U.S. Department of Energy

National Energy Technology Laboratory

PROJECT NARRATIVE

Water-related issues affecting conventional oil and gas recovery and potential oil shale development in the Uinta Basin, Utah

Submitted by:
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Topic Area 1

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LIST OF ACRONYMS

AAPG – American Association of Petroleum Geologists
BLM – Bureau of Land Management
CMG – Computer Modeling Group
DNR – Department of Natural Resources
DOE – Department of Energy
DOGM – Division of Oil, Gas & Mining
E&M – Energy and Minerals Program
EPA – Environmental Protection Agency
FOA – Funding Opportunity Announcement
FTIR – Fourier Transform Infrared Spectroscopy
GIS – Geographic Information System
IOG – Industry Outreach Geologist
mg/l – milligrams/liter
NETL – National Energy Technology Laboratory
NIR – Near Infrared Spectroscopy
PI – Principal Investigator
PMP – Project Management Plan
TDS – Total Dissolved Solids
UCRC – Utah Core Research Center
UGS – Utah Geological Survey
USGS – United States Geological Survey

1. SCIENTIFIC AND TECHNICAL MERIT

1.1 Statement of the Problem

This proposal addresses several water-related issues affecting conventional oil and gas recovery as well as potential oil shale development in the Uinta Basin, Utah. This multi-faceted, interdisciplinary study will: 1) investigate saline water disposal problems that hinder oil and natural gas development; 2) assess how saline water disposal from conventional petroleum development might create technical and economic hurdles for a prospective oil shale industry; 3) collect much needed baseline surface- and ground-water information which could be used by oil shale development companies; and 4) analyze water produced from simulated *in-situ* oil shale extraction technologies.

On March 27, 2008, the Utah Geological Survey (UGS) hosted a meeting with oil and gas operators in the Uinta Basin to discuss industry needs relevant to this proposal. The operators clearly indicated that saline water disposal is the single most pressing issue with regard to increasing petroleum production. Conventional oil fields in the Uinta Basin provide 67% of Utah's total crude oil production, while the basin's natural gas fields provide 71% of Utah's total natural gas, the latter of which has increased 175% in the last 10 years (Figure 1) (Utah Division of Oil, Gas and Mining, 2008). As petroleum production increases, so does saline water production, creating an increased need for economic and environmentally responsible disposal plans. Current water disposal wells are near capacity and permitting for new wells is being delayed because of a lack of technical data regarding potential disposal aquifers and questions concerning contamination of fresh water sources. Many companies are reluctantly resorting to evaporation ponds as a short-term solution, but these come at an environmental price. Evaporation ponds concentrate the brine often creating a more hazardous product that still requires underground sequestration. Evaporation ponds are also prone to leakage, which could potentially cause contamination of surface streams and shallow fresh water aquifers. Many Uinta Basin operators claim that petroleum production cannot reach its full potential until a suitable, long-term saline water disposal solution is determined (seven petroleum companies, two oil shale companies, and six governmental agencies have

written/signed letters indicating their support for this proposed study; these letters are included as an attached Appendix).

The second part of our study will focus specifically on the most critical priorities identified during the 2007 Oil Shale Environmental Workshop. Currently, insufficient data are available about how a potential oil shale industry would affect local Uinta Basin surface- and ground-water sources. Specifically, a baseline study of water quality and quantity needs to be completed for lands set aside by the U.S. Bureau of Land Management (BLM) as having oil shale development potential. Also, there are many questions as to how process-specific *in-situ* oil shale development technologies might impact local ground water and what options producers have for managing produced waters. Water availability and produced water quality will all be major operational and regulatory concerns facing oil shale development companies in Utah.

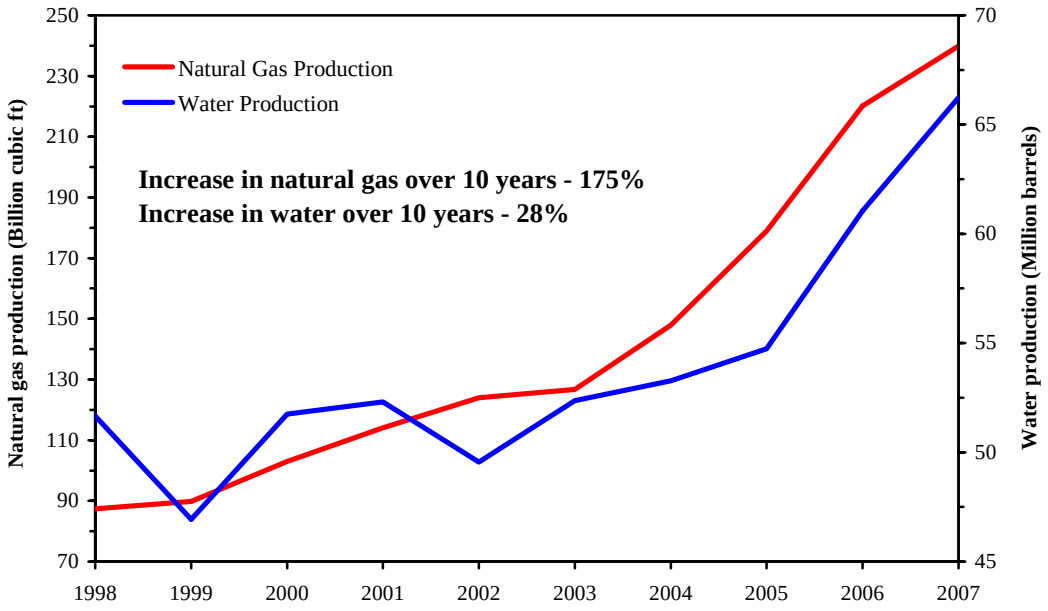

Figure 1. Water and natural gas production in Duchesne and Uintah Counties, 1998-2007 (Utah Division of Oil, Gas and Mining, 2008).

1.2 Current State-of-the-Art

The primary agencies responsible for regulating the disposal of produced water are the Utah Division of Oil, Gas and Mining (DOGM) and the U.S. Environmental Protection Agency (EPA), the latter regulating

wells on Tribal Lands. Currently these agencies use 20-year-old data amassed in a publication titled "Base of Moderately Saline Ground Water in the Uinta Basin, Utah" to try and determine zones suitable for water disposal (Howells and others, 1987). This hard copy publication provides a paper map showing the depth of the transition between moderately saline and very saline water (10,000 mg/L), below this depth it is believed saline water can be injected without damage to overlying fresh-water aquifers. Several oil and gas operators working in the basin believe this dated study needs substantial revision. The original map was based solely on calculations of water quality from geophysical logs, a method with several limitations (e.g. tar sands were recognized as fresh water aquifers). We propose to use extensive and more recent down-hole water quality information obtained from oil and gas operators, as well as

