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SOME NEIGHBORHOOD EFFECTS OF OIL-SHALE DEVELOPMENT*

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Neighborhood effects are inevitable if an oil-shale industry develops in northwestern Colorado, eastern Utah, and southwestern Wyoming as anticipated. These effects are the costs or benefits accruing to resource owners and consumers who will remain outside the industry. Their class and extent will depend on the production technology chosen and size of the industry. Any efforts to identify and quantify these effects in advance of development will facilitate: (1) determination of economic feasibilty and optimal industry size; and (2) formulation of policies to minimize socially adverse consequences and equitably allocate ultimate external costs.

What general classes of neighborhood effects will likely accompany oil-shale development?

First, prices of resources with inelastic supplies will be raised as they respond to the demands of the developing industry. Land will be required for mines, for retorting facilities, for transporting inputs and outputs of the industry, and for necessary urban development. The demand for some types of labor will increase; that for other types, e.g., agricultural labor, may decline. Rights to limited water supplies will rise in price if the technology of production requires water. On balance, other users of the same resources, particularly those in competing industries such as agriculture must expect rising costs.

Second, a number of pollution and resource defacement situations will be created as oil-shale development proceeds. Many surface uses of land containing oil-shale, such as grazing of domestic livestock and big game animals, and most types of outdoor recreation, will be curtailed, if not eliminated, unless specific programs encourage their coexistence with shale oil production. Some water pollution is almost inevitable, and the air pollution potential depends on the mechanics of retorting and ash disposal. The oil-shale industry thus may impose external costs on current land, water, and air users.

Third, neighborhood gains will be made and/or losses incurred

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by local merchants and townspeople. Business firms will benefit from such effects as a sudden increase in potential customers, and windfall gains from better transport and communication or wider selection of goods and services will be communitywide. On the other hand, the level of agricultural activity might decline in terms of the volume of production. Specialized firms furnishing that sector with goods and services could suffer income losses unless they can readily shift to serving the oil-shale industry. Similarly, childless families may feel that tax increases for expanded educational programs constitute a windfall loss.

The first and third postulated neighborhood effect classes are difficult to quantify at this time because their extent will depend largely on the scale of oil-shale development. And any forecast of how large the industry might be in 20 years must be pure conjecture; factors beyond the control of oil-shale planners and managers will determine ultimate size. The primary focus of this paper, therefore, must be upon the second group of neighborhood effects: water, land, and air problems that might follow from development.

The technological options seem to be: (1) the shale may be mined by underground methods or on the surface from trenches or pits and then retorted on the surface; or (2) the shale may be retorted *in situ* and the oil pumped to the surface. Obviously the extent of land defacement, ash production, and water and air pollution will depend primarily on how the oil is produced. We first explore the possible neighborhood effects of *in situ* production, and then take up the assumption of surface retorting.

I
IN SITU PRODUCTION AND NEIGHBORHOOD EFFECTS

The great advantage of *in situ* methods is that they would leave the land surface undisturbed. Agircultural and recreational uses could continue in much the same manner as at present.

Several *in situ* techniques are receiving some attention and undergoing experimentation. All require breaking or fracturing the shale in place and heating it to release the oil which may then be pumped to the surface.[1]

In all probability, a nuclear explosion would be used to break up the shale. Coffer and Spiess[2] describe the process as follows:

1. Oil shale is not really shale; it is a marlstone, layered in structure, which does not possess any natural porosity or permeability. The organic substance held in the marlstone, kerogen, is converted to oil by pyrolysis upon heating to temperatures of 750-900° F.

2. Coffer & Spiess, *Commercial Applications of Nuclear Explosives—The Answer to Oil Shale?,* 61 Q. Colo. School of Mines 70 (1966).

> A spherical cavity filled with hot gasses at extremely high pressures is created by the explosion. As the cavity cools, some of the gases liquify, and the molten rock runs to the bottom of the cavity. Within a few seconds, the cavity roof begins to collapse, and a kind of chimney is created filled with broken rock. Surrounding the chimney is a broad, highly fractured area which results from the shock of the explosion. . . . The broken up rock pile created by a nuclear explosion could contain as much as 47 million barrels of oil.

The real difficulty with this process is to assure that the broken shale will be properly sized. Some possible heating or "burning" methods require that hot fluids or gases contact a maximum surface area of the shale consistent with an acceptable level of penetration through the broken rubble. An additional requirement in any heating system based solely upon energy released from partially burning the shale is that the rubble is shaped and positioned such that the combustion process will spread throughout the entire cavern or chimney of its own accord.

