600977033

Oil Shale and the Environment

LIBRARY
U.S. ENVIRONMENTAL PROTECTION AGENCY
EDISON, N. J. 08817

The Resource 1
The Processes.....4
The Environment 10
Research & Development...25
The Outlook.....28
For Further Reading.....29

WHAT THIS REPORT IS ABOUT

This is a report about an American energy resource, oil shale. It is also a report about the environment and the environmental changes that an oil shale industry could bring about. This subject is currently surrounded by controversy, unresolved issues, conflicting interests, and uncertainties.

There is an urgency to produce more domestic oil as existing supplies dwindle and world oil prices rise. But what we know about the environmental consequences of oil shale development is sparse and often speculative. However, we do know that a relatively small region of the country will have to bear the full burden of these environmental consequences. So — two issues become basic to the future of oil shale:

> Should the resource be developed now with all of the attendant environmental risks, or can we afford to wait until we find out more about the risks and their prevention?

And

> Is it fair to trade local lifestyle for the national good?

The purpose of this report, then, is to put oil shale development into a realistic environmental perspective and to describe what the government is doing to insure that development does not exact an intolerable environmental price.

The Resource

GREENVILLE, COLORADO, September 1988

Since early in the twentieth century, people had been coming to Greenville, my town, a quiet, small town in a nice but somewhat desolate part of western Colorado called the Piceance Basin. It was a region characterized by high plateaus, angular cliffs, narrow valleys, and box canyons. It was always a little too hot in the Greenville summers and too cold, too bleak, in the Greenville winters. It was not a perfect place, by any means. But the air was clean, the skies were blue, and the water, what there was of it, was pure. In short, Greenville was a rough and hardy place where people lived simple, uncomplicated lives.

Some of us used to think of it as God's country. A lot more of us thought it was just plain "our" country. But the people who came from outside – engineers, businessmen, politicians, developers, and even environmentalists – knew better. They knew Greenville for what it really was. Shale Country.

OIL SHALE – WHAT IS IT?

Rock. A layered, grey-brown, sedimentary rock laid down eons ago in fresh water lakes. The oil in oil shale is contained in kerogen, a solid, powdery, largely insoluble organic substance.

Kerogen is a complex material composed mainly of carbon, hydrogen, oxygen, sulfur, and nitrogen. The kerogen molecule is large and heavy. Each molecule is bound to the other molecules by the oxygen and sulfur and hydrocarbon bridges so that a three-dimensional network is formed. This network extends through the mineral portions of oil shale and binds them together.

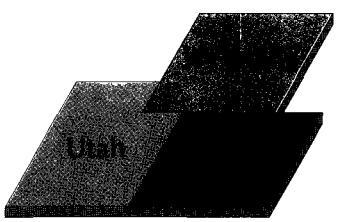
How much kerogen is in a given deposit of oil shale depends on how much organic material found its way into the prehistoric lake beds. Richer deposits of oil shale contain up to 20% kerogen. These high grade deposits produce 25 to 35 gallons of oil per ton of shale.

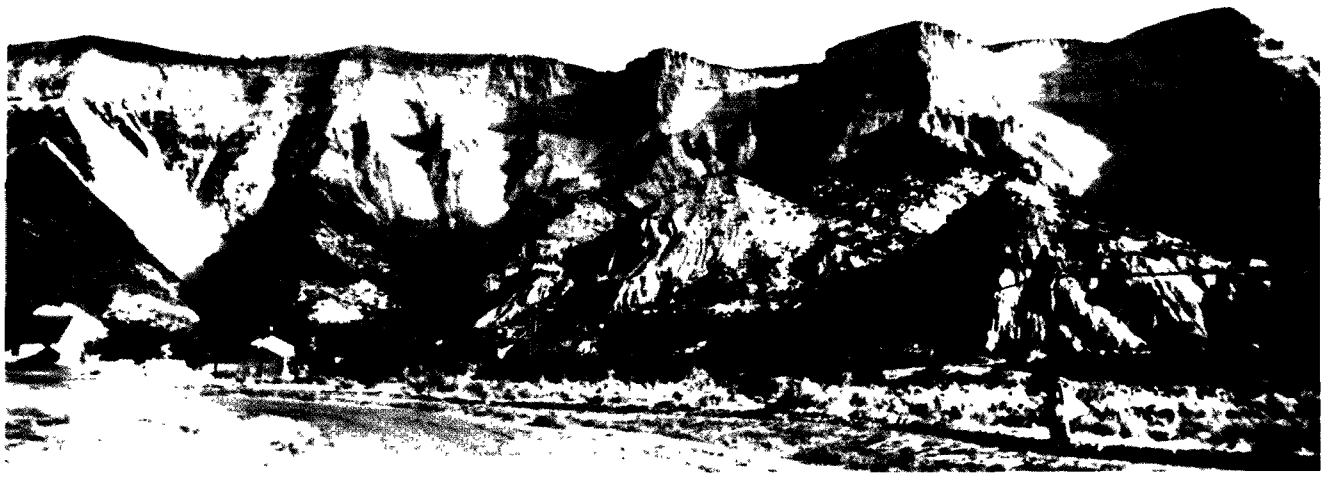
Grades of Shale

WHERE IS OIL SHALE FOUND?

In geologic basins, sandwiched between layers of other kinds of sedimentary rock. Low grade, shallow deposits underlie large parts of the eastern and central states and northern Alaska. But most of the resource, and the most valuable part of it, is locked in the Green River Formation underlying 16,500 square miles of Colorado, Utah, and Wyoming. Almost all of this oil shale land — 80% of it — is owned by the Federal government.

Colorado's Piceance Basin contains 85% of this western high grade shale. These beds of shale, called marlstone by geologists, range from 10 to 2000 feet thick. Much of this Colorado shale is relatively easy to get at, lying 100 to 1000 feet below the surface, with some outcrops near the edge of the basin. The remainder of the high grade shale is in Utah's Uintah Basin (10%) and in Wyoming (5%). Some of these deposits also outcrop along cliffs and ledges — others are buried as deep as 3000 feet.

DEPOSITS	KNOWN RESOURCE (Billion Barrels)			
	RECOVERABLE UNDER PRESENT CONDITIONS	MARGINAL & SUBMARGINAL		
Grade (Gal/Ton)	25 — 100	25 — 100	10 — 25	5 — 10
	80	520	1,400	2,000
	None	None	200	200
	Small	Small	Small	Small
TOTAL	80	520	1,600	2,200



SHALE COUNTRY

Area:	Colorado, Utah, Wyoming: 16,500 contiguous square miles.
Population:	Sparse, about 3 persons per square mile. Population centers are small towns, averaging about 2,000 people, located in river valleys adjacent shale lands.
Economy:	Ranching (cattle, sheep), farming (hay, alfalfa), mining (coal, uranium, vanadium, limestone, trona).
Landlook:	Piceance Basin, Colorado: cliffs, buttes, canyons, sagebrush, pinyon-juniper, some Douglas fir and aspen at higher elevations. Uintah Basin, Utah: high desert, desert shrubs, salt desert shrub, pinyon-juniper and sagebrush.
Elevation:	Piceance Basin: 6000 – 8500 ft; Uintah Basin: 4600 – 8000 ft.
Climate:	Semiarid. 45°F to 90°F summer, –40°F to 60°F winter. Temperature inversions are common, particularly in Colorado. Snow is major precipitation – 7 inches per year (Wyoming) to 24 inches per year (upland Colorado shale areas). Summer thunderstorms.
Water:	Main source is the Colorado River and its tributaries, the Green and White Rivers. Some underground supplies are available. River water is controlled by intricate system of water rights covering whole of Colorado River system. Runoff from oil shale land is legally committed to agricultural and stockwatering use. Some owners of privately held shale lands also own some water rights.