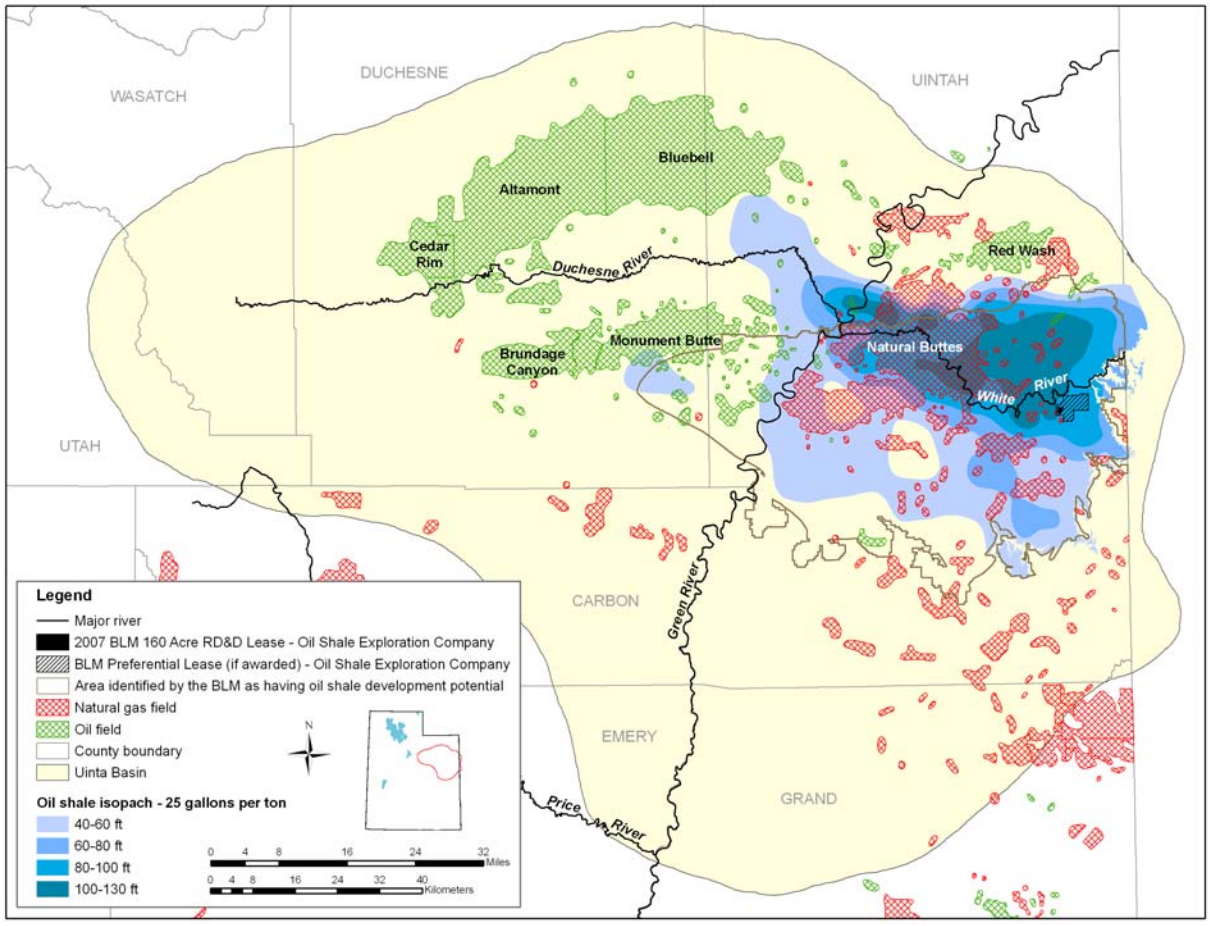

Figure 2. Map showing proposed study area, Uinta Basin, Utah. Note the prime oil shale area overlaps with several natural gas fields.

geophysical log data. The overall map structure has also been altered over the last 20 years, as more saline water is pumped underground. In order to facilitate more efficient and prudent permitting of water disposal wells, and in order to better protect fresh water resources, this dated map needs to be re-constructed using modern information and GIS technology.

Eastern Uinta Basin gas producers claim that one of the only aquifers suitable for large volume saline water disposal is the Bird's-nest aquifer located in the Parachute Creek Member of the Green River Formation. After an extensive literature search, it was determined that the Bird's-nest aquifer is poorly understood and further study is necessary before saline water disposal commences. Near the area of the BLM Research and Development Oil Shale Lease (Figure 2), the Bird's-nest is only slightly saline to moderately saline, ranging from 1000 to 4800 mg/l of total dissolved solids (TDS), while in other areas it is very saline to briny, with TDS concentrations over 30,000 mg/l (Holmes and Kimball, 1987; Dyni, 1996). A more thorough understanding is needed of the extent and nature of these different salinity zones and the barriers between them (e.g. gilsonite veins, non-fractured intervals, etc.). Also, the Bird's-nest is exposed in outcrop, but is poorly mapped (Figure 3). Our study will address whether saline water disposed of into the Bird's-nest aquifer by nearby natural gas operators could migrate to the outcrop and contaminate creeks and streams. Even the areal extent of the Bird's-nest and its lateral continuity, especially to the north and west, is poorly understood (Dyni, 1996).

Utah's oil shale deposits are also located within the Parachute Creek Member of the Green River Formation. The Bird's-nest aquifer is typically several hundred feet above the richest oil shale interval called the Mahogany zone (Figure 4). A significant concern is that saline water disposal into the

Figure 3. Bird's-nest aquifer as exposed in outcrop, Evacuation Creek, Uintah County, Utah. This aquifer lies several hundred feet above the richest oil shale unit.

Bird's-nest by conventional gas producers may hinder oil shale development by creating unforeseen economic and technical hurdles. In many areas containing rich oil shale deposits, the Bird's-nest contains fresh to slightly saline water (Holmes and Kimball, 1987). With increased saline water disposal, the quality of the water in the Bird's-nest could degrade and create additional water disposal problems for oil shale development companies.

In addition to the water-related problems mentioned above, there is a regulatory need for baseline water quality and quantity data for lands proposed for oil shale development. Water-quality degradation could result from new oil shale developments, via mining and surface retort or *in-situ* processes. Historic paper-based data needs to be gathered and combined with new data into a GIS database that will facilitate overall data analysis and manipulation by developers and regulators. This database would provide the baseline water information needed to understand potential impacts of future oil shale development.

