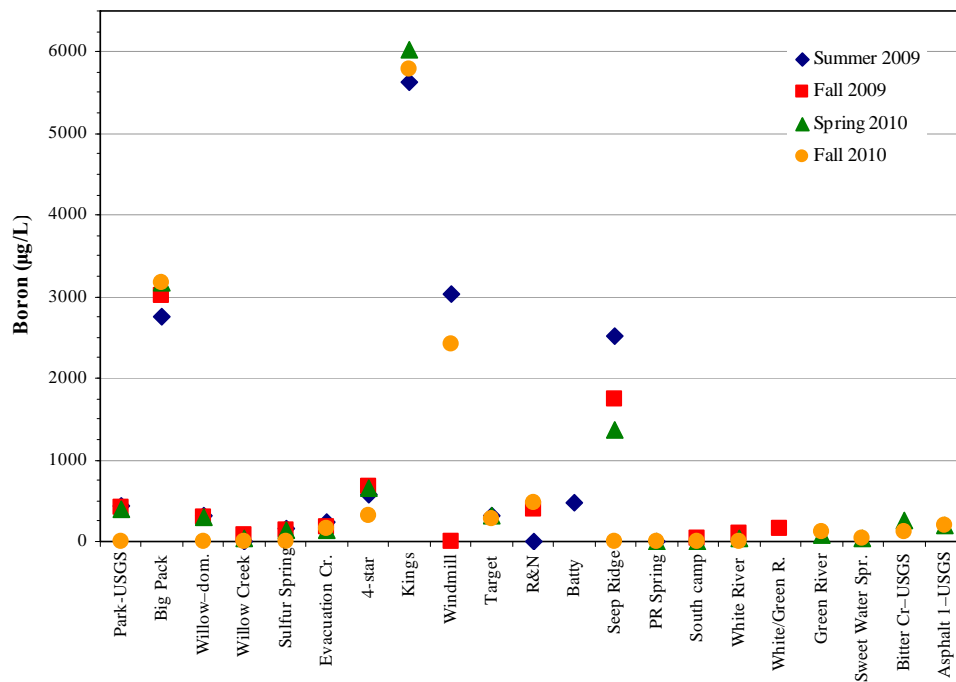


Figure 11. Boron concentrations from sites sampled as part of Task 4.

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

No work on this task was performed in this quarter.

Task 6.0: Technology Transfer

- The PI led a field trip of the UGS board members, stopping near Evacuation Creek to discuss the Birds Nest aquifer and the goals of this project.
- The PI and other team members attended the quarterly Uinta Basin Oil and Gas Collaborative Group meeting in Vernal, UT on October 14, 2010 and discussed the project with interested attendees.
- The PI presented Birds Nest aquifer-related research at the 30th Oil Shale Symposium, held at the Colorado School of Mines, Golden, CO in October 2010.
- The PI led a field trip run in conjunction with the 30th Oil Shale Symposium, stopping near Evacuation Creek to discuss the Birds Nest aquifer and the goals of this project.
- An abstract was accepted for the AAPG Annual Meeting in Houston, TX. A poster will be presented in the Water Resource Management and Impacts session on April 11, 2010, highlighting the progress made thus far on the mapping of the base of the moderately saline aquifer and the geologic characterization of the Birds Nest aquifer.
- The PI traveled to Denver to discuss recent Birds Nest aquifer research with colleagues at Anadarko, Norwest, and the EPA.
- The project Web site (http://geology.utah.gov/emp/UBwater_study) was updated with new quarterly reports, abstracts, and presentations prepared by project team members.

CONCLUSION

The project team expects at least one more quarter of data collection before the project reaches its final phase of interpretation and synthesis. 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 14 cores containing the Birds Nest aquifer and measured three outcrop sections; and the Task 4 team has collected four sets of water samples from 21 sites in central Uintah County as part of a biannual sampling plan to develop baseline water quality data for the area.

COST STATUS

Significant time was dedicated to the project this quarter, more than originally budgeted, bringing the overall actual budget within 93.5% of the projected budget (figure 13). An accounting adjustment in November resulted in a credit of \$3,834; funds that were originally charged UGS overhead were moved into a different accounting category that does not incur overhead charges.