To support self-sustained burning it has been suggested that air can be forced down the chimney of broken shale in the manner of surface retorting.[3] The burning process would proceed downward as the released oil is drawn off at the chimney bottom. A variant of this, utilizing hot natural gas to induce and sustain combustion, is reportedly under test. Whether the effect will be to increase the range of tolerable rock sizes is unknown, for results have not been announced.[4]

Humble Oil Company is presently experimenting with a technique which utilizes the injection of super-heated steam into the fractured shale to convert the oil-bearing constituents to liquid form. This would bypass some of the difficulties associated with burning, but water requirements would be enormous. Furthermore, at least one observer[5] believes that steam injection will not provide the temperatures necessary to extract the oil effectively from the shale.

Development of successful processes for *in situ* combustion is believed by some experts to be the only practical and economically feasible long-run plan.[6] In addition, this method would presumably qualify for the 27.5 percent depletion allowance. Underground retorting eliminates the necessity of mining, crushing, and handling

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3. *Id.* at 73.

4. Letter from N. deNevers, Chemical Engineer, Univ. of Utah, April 1, 1968.

5. Cameron & Jones, Inc., *The Development of Utah Oil-Shale Resources* 27 (1964) (report prepared for the Utah Water & Power Bd.).

6. Lekas, *Economics of Producing Shale Oil—The Nuclear In Situ Retorting Method,* 61 Q. Colo. School of Mines 105 (1966); Childs, *The Status of the Oil Shale Problem,* 60 Q. Colo. School of Mines 5 (1965).

millions of tons of shale. Disposal of spent ash associated with surface retorting and need for air pollution control would be greatly reduced.

Lekas[7] has provided some rough estimates of the economic feasibility of *in situ methods* and of how widely they may be applied in the shale area. If the oil were worth $1.25 per barrel at the production site, as has been assumed by Steele,[8] Lekas believes that the nuclear technique could be economically applied in areas containing at least 15 gallons of oil per ton of shale in beds or strata at least 400 feet thick. A 25-gallon content requires thicknesses of 200 feet or more. These standards are met by essentially the entire Piceance Creek Basin in northwestern Colorado and by a major portion of Utah's deposit (which appears to be too deep for economic underground mining).[9] The figure of $1.25 per barrel may be too low, in which case shales of poorer quality would also be economically feasible to exploit with *in situ* methods.

Even if *in situ* methods were technically feasible, however, one issue clouds the economic picture. In the richest and deepest shale area in the Piceance Creek Basin in Colorado, valuable minerals coexist with oil. These deposits consist of dawsonite, which contains alumina, and nahcolite, which is a source of soda ash. These products may be recoverable from retorted shale if the oil is removed by surface retorts.[10]

Potential supplies of alumina from dawsonite are impressive. About 42 million tons of dawsonite alumina are present under one particular square mile in the Piceance Creek Basin.[11] This is nearly 1.5 times the known bauxite alumina reserves of the entire United States. Not every square mile would have the same potential, but the Piceance Creek Basin covers approximately 100 square miles.

While the sodium aluminate in dawsonite can be recovered with a water leach, the yield is lower than with more expensive acid or base leaches.[12] It is possible that relatively low yields would not be too great a drawback in a byproduct operation; however, the economic feasibility is not really known.

Nahcolite is also water soluble and soda ash can be removed by a simple water leach either before or after firing the oil shale.[13] The

7. Lekas, *supra* note 6, at 103.

8. Steele, *Development of the Shale Oil Industry,* 2 W. Econ. J. 60 (1963).

9. Cameron & Jones, Inc., *supra* note 5, at 3.

10. Hite & Dyni, *Potential Resources of Dawsonite and Nahcolite in the Piceance Creek Basin, Northwest Colorado,* 63 Q. Colo. School of Mines 33 (1967).

11. *Id.* at 35.

12. *Id.*

13. *Id.* at 33.

approximately 130 million tons of nahcolite in the same one square mile of Piceance Basin would reduce to about 82 million tons of soda ash. Again economic feasibility of a byproduct operation is unknown.

Thus far only some estimates of gross values have been made. The ratio of recovered and refined equivalent products in the known maximum 2,000-foot pay-section of oil-shale is one ton of aluminum metal to 16 tons of soda ash to 30 tons of oil shale, with each of these being roughly worth $500 at today's prices. Thus the total potential value of the Piceance basin reserves is about tripled by adding the sodium (dawsonite and nahcolite) byproducts.[14]

In other areas, however, dawsonite and nahcolite appear less significant. For example, analyses on core filings from the Utah shale deposits thus far have indicated no significant dawsonite deposits. These tests indicate that nahcolite may be present, but not to the extent found in Colorado.