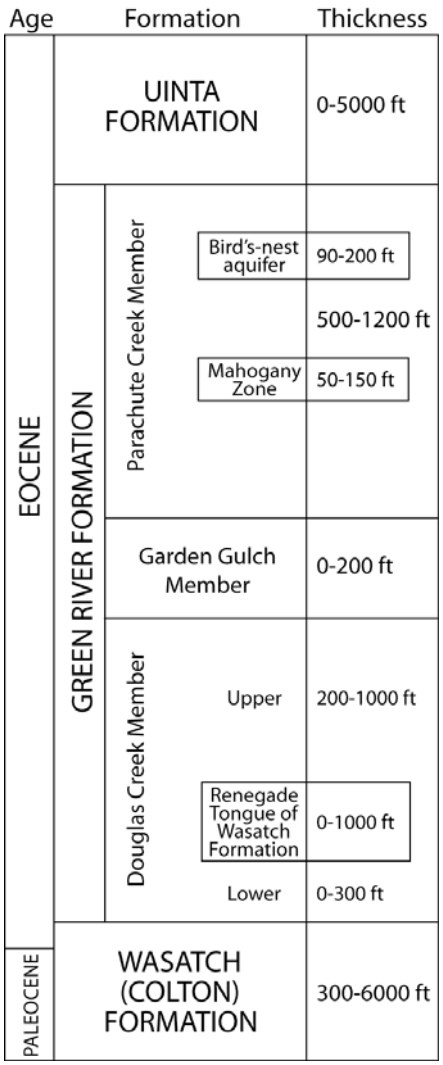

Figure 4. Generalized stratigraphic section of the formations of Eocene age located in the Uinta Basin, Utah. (modified from Lindskov and Kimball, 1984 and Hintze, 1993)

Finally, the impacts on underground aquifers from *in-situ* oil shale extraction techniques need to be fully investigated before any technologies are implemented in the field. The chemistry of the produced water from *in-situ* processes is poorly understood, as is the potential impact this water could have on nearby aquifers. The proposed laboratory pyrolysis experiments and reservoir modeling should generate the data needed to determine the environmental effects of *in-situ* retort technologies.

1.3 Proposed Solution

In order for significant increases in oil and natural gas production to take place in the Uinta Basin, a solution to the growing saline water disposal problem must be found. By re-mapping the base of the moderately saline aquifer using more robust data and more sophisticated GIS techniques, regulators will have the information needed to more expeditiously grant water disposal permits while still protecting fresh water resources. The water chemistry data that will be used to create a more accurate GIS map will come mostly from down-hole water quality information provided by operators and other governmental agencies. This ground-truth data will be supplemented with water chemistry information calculated from geophysical logs, recognizing certain limitations. In addition to the new GIS-based map, operators and regulators alike will benefit from new cross sections showing the stratigraphic position of the moderately saline to very saline transition and its relationship to potential seals and disposal zones in the Uinta Basin.

Secondly, our proposed geologic investigation of the Bird's-nest aquifer will determine its suitability as a saline water disposal interval for conventional gas producers. By examining this aquifer in outcrop, cores, and on geophysical logs, we will gain a better understanding of its areal extent, thickness, zones of differing water chemistry, and why some areas are confined while others are unconfined. We will also examine the potential impacts of saline water disposal by petroleum operators on future oil shale development.

Thirdly, we will develop an integrated regional baseline water quality and quantity database to provide water management solutions for lands identified by the BLM as having potential for future oil shale development. This study will identify 50 sample sites from wells, springs, and creeks for water quality testing including general chemistry, nutrients, dissolved oxygen, dissolved metals, volatile organic compounds, and total organic carbon. Samples will be taken each of the three years to determine possible annual changes.

Finally, we will conduct varying pyrolysis experiments on Utah's oil shale to simulate thermal treatments similar to planned *in-situ* oil shale extraction techniques and study the chemistry of the resultant produced water. We will then investigate the transfer of the determined species from the

productive zone to adjacent aquifers and beyond using computer simulations. These studies will help determine generated constituents from process-specific *in-situ* oil shale technologies and help evaluate best available control technologies that will help avoid impacts on the non-saline aquifers of the Uinta Basin.

1.4 Likelihood of Success

Several oil and gas companies operating in the Uinta Basin have already committed to supplying water chemistry data to aid in the re-mapping the base of the moderately saline aquifer. For example, Anadarko Petroleum Corp. has already provided water chemistry data for 129 wells in the Natural Buttes gas field. Also, several governmental agencies, including the EPA, DOGM, and U.S. Geological Survey (USGS) have expressed their willingness to supply data and expertise (a list of companies and agencies willing to support this study, along with letters of their support are included in an Appendix). This multidisciplinary support, as well as the extensive expertise of the UGS and the task leader, will ensure the success and timeliness of this part of the study.

Similar to the task mentioned above, many oil and gas operators located in the eastern Uinta Basin have committed to share data about the Bird's-nest aquifer as encountered in their production wells. This information will particularly help define the aquifer's poorly understood areal extent, lateral continuity, and its northern and western boundaries. Also, UGS geologists have extensive experience working in Utah, analyzing surface exposures, and studying core. This expertise will ensure a thorough investigation of the Bird's-nest and result in an improved understanding of its hydrologic framework, as well as a modern GIS-based database, that could be used to determine responsible saline water disposal.

The likelihood of success of creating a regional baseline water quality and quantity database for the lands with oil shale development potential is excellent because UGS geologists have performed similar studies in other locations throughout the state. The ground-water section of UGS has developed a proven methodology and maintains the expertise, knowledge, qualifications, and resources to successfully complete the objectives of this part of the project.

Finally, the likelihood of achieving the objectives to the final area of study, *in-situ* oil shale extraction modeling, is also excellent. The UGS has a range of oil shale core available for study, the reactors for the pyrolysis experiments are already built and tested, and the techniques for analyzing the produced water and hydrocarbons are standard and proven. In addition, the research group at the University of Utah has extensive research experience in simulating subsurface multiphase transport.

1.5 Relevance to the Announcement Objectives

This project will specifically address all or part of Topic Areas 1.1 and 1.2 as described in the Funding Opportunity Announcement (FOA). We propose to study environmental and regulatory concerns that might limit conventional oil and gas operators' options for managing produced water (Area 1.1, part 3). The main hindrance to increased oil and natural gas production in the Uinta Basin is the increased need to dispose of saline water into underground aquifers. Our proposal to use GIS technology to re-map the base of the moderately saline aquifer will provide regulatory agencies, both DOGM and EPA, with the information needed to more confidently and efficiently permit additional saline water disposal wells without adversely affecting culinary water sources. Also, our study of the Bird's-nest aquifer will determine its potential as a site for disposal of produced saline water from conventional gas production and any adverse effects on future oil shale development.

We also propose to develop an integrated regional baseline for surface- and ground-water quality and quantity data, delivered as a GIS-based product for easy analysis and data manipulation (Area 1.2, part 1). This basin-wide study will be vital to future oil shale development companies looking to produce oil from Utah's vast oil shale deposits. Finally, we will perform laboratory tests and create computer models to determine generated constituents and their resultant transport from process-specific *in-situ* oil shale extraction technologies for evaluation of best available control technology (Area 1.2, part 2).

1.6 Expected Impacts and Benefits

Combined together, each successful part of this multi-faceted study will provide the information needed to achieve our two goals: alleviating problems associated with produced water as a means to facilitate increased conventional hydrocarbon production and resolving environmental barriers to possible oil shale development.

Using GIS to map the base of the moderately saline aquifer in the Uinta Basin will help both regulators and oil and gas operators make improved saline water disposal management decisions and protect fresh water resources. If new, appropriate saline water disposal intervals can be identified, like the Bird's-nest aquifer, oil and natural gas production can continue to increase, supplying the nation's growing demand with safe, domestic resources.

In order to develop environmentally sound water management solutions for a future oil shale industry, we need to assess the sensitivity of the alluvial and bedrock aquifers on lands proposed by the BLM as having oil shale development potential. Our proposed regional baseline water study will provide GIS-based information to help local planners and potential developers to preserve the quality of ground and surface water by establishing best management practices through careful land-use planning.