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

	Oct 2010		Nov 2010		Dec 2010	
	Plan	Actual	Plan	Actual	Plan	Actual
UGS-personnel	\$8,355	\$13,769	\$8,994	\$9,043	\$6,541	\$10,489
Travel Expenses ¹	\$2,431	\$1,359	\$1,136	\$535		\$1,642
Water Chemistry		\$894	\$4,237			\$1,269
Miscellaneous ²				\$1,000		\$8
SUBTOTALS	\$10,786	\$16,022	\$14,367	\$10,578	\$6,541	\$13,407
UGS OVERHEAD (32.40%)	\$3,495	\$5,191	\$4,655	\$3,427	\$2,119	\$4,344
SUBCONTRACTS						
P. Anderson ³	\$6,777	\$9,180	\$6,777	\$8,240	\$6,777	\$8,140
Accounting adjustment/credit ³				\$3,834		
GRAND TOTALS	\$21,058	\$30,394	\$25,798	\$18,411	\$15,436	\$25,890

¹October – Water sampling, 30th Oil Shale Symposium in Golden, CO; November – Outcrop work in Uinta Basin; December – Outcrop work in Uinta Basin, core description and meetings in Denver, CO

²November – software license; December – office supplies

³Money was subsequently transferred between categories resulting in a UGS overhead credit

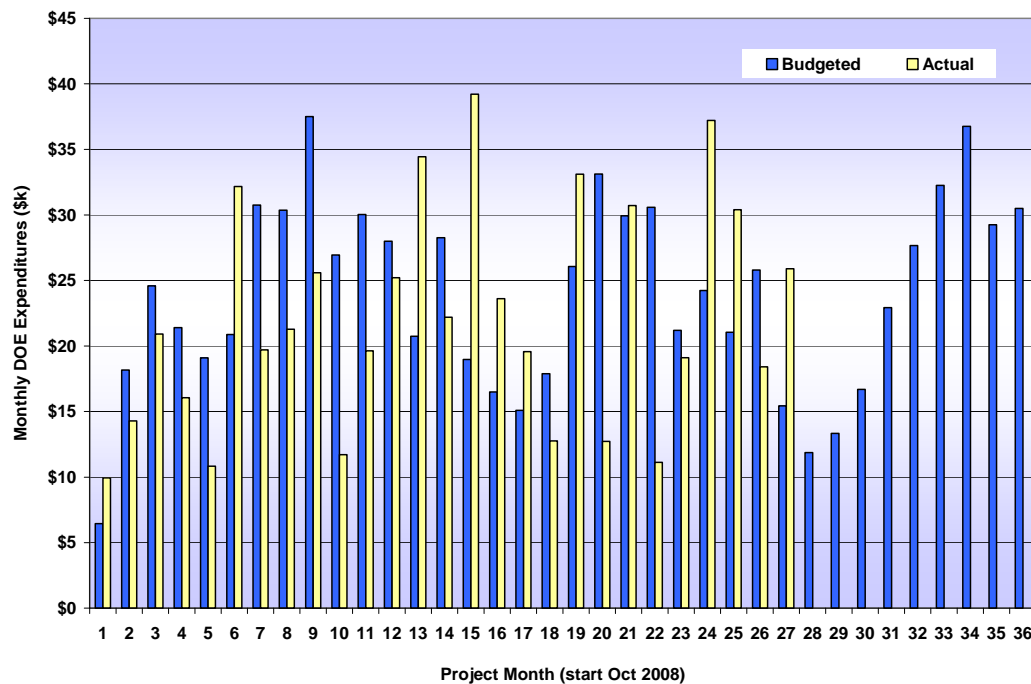


Figure 12. Project costing profile.