HOW MUCH OIL IS THERE IN U.S. OIL SHALE DEPOSITS?

A large amount. The U.S. Department of the Interior estimates that 80 billion barrels of oil can be recovered from western marlstone using present day technology. This is more energy than is contained in known U.S. oil and natural gas reserves. But it is only about one tenth of the estimated 800 billion barrels of shale oil that might eventually be recoverable under more advanced technology and different economic conditions.

The U.S. consumes about 6 billion barrels of petroleum products annually.

The Processes

GREENVILLE, COLORADO, September 1988

Oil Shale. The fact of the matter was, Greenville was sitting next to one of the richest deposits of oil shale in the United States. And ever since the talk about shale began over seventy years ago, we always knew – our parents always knew – that it was just a matter of time before someone would come and get it.

HOW DO YOU GET THE OIL OUT OF THE SHALE?

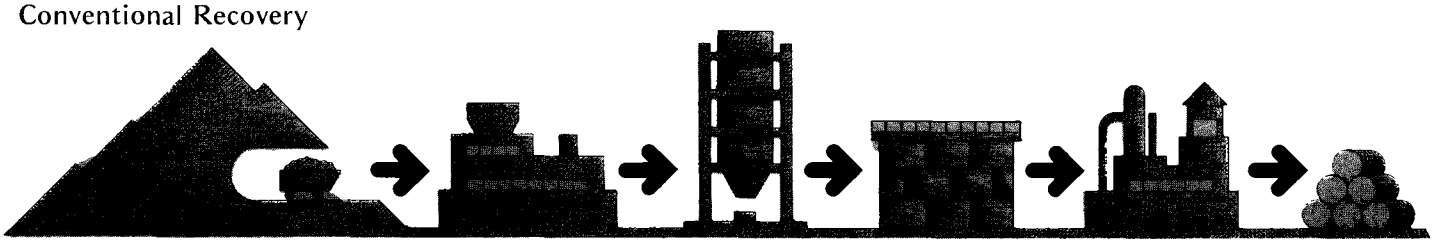
By heating it. Heating breaks the chemical network holding the heavy kerogen molecules together, and "cracks" the individual large molecules into smaller molecules. This releases a liquid hydrocarbon mixture, some combustible gases, and a coke-like residue. It is the liquid hydrocarbon mixture, the shale oil, that is the most valuable.

Long ago, Indians of the mountain west accidentally found that marlstone would burn, so they threw chunks of it on their campfires. Later, some settlers in the region used marlstone to build their fireplaces, only to find their fireplaces caught fire. Today's methods of getting the oil out all involve heating processes.

The well established method of room and pillar mining can be used for underground extraction. In room and pillar mining, part of the shale is blasted to rubble, leaving a large room with pillars of shale left standing to support the roof of the mine. About 30% to 40% of the shale in the mine is left behind in these supporting pillars. The shale broken up by blasting is then taken to primary crushers within the mine to be reduced to a size that can be placed on conveyor belts for delivery to the main crushing plant on the surface.

If shale deposits lie close enough to the surface, they can be mined by the open pit method. Only four or five oil shale sites in Colorado are suitable for open-pit mining.

Conventional Recovery



BUT HOW DO YOU GET THE OIL OUT?

One way is to mine the shale and put it through the heating process above ground. This is a conventional way of recovery, a familiar process used in such industries as copper refining and steel-making.

Another, newer way is to break up the shale while it is still in the ground and heat it in place (in situ).

Conventional Recovery

Conventional recovery consists of four basic steps: mining the shale, crushing it to the proper size for the retort vessel, retorting the shale to release the oil, and refining the oil to bring it up to a high-quality product. In this recovery method, the shale can be mined underground or on the surface, depending on the depth and nature of the oil shale deposit.

In open pit mining, the overburden on top of the shale is blasted loose and carried to a disposal area away from the mine. Then, the exposed shale is reduced to rubble by explosives and taken to the crushing plant on the surface by truck or conveyor belt, as in underground mining. As the overburden and shale are removed in successive stages, the mine widens and deepens, forming a stadium-like pit that can cover many square miles.

Minimum shale thickness for underground mining is about 30 ft, but 60-ft seams are preferred.

Whether to use underground or surface mining depends largely on the stripping ratio – the thickness of the overburden compared to the thickness of the shale. A ratio of less than 2.5:1 favors surface mining. If the stripping ratio is greater than

2.5:1, underground mining is generally indicated. In the center of the Piceance Basin, 2000-foot thick shale beds are overlaid by 1000 feet of overburden giving a stripping ratio of 0.5:1. Or, for every foot of overburden removed, the mine will yield two feet of oil shale.

Once delivered to the crushing plant, fractured shale is broken up into still smaller pieces, with the size depending on the size necessary for the particular heating method used in the next step of the process that gets the oil out of the shale.

The crushed shale is then fed into a closed retorting vessel and heated to very high temperatures – between 800°F and 1000°F – to decompose the kerogen. About 75% of the kerogen is separated from the rock at these temperatures.

The retort is essentially a large kiln with a raw shale feeder hopper, various mechanisms that introduce heat to the shale, pipes to collect the oil and gas products, and a grate to discharge the shale residue that remains after the oil is released.

A 100,000 bbl/day retorting and upgrading plant would process about 50 million tons of shale per year.

Different retorting processes apply heat to the shale in different ways. The heat carrier can be either a gas or noncombustible solids such as ceramic balls or sand. Internal combustion retorts are used in some processes in which gas is the heat carrier. The heat-carrying gas is formed in the combustion of the carbon portion of the shale. This gas circulates through the crushed shale mass releasing additional gas and an oily vapor. Other processes recycle gas heated outside the retort through the shale. In processes that use hot solids, the solids come into direct contact with the shale in the retort and transfer their heat to it. Generally speaking the internal-combustion gas retort produces slightly less oil, and oil of somewhat lower quality, than does the gas-recycle or hot-solids retort.

The oily vapor produced as the kerogen decomposes during retorting is condensed to form the raw shale oil. This oil has a high nitrogen content as well as appreciable sulfur and oxygen. The amount of nitrogen, sulfur, and oxygen in the raw shale oil varies with the retorting process.