Finally, the modeling of *in-situ* production of oil shale will determine its relationship to potential water transport and disposal in the basin. If significant quantities of water are produced along with shale oil, the concentrations of organic and inorganic constituents in this water will be important in determining what special handling procedures will be needed.

2. TECHNICAL APPROACH

2.1 Detailed Statement of Project Objectives

Title: ***Water-related issues affecting conventional oil and gas recovery and potential oil shale development in the Uinta Basin, Utah***

2.1.1 Objectives

The overall objectives of this multi-faceted, three-year study of water issues affecting conventional oil and gas recovery and possible oil shale development in the Uinta Basin, Utah are to (1) re-map the base of the moderately saline water aquifer in order to better facilitate water disposal permitting and protect fresh water resources, (2) create new geologic cross sections displaying the stratigraphic position of the base of the moderately saline water and identify potential seals and disposal intervals, (3) study the spatial and stratigraphic extent of the Bird's-nest aquifer to determine the possible impacts of saline water disposal on future oil shale development, (4) create a baseline water quality and quantity GIS database for lands in the Uinta Basin identified by the BLM as having oil shale development potential, (5) perform laboratory experiments simulating process-specific *in-situ* oil shale extraction technologies to determine chemistry of produced water, (6) perform computer modeling showing the transfer of produced *in-situ* products to adjacent water aquifers and beyond, and (7) make all results available to regulatory agencies, the petroleum industry, and oil shale development companies through a proven technology transfer plan.

2.1.2 Scope of Work

All project objectives will be achieved simultaneously during the three-year project, each headed by a qualified task leader. Project management tasks (Tasks 1 and 2) will be completed by the Principal Investigator (PI) as outlined in the FOA. Each research task (Tasks 3, 4, 5, and 6) is separated into subtasks generally consisting of (1) historic data collection, (2) gathering of new data, (3) interpretation of data, and (4) creation of final reports stating study results and recommendations. The final task (Task 7), technology transfer, will be performed by all members of the research team throughout the duration of the project.

2.1.3 Tasks to be Performed

Task 1.0: Project Management Plan *(Year 1-3)*

1.1 The UGS shall work with the Department of Energy (DOE) Project Officer to modify and

update the Project Management Plan (PMP) submitted as part of the original application package, as necessary. A revised PMP shall be submitted within 30 days of the award. Within 15 calendar days after receipt of the DOE's comments, the UGS shall submit a final PMP to the DOE Project Officer for review and approval. The UGS shall negotiate the final contract with DOE in consultation with other team members, including partners/subcontractors. *(Year 1)*

1.2 The UGS will be responsible for ensuring that all required technical and financial reports are prepared and delivered to DOE as stated in the final contract. *(Year 1-3)*

Task 2.0: Technology Status Assessment *(Year 1)*

2.1 The UGS will perform a Technology Status Assessment and submit a summary report describing the current state of information and/or technology relevant to the proposed work. This report, not exceeding five typewritten pages, shall include both positive and negative aspects of each existing approach or technology. The report will not contain any proprietary or confidential data, as it will be posted on the NETL website for public viewing. The report shall be submitted within 60 days of the award. Within 15 calendar days after receipt of DOE's comments, the UGS will submit a final report to the DOE Project Officer for review and approval. *(Year 1)*

Task 3.0: Moderately Saline Aquifer Study *(Year 1-3)*

3.1 Create a GIS-database with all available down-hole water quality data for the Uinta Basin, Utah. Select suitable geophysical logs in areas lacking water quality data and calculate salinity using appropriate equations, creating digitized log files as necessary. *(Year 1-2)*

3.2 Use GIS methods to re-map the base of the moderately saline aquifer in the Uinta Basin, Utah. Mapping will cover the same area as mapped previously and shown in Plates 1 and 2, from Technical Publication 92, 1987,"*Base of the moderately saline ground water in the Uinta Basin,*

Utah, with an introductory section describing the methods used in determining its position" by Lewis Howells and others. *(Year 3)*

3.3 Develop new geologic cross sections showing the stratigraphic position of the transition from the moderately saline to very saline aquifer. At least two such cross sections will be created, one trending in a general north-south direction and a second in a general east-west direction. Additional sections may be generated, as the budget permits, or where more detail of the complex 3-D nature of this boundary is desirable. Important seals and potential disposal aquifers will be identified on the cross sections. *(Year 3)*

3.4 Evaluate the changes in the elevation of the base of the moderately saline aquifer between the 1987 study and the new mapping. *(Year 3)*

3.5 Write a report to document the methods, frame the geologic context, and describe the results. The report will address any regional or important local aquifer seals and potential disposal zones. The disposal zones will be based on technical feasibility without consideration of possible regulatory constraints. *(Year 3)*

Task 4.0: Geologic Examination of the Bird's-nest Aquifer *(Year 1-3)*

4.1 Compile a bibliography of published data on the Bird's-nest aquifer and surrounding stratigraphic units. *(Year 1)*

4.2 Evaluate cores from wells that captured the Bird's-nest interval both at the UGS-operated Utah Core Research Center (at least three cores are available) located in Salt Lake City, UT and the USGS's Core Research Center (at least 5 cores are available) in Denver, CO. *(Year 1)*

4.3 Map in detail the outcrop expression of the Bird's-nest aquifer in Uintah County, Utah. This will include analysis of the lithology, porosity structures, fracture density, surrounding rock types, and overall thickness. *(Year 1-2)*

4.4 Create a GIS well database identifying the top of the Bird's-nest and its thickness, as well as water quality and quantity information. *(Year 1-2)*

4.5 Create a detailed GIS geologic map showing the areal extent of the Bird's-nest aquifer, changes in water chemistry, outcrop locations, and thickness. *(Year 3)*

4.6 Prepare a report describing in detail the geology of the Bird's-nest aquifer and the possible affects of using this interval as a potential saline water disposal zone. *(Year 3)*

Task 5.0: Baseline Water Quality and Quantity GIS Database *(Year 1-3)*

5.1 Conduct a well inventory, compiling and digitizing maps and previous water quality and quantity data on lands identified by the BLM as having potential for future oil shale development in the Uinta Basin, Utah. *(Year 1)*

5.2 Create a current water quality assurance project plan that identifies 50 sample sites for water quality sampling from wells, creeks, and springs. Initial samples will be taken within the first six months of the project, with follow-up sampling in years two and three. *(Year 1-3)*

5.3 Generate a suite of water quality analyses including general chemistry (including total dissolved solids), nutrients (including nitrate-nitrogen, nitrite-nitrogen, phosphorous, and ammonia), dissolved oxygen, dissolved metals, volatile organic compounds (including benzene), and total organic carbon. *(Year 1-3)*

5.4 Prepare a final report and GIS database summarizing water quality information. Produce chemistry compilation maps, analyze various chemical constituents through graphs and statistics, and estimate baseline water quantity. *(Year 3)*

Task 6.0: Analysis of Produced Water from Simulated *In-situ* Oil Shale Extraction Technologies *(Year 1-3)*

