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Water for Western Oil Shale Development--

Potential Local Supplies

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WATER FOR WESTERN OIL SHALE DEVELOPMENT--POTENTIAL LOCAL SUPPLIES *

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Introduction

Commercial-scale development of western oil shale resources will require a supply of water for both extraction and reclamation purposes.[15] This paper summarizes some of the information on the occurrence of potential local supplies of water in the Piceance Creek Basin-Uinta Basin areas of northwest Colorado and northeast Utah. The discussion is somewhat hypothetical in that it is restricted to the physical occurrence of water with emphasis on water resources in each basin. Of course, the many potential constraints on water use (including economics, water quality, legal and other institutional factors) are necessarily secondary to the ultimate constraint, its physical occurrence. Perhaps the most obvious constraint is that of water rights and water laws. For example, "mining" of some of the ground water is herein assumed to be necessary for technically sound management and utilization of the water resource, but the hydrologic effects of such "mining" would require accommodation under water laws and agreements.

Water Requirements for Oil Shale Extraction

Consumptive uses of water at an oil-shale mine and plant include moistening retorted shale, dust control, stack-gas scrubbing, revegetation, process steam, product upgrading, mining, drilling, and power generation. Where mines are wet, a significant amount of mine water will be removed as moist air and exhausted to the atmosphere by mine ventilation. Estimates of consumptive water requirements vary widely, but many are in the range of between 1 to 4 barrels of water per barrel of shale oil produced.[4,5,7,8,10,14,15,16,19,20,23] This range is used in the following discussion on water availability.

Local Supplies of Surface Water

The oil shale areas are drained by the Upper Colorado River System, both by the main stem and by major and minor tributaries. The Piceance Creek Basin (as referred to herein) is drained by the Colorado River on the south and by the White River on the north. In Utah most oil shale areas now of interest are in the eastern part of the Uinta Basin, which is drained by the White River. The White River flows into the Green River near the central part of the basin.

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Average annual flow in the Colorado River near the Piceance Creek Basin is about 2.8 million acre-feet; the White River annual flow averages about 0.5 million acre-feet near the Colorado-Utah boundary.[17] Average annual flow in the Green River above the confluence with the White River in the Uinta Basin is about 4 million acre-feet.[18] These streams could supply water for a very large oil shale industry.

Surface-water supplies in local tributaries of the White and Colorado Rivers are significant in the Piceance Creek Basin, where the average annual outflow from such streams is about 72,000 acre-feet.[17] It may not be practical to utilize all of this water because of variations in flow and resulting storage requirements. The average annual flow in Piceance Creek and Yellow Creek totals about 18,000 acre-feet, of which about 80 percent (or 14,000 acre-feet) is base flow that is supplied to the streams by ground-water discharge.[22] Average annual combined flow in Roan and Parachute Creeks is about 54,000 acre-feet, of which perhaps slightly less than one-third (or about 18,000 acre-feet) is base flow.[1] Much of the total annual average base flow, about 32,000 acre-feet, can be looked upon as a reasonably firm potential supply during most years. For example, even in the extremely dry water year of 1977, flow from Piceance and Yellow Creeks was about 11,500 acre-feet (or about 82 percent of average base flow).

In the Uinta Basin, the total average annual local runoff from tributaries to the White River in the oil shale area is about 28,000 acre-feet, of which Willow Creek contributes about 18,000 acre-feet.[9]

Local Supplies of Ground Water

Ground water in the Piceance Creek and Uinta Basins occurs in two general types of aquifer systems that are distinguishable by depth. One type consists of near-surface aquifers that probably are recharged and, in large part, discharge locally within the oil shale area. In Piceance Creek Basin, this near-surface system consists of the alluvium, the Uinta Formation, and the Green River Formation, for an aggregate thickness of about 2,000 feet. In the Uinta Basin, the near-surface aquifers include the alluvium, the Duchesne River Formation, the Uinta Formation, and probably most of the Green River Formation.[6] A second type of aquifer, consisting of older strata of sandstone and limestone, is deep-lying and apparently is neither discharged or recharged in significant quantities within the oil-shale rich parts of the basins. Little is known of the water-bearing characteristics of these older units in the deep part of the basins. Important units of this type of potential aquifer are the Entrada Sandstone and Glen Canyon Group of Mesozoic age, and the Weber Sandstone and Leadville Limestone of Paleozoic age. Several other geologic units are known to be water bearing in parts of both basins, but they appear to be of less potential importance than those noted above.

