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ENERGY DEVELOPMENT AND WATER USE

Impacts of Potential Oil Shale Development on Water Resources

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Chairman Lamborn, Ranking Member Holt, and Members of the Subcommittee:

I am pleased to be here today to participate in your field hearing on oil shale development. As you know, being able to tap the vast amounts of oil locked within U.S. oil shale could go a long way toward satisfying our nation's future oil demands. The Green River Formation—an assemblage of over 1,000 feet of sedimentary rocks that lie beneath parts of Colorado, Utah, and Wyoming—contains the world's largest deposits of oil shale. The U.S. Geological Survey (USGS) estimates that the Green River Formation contains about 3 trillion barrels of oil and that about half of this may be recoverable, depending on available technology and economic conditions. This is an amount about equal to the entire world's proven oil reserves. The thickest and richest oil shale within the Green River Formation exists in the Piceance Basin of northwest Colorado and the Uintah Basin of northeast Utah (see app. I). The federal government is in a unique position to influence the development of oil shale because 72 percent of the oil shale within the Green River Formation is beneath federal lands managed by the Department of the Interior's (Interior) Bureau of Land Management (BLM). The Department of Energy (DOE) has provided technological and financial support for oil shale development through its research and development efforts, but oil shale development has been hampered by technological challenges, average oil prices that have been too low to consistently justify investment, and concerns over potential impacts on the environment.

One area of particular concern is that developing oil shale will require large amounts of water—a resource that is already in scarce supply in the arid West where an expanding population is placing additional demands on water. Some analysts project that large scale oil shale development within Colorado could require more water than is currently supplied to over 1 million residents of the Denver metro area and that water diverted for oil shale operations would restrict agricultural and urban development. The potential demand for water is further complicated by the past decade of drought in the West and projections of a warming climate in the future. In October 2010, we issued a report that examined the nexus between oil shale development and water impacts.[1]

[1]GAO, *Energy-Water Nexus: A Better and Coordinated Understanding of Water Resources Could Help Mitigate the Impacts of Potential Oil Shale Development,* GAO-11-35 (Washington, D.C.: Oct. 29, 2010).

My testimony today will summarize the findings of that report. Specifically, I will discuss (1) what is known about the potential impacts of oil shale development on surface water and groundwater, (2) what is known about the amount of water that may be needed for the commercial development of oil shale, (3) the extent to which water will likely be available for commercial oil shale development and its source, and (4) federal research efforts to address impacts on water resources from commercial oil shale development. To perform this work we, among other things, reviewed an environmental impact statement on oil shale development prepared by BLM and various studies from private and public groups; we also interviewed officials at DOE, USGS, BLM; state regulatory agencies in Colorado and Utah; oil shale industry representatives; water experts; and organizations performing research, including universities and national laboratories, and reviewed relevant documents describing their research. We conducted this work in accordance with generally accepted government auditing standards.

Background

Interest in oil shale as a domestic energy source has waxed and waned since the early 1900s. More recently, the Energy Policy Act of 2005 directed BLM to lease its lands for oil shale research and development. In June 2005, BLM initiated a leasing program for research, development, and demonstration (RD&D) of oil shale recovery technologies. By early 2007, it granted six small RD&D leases: five in the Piceance Basin of northwest Colorado and one in Uintah Basin of northeast Utah. The leases are for a 10-year period, and if the technologies are proven commercially viable, the lessees can significantly expand the size of the leases for commercial production into adjacent areas known as preference right lease areas. The Energy Policy Act of 2005 also directed BLM to develop a programmatic environmental impact statement (PEIS) for a commercial oil shale leasing program. During the drafting of the PEIS, however, BLM realized that, without proven commercial technologies, it could not adequately assess the environmental impacts of oil shale development and dropped from consideration the decision to offer additional specific parcels for lease. Instead, the PEIS analyzed making lands available for potential leasing and allowing industry to express interest in lands to be leased. Environmental groups then filed lawsuits, challenging various aspects of the PEIS and the RD&D program. Since then, BLM has initiated another round of oil shale RD&D leasing.