More testing is necessary to determine the quantity of these materials contained in all shale deposits. In addition, some production cost estimate must be set by qualified engineers. Only when this information is available can economic analysis reveal the optimal method of oil extraction. Losses of net revenue from failure to exploit dawsonite and nahcolite deposits due to utilization of *in situ* techniques can then be juxtaposed with neighborhood costs of resource pollution and defacement resulting from surface retorting that will be a corollary of the exploitation of these minerals.

II

NEIGHBORHOOD EFFECTS IN WATER USE

Few of the issues connected with oil-shale development have been as controversial as those surrounding water requirements. Opinions run the gamut from belief that water supplies are quite adequate to the notion that water shortages will constrain the size of the industry. Typically, engineers perceive water availability in terms of "needs" or "requirements" of the shale industry. When these are added to the "needs" of those presently using water in the area, the situation is bleak. New water supplies provided by storage or importation would seem to be mandatory.

From the viewpoint of the economist, however, the water problem is much less acute. If legal and administrative practices were altered, water could be allocated like any other marketed com-

14. Heinrichs, *Impact of Dawsonite & Nahcolite on Piceance Creek Basin on Shale Economics*, 62 Q. Colo. School of Mines 22 (1967).

modity and would be price-rationed to the highest bidder. Water supplies would thus be stretched to cover the most economic uses. Ample water would be available through the market if the shale developers bid high enough.

Economic impact on the local economy, especially the agricultural sector, will be determined largely by transfer flexibility and whether new water supplies become available. If agriculture declines, neighborhood effects on parties selling to and buying from agriculture will be evident. Effects on individual farmers and ranchers will depend on whether or not they must give up their water by condemnation procedures providing inadequate compensation, or by voluntary sales to water right purchasers. If farmers are free to sell water or continue to hold and use it, then sale of water should provide ample compensation and minimize neighborhood effects.

A. Some Estimates of Water Utilization

With *in situ* technology, water needs will be linked closely to the method used to apply heat underground to the broken shale. As indicated previously, the use of super-heated steam as the heating agent requires vast amounts of water.[15] If a burn were effected in the underground chimney by forcing air into the burn area, the water requirements would be more modest. Pumping the oil to the surface would not involve significant amounts of water.

If the shale is mined and brought to the surface for retorting, then water depends on the chosen mining and retorting technology. Strip or open-pit mining would not require heavy amounts of water. If shale is mined underground, water requirements will depend on the type of drills used and whether water or air serves as the cooling agent.

Most experimental retorting methods presently being used require minimal quantities of water. Water utilization is heaviest in the refining stage.

Whether refining will take place close to the retorts in the shale area or near large population centers has not yet been decided. Apparently shale oil is highly viscous and difficult to move through a pipeline.[16] If pipeline transportation proves to be technically infeasible, then refining must occur near the retorts. Obviously, in this case, the area water demand might be greatly augmented. Under some circumstances, however, air cooling may be economically su-

15. Cameron & Jones, Inc., *supra* note 5, at app. 3.
16. Carver, *Conversion of Oil Shales to Refined Products,* 59 Q. Colo. School of Mines 25 (1964).

perior to water cooling for refining operations. Thus, if water were expensive or simply unavailable, refining could nevertheless proceed with minimal amounts.

In some Ohio tests the initial capital costs for air cooling equipment were slightly higher than for water using equipment ($500,000 for air to $410,000 for water). However, the annual operating costs were substantially lower for air than for water ($85,500 for water to $23,000 for air). This difference more than offsets the increased amortized annual cost of the initial capital. In addition, costs of pipe corrosion and water fouling can be substantial with water cooling especially if water is of poor quality.[17]

Current thinking on this problem by chemical engineers seems to be about as follows:[18] (1) If there is a limitless supply of cold, clean, fresh water which can be used on a once-through basis, then water cooling is likely to be less costly than air. This is a non-consumptive use of water but requires vast quantities. (2) If salt water must be used rather than fresh water, then the economics become clouded because of increased corrosion problems. (3) When water supplies are moderately short, two alternative cooling methods are evaporative cooling towers, which are water consumptive, and air cooling. Generally, if the outlet temperature of the cooled stream is above 150° F, air cooling is more economical; and if it is below 150° F, the evaporative cooling is more economical.

The specific characteristics of water supply in the oil-shale region would seem to favor air cooling. Water is neither plentiful nor of high quality. Water used for irrigation in the upper reaches of the Colorado Basin collects salts which would create some corrosion problems (although it is true that lower quality water is often used for industrial purposes). If water were demanded by the industry in large quantities, it might be obtainable only at a high price.