6.1 Perform varying pyrolysis experiments on Utah oil shale at temperatures ranging from 300º C to 500º C to simulate thermal treatments similar to planned process-specific *in-situ* oil shale extraction technologies. *(Year 1)*

6.2 Analyze the different compositions of water generated during simulated *in-situ* extraction using a gas chromatograph-mass spectrometer and an Inductively Coupled Plasma Mass Spectrometer (ICP-MS). *(Year 2)*

6.3 Model the transfer of the determined species in the oil and water phase from the productive zone to adjacent water aquifers and beyond. *(Year 3)*

6.4 Prepare final report(s) discussing conclusions and offering recommendations. *(Year 2-3)*

Task 7.0: Technology Transfer *(Year 1-3)*

The technology transfer will consist of, but not be limited, to the following subtasks:

7.1 Webpage: The UGS will maintain a Web site dedicated to the project displaying project news, results, and reports. *(Year 1-3)*

7.2 Industry Outreach: The UGS will email quarterly project updates to all companies and institutions that provide a letter of support, and to any other interested party. The UGS will also hold an annual debriefing meeting in Vernal, UT for all interested parties: conventional oil and gas operators, oil shale companies, governmental agencies, research institutions, and the general public. In addition, the UGS Industry Outreach Geologist will set up technical displays at two major industry conventions: regional and national meetings of the American Association of Petroleum Geologists (AAPG). *(Year 1-3)*

7.3 Technical Presentations: Members of the project may give oral or poster presentations at AAPG conventions, the annual Oil Shale Symposium, or other appropriate local, regional, and national technical meetings. *(Year 1-3)*

7.4 Publications: The UGS will report all aspects of the project in a series of formal publications. *(Year 2-3)*

2.1.4 Deliverables

The UGS shall submit the periodic, topical, and final reports in accordance with the Federal Assistance Reporting Checklist and the instructions accompanying the checklist. The UGS will be responsible for completing and submitting Progress Reports, Special Status Reports, Final Reports including any conference papers and proceedings, and all Financial Status Reports.

The UGS or specified subcontractors shall also provide specific deliverables listed below for each task:

Task 1.0: Project Management Plan

- Project Management Plan as specified in the FOA.
- Progress Reports, Special Status Reports, and Final Reports as specified in the Federal Assistance Reporting Checklist.

Task 2.0: Technology Status Assessment

- Technology Status Assessment report as specified in the FOA.

Task 3.0: Moderately Saline Aquifer Study

- Final published report documenting the methods, geologic context, and results of the study. Other deliverables include:
    - New, fully digital map of the base of the moderately saline aquifer in the Uinta Basin, Utah.
    - A database with all relevant water chemistry and log calculation data, as well as general well information used in mapping the boundary.
    - At least two new color cross sections, one north-south and one east-west, showing the major geologic units, the boundary(s) between moderately saline and very saline water, and possible seals and disposal zones.
    - A digital map showing the difference over time of the base of the moderately saline aquifer.

Task 4.0: Geologic Examination of the Bird's-nest Aquifer

- Final published report describing the geology of the Bird's-nest aquifer and the possible affects of using this interval as a potential saline water disposal zone. Other deliverables include:
    - A complete bibliography of previously published data on the Bird's-nest aquifer.
    - Fully digital GIS map showing the outcrop expression of the Bird's-nest, the areal extent, changes in water chemistry, and thickness.
    - A GIS database listing basic well information, the top of the Bird's-nest and its thickness, as well as water quality and quantity information.
    - Stratigraphic columns prepared by studying outcrop and cores.

Task 5.0: Baseline Water Quality and Quantity GIS Database

- Final published report summarizing water quality information and estimating baseline water quantity. Other deliverables include:
    - A GIS database of previous water quality and quantity information.
    - A GIS database showing results of new water chemistry analyses.
    - Chemistry compilation maps and graphs.

Task 6.0: Analysis of Produced Water from Simulated *In-situ* Oil Shale Extraction Technologies

- A final report discussing the concentrations of hydrocarbons in the aqueous phase generated from oil shale under various simulated process-specific *in-situ* reacting conditions.
- A final report discussing the possible impact of *in-situ* pyrolysis of oil shale on hydrocarbon products on adjacent water aquifers and beyond.

Task 7.0: Technology Transfer

- In addition to the series of published reports described above, other technical transfer deliverables will include:

- A website dedicated to the project displaying project news, results, and reports.
- Quarterly emails detailing project updates to companies, institutions, and all other interested parties.
- An annual debriefing meeting in Vernal, UT for all interested parties discussing project progress and results.
- Technical displays set up at major industry conventions, such as AAPG (as part of the UGS exhibit booth), describing the project and highlighting results and progress.
- Technical presentations, both oral and poster, delivered at AAPG conventions, annual Oil Shale Symposiums, and/or other local, regional, and national technical meetings.

2.1.5 Briefings/Technical Presentations

The PI shall prepare detailed briefings to the Project Officer explaining the plans, progress, and results of the technical effort on an annual basis. This meeting shall take place at the Project Officer's facility located in Pittsburgh, PA or Morgantown, WV, or an agreed upon alternative. DOE may substitute attendance of meetings at NETL with UGS participation in external project/merit reviews.

The PI shall provide and present a technical paper at the DOE/NETL Annual Contractor's Review Meeting held at the NETL facility located in Pittsburgh, PA or Morgantown, WV, or at an alternate location mutually agreed upon by the NETL Project Officer and the UGS.

2.2 Labor Hours and Categories

Table 1 provides estimated labor hours and labor categories, including subcontractors, required for each task by year.

Table 1. List of estimated labor hours.

	Description	Key Personnel	General Labor Category	Fed FY 2009	Fed FY 2010	Fed FY 2011
				Year 1	Year 2	Year 3
Task 1	Project Management Plan	**M. Vanden Berg (Task Leader)**	PI/Geologist	200	200	200
		D. Tabet	Geologist/Manager	40	40	40

Task 2	Technology Status Assessment	**M. Vanden Berg (Task Leader)**	PI/Geologist	40	0	0
Task 3	Moderately Saline Aquifer Study	**P. Anderson (Task Leader)**	Consulting Geologist	1000	1000	1000
		C. Morgan	Geologist	80	80	80
		A. McDonald	Geotech	360	360	360
		S. Heuscher	GIS	0	0	160
Task 4	Geologic Examination of Bird's-nest Aquifer	**M. Vanden Berg (Task Leader)**	PI/Geologist	300	300	300
		C. Morgan	Geologist	300	300	200
		S. Carney	Geologist	300	300	200
		M. Laine	Geologist/Curator	40	0	0
		T. Dempster	Geotech	40	0	0
		A. McDonald	Geotech	280	280	280
		S. Heuscher	GIS	80	80	100
Task 5	Baseline Water Quality and Quantity GIS Database	**J. Wallace (Task Leader)**	Geologist	560	360	360
		M. Lowe	Geologist/Manager	60	40	40
		R. Emerson	GIS	200	100	100
		K. Nay	Geotech	200	100	100
Task 6	Analysis of Produced Water from Simulated *In-situ* Oil Shale Extraction Technologies	**M. Deo (Task Leader)**	Professor, University of Utah	60	60	60
		Graduate student(s)	Student(s), University of Utah	960	960	960
Task 7	Technology Transfer	**R. Bon (Task Leader)**	Outreach Geologist	100	100	100
		M. Vanden Berg	PI/Geologist	80	80	120
		C. Morgan	Geologist	40	40	40
		S. Carney	Geologist	40	40	40
		J. Wallace	Geologist	40	40	40

2.3 Proposed Travel

Task 1.0: Project Management Plan

- The PI will travel from Salt Lake City, UT to either Pittsburgh, PA or Morgantown, WV (or alternate) each year to update DOE on project plans, progress, and results. Trip duration is estimated to be approximately four days.
- The PI will travel from Salt Lake City, UT to either Pittsburgh, PA or Morgantown, WV (or alternate) each year to present a technical paper at the DOE/NETL Annual Contractor's Review Meeting. Trip duration is estimated to be approximately four days.