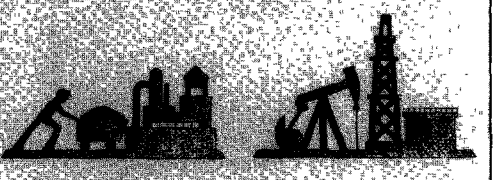
These contaminants in the raw shale oil have to be reduced through intermediate processing before the oil can be used directly as refinery feedstock.

Raw shale oil has a pour point ranging from 70°F to 90°F. Below this temperature, it becomes an elastic mass and will have to be processed or blended to reduce its viscosity if it is to be shipped via conventional pipeline to the refinery. However, it may be possible to ship the oil by heated pipeline or heated rail tank cars without having to change its flow characteristics.

Pour point is the temperature at which the oil will flow. The pour point of conventional high grade petroleum is about 40°F.

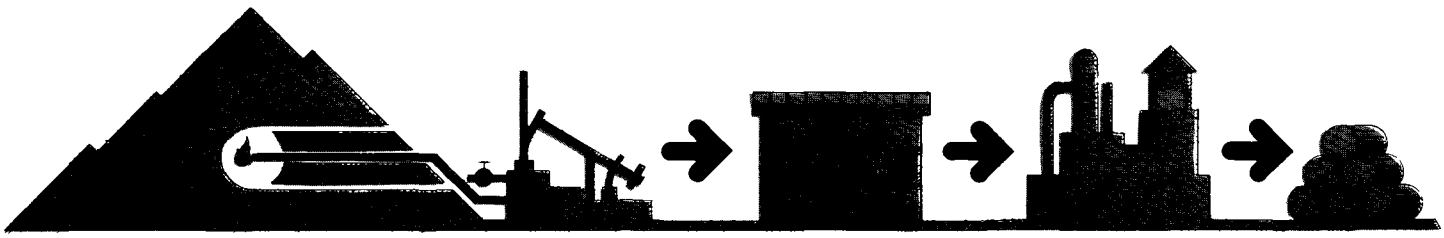
At the refinery, raw shale oil is upgraded to further remove its nitrogen, oxygen, and sulfur content. This is done by chemically reacting the oil with hydrogen so that it becomes a synthetic crude oil that is essentially the same as high grade conventional crude oil.

Impurities in Shale and Conventional Crude Oil



Impurity	Raw Shale Oil (wt %)	Conventional Crude Oil (wt %)
Nitrogen	1.7 – 2.1	More than 0.5
Oxygen	1.3 – 1.6	More than 0.5
Sulfur	0.7 – 1.0	More than 5.0

In-Situ Process



In Situ Recovery

In "true" in-situ processing, a central well is first drilled into the bed of shale. Several other wells are then drilled in a pattern around the central well. Explosive charges are placed in the wells and detonated to fracture the surrounding shale. Sometimes the shale is fractured by pumping water into the wells under very high pressure. This fracturing process is necessary to create pathways (void spaces) in the normally impermeable shale so that heat can be transferred to it. For a given in-situ site, about 30% of the shale volume has to contain void spaces for enough combustion to take place to decompose the kerogen.

Once the shale is fractured, it is ignited by a flame from compressed air and a combustible gas pumped into the central well. The hot combustion gases circulate along the pathways in the fractured shale, heating it to retorting temperatures and releasing the gas and oil from the kerogen. After a few hours, the externally-fed gas is shut off, but compressed air continues to be fed to the burn zone where combustion is sustained by the carbon residue that remains as the shale is retorted.

The gas produced in the retorting process is withdrawn from a well downstream from the central injection well. Some of this gas is recirculated to the central well to aid combustion.

The vapor produced in in-situ retorting condenses to liquid in a sump at the base of the shale area and is pumped to the surface.

In a "modified" version of in-situ recovery, about 30% of the lower portion of the shale bed is first mined by conventional methods. This leaves a void space beneath the shale. The shale is then fractured with explosives, filling the mined-out space with shale rubble. The rubble column is ignited, retorting the shale in place, as in the "true" in-situ method, to produce gas and oil.

The oil from in-situ processing has the same characteristics as the oil retorted on the surface and has to be processed to remove impurities before being used as refinery feedstock.

WHICH WAY IS BEST – CONVENTIONAL OR IN SITU?

It's hard to say. Each method has its advantages and disadvantages – economically and environmentally.

Conventional, aboveground retorting will give higher oil yields for a given amount of shale retorted. But in-situ recovery may cost less, although comparative costs for the two methods have not yet been firmly established.

Each technique poses equally severe environmental problems, even though they may be different. For example, in-situ recovery may not produce as much air pollution as aboveground retorting, but controlling potential water pollution underground may be more difficult in in-situ recovery than in aboveground retorting.

When an oil shale industry gets under way in full force, both conventional and in-situ recovery methods will probably be used, sometimes in combination for certain oil shale deposits.

WHAT IS LEFT AFTER THE OIL IS TAKEN OUT OF THE ROCK?

Most of the rock – in the form of spent shale. Whether conventional or in-situ recovery is used, all of the inorganic material in the shale remains after the oil is removed. This amounts to about 85% of the total weight of the shale.

Spent shale is relatively useless. Some of it can be used in fill for roads, but there is essentially no market value in spent shale. What to do about the huge quantities of this leftover rock will be a major problem in an oil shale industry.

Only about 15% (by weight) of oil shale can be converted to oil.

WHAT CAN YOU GET FROM OIL SHALE OTHER THAN OIL?

Gas. Some of the gas produced in the gas-recycle retort and the hot-solids retort and in some in-situ recovery methods has a high heating value. This gas can be processed relatively inexpensively to provide on-site electric power for mining, retorting, and refining. It can also be treated to become high quality pipeline gas suitable for other industrial as well as residential consumption. The gas produced by the internal-combustion gas retort, however, is of low heating value and requires special, costly processing for it to be made suitable for power generation.

High-Btu gas from a 10,000 bbl/day retort could supply the energy needs of a town of 2000 people.

WHAT ELSE CAN YOU GET FROM OIL SHALE?

A few byproduct minerals. Some oil shale deposits contain sodium bicarbonate (nahcolite) and a form of aluminum (dawsonite). Dawsonite can be extracted and converted to aluminum which could lessen to some degree the U.S. need to import aluminum ore. Nahcolite could be extracted and transformed to soda ash, or used for sulfur removal from power plant stack gas. But, in general, oil and gas are the main products of oil shale.

IS SHALE OIL IN COMMERCIAL PRODUCTION IN THE U.S.?

No. Not yet. People have thought about producing oil from U.S. shale on and off for more than 100 years. Shale oil has been produced for a number of years on a relatively small scale in Scotland, Estonia, as well as in South Africa and China. But each time it looked as though a U.S. shale oil industry was about to come into being, it was shelved because a more economical energy supply appeared. In 1850, an oil-shale boom appeared to be imminent in the United States – a plant to process shale went into operation in Ohio – but in 1859, the landmark discovery of natural liquid petroleum in Titusville, Pennsylvania, cut short the oil shale boom before it really began. Again, in 1915, an oil shale rush began after the U.S. Geological Survey reported finding rich shale deposits in the Rocky Mountains. But soon the East Texas oil fields dimmed the future of oil shale.