Stakeholders in the future development of oil shale are numerous and include the federal government, state government agencies, the oil shale industry, academic institutions, environmental groups, and private citizens. Among federal agencies, BLM manages the land and the oil shale beneath it and develops regulations for its development. USGS describes the nature and extent of oil shale deposits and collects and disseminates information on the nation's water resources. DOE, through its various offices, national laboratories, and arrangements with universities, advances energy technologies, including oil shale technology. The Environmental Protection Agency (EPA) sets standards for pollutants that could be released by oil shale development and reviews environmental impact statements, such as the PEIS. Interior's Bureau of Reclamation (BOR) manages federally built water projects that store and distribute water in 17 western states and provides this water to users. BOR monitors the amount of water in storage and the amount of water flowing in the major streams and rivers, including the Colorado River, which flows through oil shale country and feeds these projects. BOR provides its monitoring data to federal and state agencies that are parties to three major federal, state, and international agreements that together with other federal laws, court decisions, and agreements, govern how water within the Colorado River and its tributaries is to be shared with Mexico and among the states in which the river or its tributaries are located.[2]

The states of Colorado and Utah have regulatory responsibilities over various activities that occur during oil shale development, including activities that impact water. Through authority delegated by EPA under the Clean Water Act, Colorado and Utah regulate discharges into surface waters. Colorado and Utah also have authority over the use of most water resources within their respective state boundaries. They have established extensive legal and administrative systems for the orderly use of water resources, granting water rights to individuals and groups. Water rights in these states are not automatically attached to the land upon which the water is located. Instead, companies or individuals must apply to the state for a water right and specify the amount of water to be used, its intended use, and the specific point from where the water will be diverted for use, such as a specific point on a river or stream. Utah approves the application for a water right through an administrative process, and Colorado approves the application for a water right through a court proceeding. The date of the application establishes its priority—earlier

[2]These three major agreements are the Colorado River Compact of 1922, the Upper Colorado River Basin Compact of 1948, and the Mexican Water Treaty of 1944.

applicants have preferential entitlement to water over later applicants if water availability decreases during a drought. These earlier applicants are said to have senior water rights. When an applicant puts a water right to beneficial use, it is referred to as an absolute water right. Until the water is used, however, the applicant is said to have a conditional water right. Even if the applicant has not yet put the water to use, such as when the applicant is waiting on the construction of a reservoir, the date of the application still establishes priority. Water rights in both Colorado and Utah can be bought and sold, and strong demand for water in these western states facilitates their sale.

A significant challenge to the development of oil shale lies in the current technology to economically extract oil from oil shale. To extract the oil, the rock needs to be heated to very high temperatures—ranging from about 650 to 1,000 degrees Fahrenheit—in a process known as retorting. Retorting can be accomplished primarily by two methods. One method involves mining the oil shale, bringing it to the surface, and heating it in a vessel known as a retort. Mining oil shale and retorting it has been demonstrated in the United States and is currently done to a limited extent in Estonia, China, and Brazil. However, a commercial mining operation with surface retorts has never been developed in the United States because the oil it produces competes directly with conventional crude oil, which historically has been less expensive to produce. The other method, known as an in-situ process, involves drilling holes into the oil shale, inserting heaters to heat the rock, and then collecting the oil as it is freed from the rock. Some in-situ technologies have been demonstrated on very small scales, but other technologies have yet to be proven, and none has been shown to be economically or environmentally viable.

Nevertheless, according to some energy experts, the key to developing our country's oil shale is the development of an in-situ process because most of the richest oil shale is buried beneath hundreds to thousands of feet of rock, making mining difficult or impossible. Additional economic challenges include transporting the oil produced from oil shale to refineries because pipelines and major highways are not prolific in the remote areas where the oil shale is located, and the large-scale infrastructure that would be needed to supply power to heat oil shale is lacking. In addition, average crude oil prices have been lower than the threshold necessary to make oil shale development profitable over time.

Large-scale oil shale development also brings socioeconomic impacts. There are obvious positive impacts such as the creation of jobs, increase in wealth, and tax and royalty payments to governments, but there are also negative impacts to local communities. Oil shale development can bring a sizeable influx of workers, who along with their families, put additional stress on local infrastructure such as roads, housing, municipal water systems, and schools. Development from expansion of extractive industries, such as oil shale or oil and gas, has typically followed a “boom and bust” cycle in the West, making planning for growth difficult. Furthermore, traditional rural uses could be replaced by the industrial development of the landscape, and tourism that relies on natural resources, such as hunting, fishing, and wildlife viewing, could be negatively impacted.