Task 4.0: Geologic Examination of the Bird's-nest Aquifer

- Two members of the research team for Task 4 will travel from Salt Lake City, UT to the Uinta Basin to study outcrop sections of the Bird's-nest aquifer. Two trips are planned for each of the first two years of the project, each scheduled to be five days in length for a total of 20 days.

- Two members of the research team for Task 4 will travel from Salt Lake City, UT to Denver, CO to examine the Bird's-nest in core samples at the U.S. Geological Survey's Core Research Center. This trip will take place in the first year and be three days in length. This trip could possibly be combined with the trip to Denver for the 2009 AAPG annual convention.

Task 5.0: Baseline Water Quality and Quantity GIS Database

- J. Wallace (leader for Task 5) will travel from Salt Lake City, UT to the Uinta Basin to sample water from wells, springs, and streams for chemical analysis. Four separate trips will be made in the first year, each estimated to be five days long. These trips are needed to scout potential water collecting sites over the very large study area. Three separate trips, each four days in length, will be needed in both years two and three for follow-up sampling.

Task 7.0: Technology Transfer

- The PI and various task leaders will travel from Salt Lake City to Vernal, UT each year in the fall to present project progress and results to all interested oil and gas operators, oil shale companies, governmental agencies, research institutions, and the general public. These annual debriefing meetings will be one-day trips.
- Project results, plans, and objectives will be displayed at the UGS exhibit booth during AAPG annual national and regional conventions. The AAPG annual conventions for 2009, 2010, and 2011 will be in the following cities, respectively: Denver, CO; New Orleans, LA; and Houston, TX. The AAPG Rocky Mountain Section regional meetings for 2010 and 2011 will be in the following cities: Durango, CO and Casper, WY, respectively (the 2009 regional meeting will be held in conjunction with the national meeting in Denver). At least two key personnel will travel to the meeting venues and staff the exhibit booth, answer questions about the project, and present project results (if abstracts are accepted) at a technical session.

- Project results, plans, and objectives will also be presented at the annual Oil Shale Symposium, in both 2010 and 2011, held at the Colorado School of Mines in Golden, CO.

2.4 Technology Transfer Plan

The UGS already carries out an aggressive technology transfer and marketing campaign to promote prudent development of Utah's energy resources. The UGS displays recent petroleum-related research at regional and national technical meetings with UGS scientists staffing the display. The UGS maintains a Web page for each of its major petroleum-related research projects. As a result, UGS receives and responds to hundreds of inquires annually for further information.

The specific components of the technology transfer plan (Task 7) for the proposed project are as follows:

Sub Task 7.1. The UGS will maintain a Web page, dedicated to the project (the UGS currently maintains Web pages for current and past DOE projects). The web page will have a list containing e-mail addresses of personnel involved in the project. A description of the study and objectives will be posted, as well as quarterly and annual reports, announcements of activities, and press releases. The project Web page will provide instant access to information about the project, the latest results, and eventually the release of final publications.

Sub Task 7.2. The UGS Industry Outreach Geologist (IOG) will set up technical displays at the annual national AAPG convention each year as part of the UGS Industry Outreach Program. The IOG will also compile and maintain a contact list of people and companies interested in the project and provide them with technical progress reports, the UGS news magazine *Survey Notes*, and press releases. The Industry Outreach Program will ensure that people and companies interested in the project are aware of ongoing developments, significant activities, and other information exchange opportunities. In addition, the PI will set-up annual debriefing meetings in Vernal, UT for all interested companies and governmental agencies that would like to learn about

the projects progress and results. The UGS has successfully operated this outreach program for other grants for over 15 years.

Sub Task 7.3. Technical talks and poster displays will be submitted to the Rocky Mountain Section and national AAPG meetings and the Colorado School of Mines' annual Oil Shale Symposium. Additionally, presentations may be given at local and regional geologic and engineering societies. Technical presentations ensure that attendees interested in the project will have the latest information, results, and recommendations to apply to fields they operate or areas they explore.

Sub Task 7.4. The UGS will submit for publication the findings of the research in regional and national journals as well as regional and local geologic guidebooks. The bulk of the research and data derived from the research will be submitted to the UGS for publication on CD or DVD. The CD/DVD publication allows for extensive material to be presented at a low cost. Text, figures, plates, maps, cross sections, and data tables will be available in Adobe Acrobat (pdf) format. The CD/DVD publication will also contain data tables in .xls or .dbf format and GIS shape files.

3. TECHNICAL AND MANAGEMENT CAPABILITIES

3.1 Organizational Capabilities and Experience

Utah Geological Survey. The UGS, one of eight divisions of the Utah Department of Natural Resources (DNR), was established in 1931 to survey the geology and energy and mineral resources of the state. The UGS is empowered to undertake cooperative efforts with government and quasi-government agencies, academic institutions, private companies, and individuals in order to carry out its duties. Support staff to geologists include: geotechs, secretaries, cartographers, graphic artists, sample curator, and log librarian. The UGS geologic support staff, access to data, sample storage facilities, as well as computer and editorial capabilities will be applied to the completion of the technical research and tech-transfer tasks.

The Energy and Minerals (E&M) Program of the UGS is, or has been, the Principal Investigator and prime contractor for eight DOE petroleum research projects (Class I, Class II, Class II Revisit, Fundamental Geoscience for Reservoir Characterization, Geoscience/Engineering Reservoir Characterization, PUMPII, Advanced & Key Oilfield Technologies for Independents programs, and Unconventional Onshore Program). The UGS also funds companies, consultants, and universities doing oil and gas research. The UGS program *Characterization of Utah's Hydrocarbon Reservoirs and Potential New Reserves* has funded 18 oil and gas research projects since it began in 2004.

The E&M Program of UGS also conducts extensive oil shale research in conjunction with the USGS, BLM, and the State of Utah School and Institutional Trust Lands Administration. This research focuses on a re-assessment of Utah's oil shale resource with the creation of new richness and thickness maps and revised resource calculations. The UGS also works cooperatively with several university labs (e.g., University of Utah, Brown University) and private companies (e.g., TerraTek, a Schulumberger Company) researching other aspects of oil shale including *in-situ* extraction modeling, physical property analyses, and paleoclimatic interpretations. The UGS-operated Utah Core Research Center also has a large supply of oil shale core available for research.