Now the story is different. Known U.S. liquid petroleum supplies are dwindling and the country is searching for new sources of energy for the future. Diminishing U.S. oil reserves and the rise in the price of world oil has prompted major advances in oil shale recovery technology. Of all the new ways to supply U.S. liquid energy needs that are under development, oil shale is the closest to commercialization.

But bringing an oil shale industry on stream is by no means an easy matter. Many troublesome questions remain – political, economic, and environmental. People in industry and government are working to find answers to these questions. The public is waiting for the answers, and for the oil.

ARE ANY OIL SHALE PROCESSES READY FOR FULL-SCALE PRODUCTION?

Yes, several. Concentrated development of both conventional and in-situ recovery processes has been going on since the 1960s, and is continuing today, under both industry and government sponsorship.

At the moment, three types of hot-gas retorting methods are sufficiently well developed to be ready for installation in full-scale plants.

- Union Oil Company has announced plans to begin operation of its vertical gas-recycle Retort B process in a 50,000-bbl/day plant at a site in Colorado. This process was tested at Union's 5-ton/day pilot plant at Brea, California.
- Paraho Development Corporation, a 17-company consortium, is scheduled to produce a total of 80,000 barrels of shale oil in its vertical gas-combustion kiln on Navy oil shale land at Anvil Points, Colorado, under joint Navy/ERDA financing. The Paraho process is based on a design that has been used for many years to process limestone. Paraho has also proposed to build an 11,500 ton/day commercial plant.

– Superior Oil Company will utilize a unique, circular gas-combustion retort in which the shale travels horizontally through the retorting zone. Superior intends to use this retort on its own shale properties in Colorado. This shale contains dawsonite and nahcolite, which will be recovered as part of the shale oil processing sequence.

Of the heated-solids retorting methods, two are ready to be considered for commercial operation.

– The Lurgi-Ruhrgas process is a modified coal carbonization technique developed in the 1950s by Lurgi and Ruhrgas A.G. in Germany. The oil shale version uses sand or recycled shale ash heated to about 900°F to retort the shale. The raw shale for this process has to be crushed to a fineness of less than ¼ to ½ inch.

– Another hot-solids process is the TOSCO II retort. This method, developed by the TOSCO Corporation from a Swedish design, uses ½-inch ceramic balls heated to about 1000°F to transfer heat to the shale. To be used in this process, the shale has to be crushed to a fineness of less than ½ inch. A semi-works TOSCO retorting plant built at Parachute Creek, Colorado, by Colony Development Operations (then a joint venture of Sohio Oil Company, Cleveland Cliffs Iron Company, and TOSCO) produced 200,000 barrels of shale oil in eight years of pilot tests. Recently, the TOSCO Corporation, in conjunction with Colony, designed a commercial-sized plant for Parachute Creek to produce 47,000 bbl/day of shale oil and 4300 bbl/day of liquefied petroleum gas (LPG).

– TOSCO also plans to begin pilot plant development on its Sand Wash Unit, leased from the state of Utah.

Four in-situ processes are being readied for potential commercial development.

– Occidental Oil Company's "modified" vertical in-situ process is the closest to commercialization of the in-place recovery methods. A recent run on one of their two commercial-sized (120 feet square by 270 feet high) in-situ complexes produced 30,000 barrels of oil in six months from 17-gal/ton shale. The second of these commercial-sized in-situ complexes has been ignited.

– Lawrence Livermore Laboratory (LLL), under the auspices of the newly formed Department of Energy (DOE), is developing a modified horizontal in-situ process – rubble in-situ extraction (RISE) – that is particularly efficient in retorting shale beds 400 to 2000 feet thick.

– In addition, Geokinetics Inc., is producing oil from a horizontal modified in-situ pilot process on its Uintah Basin properties in Utah.

– One "true" in-situ process being considered is in the pilot plant stage at DOE's Laramie Energy Research Center (LERC), near Rock Springs, Wyoming. A recent run of the retort on Green River shale averaging 21 gal/ton produced 700 gallons of oil in the first 35 days of operation. A second "true" in-situ process is being prepared for production by Equity Oil Company in the Piceance Creek Basin. The heating fluid will be superheated steam.

Several groups of oil companies have leased federal oil shale land in Colorado and Utah (Tracts C-a, C-b, U-a, and U-b) under the U.S. Department of Interior's Prototype Oil Shale Leasing Program completed in 1974.

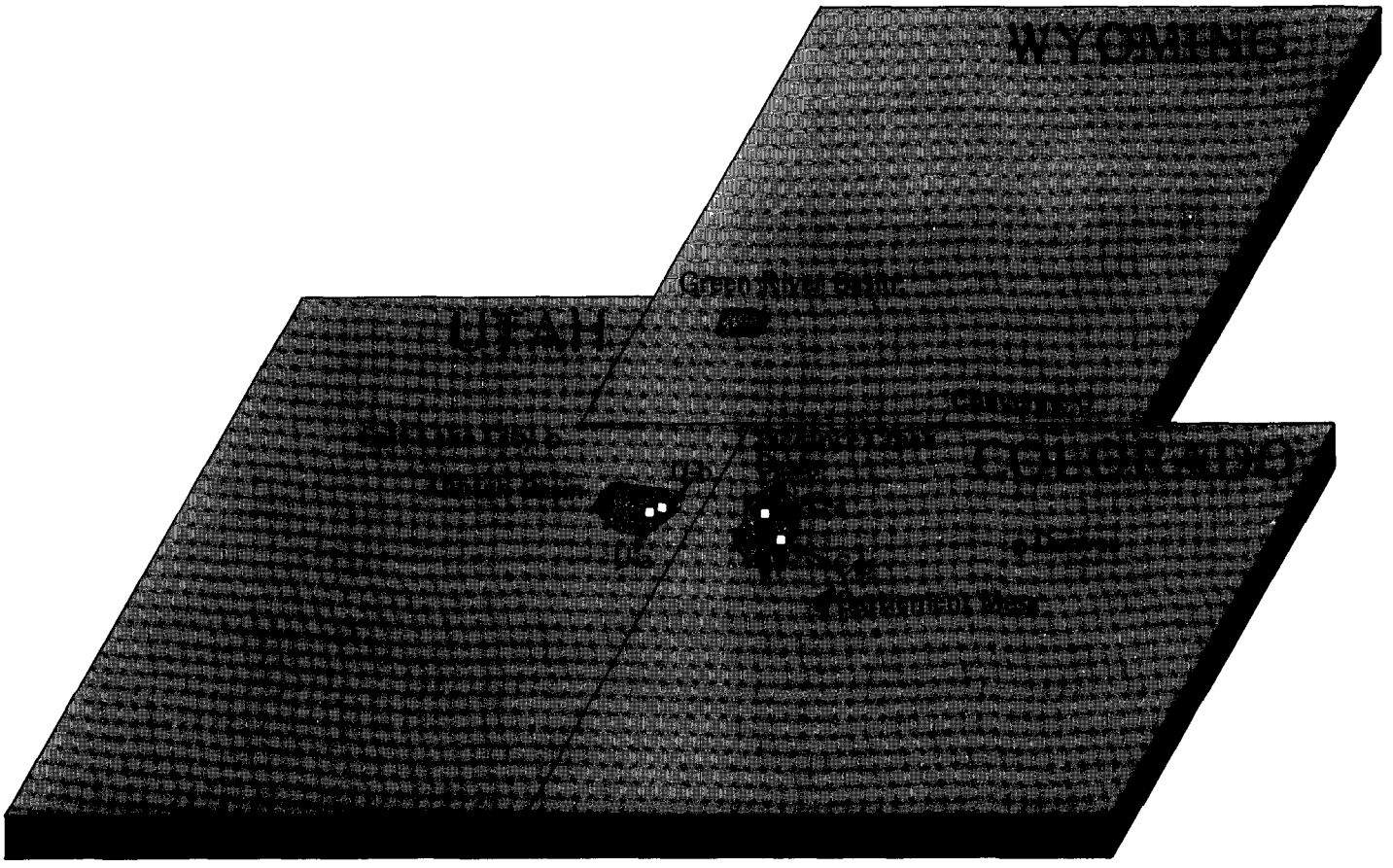
– Gulf Oil Corporation and AMOCO plan to develop a 50,000 bbl/day TOSCO II plant on Tract C-a, along with tests of LLL's RISE in-situ method.