Developing oil shale resources also faces significant environmental challenges. For example, construction and mining activities can temporarily degrade air quality in local areas. There can also be long-term regional increases in air pollutants from oil shale processing, upgrading, pipelines, and the generation of additional electricity. Pollutants, such as dust, nitrogen oxides, and sulfur dioxide, can contribute to the formation of regional haze that can affect adjacent wilderness areas, national parks, and national monuments, which can have very strict air quality standards. Because oil shale operations clear large surface areas of topsoil and vegetation, some wildlife habitat will be lost. Important species likely to be negatively impacted from loss of wildlife habitat include mule deer, elk, sage grouse, and raptors. Noise from oil shale operations, access roads, transmission lines, and pipelines can further disturb wildlife and fragment their habitat. Environmental impacts could be compounded by the impacts of coal mining, construction, and extensive oil and gas development in the area. Air quality and wildlife habitat appear to be particularly susceptible to the cumulative effect of these impacts, and according to some environmental experts, air quality impacts may be the limiting factor for the development of a large oil shale industry in the future. Lastly, the withdrawal of large quantities of surface water for oil shale operations could negatively impact aquatic life downstream of the oil shale development. My testimony today will discuss impacts to water resources in more detail.

Oil Shale Development Could Adversely Impact Water Resources, but the Magnitude of These Impacts Is Unknown

In our October report, we found that oil shale development could have significant impacts on the quantity and quality of surface and groundwater resources, but the magnitude of these impacts is unknown. For example, we found that it is not possible to quantify impacts on water resources with reasonable certainty because it is not yet possible to predict how large an oil shale industry may develop. The size of the industry would have a direct relationship to water impacts. We noted that, according to BLM, the level and degree of the potential impacts of oil shale development cannot be quantified because this would require making many speculative assumptions regarding the potential of the oil shale, unproven technologies, project size, and production levels.

Hydrologists and engineers, while not able to quantify the impacts from oil shale development, have been able to determine the qualitative nature of its impacts because other types of mining, construction, and oil and gas development cause disturbances similar to impacts that would be expected from oil shale development. According to these experts, in the absence of effective mitigation measures, impacts from oil shale development to water resources could result from disturbing the ground surface during the construction of roads and production facilities, withdrawing water from streams and aquifers for oil shale operations, underground mining and extraction, and discharging waste waters from oil shale operations. For example, we reported that oil shale operations need water for a number of activities, including mining, constructing facilities, drilling wells, generating electricity for operations, and reclamation of disturbed sites. Water for most of these activities is likely to come from nearby streams and rivers because it is more easily accessible and less costly to obtain than groundwater. Withdrawing water from streams and rivers would decrease flows downstream and could temporarily degrade downstream water quality by depositing sediment within the stream channels as flows decrease. The resulting decrease in water would also make the stream or river more susceptible to temperature changes—increases in the summer and decreases in the winter. These elevated temperatures could have adverse impacts on aquatic life, which need specific temperatures for proper reproduction and development and could also decrease dissolved oxygen, which is needed by aquatic animals.

We also reported that both underground mining and in-situ operations would permanently impact aquifers. For example, underground mining would permanently alter the properties of the zones that are mined, thereby affecting groundwater flow through these zones. The process of removing oil shale from underground mines would create large tunnels from which water would need to be removed during mining operations. The removal of this water through pumping would decrease water levels in shallow aquifers and decrease flows to streams and springs that are connected. When mining operations cease, the tunnels would most likely be filled with waste rock, which would have a higher degree of porosity and permeability than the original oil shale that was removed. Groundwater flow through this material would increase permanently, and the direction and pattern of flows could change permanently. Similarly, in-situ extraction would also permanently alter aquifers because it would heat the rock to temperatures that transform the solid organic compounds within the rock into liquid hydrocarbons and gas that would fracture the rock upon escape. The long-term effects of groundwater flows through these retorted zones are unknown. Some in-situ operations envision using a barrier to isolate thick zones of oil shale with intervening aquifers from any adjacent aquifers and pumping out all the groundwater from this isolated area before retorting.