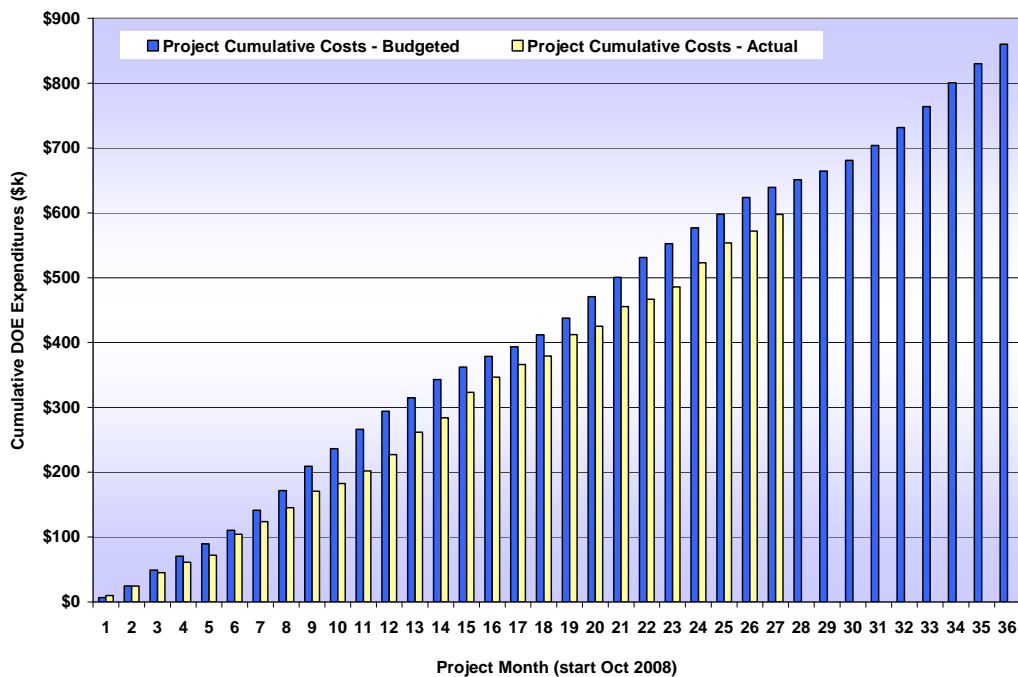


Figure 13. Project cumulative costs.

MILESTONE STATUS

Table 4. Milestone log for Budget Period 3.

	Title	Description	Related task or subtask	Completion Date	Update/comments
Milestone 3.1	Map the base of the moderately saline aquifer	Re-map the base of the moderately saline aquifer, including cross-sections, based on data collected during the previous two years	Subtask 2.2	3/31/2011	Currently have 2431 individual water analyses from 1374 wells; determined the BMSA using geophysical logs in 204 of 264 wells, re-mapping will commence after all 264 wells are analyzed
Milestone 3.2	Creation of Birds Nest aquifer maps	Map the thickness, extent, and water chemistry of the Birds Nest aquifer	Subtask 3.5	6/30/2011	Still collecting data
Milestone 3.3	Water quality and quantity analysis	Combine all collected water data and combine into a final report	Subtask 4.4	9/30/2011	One round of water sample collection remains (Spring 2011)
Milestone 3.4	Integration analysis	Model transfer of oil and water to adjacent aquifers and beyond	Task 5	6/30/2011	Yet to be discussed with researchers at the University of Utah

ACCOMPLISHMENTS

- Led two field trips (UGS Board and 30th Oil Shale Symposium) with stops to look at Birds Nest aquifer in outcrop and discuss project
- Measured three stratigraphic sections through the Birds Nest aquifer
- Described four cores containing Birds Nest aquifer
- Completed the fourth round of water quality sampling and obtained chemistry data

PROBLEMS OR DELAYS

None at this time

PRODUCTS AND TECHNOLOGY TRANSFER ACTIVITIES

- Completed eighth quarterly report
 - July 2010 through September 2010 – available on the UGS project Web site
- Updated project Web site
 - Posted various new reports, abstracts, and presentations prepared by project team members.
 - http://geology.utah.gov/emp/UBwater_study
- Co-led UGS Board field trip
 - Stopped near Evacuation Creek to look at the Birds Nest aquifer in outcrop and discuss project.
- Attended the quarterly Uinta Basin Oil and Gas Collaborative Group meeting in Vernal, UT – October 14, 2010
 - Discussed project with interested attendees.
- Oral presentation – 30th Oil Shale Symposium – Colorado School of Mines – Golden, CO – October 18-20, 2010
 - The presentation detailed the research done to date on the Birds Nest aquifer and how it relates to oil shale deposits
 - The presentation is available on the UGS project Web site
- Co-led 30th Oil Shale Symposium field trip – October 21-22, 2010
 - Stopped near Evacuation Creek to look at the Birds Nest aquifer in outcrop and discuss project.
- Poster presentation – AAPG Annual Meeting – Houston, TX – April 10-13, 2011
 - An abstract was accepted for the 2011 AAPG Annual Meeting
 - The poster will be presented during the Water Resource Management and Impacts session on April 11 and will detail the project's overall progress on all tasks
 - The abstract is available on the UGS project Web site
- The PI met with colleagues from Anadarko, Norwest, and EPA Region 8 to discuss research performed on the Birds Nest aquifer.
- The PI completed three measured sections through the Birds Nest and described four new Birds Nest cores.

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