– Occidental Oil Company and Ashland Oil plan to establish a 57,000 bbl/day Occidental "modified" in-situ process on Tract C-b, perhaps coupled later with a TOSCO II plant.

– In Utah, Sun Oil Company and Phillips Petroleum may use the Paraho and TOSCO II processes to produce shale oil on Tract U-a, while Sun, Phillips, and Sohio hold an option on Tract U-b to install the Paraho process.

In addition, the Department of the Interior selected four additional federal tracts in Colorado and Utah in 1975 for development of prototype in-situ processes. These tracts will be offered for bid following approval of the environmental impact statement to be issued in late 1977.

Map of Leased Lands



	TRACT	AREA (acres)	ESTIMATED RECOVERABLE SHALE OIL (million barrels)
Colorado	C-a	5088	1300
	C-b	5093	723
Utah	U-a	5120	331
	U-b	5120	271

The Environment

GREENVILLE, COLORADO, September 1988

In 1978, ten years ago, they came to get the shale out – began to, at least. They built a half dozen oil shale plants, then started mining and retorting it a couple of years later.

Since then, Greenville has never been the same. Not that we expected it would be. Before any of it happened there were dozens of reports that tried to define what oil shale would bring to . . . and take from . . . life in Greenville.

In the old days, before the mining began, it was still possible to talk about Greenville without having to talk about oil shale. Today, Greenville is oil shale. And oil shale is Greenville's environment – air, water, land and life.

So, fortunately, a lot of thinking went into it. Because if it hadn't . . .

WHO IS WATCHING OUT FOR THE ENVIRONMENT?

Everybody. The Environmental Protection Agency, the Department of Energy, other governmental agencies, industry, and public action groups.

Everyone knows that an oil shale industry will cause some environmental changes – changes that could be disagreeable, even dangerous.

EPA is studying many aspects of oil shale development. These studies are developed by EPA through funding provided by the Interagency Energy/Environment Research and Development Program to obtain information on health and ecological effects from pollutants created by the development. EPA is also developing information on methods that can be used to control the release of those pollutants. The purpose of these studies is to ensure that an oil shale industry will have the fewest possible adverse environmental effects.

As yet, however, there remain a number of unanswered environmental questions. And it may not be possible to satisfactorily answer the questions until an operating plant exists. The technologies are just too new, the affected ecologies not well-understood, and the scale of operations just too massive to be able to predict with any certainty what effects an oil shale industry will really produce. And, environmental controls for the oil shale industry are subject to large uncertainties. Simple extrapolation from existing controls may be insufficient for oil shale or may not, for a host of engineering reasons, work with efficiencies required to meet federal and state standards.

In addition to EPA, sixteen other federal agencies are studying oil shale development – both processes and environmental controls – through the Interagency Program. Industry, too, is developing production methods with an eye toward reducing adverse environmental effects. Public action groups are also contributing information on potential areas of disruptive effects.

Often there is overlap in this research and development. While this overlap may involve some duplication of effort, it does offer the advantage that all those who will have a hand in the production of shale oil or who will be affected by the production processes are being made more aware of each other's interests. Out of this awareness can come the solutions to the many problems associated with an oil shale industry. This will allow the industry to develop in an economically and environmentally sound fashion with the best and most practicable technology.

This approach is relatively new in the energy business. In the past, little thought was generally given to the adverse effects of energy development. In this respect, oil shale development may set the practice for future energy development. Since oil shale is the liquid energy resource closest to commercialization, it will be the first to have been so thoroughly environmentally studied before it becomes established as an industry.

HOW WILL GETTING THE OIL OUT AFFECT THE ENVIRONMENT?

In four potentially adverse ways.

- By creating air, water, and solid waste pollution.
- By creating possibly hazardous health effects.
- By disrupting the land.
- By creating boom towns with their stressing side effects.

GREENVILLE, COLORADO, September 1988

Oil shale is Greenville's air. Not what it used to be, but still pretty good. After all, there were standards to be met, state and federal, and the industry worked to meet them with all due speed.

Which is not to say that in those early development years, when standards couldn't be met, when we first saw that film of dust on the cars we parked on the street, or when our eyes would smart from fumes from the retorting, that we were not dubious. Mad, in fact. Furious.

But they worked it out like they said they would, and now, except for those rare times when one of the stack scrubbers goes on the fritz, the air is good. Not as good as it used to be, but better than the air in New York City, Los Angeles, or even Lake Tahoe, California. But it's just not the old Greenville air.

WHAT ABOUT OIL SHALE AND AIR POLLUTION?

Currently, the air in the tri-state western oil shale region is relatively clean. But this relatively clean quality of the air is expected to decline somewhat in the long term as a mature oil shale industry becomes rooted in the region. It can also be expected that some people in the area may be affected by the local concentration of air pollution caused by the temperature inversions that frequently occur, especially in Colorado.

In an oil shale industry air pollution will come from a large number of sources, but basically the pollution will be in the form of dust and larger particulates, and gases containing sulfur, nitrogen oxides, carbon monoxide, and trace hydrocarbons.