The discharge of waste waters from operations would also temporarily increase water flows in receiving streams. These discharges could also decrease the quality of downstream water if the discharged water is of lower quality, has a higher temperature, or contains less oxygen. Lower-quality water containing toxic substances could increase fish and invertebrate mortality. Also, increased flow into receiving streams could cause downstream erosion. However, if companies recycle waste water and water produced during operations, these discharges and their impacts could be substantially reduced.

Estimates of Water Needs for Commercial Oil Shale Development Vary Widely

Commercial oil shale development requires water for numerous activities throughout its life cycle; however, we found that estimates vary widely for the amount of water needed to produce oil shale. These variations stem primarily from the uncertainty associated with reclamation technologies for in-situ oil shale development and because of the various ways to generate power for oil shale operations, which use different amounts of water.

In our October report, we stated that water is needed for five distinct groups of activities that occur during the life cycle of oil shale development: (1) extraction and retorting, (2) upgrading of shale oil, (3) reclamation, (4) power generation, and (5) population growth associated with oil shale development. However, we found that few studies that we examined included estimates for the amount of water used by each of these activities. Consequently, we calculated estimates of the minimum, maximum, and average amounts of water that could be needed for each of the five groups of activities that comprise the life cycle of oil shale development. Based on our calculations, we estimated that about 1 to 12 barrels of water could be needed for each barrel of oil produced from in-situ operations, with an average of about 5 barrels (see table 1); and about 2 to 4 barrels of water could be needed for each barrel of oil produced from mining operations with a surface retort operation, with an average of about 3 barrels (see table 2).

Table 1: Estimated Barrels of Water Needed for Various Activities per Barrel of Shale Oil Produced by In-Situ Operations

Activity	Minimum estimate	Average estimate	Maximum estimate
Extraction/retorting	0	0.7	1.0
Upgrading liquids	0.6	0.9	1.6
Power generation	0.1	1.5	3.4
Reclamation	0	1.4	5.5
Population growth	0.1	0.3	0.3
Total	**0.8**	**4.8**	**11.8**

Source: GAO analysis of selected studies.

Notes: GAO used from four to six studies to obtain the numbers for each group of activities. See GAO-11-35 to identify the specific studies. The average for reclamation may be less useful because estimates are either at the bottom or the top of this range.

Table 2: Estimated Barrels of Water Needed for Various Activities per Barrel of Shale Oil Produced by Mining and Surface Retorting

Activity	Minimum estimate	Average estimate	Maximum estimate
Extraction/retorting and upgrading liquids	0.9	1.5	1.9
Power generation	0	0.3	0.9
Reclamation	0.6	0.7	0.8
Population growth	0.3	0.3	0.4
Total	**1.8**	**2.8**	**4.0**

Source: GAO analysis of selected studies.

Note: GAO used from three to six studies to obtain the numbers for each group of activities. See GAO-11-35 to identify the specific studies.

Water Is Likely to Be Available Initially from Local Sources, but the Size of an Oil Shale Industry May Eventually Be Limited by Water Availability

In October 2010, we reported that water is likely to be available for the initial development of an oil shale industry, but the eventual size of the industry may be limited by the availability of water and demands for water to meet other needs. Oil shale companies operating in Colorado and Utah will need to have water rights to develop oil shale, and representatives from all of the companies with whom we spoke were confident that they held at least enough water rights for their initial projects and will likely be able to purchase more rights in the future. According to a study by the Western Resource Advocates, a nonprofit environmental law and policy organization, of water rights ownership in the Colorado and White River Basins of Colorado companies have significant water rights in the area. For example, the study found that Shell owns three conditional water rights for a combined diversion of about 600 cubic feet per second from the White River and one of its tributaries and has conditional rights for the combined storage of about 145,000 acre-feet in two proposed nearby reservoirs.