Despite the uncertainties connected with almost every aspect of producton of oil from shale, some observers have made estimates of anticipated water "needs." These estimates will be reviewed, but their accuracy is necessarily problematical.

As early as 1953 a study committee was appointed to assess how much water would be required.[19] This committee concluded that a 2-million-barrel-per-day operation would require a withdrawal of 455,000 acre-feet per year. The return flow could be expected to be about 165,000 acre-feet per year, resulting in a net consumption of

17. Thomas, *Air vs. Water Cooling—Cost Comparisons,* 55 Chem. Eng'r. Progress 41 (1959).

18. N. deNevers, *supra* note 4.

19. Delaney, *The Necessity of Water Storage for the Oil-Shale Industry,* 60 Q. Colo. School of Mines 113 (1965).

290,000 acre-feet per year. One acre-foot of water per year would be needed for every 4.4 barrels of daily capacity.

Another estimate[20] is that 250,000 acre-feet of water per year would be needed for an industry producing 1,250,000 barrels of oil per day. This amounts to 1 acre-foot per year for every 5 barrels of daily capacity. On the assumption that the industry would begin production on a small scale in the late 1960's, anticipated water needs were estimated at 27,000 acre-feet per year by 1970 and 250,000 acre-feet per year by 1975. By using a consumption of 1 acre-foot per year for every 4 to 5 barrels of daily capacity, one could roughly program water needs for an industry of any size.

Still a third observer[21] indicates that a 2-million-barrel-per-day industry will consume between 110,000 and 200,000 acre-feet of water per year depending on whether refining is done in the area. Domestic and municipal water requirements are estimated to be 165,000 additional acre-feet of water annually, of which 55,000 will be consumed. Taking the highest industry-need figure of 200,000 acre-feet, this would put the requirement at about 1 acre-foot per year for every 5.5 barrels of daily capacity.

Some analysis of these water utilization figures is necessary. For the first of the 2-million-barrel-per-day industry figures, water requirements are about 130 gallons per barrel of oil. For the estimate based on a 1,250,000-barrel-per-day operation, the water needed amounts to about 179 gallons per barrel. Charles H. Prien, of the Denver Research Institute, believes that water requirements for mining and retorting only are about 10 gallons per barrel of oil produced.[22] Refineries in the Salt Lake City area presently use about 30 gallons per barrel of crude petroleum processed.[23] It would appear, therefore, that by these estimates the industry requirements would be only about 40 gallons of water per barrel of oil produced, and that the remainder of the total requirement must be the secondary demand for municipal and domestic purposes.

This conclusion is not consistent with the second of the 2,000,000-barrel-per-day estimates, where domestic demands are set at less than half the total. There are simply too many unknowns at the present time to have much confidence in any estimate. Obviously, the availability and price of water will determine in large part how

20. Cameron & Jones, Inc., *Status and Problems of Colorado Shale Development 1963, A Report for the State of Colorado* 30 (1963).

21. Moses, *Where is the Water Coming From,* 61 Q. Colo. School of Mines 24 (1966).

22. Harline, *Factors Affecting Development of Utah's Oil-Shale and Bituminous Sand Deposits* 10 (undated) (unpublished report prepared for the Utah Water & Power Bd.).

23. *Id.*

much will be employed. Even for domestic purposes it has been shown that the price elasticity of water is much higher than is often suspected.[24] People will resort to a number of water saving practices to conserve on expensive water.

B. *Possibilities for Providing the Necessary Water*

Let it be assumed that technology and water prices are such that the industry will demand approximately 250,000 acre-feet of water per year. What are the prospects of acquiring this volume of water? Two general courses of action are possible: (1) file for rights on newly-developed water as yet unappropriated; and (2) purchase rights from present users of already appropriated water.

The difficulty with the first alternative is that inter-state compacts between Upper Basin and Lower Basin states and an international treaty with Mexico greatly limit the amount of water that is available to Colorado, Utah, and Wyoming. Based on a joint hydrologic investigation, the Upper Basin states (Colorado, Wyoming, Utah, and New Mexico) have recently decided that a dependable supply of about 6.2 million acre-feet are available to these four states for all uses.[25] Allowing for reservoir evaporation of 700,000 acre-feet, this leaves a net supply available for consumptive use of about 5.5 million acre-feet. A further assumption is that the Upper Basin states will not have to deliver additional water to meet the requirements of the Mexican Treaty in the event of water shortages.