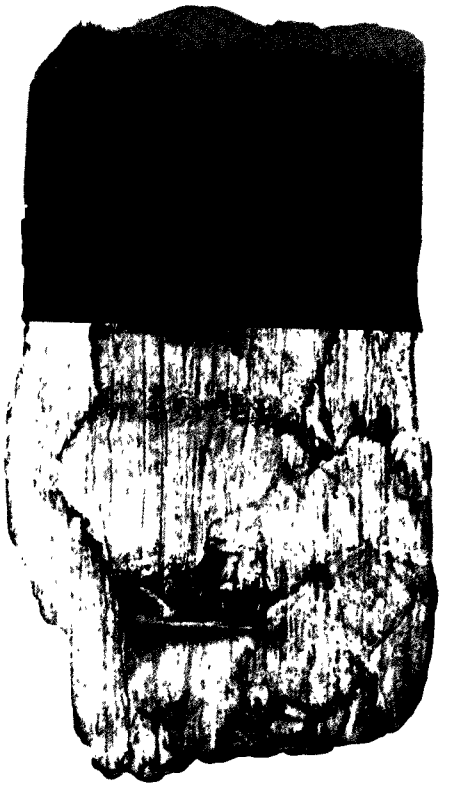
What About Dust?

There will be dust and larger particulates in the air from blasting, from mining, and from crushing the source shale and transporting it. There will also be dust as a byproduct of hauling the enormous amounts of spent shale from the retorting area to the storage sites, some of which could be miles away.

To minimize the amount of air pollution resulting from dust and larger particulates, a number of major steps will be taken.

In all mining operations, wetting agents will be mixed with water, thus holding down dust during drilling, after blasting, and along the routes that take the shale out of the mine.

In the crushing and retorting plants, the shale will be carried along in covered conveyors and sprayed with water at points where it is to be transferred from these conveyors to processing units. Baghouse filters similar to those used in industrial smokestacks will be used in crusher units to capture the dust from the shale as it is being pulverized.



Wet scrubbers will control any particulates generated in retorting operations. Then, sprays of water will be used to cut down dust during the transport and stockpiling of spent shale at disposal sites.

Applied conscientiously, these steps should in great measure reduce most of the dust and large particulates that would be potential hazards to air quality in a modern oil shale operation.

What About Gases?

Gases will enter the air from retorting and refining operations and from electric power generation. There will also be emissions to the air from vehicles of all sorts — trucks, earthmoving equipment, workers' automobiles, as well as from commercial developments that will spring up to serve the new urban populace. It is expected that there will be increased haze and lowered visibility in the area. In addition to taking some toll of the quality of the air humans will breathe, air emissions could cause cumulative adverse effects on local vegetation and wildlife.

As with dust and dust control, numerous preventive measures and controls can greatly diminish the danger posed by gases released into the air as byproducts of the oil shale processes.

Sulfur emissions from all gaseous fuels produced in the retorting process will first be treated to recover ammonia and will then be desulfurized before being used to heat the shale. Well established techniques will be used to remove the sulfur from the retorting and output gases — a Stretford chemical recovery system will be used for the low-Btu gases produced in the Paraho process, and the high-Btu gases that are produced by the TOSCO process will be reacted with hydrogen, followed by chemical removal methods, to clean out most of the remaining sulfur.

Diesel equipment used in underground mining will be equipped with devices to reduce particulates and nitrogen oxide emissions in the exhaust.

How well nitrogen oxides emitted from gases produced in shale oil processing are controlled will depend on how much of the nitrogen in the shale can be converted to ammonia before the gases are used as power plant fuel. Additionally, burners that use the gas for fuel will be designed to reduce nitrogen oxide emissions. If liquid fuels are used in shale processing, they will be reacted with hydrogen to transform their nitrogen content to ammonia before they are burned.

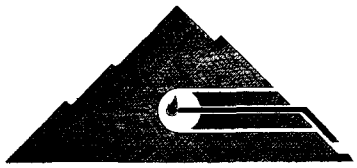
The amount of trace hydrocarbons and carbon monoxide given off to the air from oil shale operations is expected to be within state and federal standards. If there is any question of their quantity, the gas streams in which they are contained will be incinerated before being emitted to the atmosphere. Likewise, trace elements, like arsenic and antimony, are not expected to be emitted from plant gases in large enough quantities to become a hazard.

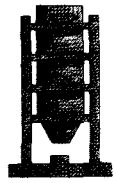
How Much Air Pollution?

Enough to worry about. The amount of pollutants emitted to the air from retorting operations will vary among the different processes.

In a full-scale industry, several types of processes will be in operation at one time, centered near the sources of shale. Pilot plants used to test these processes now operate under variances to air quality standards granted by federal and state agencies. Emissions from commercial-sized plants, of course, will have to meet air quality standards, and ways to reduce emissions are being studied. But at present none of the processes being considered for a commercial-sized oil shale industry can meet both federal air quality standards and those in force in Colorado.

Predicted Emission Rates from Oil Shale Retorting Processes Producing 50,000 bbl/day (tons/year)





Pollutant	In-Situ Retorting	Surface Retorting
Particulates	1,600	300 — 3,250
Sulfur Dioxide	8,500	960 — 5,800
Nitrogen Oxides	2,300	600 — 6,400
Carbon Monoxide	70	300 — 3,600
Hydrocarbons	1,000	1,400 — 4,000

GREENVILLE, COLORADO, September 1988

Oil shale is Greenville's water – what there is of it. And there never was all that much to begin with, what there was came from the Colorado River and its tributaries, the Green, White, and Roaring Fork Rivers, as well as from underground sources and surface streams.

Oil shale took the water, sometimes as much as three barrels of water for every barrel of shale oil, and while no one ever died of thirst in Greenville, there were some rough times for ranchers. One summer, in the early 1980s, there was a real drought, and the cattle suffered. Some ranchers went out of business. But it was a fluke year to begin with, half the normal precipitation, very dry. Still, without oil shale, it might have been a different story. It could happen again, of course, but probably it won't, mostly because almost all of the ranchers sold their land to the oil companies and moved out.

Lucky for Greenville that there was enough advance planning in the late 1970s to assure that all this water, after it had been used for processing the shale, would go to good, safe use – which it did. It's been recycled and reused in the processing, again and again. Or, it's been used to irrigate the new vegetation that the companies planted on the huge mounds of spent shale that built up in the area over the years.

Still, I think I feel a little less comfortable each time I go to the tap for a cold drink on hot summer days.

WHAT ABOUT OIL SHALE AND WATER?

The water question has two parts. What will withdrawal of the large amounts of water necessary for extracting and processing oil shale do to local supplies?

And, what kind and how much water contamination will an industry and its associated towns cause?

Supply – Is There Enough?

People disagree about how much water a 1-million bbl/day oil shale industry and its associated towns will use. One estimate by the U.S. Department of the Interior is 120,000 to 190,000 acre-ft per year. This is about 2 to 3 barrels of water for every barrel of oil produced by aboveground retorting. Another estimate by the Colorado Water Conservation Board is 230,000 to 250,000 acre-ft per year. If nahcolite and dawsonite are recovered along with the shale oil, another 50,000 acre-ft will be consumed.

An acre-ft is the amount of water that would cover 1 acre to a depth of 1 foot.

Water for an oil shale industry will be taken mainly from the rivers of the region. Although much of the water in these rivers is already allocated by law to other consumers under the Colorado River Compact of 1922, the Upper Colorado River Basin Compact of 1948, and the Mexico Treaty of 1944, the U.S. Department of Interior projects that there will be ample surface water potentially available for a 1-million bbl/day oil shale industry.