The Ground-Water and Paleontology Program of the UGS has successfully been involved in other ground-water quality projects within Utah funded by the EPA, Utah's Permanent Community Impact Fund Board, various water conservancy agencies, and other Utah state entities. Some examples in rural Utah for which UGS has received federal funding include: Morgan Valley, Morgan County and Castle Valley, Grand County. The ground-water section of the Ground-Water and Paleontology Program has been involved in 10 similar projects over the past 12 years. They have successfully passed each petition before the Utah Water Quality Board and have received accolades based on presentations of their data and maps at local public hearings and national scientific conferences. In fact, many projects were instigated by local residents who sought UGS expertise to perform ground-water studies in their communities.

Paul Anderson, Consulting Geologist. Mr. Anderson has managed seven people in his position of Manager of Permitting and Regulatory Affairs with Eureka Energy Company. He served as the General

Chairman of the Rocky Mountain Section of the AAPG from 2004 to 2007, organizing and executing a successful meeting with a $180,000 budget. The meeting met the profit expectations of the organization. He has successfully worked for years with clients and organizations, meeting budgets and staying on schedule. Mr. Anderson has worked on a previous DOE-funded study with the UGS and met the required deliverables and schedule.

University of Utah, Petroleum Research Center. The University of Utah is a Research I university with the College of Engineering managing about $50 million in research. The Petroleum Research Center, located in the Department of Chemical Engineering, is particularly strong in energy-related research focusing on petroleum production and processing.

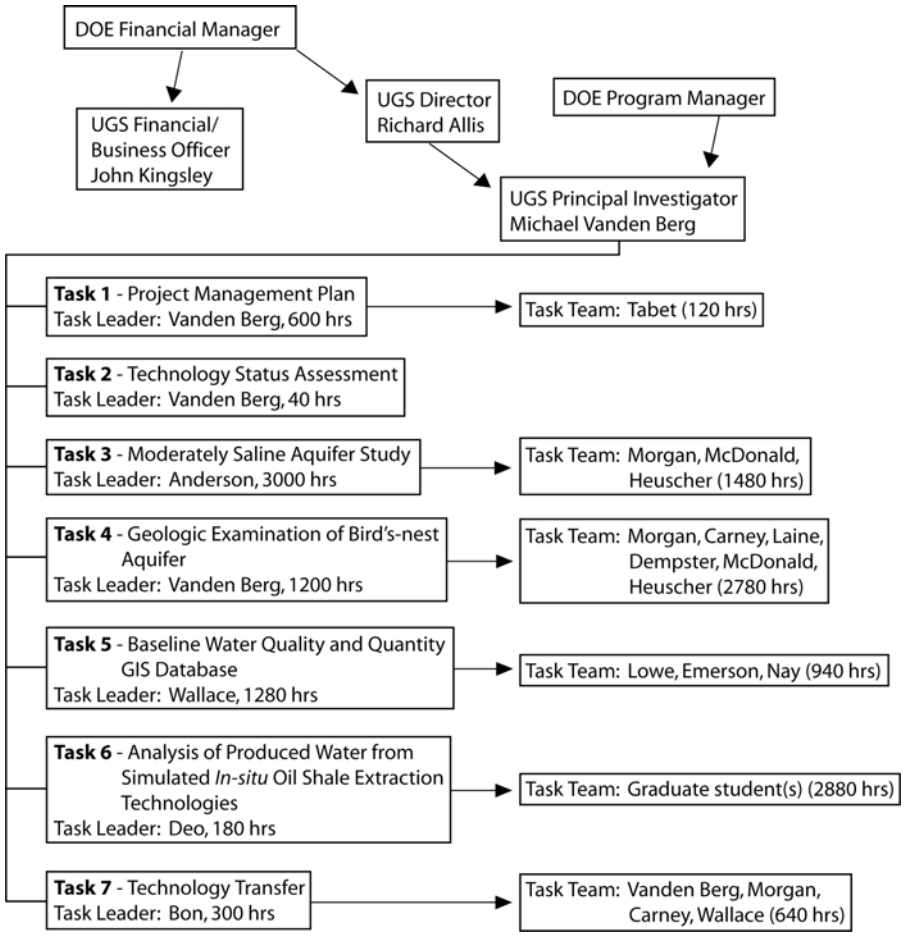

Figure 5. Organizational chart depicting the project team structure, including task leaders and task team hours. See Table 1 for breakdown of individual team member's time.

An organizational chart depicting the project team structure that will be used to manage the study is shown in Figure 5. The PI directly reports to the UGS Director and will be responsible for the oversight of the entire project. Task leaders report to the PI and are responsible for all activities and deliverables associated with their tasks. The task leaders were determined according to their expertise and role in the project. The UGS Associate Director will serve as Business Coordinator and will be responsible for ensuring that DOE budget requirements are met.

3.2 Qualifications of Key Personnel

Michael D. Vanden Berg is a Project Geologist working in the Energy and Minerals Program of the UGS. He is the principal investigator for all UGS studies concerning Utah's vast oil shale deposits including a statewide resource assessment and an analysis of oil shale physical properties. He is also a collaborator on other oil shale projects including *in-situ* laboratory simulations and Green River Formation paleoclimatic studies. In addition to work on oil shale, Vanden Berg has conducted field investigations as part of the DOE-funded grant *The Mississippian Leadville Limestone Exploration Play, Utah and Colorado: Exploration Techniques for Independents* and as part of the CO_2 sequestration field demonstration at the Aneth oil field in southeastern Utah, funded by DOE through the Southwest Regional Partnership for Carbon Sequestration. Vanden Berg also writes several energy-related publications for UGS and the Utah legislature, including the Annual Utah Coal Report, and participates on several energy-related legislative committees. Vanden Berg will serve as the project Principal Investigator and Manager, Task Leader of Tasks 1, 2, and 4, as well as a member of the geologic technical team performing Task 7, Technology Transfer. He will devote 30% of his time to the project.

Paul B. Anderson has over 35 years of geologic experience that has varied from hydrogeology to hydrocarbon exploration and development. Anderson has worked in coal exploration and permitting with responsibilities for ground-water studies and monitoring. Work with a small, utility-based oil and gas exploration company provided training and experience in geophysical log interpretation. Anderson's

consulting activities include 3-D ground-water modeling, ground-water research related to environmental problems, and various resource development projects. He has also been responsible for obtaining underground injection permits and has worked on a multi-year reservoir characterization project as a contractor for UGS on a previous DOE grant. Involvement in coalbed methane projects in the Uinta Basin has required his careful examination of produced water disposal issues. Anderson has published with the UGS on the geology of the Mesaverde Group in the Uinta Basin and is currently working with clients involved in Uinta Basin exploration and development. Anderson will serve as Task Leader for Task 3 and will devote roughly 50% of his time to the project.