The Upper Colorado River Basin Compact, initiated in 1948, apportions the water annually as follows: Arizona gets 50,000 acre-feet; of the remainder Colorado gets 51.75 percent, New Mexico 11.25 percent, Utah 23 percent, and Wyoming 14 percent.[26]

It has been pointed out by Ely[27] that over 11 million acre-feet of water supply originates in the state of Colorado, but more than 8 million acre-feet must flow out of the state to fulfill the compact and treaty commitments to down-stream users. It is Ely's view that substantially all of Colorado's dependable supply is or soon will be committed.

Another unknown, as far as Colorado is concerned, is that the inter-state compacts do not indicate which streams leaving the state must cover the commitments to the lower states.

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24. Gardner & Schick, *Factors Affecting Consumption of Urban Household Water in Northern Utah,* Utah Ag. Exp. Sta. Bull. 449 at 1 (1964).
25. Ely, *The Oil-Shale Industry's Water Problems,* 62 Q. Colo. School of Mines 13 (1967).
26. *Id.*
27. *Id.* at 12.

> As to the White River, figures furnished by the State show a virgin production of 610,000 acre feet annually, a present consumptive use of 35,000, and a state-line flow of 575,000 acre-feet. But if the White River is to bear the same proportion of burden of supplying the guaranteed flow at Lee's Ferry as Colorado's streams as a whole must bear (77 percent), then of the White River's total virgin production of 610,000 acre-feet, only 23 percent, or about 140,000 is permanently available for use in Colorado. Existing appropriations add up to more than this.[28]

If Colorado is permitted to use a greater proportion of the White River and meet her downstream commitments from other sources, Utah's development of oil shale might be jeopardized since Utah is largely dependent upon White River water.

According to attorneys-at-law, a firm water right from a natural stream in Colorado can only be obtained by surmounting several legal barriers. Adjudication decrees for substantial amounts of water have been granted major oil companies in the Grand Valley area. These rights can be lost unless diligence is shown in developing and completing the appropriation by use. In addition, the rights conferred only relate to flood flows and some winter flows because prior rights exist for the remainder.[29] Water rights can be obtained through purchase of irrigated farmland, but benefits cannot be exercised during non-irrigation, or winter seasons, or through alteration of diversion points. "[T]o change the point of diversion, the purchaser is required to prove in court that the change will not adversely affect the rights of other users, even those junior or inferior to himself."[30]

If seasonal rights are to be converted into firm supplies available for year-round use, it is obvious that storage facilities will be required. Recently some oil companies have expressed a willingness to finance construction and development of the Iron Mountain reservoir in return for guaranteed supplies of this particular western Colorado water.[31]

Wyoming presently has a larger quota under the Upper Colorado River Basin Compact than it has ever used. It is likely, therefore, that Wyoming can supply sufficient water for an oil-shale industry with little difficulty. However, Wyoming's ores are not as rich as those in Colorado and Utah, and consequently development will probably occur more slowly in that state. This may give competing water users time to appropriate unused water. Despite this, few

28. *Id.* at 14.
29. DeLaney, *supra* note 19, at 111.
30. *Id.* at 112; Moses, *supra* note 21, at 25.
31. DeLaney, *supra* note 19 at 112.

people see any foreseeable shortages of water in the oil-shale areas of Wyoming.[32]

A somewhat similar situation prevails in Utah. The Water and Power Board filed on water from the White River for the purpose of allocating it eventually to oil-shale development.[33] It is not known at present whether such filing will be granted, and if so, how the Water and Power Board will dispose of the water to the private users who need it to exploit the shale. Numerous oil companies have filed for rights for unappropriated water in Utah, but these filings are still pending. Meanwhile, many of the oil companies are purchasing firm rights from agricultural users with the option of taking control when shale oil is produced.[34]

Utah is not presently using her full quota of Colorado River water. There is not enough surplus, however, to satisfy recent applications for appropriations, especially since the Central Arizona Project Act became law.[35] The new act creates several new multipurpose projects, all of which have irrigation components. When this additional irrigation becomes a reality, the Upper Basin states will be able to utilize their full quotas of water, and if any is held for oil-shale development, it will have to be at the expense of competing uses.

Oil-shale developers will therefore have to buy additional irrigation rights from agricultural users in the area. This should be relatively simple since the overwhelming proportion of the agricultural areas in the oil-shale region are marginal. The State Engineer of either Wyoming or Utah has discretionary power to approve or disapprove water transfers. It should not be difficult to prove that the water is being transferred to a higher value use in the agriculture v. oil-shale situation.