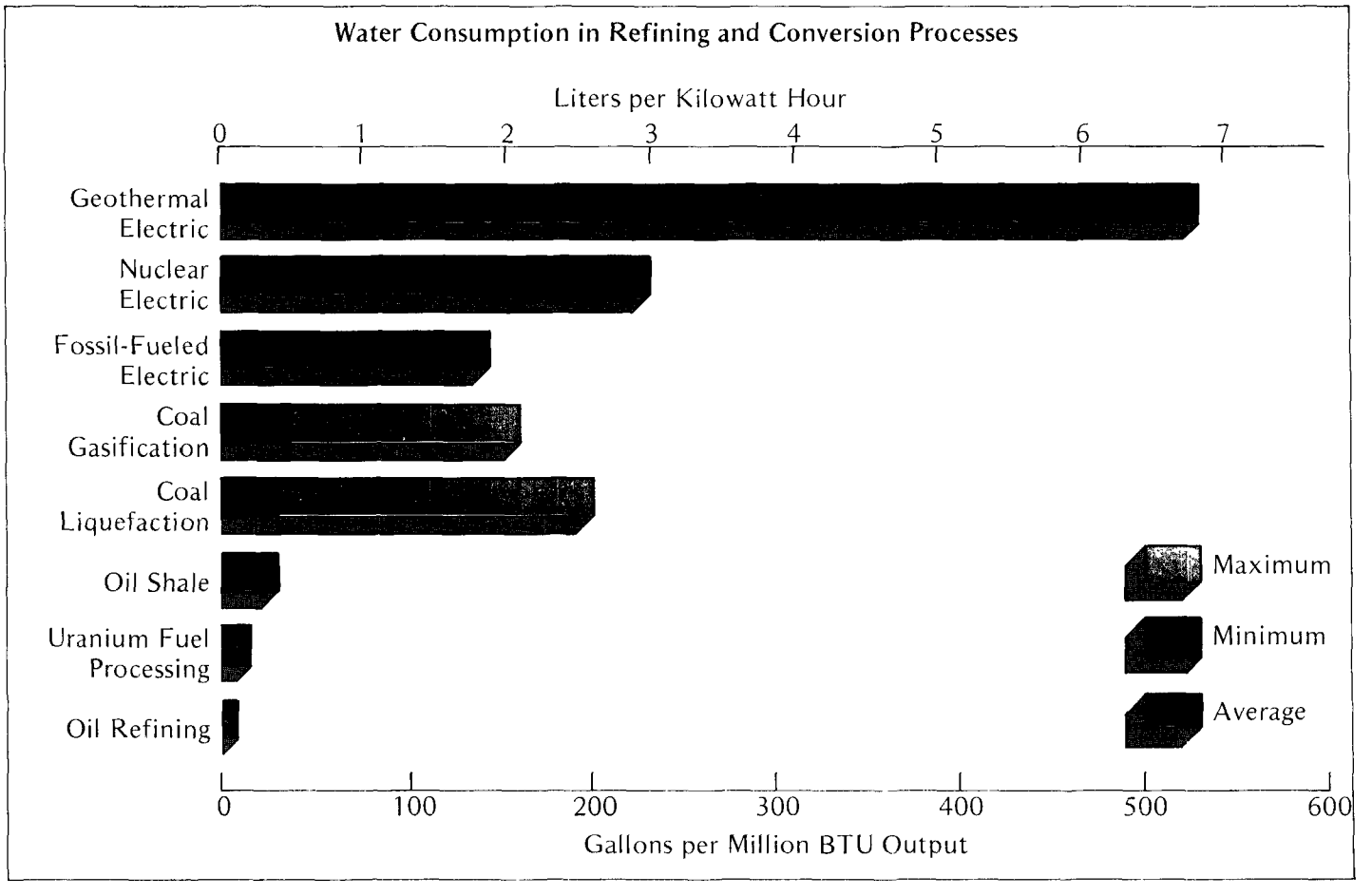
Some people have looked into the alternative of using groundwater locked in underground strata (aquifers) to satisfy an oil shale industry's water needs. One estimate puts the total volume of water stored in aquifers at about 10 million acre-ft, enough to supply a 1-million bbl/day industry for 50 years.

The U.S. Geological Survey estimates that oil shale operations will consume less water for a given amount of energy output than other existing and emerging energy production processes. However, whether water is taken from surface streams or underground aquifers, there is concern about the effects of depletion, and the disruption of streambeds and underground water-bearing strata caused by mining, well-drilling, and spent shale storage. And, among some experts, there is also concern about the long-term availability of water as an oil shale industry expands.

Salinity: When Oil Shale Drinks, What Suffers?

Heavy depletion increases the salinity of surface streams. The U.S. Department of the Interior estimates that a shale oil industry using 120,000 to 190,000 acre-ft of water a year would increase the salinity of the Colorado River downstream at Hoover Dam by 10 to 15 milligrams per liter. But the Colorado River is already heavily salt-laden from withdrawal of water for agricultural use, and desalinization plants are being built on the lower Colorado River so that the water obligated to Mexico will be of the quality specified by treaty.

Some of the groundwater in shale country is as salty as seawater, and, if it were used in oil shale operations, it could be highly corrosive to metal parts. Furthermore, saline aquifers disrupted by mining activity could release salt into pure water aquifers adjacent to some of the richest oil shale deposits. Moreover, saline aquifers punctured by mining activities could flood the mines, making continuous pumping necessary and creating the problem of disposing of brackish water in an environmentally acceptable fashion. As yet, the groundwater consequences cannot be estimated with any accuracy since so little is known about the aquifers and the general groundwater flow patterns.



Water Contamination: With Oil Shale's Gain, What Loses?

Potential contamination of water supplies has implications not only for human, agricultural, and industrial use, but it could threaten the habitat of wildlife and aquatic species. The large herds of migratory mule deer and antelope and elk as well as birds and water species could be adversely affected by a reduced supply of water or the contamination of their watering places in the semiarid regions of Colorado, Utah, and Wyoming.

The enormous amount of water used in oil shale operations will inevitably become contaminated — from retorting the shale and upgrading the product oil, from controlling emissions of pollutants to the air, from cooling processing units and spent shale, from boiler blowdown, and from sanitary facilities. Contaminants will be toxic chemicals, minerals, and trace metals.

The water released from the oil shale itself in the retorting process is contaminated with ammonia, chlorine, carbonates, sulfates, mercury, selenium and arsenic and various organics such as phenols and carboxylic acids. The amount of this contaminated water is 2 to 5 gallons per ton of shale.

Retorting processes being developed incorporate ways to treat this wastewater to rid it of contaminants. In a typical plant, wastewater will be cleansed using a series of methods — a foul water stripping system to remove dissolved hydrogen sulfide and ammonia, a holding pond and gravity separation unit to separate solid contaminants, and chemical additives.

Cleaned up wastewater will be recycled through the process stream so that there will be zero discharge of harmful effluents into surface streams and groundwater supplies. Moreover, recycling would reduce consumption by 10,000 to 40,000 acre-ft per year.