In the northern part of the Piceance Creek Basin (beneath areas drained by Piceance Creek and Yellow Creek), estimates of ground water

in storage in the near-surface aquifers range from 2.5 million to 25 million acre-feet.[22] This wide range in estimates reflects the paucity of field data on the storage characteristics of the extremely heterogeneous aquifers which consist in large part of fractured and vuggy rock. The entire basin, including the area underlying the drainages of Roan and Parachute Creeks, contains more than 500 mi^3 of saturated rock (Green River and Uinta Formation only) and may contain as much as 40 million acre-feet of stored water.[13]

The deeper aquifer systems beneath Piceance Basin, which in the aggregate probably exceed 500 feet in thickness, may contain several million additional acre-feet of ground water. Few data are available on the storage characteristics, permeability, or quality of ground water in storage in these aquifers, but at several locations on and adjacent to the Colorado Plateau they yield supplies of water to wells and springs.[6,21]

The aquifer systems beneath the Uinta Basin have not been studied as intensively as in the Piceance Creek Basin, but available data indicate that ground water occurs in the same, or similar, geologic units as in the Piceance Creek Basin. At Federal Oil Shale Lease Tracts U-a and U-b, ground water in storage in the "Birds Nest Zone" (approximately 115 feet thick) of the Green River Formation has been estimated to be about 8 acre-feet/acre.[20] Aquifers in the Duchesne River, Uinta, and Green River Formations, which commonly occur within a few hundred to a few thousand feet of the surface in the Uinta Basin, probably aggregate more than 1,000 feet in thickness over an area of more than 1,000 mi^2. In the oil shale area of about 3,000 mi^2, usable storage in the alluvium, the "Birds Nest Zone," and the Douglas Creek Member of the Green River Formation is estimated to be about 18 million acre-feet.[9] Most of the potential aquifers of Mesozoic and Paleozoic age that underlie the Piceance Creek Basin also underlie the Uinta Basin at great depths.[6,12] Ground water in storage in these deeper aquifers, assuming their hydrologic characteristics are similar to those in better known areas, could also be in the range of tens of millions of acre-feet.

Potential Role of Local Water Supplies

The local surface-water and ground-water resources can play a significant role in the prudent management of water resources to meet the water needs of an oil-shale industry. For the Piceance Creek and Uinta Basins (Tables 1 and 2) a combination of local supplies from ground water and the major tributary streams probably could:

1. Support a considerable fraction of the total water needs for a large industry.

2. Be adequate to extract a large percentage of the total higher grade oil shale resource at a significant rate of production.

3. Greatly enhance man's ability to effectively and economically manage the total water resources needed for an oil-shale industry.

The importance of local supplies in prudent water management for an oil shale industry is self-evident. The greatest technical uncertainty in these projections is the amount and quality of available ground water in storage.

Table 1. Local Surface Water Resources in Piceance and Uinta Basins--Potential for use in oil shale extraction
(All numbers rounded)

Stream or Basin	Annual Flow		Shale oil production potentially supportable, in BPD (assuming 1-4 bbls of water/bbl of oil)		
	Ac-ft	CFS			
Piceance Creek Basin					
Piceance Cr	17,000	24	90,000	to	360,000
Yellow Cr	1,200	1.7	6,500	to	26,000
Roan Cr	32,000	44	170,000	to	680,000
Parachute Cr	22,000	30	120,000	to	470,000
Uinta Basin	28,000	39	150,000	to	600,000
Total	100,000	140	540,000		2,100,000

Table 2. Potential Capability of Ground Water to Supply Oil Shale Industry
(All numbers rounded)

Usable ground water in storage	Shale Oil Extractable, in billions of BBL, and percent of higher-grade resource recoverable*		Yrs of Operation at 2 production levels (assuming 1-4 bbls of water/bbl of oil)	
10^6 ac-ft	10^9 Bbls	percent higher grade recoverable	10^5 BPD	10^6 BPD
1	1.9 - 7.8	1 - 5	50 - 200	5 - 20
10	19 - 78	11 - 47	500 - 2000	50 - 200
25	48 - 200	29 - 100	1200 - 5000	120 - 500
40	76 - 310	46 - 100	2000 - 8000	200 - 800

* Piceance Creek Basin only, conservatively estimated to be "167 x 10^9 BBL." Remainder of table applies to both basins.

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