C. *Water Pollution Effects*

As already indicated, water used for irrigation in the development area usually has a high salt content, so any pollution contributed by oil-shale activities would only compound a presently existing problem rather than create an entirely new one. Nevertheless, additional water pollution, like all pollution, is objectionable precisely because it imposes undesired neighborhood effects upon third parties. Certain tributary streams are important for sport fishing, but other

32. Letter from J. Goodier, Asst. Chief of Water Resources, Wyoming Natural Resource Bd., June, 1968.
33. Interview with H. Lambert, Utah State Engineer, April, 1968.
34. *Id.*
35. Pub. L. No. 90-537 (Sept. 30, 1968).

forms of water-based recreation should be little affected by some further degree of pollution. Ranching and livestock activities would also be little affected, except where smaller tributary streams are involved.

But river pollution has the capability of spreading neighborhood effects over an area far beyond the oil-shale region. Sport fishing or other recreational use of Lake Powell, Lake Mead, and other downstream areas might be adversely affected. And it must be borne in mind that Colorado River water sustains some irrigated agriculture in Arizona and Southern California, and is a supplementary source of domestic supply in the latter areas. Finally, salinity in the lower reaches of the Colorado has already reached levels high enough to create problems with Mexico.[36]

Assuming that the shale is retorted on the surface, and that water is used to leach out the dawsonite and nahcolite, return flows to the river would be seriously polluted.

Significant pollution could also be caused by operating surface mines. Control of water runoff and erosion would be imperative. Therefore, establishment of quality standards, though difficult, is necessary. Standards are also necessary because quality needs vary from place to place along a given watercourse depending on present uses made of the water.

The pollution possibilities associated with *in situ* technology will vary according to the rock fracturing system employed, for all underground retorting methods require somewhat similar boring and tunneling operations to draw off the oil. Such operations would require suitable water pollution safeguards. Fracturing, itself, assuming hydraulic or electrical methods are used, would not need to cause much air or water pollution. On the other hand, nuclear explosions require an assessment of radiation danger or pollution.

Although nuclear devices have not been set off in oil-shale formations, since 1957 over 150 underground explosions have been initiated as part of Project Plowshare.[37] From this experience, some conclusions can be drawn.

The size of any explosion must be limited by the tolerable level of seismic effect, and this has limits even in relatively uninhabited shale regions.[38] Thus, venting of radioactivity to the atmosphere is not considered a serious problem due to limitations on device size and the depth of the better shale zones.[39] Studies in the shale region

36. Ely, *supra* note 25, at 11.

37. Lekas & Carpenter, *Fracturing Oil-Shale with Nuclear Explosives for In Situ Retorting,* 60 Q. Colo. School of Mines 9 (1965).

38. *Id.* at 19, 27.

39. *Id.* at 26.

indicate no mobile water at the explosive emplacement levels and direct contamination of ground water is unlikely. Overhead aquifers might be contaminated from rising radioactive gases.[40] Experience thus far with underground water contamination suggests that radioactivity entering an underground water system is limited to a few miles from the shot point; however, "this is a complicated question."[41] In the absence of actual nuclear experiments in shale formations, it appears that little more than this can be said.

Discussions of radioactivity dangers in oil-shale operations tend to emphasize the environment within the chamber or chimney following the blast. Most of the solid radioactive fission products are trapped in the cavity lining which melts off and collects in a pool at the bottom, thereby effectively immobilizing radionuclides.[42] If the explosion is largely due to fusion, radioactve krypton and tritium will be formed. "Much of the tritium would combine with water and hydrogen vapors in the cavity to form tritiated oil, water, and gas."[43] It might be possible to circulate a sufficient volume of air through the broken shale to remove the "small amount of radioactivity."[44] Assuming, therefore, that the explosions can be isolated from underground aquifers, radiation pollution may not be much of a factor.

On balance it must be concluded that any substantial shale development will require establishment of water quality standards for the waters of the Colorado. If the states cannot or will not cooperate, the federal government must impose quality standards on all tributary streams that cross state boundaries.

If a state does not adopt water quality criteria acceptable to the Secretary of Interior, recent legislation[45] allows the Secretary to impose water quality standards that are enforceable by the federal government. Authority for establishing a Federal Water Pollution Control Administration (1966) and for provision of technical and financial assistance to the various states in preparation of comprehensive pollution and water supply investigations are also embodied in the acts.[46]

40. *Id.* at 27.
41. *Id.* at 30.
42. *Id.* at 13.
43. *Id.*
44. Coffer & Speiss, *supra* note 2, at 77.
45. Federal Water Pollution Control Act Amendments of 1961, 33 U.S.C. §§ 466, 466a-g, h-j, 43 U.S.C. § 390b; Water Quality Act of 1965, 33 U.S.C.A. §§ 466-1, 466c-l, d-e, g-i, 5 U.S.C.A. §§ 623i, 2211; Clean Water Restoration Act of 1966, 33 U.S.C.A. §§ 431-7, 466c, c-l, d-e, g, j, l-n.
46. Dep't of Interior, *Special Report to the Nation on Surface Mining and Our Environment* 100 (1967).