In addition to exercising existing water rights and agreements, there are other options for companies to obtain more water rights in the future, according to state officials in Colorado and Utah. In Colorado, companies can apply for additional water rights in the Piceance Basin on the Yampa and White Rivers. For example, Shell recently applied—but subsequently withdrew the application—for conditional rights to divert up to 375 cubic feet per second from the Yampa River for storage in a proposed reservoir that would hold up to 45,000 acre-feet for future oil shale development. In Utah, however, officials with the State Engineer’s office said that additional water rights are not available, but that if companies want additional rights, they could purchase them from other owners.

Most of the water needed for oil shale development is likely to come first from surface flows, as groundwater is more costly to extract and generally of poorer quality in the Piceance and Uintah Basins. However, companies may use groundwater in the future should they experience difficulties in obtaining rights to surface water. Furthermore, water is likely to come initially from surface sources immediately adjacent to development, such as the White River and its tributaries that flow through the heart of oil shale country in Colorado and Utah, because the cost of pumping water over long distances and rugged terrain would be high, according to water experts.

Developing a sizable oil shale industry may take many years—perhaps 15 or 20 years by some industry and government estimates—and such an industry may have to contend with increased demands for water to meet other needs. For example, substantial population growth and its correlative demand for water are expected in the oil shale regions of Colorado and Utah. State officials expect that the population within the region surrounding the Yampa, White, and Green Rivers in Colorado will triple between 2005 and 2050. These officials expect that this added population and corresponding economic growth by 2030 will increase municipal and industrial demands for water, exclusive of oil shale development, by about 22,000 acre-feet per year, or a 76 percent increase from 2000. Similarly in Utah, state officials expect the population of the Uintah Basin to more than double its 1998 size by 2050 and that correlative municipal and industrial water demands will increase by 7,000 acre-feet per year, or an increase of about 30 percent since the mid-1990s. Municipal officials in two communities adjacent to proposed oil shale development in Colorado said that they were confident of meeting their future municipal and industrial demands from their existing senior water rights and as such will probably not be affected by the water needs of a future oil shale industry. However, large withdrawals could impact agricultural interests and other downstream water users in both states, as oil shale companies may purchase existing irrigation and agricultural rights for their oil shale operations. State water officials in Colorado told us that some holders of senior agricultural rights have already sold their rights to oil shale companies. A future oil shale industry may also need to contend with a general decreased physical supply of water regionwide due to climate change; Colorado's and Utah's obligations under interstate compacts that could further reduce the amount of water available for development; and limitations on withdrawals from the Colorado River system to meet the requirements to protect certain fish species under the Endangered Species Act.

Oil shale companies own rights to a large amount of water in the oil shale regions of Colorado and Utah, but we concluded that there are physical and legal limits on how much water they can ultimately withdraw from the region's waterways, which will limit the eventual size of the overall industry. Physical limits are set by the amount of water that is present in the river, and the legal limit is the sum of the water that can be legally withdrawn from the river as specified in the water rights held by downstream users. Our analysis of the development of an oil shale industry at Meeker, Colorado, based on the water available in the White River, suggests that there is much more water than is needed to support the water needs for all the sizes of an industry that would rely on mining and surface retorting that we considered. However, if an industry that uses in-situ extraction develops, water could be a limiting factor just by the amount of water physically available in the White River.

Federal Research Efforts on the Impacts of Oil Shale Development on Water Resources Do Not Provide Sufficient Data for Future Monitoring

Since 2006, the federal government has sponsored over $22 million of research on oil shale development and of this amount about $5 million was spent on research related to the nexus between oil shale development and water. Even with this research, we reported that there is a lack of comprehensive data on the condition of surface water and groundwater and their interaction, which limits efforts to monitor and mitigate the future impacts of oil shale development. Currently DOE funds most of the research related to oil shale and water resources, including research on water rights, water needs, and the impacts of oil shale development on water quality. Interior also performs limited research on characterizing surface and groundwater resources in oil shale areas and is planning some limited monitoring of water resources. However, there is general agreement among those we contacted— including state personnel who regulate water resources, federal agency officials responsible for studying water, water researchers, and water experts—that this ongoing research is insufficient to monitor and then subsequently mitigate the potential impacts of oil shale development on water resources. Specifically, they identified the need for additional research in the following areas:

- *Comprehensive baseline conditions for surface water and groundwater quality and quantit*y. Experts we spoke with said that more data are needed on the chemistry of surface water and groundwater, properties of aquifers, age of groundwater, flow rates and patterns of groundwater, and groundwater levels in wells.