Janae Wallace, a Project Geologist with the UGS, will be the UGS Task Leader for the water quality component (Task 5) of the study and has the necessary expertise, knowledge, qualifications, and resources to successfully complete the project's goals. Wallace has been involved in 10 similar water quality projects within Utah over the past 12 years funded by the EPA, Utah's Permanent Community Impact Fund Board, various water conservancy agencies, and other Utah state entities. Some areas of study in rural Utah for which federal funding was awarded include: Morgan Valley in Morgan County and Castle Valley in Grand County. For each of these valleys, Wallace collected and analyzed on average 50 ground-water samples for chemistry, generated total-dissolved-solids-concentration, ground-water classification, potential-contaminant source maps, created a written petition to classify ground water, and presented the study to the Utah Water Quality Board. For a baseline water quality project in Delta, Utah, Wallace was responsible for the supervision of water-well installation, sited strategically to gain information on existing ground-water quality prior to the establishment of an egg-farm manufacturer. Wallace is a licensed ground-water and soil sampler and certified soil evaluation and percolation tester for onsite wastewater systems. Wallace will serve as Task Leader for Task 5, as well as a member of the geologic technical team performing Task 7, Technology Transfer. She will devote approximately 22% of her time to the project.

Milind D. Deo, Professor of chemical engineering at the University of Utah, has over 20 years experience in all aspects of oil and gas characterization, production, and processing. Some examples of

his project experience include: performed thermal reservoir simulations as part of the DOE funded *Reactivating an Idle Lease on the ARCO PRU Property in the Midway Sunset Field* with ARCO Western Energy and AERA LLC (this project was selected as one of the best in the Pacific Region by Hart Oil and Gas News and was recognized by DOE), researched asphaltene problems in carbon dioxide floods and proposed solutions as part of the DOE funded project *Enhancing the Effectiveness of Carbon Dioxide Floods by Managing Asphaltene Precipitation,* and is currently the PI on oil shale and oil sand projects through the University of Utah Heavy Oil program. Deo will serve as Task Leader for Task 6 and will devote roughly 3% of his time to the project. In addition, one or more graduate students working under Deo's supervision will spend 960 hours per year on Task 6.

Craig D. Morgan is a Senior Petroleum Geologist with the UGS. He worked 10 years with Celsius Energy Company and one year with UV Industries as an exploration geologist, and two years with Tooke Engineering as a well site mudlogger and geologist. He was project manager for a DOE Class I project entitled *Increased Oil Production and Reserves from Improved Completion Techniques in the Bluebell Field, Uinta Basin, Utah,* and the DOE Fundamental Geoscience for Reservoir Characterization project *Reservoir Characterization of the Lower Green River Formation, Southwest Uinta Basin, Utah*. He has been a major contributor to UGS/DOE Class II, Class III, and PUMP II projects. He is the project manager for the UGS program *Characterization of Utah's Hydrocarbon Reservoirs and Potential New Reserves* that has funded 18 oil and gas research projects since it began in 2004. Morgan will serve as a member of the geologic technical team performing Tasks 3, 4, and 7. He will devote approximately 20% of his time to the project.

Stephanie Carney is a Petroleum Geologist with the Utah Geological Survey. She has worked three years with UF3 LLC Geological Consultants as a staff geologist before joining the UGS in June of 2006. Major projects with the UGS include: (1) working with the Southwest Partnership for Carbon Sequestration on the field demonstration site at Aneth oil field, Utah, providing subsurface and surface geologic mapping and structural analysis of the demonstration site; and (2) a collaborative study titled *Surface to Subsurface Reservoir Characteristics and Facies Analysis of the Jurassic Navajo Sandstone,*

Central Utah with Brigham Young University as part of the UGS Mineral Lease Grant Program. Carney will serve as a member of the geologic technical team performing Tasks 4 and 7. She will devote roughly 15% of her time to the project.

Roger L. Bon is the Industry Outreach Geologist at the UGS where he has coordinated information exchange between the state and the energy and mineral industries since 1989. He spent 20 years in coal exploration across western North America previously. Bon has organized and presented exhibits at over 20 professional and national geologic conventions. He has been general chairman of oil and gas symposiums for the Uinta Basin (1992) and Paradox Basin (1996), and published oil field studies on the Uncompahgre uplift and thrust belt oil plays. Bon will serve as the Task Leader for Task 7, Technology Transfer. He will devote 5% of his time to the project.

3.3 Quality and Suitability of Facilities, Equipment, and Materials

Utah Geological Survey. UGS moved into new facilities on the DNR campus in 1996. These facilities provide more efficient space and allow for closer working relationships with other divisions such as the Utah Division of Water Resources and the Utah Division of Oil, Gas and Mining (DOGM), the latter being a regulatory agency. There are over 19,000 square feet of office and laboratory space presently occupied. The UGS is well equipped for field work and has access to all necessary field equipment and vehicles. Well files, completion and production data, and geophysical well logs are readily available from the DOGM. In addition, the Utah Department of Epidemiology and Lab Services are available to analyze all water samples.

The UGS Editorial Section, which includes editorial, cartographic, drafting, and graphic design personnel, prepares full color and black-and-white maps, charts, and camera-ready text copy and digital products. This group also prepares digital text figures, slide copies, and poster material for meetings and for UGS publications.

The DNR Information Technology Section supports programming, database applications, and network operations for its LAN network, Macintosh, AutoCAD digitizing system, and analytical stereo

plotter. The UGS's main computer system consists of 50 IBM-compatible PC's tied to an asynchronous Novell network with many peripherals, including laser printers and color plotters. UGS is connected to DNR servers with access to ArcGIS systems. PC-based software includes programs for digitizing, databases, spreadsheets, interactive graphics, contour mapping, cross-section construction, statistical analysis, and reservoir modeling/characterization.

The UGS-operated Utah Core Research Center (UCRC) is a modern warehouse of 12,000 square feet with core preparation and layout facilities. It is the only public repository of subsurface data in Utah, with samples from more than one-third of the state's wells, including several oil shale wells. The UCRC houses Utah cores, cuttings, mineral samples, crude oils, and fossil collections. It has rock saws capable of cutting up to 8-inch diameter core, a drill press for taking core plugs, ultraviolet lights for identifying hydrocarbon-bearing core intervals, and triocular microscopes for examination of drill cuttings. The UCRC is set up to produce high-resolution digital and film-based images of core and cuttings. The main core examination area is capable of displaying more than 1000 feet of core and accommodating up to 30 patrons.

Paul Anderson, Consulting Geologist. Mr. Anderson maintains professional office space in Salt Lake City with computers, printers, plotters, internet connection, materials, and software sufficient to perform the proposed tasks.

University of Utah, Petroleum Research Center. The Petroleum Research Center labs at the University of Utah are equipped with gas chromatographs, mass spectrometers, liquid chromatographs, optical detection (FTIR and NIR) equipment, differential scanning calorimetry, molecular weight measuring instruments, and other analytical instrumentation. A number of bench-scale evaluation facilities have been built to study problems associated with heavy oils, oil sands, and oil shale. Computational resources include state-of-the-art computing systems and academic licenses to most commercial simulators (Eclipse, Petrel, CMG, Comsol, etc.).