Who shall bear the cost of pollution control, the developers or society? The answer to this question will bear directly upon profit potentials and thus upon investment timing. Since practically all production of oil from shale is still in the exploratory and experimental stage, private resources have not yet been committed to commercial production. In addition, the federal government has not defined its lease policy. But this interim situation need not preclude some decision about pollution cost absorption. Private developers would suffer no wealth losses if they receive early warning of the need to bear the cost of meeting quality standards.

When viewed from the standpoint of economic efficiency, shale oil production should not proceed unless the industry will assume the costs of resource conservation and pollution abatement. If the industry does not bear the costs, third parties will suffer diseconomies, and the industry will have a tendency to over-invest. Pollution regulations must be established as soon as practicable so that developers can make the necessary resource allocation decisions. Control costs then can be taken into account when land, water, and leases are purchased. The result will tend towards a socially optimum scale of oil-shale development.

III

LAND USE EFFECTS

In the oil-shale region land is currently being used for livestock grazing, big game winter range, tillable agriculture, water production, and recreation. Whether these uses will be affected adversely by oil-shale development depends on the size of the industry, the techniques employed to mine and retort the shale, and conservation regulations that accompany development.

A. Land Defacement and Reclamation

The oil-shale deposits of Wyoming, Utah, and Colorado vary tremendously in terms of oil-bearing content, thickness of vein, and depth of overburden. Therefore, mining techniques other than *in situ* cannot be ruled out. It is possible that strip mining and open-pit mining, as well as underground mining, will prove to be technically and economically feasible.

If surface mining is employed, the landscape will be marked by gaping holes and/or long, deep trenches. Underground mining will not itself harm surface amenities, but disposal of spent ash following retorting could be unsightly even though adjacent canyons or dry gulches would accomodate large volumes. In fact the need to handle large quantities of ash may be less disruptive with surface mining than with underground mining since the holes and trenches could provide necessary dumps, and much of the remaining land could be left undistrubed.

The ash magnitudes involved are illustrated by the fact that about one-half barrel of oil may be recovered from a ton of oil shale by most retorting processes.[47] For a 50,000-barrel-per-day operation (considered to be near the minimum size that would be economically feasible), about 100,000 tons of spent shale would have to be disposed of each day. In addition, if dawsonite and nahcolite deposits were being leached out of the spent ash, the ash might be even more difficult to handle, or take longer to cover up.

It has been demonstrated that ash dumps can support substantial weights;[48] they pose no hazard to large wildlife such as mule deer and other migratory animals. These dumps can be revegetated within 3 years,[49] and they could provide plant forage for game and domestic livestock and serve as effective watersheds.

Thus not all neighborhood effects of ash disposal need to be negative. Certain third party benefits, such as better livestock or big game ranges, can be imagined. Society could share in disposal costs to the extent of any such positive benefits. Unfortunately, such cost and benefit data are not now available and never will be until appropriate studies are undertaken. In their absence, intelligent judgments cannot be made concerning conservation regulations that should be imposed upon developers.

Only states in Appalachia have had experience with reclaiming such land scars. Conditions may be similar enough for cost data from Appalachia to be a rough guide in the oil-shale region; benefits are another matter. Many more people live in Appalachia than near the oil-shale lands of the West, and land uses are quite different.

A Bureau of Mines survey[50] of reclamation work conducted in 1964 on strip-mined coal fields in Appalachia indicates that average costs of complete reclamation range from $169 per acre in the South Atlantic states to $362 in the Middle Atlantic states. For partial reclamation, costs range from $74 per acre in the Eastern and South Central regions to $261 in the Mid-Atlantic region. Exactly what constitutes the distinction between partial and complete is unclear.

47. *Id.* at 69.

48. *Competitive Aspects of Oil-Shale Development, Hearings on S. Res. 26 Before the Subcomm. on Anti-Trust and Monopoly of the Senate Comm. on the Judiciary,* 90th Cong., 1st Sess. 315 (1967).

49. *Shale Oil, Problems and Prospects,* Oil & Gas J., March, 1964, at 65.

50. Dep't of Interior, *supra* note 46, at 90.

Benefit-cost analysis must determine whether land reclamation is feasible. The task is formidable, despite the many data available from analogous studies of agricultural and recreational problems. At this point in time, the desirability of requiring all developers to undertake certain conservation measures without some sound economic studies is questionable. Land in the area is owned by federal and state governments as well as by private users, and interests in land use are highly diverse. But following an economic determination of the kinds of reclamation procedures that are desirable, it would seem appropriate to have a single set of standards irrespective of ownership.