- *Groundwater movement and its interaction with surface water*. Experts we spoke with said that additional research is needed to develop a better understanding of the interactions between groundwater and surface water and of groundwater movement for modeling possible transport of contaminants. In this context, more subsurface imaging and visualization are needed to build geologic and hydrologic models and to study how quickly groundwater migrates. Such tools will aid in monitoring and providing data that does not currently exist.

In addition, we found that DOE and Interior officials seldom formally share the information on their water-related research with each other. USGS officials who conduct water-related research at Interior and DOE officials at the National Energy Technology Laboratory (NETL), which sponsors the majority of the water and oil shale research at DOE, stated they have not talked with each other about such research in almost 3 years. USGS staff noted that although DOE is currently sponsoring most of the water-related research, USGS researchers were unaware of most of these projects. In addition, staff at DOE's Los Alamos National Laboratory who are conducting some water-related research for DOE noted that various researchers are not always aware of studies conducted by others and stated that there needs to be a better mechanism for sharing this research. Based on our review, we found there does not appear to be any formal mechanism for sharing water-related research activities and results among Interior, DOE, and state regulatory agencies in Colorado and Utah. The last general meeting to discuss oil shale research among these agencies was in October 2007, but there have been opportunities to informally share research at the annual Oil Shale Symposium, such as the one that was conducted at the Colorado School of Mines in October 2010. Of the various officials with the federal and state agencies, representatives from research organizations, and water experts we contacted, many noted that federal and state agencies could benefit from collaboration with each other on water-related research involving oil shale. Representatives from NETL stated that collaboration should occur at least every 6 months.

As a result of our findings, we made three recommendations in our October 2010 report to the Secretary of the Interior. Specifically, we stated that to prepare for possible impacts from the future development of oil shale, the Secretary should direct the appropriate managers in the Bureau of Land Management and the U.S. Geological Survey to

- establish comprehensive baseline conditions for groundwater and surface water quality, including their chemistry, and quantity in the Piceance and Uintah Basins to aid in the future monitoring of impacts from oil shale development in the Green River Formation;
- model regional groundwater movement and the interaction between groundwater and surface water, in light of aquifer properties and the age of groundwater, so as to help in understanding the transport of possible contaminants derived from the development of oil shale; and
- coordinate with the Department of Energy and state agencies with regulatory authority over water resources in implementing these recommendations, and to provide a mechanism for water-related research collaboration and sharing of results.

Interior generally concurred with our recommendations. In response to our first recommendation, Interior commented that there are ongoing

USGS efforts to analyze existing water quality data in the Piceance Basin and to monitor surface water quality and quantity in both basins but that it also plans to conduct more comprehensive assessments in the future. With regard to our second recommendation, Interior stated that BLM and USGS are working on identifying shared needs for modeling. Interior underscored the importance of modeling prior to the approval of large-scale oil shale development and cited the importance of the industry's testing of various technologies on federal RD&D leases to determine if production can occur in commercial quantities and to develop an accurate determination of potential water uses for each technology. In support of our third recommendation to coordinate with DOE and state agencies with regulatory authority over water resources, Interior stated that BLM and USGS are working to improve such coordination and noted current ongoing efforts with state and local authorities.