An example is provided by the states of Illinois, Indiana, Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia, all of which have enacted legislation to control the ravages of surface mining.[51] Although these controls are directed mainly towards surface mining of coal, their existence has prompted a closer look into the surface mining of other commodities and has induced other states and industries to give serious thought to the possible need for mining laws and standards for land reclamation. Alabama, California, Georgia, Iowa, and Montana are among the states that are seriously considering the need for legislation dealing with mining and land reclamation. As yet the oil-shale states, Colorado, Wyoming, and Utah, have failed to act.

Several states, including Kentucky, Maryland, Ohio, Pennsylvania, and West Virginia,[52] require that mine operators replant surface acreage that has been mined. The general practice is to have operators prepare the soil and plant vegetation according to criteria adopted by a state reclamation commission. Arizona requires mining prospectors to fill holes, ditches, or other excavations and restore the surface to its former condition so far as is reasonably possible. Maine stipulates that permittees and licensees must fill or repair all pits, trenches, or other openings prior to abandoning an area; and Oregon requires restoration of soil and ground cover removed in dredge mining operations.[53] This legislation may provide useful guides to the oil-shale states.

In the case of ownership by the federal government, deposits of oil shale are not subject to general mining laws, but are covered by the Mineral Leasing Act of February 25, 1920. This Act provides for the disposition of certain minerals (including oil shale) not on

51. *Id.* at 74.

52. Dep't of Interior, *Study of Strip and Surface Mining in Appalachia, Interim Report to Appalachian Regional Commission* 4 (1966).

53. Dep't of Interior, *supra* note 46, at 98.

the basis of discovery at location of claim, but by means of leases issued by the Secretary of the Interior.

The issuance of leases depends on the discretion of the Secretary. He may refuse to issue a lease if, in his judgment, exploitation of the mineral deposit would impair other important uses of the land. Also, the Act confers upon the Secretary responsibility for establishing standards for mining operations and for requirements which may be imposed concerning restoration of land when mining operations cease. Therefore, it would seem that federal statutes provide ample scope to permit the Secretary of Interior to consider conservation or third party interests when issuing leases for development of oil-shale lands owned by the federal government.

B. *Effects on Recreation Uses*

The oil-shale area is one of the finest recreation areas in the Western United States and promises to be even more popular in the future as accssibility to the area is improved. Canyons of the Colorado, Yampa, and Green Rivers are magnificent. Flaming Gorge Reservoir is a splendid boating and sport fishing resource. The region also contains Dinosaur National Monument. Esthetic and physical enjoyment of these resources by third parties could easily be impaired in the absence of pollution and conservation measures.

Furthermore, the oil-shale country is the wintering ground for the largest migrating deer herd in North America.[54] Mule deer and elk feed in the lowlands that contain the shale. The vegetative cover in these areas might be seriously disrupted by surface retorting, especially if lands are ripped up by strip mining, and ash is indiscriminantly dumped wthout provision for revegetation.

C. *Air Pollution Effects*

Williamson believes the dust problems may be significant.

> All oil-shale retorts have a gas base in motion. Most of them have a moving charge of solids and some retort chambers move themselves. . . . Other things being equal, dust is produced disproportionately larger the more vigorously the retorting charge is agitated.[55]

In addition, surface mining may also be a significant contributor to air pollution in the area. Vibrations resulting from blasting and

54. *Competive Aspects of Oil-Shale Development, supra* note 48, at 258.

55. Williamson, *Oil Shales, Pt. 5—Oil Shale Retorts,* 8 Colo. School of Mines Min. Ind. Bull 4 (1965).

movement of equipment during mining operations would no doubt raise a considerable amount of dust. Fortunately, however, the oil-shale area is far removed from existing major population centers and is in an area where fairly strong winds are common. This would suggest that any pollution of the atmosphere even in the immediate area would be of fairly short duration, thus minimizing neighborhood effects.

A CONCLUDING COMMENT

A review of the conservation issues quickly demonstrates the paucity of reliable information on which policy decisions can be based. One reason for this lack, of course, is that the best technology for mining and retorting has not been fully determined. But, perhaps more importantly, the research effort necessary to obtain answers to relevant questions about neighborhood effects simply has not been expended. What is particularly needed is a thorough study of economic impacts on third parties, and a benefit-cost analysis of alternative ways of alleviating resource pollution and defacement expected to accompany oil-shale development. This research is urgently needed. Without it, the social cost of policies that must be initiated in the near future could be exceedingly high.