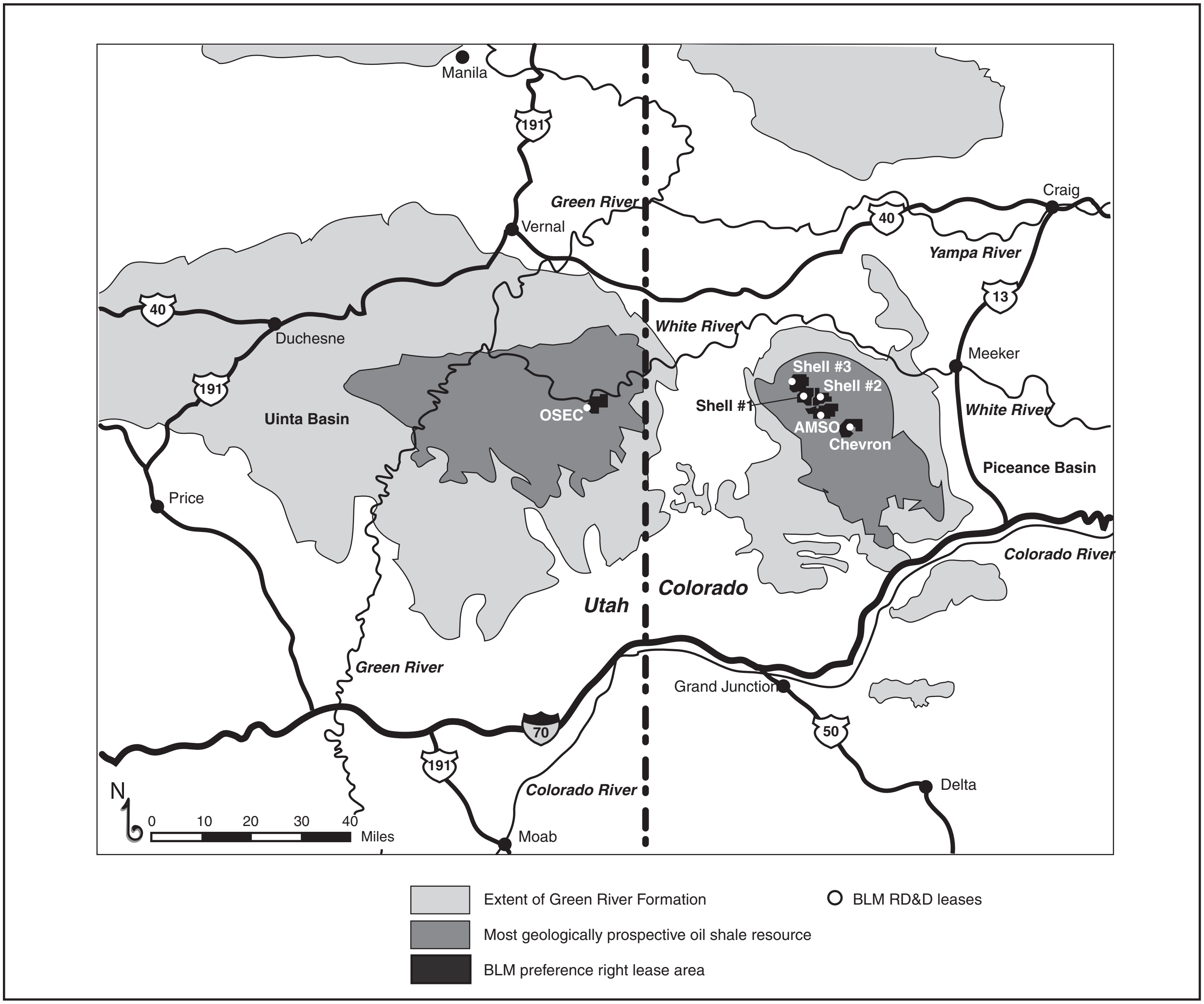
In conclusion, Mr. Chairman, attempts to commercially develop oil shale in the United States have spanned nearly a century. During this time, the industry has focused primarily on overcoming technological challenges and trying to develop a commercially viable operation. However, there are a number of uncertainties associated with the impacts that a commercially viable oil shale industry could have on water availability and quality that should be an important focus for federal agencies and policymakers going forward.

Chairman Lamborn, Ranking Member Holt, and Members of the Committee, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

Contact and Staff Acknowledgments

Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this testimony. For further information about this testimony, please contact Anu K. Mittal, Director, Natural Resources and Environment team, (202) 512-3841 or mittala@gao.gov. In addition to the individual named above, key contributors to this testimony were Dan Haas (Assistant Director), Quindi Franco, Alison O'Neill, Barbara Timmerman, and Lisa Vojta.

Appendix I: Location of Oil Shale Resources in Colorado and Utah



Source: Adopted from BLM.

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