Wastewater from mine dewatering, boiler blowdown, and cooling towers will be used directly, without treatment, to suppress dust or wet down retorted shale.

All of these measures apply to mining and aboveground retorting. In-situ retorting presents a more severe problem because of the difficulty of controlling the large amounts of wastewater that will result from underground operations.

Some disposal methods being considered for in-situ processing are to channel the wastewater into the piles of retorted shale left in the ground, to pump it into aquifers that are already heavily salt loaded, or to let it collect in large evaporation ponds. However, none of these methods is totally satisfactory, and the problem remains to be solved for in-situ processes.

The potentially far-ranging effects of water pollution from the various oil shale processes means that keen examination of all the potential hazards must be made and factors carefully weighed before the shale industry develops.

GREENVILLE, COLORADO, September 1988

The first thing I remember hearing about oil shale was that the rock would expand like popcorn when they pulled it out of the ground and took the oil out. But, the experts assured us that this wasn't only the case with oil shale. The fact of the matter was, anything that's mined by breaking it up into smaller pieces expands; more surface area.

What it finally meant for oil shale, after all the explaining was over and the dust literally settled down, was a lot of rock – tons of the stuff left over. The oil companies called it spent shale. The environmentalists called it solid waste. We had another name for it. . . .

WHAT ABOUT OIL SHALE AND SOLID WASTE?

There will be a lot of it. Solid waste from oil shale takes three different forms:

- Fine particles of raw shale produced in crushing operations
- Catalysts from refining processes if refining is performed in the area
- Spent shale that remains after the oil is removed.

Particles

One form will be the fine particles of raw shale produced in crushing operations. For example, the Paraho process uses fairly large chunks of raw shale (about 3 inches). In crushing the shale to this size, about 5% to 10% is left over as granules too small to be retorted. Some of these small pieces of shale could be fused to form briquettes that are the right size for retorting. The remainder will be mixed with the spent shale for disposal. But inevitably some finer particles will reach the air to contribute to air pollution.

Spent Catalysts

Subjecting shale oil to intermediate refining near the site of retorting operations could produce another type of solid waste – spent catalysts. Nickel and cobalt residues used in hydrogen-treating the oil will be left behind as well as other substances used in recovering sulfur and removing arsenic from the oil. These catalysts, contaminated with potentially harmful compounds, could pollute the air and water if their disposal is not carefully controlled.

If intermediate refining is carried out on-site, spent catalysts and deactivated carbon used in removing contaminants from the product gas will be discarded in the spent shale storage areas.

Spent Shale – Potentially Dangerous Leftovers

The greatest environmental roadblock to oil shale development is the disposal of spent shale. The potential effects of the enormous amount of spent shale cross all major environmental boundaries.

A 1-million bbl/day oil shale industry using high grade (30 gallons per ton) shale will generate 1.5 million tons of spent shale a day. This is after mining, crushing, and retorting. Mining and crushing operations decrease the density and thus increase the original volume of rock by as much as 30% to 40% – retorting shrinks the shale somewhat, but the volume left after retorting is still substantially more than was mined.

Spent shale will vary in consistency – depending on the retorting process – from a lumpy ash-like material resembling dry chunky peanut butter to a fine ash-like substance with a carbon residue that looks like grey talcum powder.

Spent shale will contain potentially harmful amounts of mineral salts as well as toxic trace metals.

Spent shale stored on the surface could interrupt water courses, destroy grazing land and the natural habitat of animal and aquatic species. Stored on the surface or underground it will be subject to leaching and erosion. Contamination from leaching and erosion could have widespread adverse effects on local use of water by industry, by residents, by wildlife and aquatic species in the region, and on downstream water quality as the contamination reached the major river systems.

And, if it is stored on the surface, it will mar the natural beauty of the countryside. For emphasis, people point to the miles of naked rock piles thrown up on the banks of the Blue River near Breckenridge, Colorado, by gold dredges in the 1890s that remain as an eyesore today.

Current plans call for spent shale to be stored mainly on the surface, much of it in gullies and canyons. Control measures have been worked out to reduce the possibility of leaching and erosion of spent shale stored on the surface.

After retorting, the hot shale, which will contain 3% to 5% carbon, will be sprayed with water to cool it and control dust. It will then be transported by conveyor belt or truck to the disposal site. Here, the spent shale will be piled to a specified height. As the pile is developed, it will be graded, and then compacted to a density of 80-90 lbs/cu ft. Compaction will give the pile stability and will slow down weathering. It will also retard leaching since spent shale is highly absorptive and, once compacted, percolation of contaminants through it is minimal. The slope of the sides of the pile will be no greater than a three- or four-to-one grade to prevent sliding.

A catchment basin will be built downstream from the spent shale pile to control leaching and runoff caused by rain or snow, and an impervious layer of material will be laid down beneath the pile to prevent groundwater contamination. Any runoff will be returned to the pile to keep it moist. Likewise, if the spent shale is stored in a canyon, a 100-year flood dam or retention structure will be built above the spent shale to control water flow through the canyon, and a dam will be built below the pile to catch runoff. The water that reaches the lower dam will be recycled back to the spent shale.

When the pile reaches its final height, alkaline salts in the upper layers will be removed. The spent shale will then be fertilized and planted with grazing grass and shrubs that can provide feed for wild herds. Taking out the salts and fertilizing allows for planting directly on the shale, without adding topsoil. The liquid used to remove the salts from the top of the pile will be captured and cleansed to remove contaminants before it is released to the ground.

Experiments in revegetating spent shale have been going on for 10 years, but the composition of spent shale and its lack of nutrients lead many to question the long-term success of any revegetation efforts. For example, will plants now growing on spent shale continue growing after irrigation is stopped? How many plant types will grow on the spent shale? Will the plants tend to concentrate any of the contaminants in the roots and leaves? And what about capillary action that could in time bring salts to the surface of the revegetated shale and destroy the plant growth?

Spent shale also can be returned to the mine, which would help to preserve the scenic quality of the landscape. This is a readily simple process in surface mining since it can be done in conjunction with the return of the overburden to the mined out areas. It could also be returned to an underground mine in its dry form or as a slurried sludge although there are some economic, logistic, and safety constraints to be overcome.

However, spent shale returned to the mine (open pit or underground), or left in the ground after in-situ retorting, could pose a greater contamination problem than surface storage because leaching would be more difficult to control.

Clearly, the problem of what to do with spent shale is paramount to the success of the oil shale industry. And it is also clear that the problem has to be dealt with in relationship to air, water, land, and the general look and quality of life in the processing area.

GREENVILLE, COLORADO, September 1988

As for the land, I can't claim that Greenville looks like Ireland these days. But it's important to remember that it wasn't green to begin with. Now, it's actually greener than it used to be. They tore up thousands of acres to get to the shale, then built up hundreds of mounds of spent shale that now cover the countryside. But they planted it, and the large herds of mule deer we were so worried about ten years ago are doing quite well after a few bad years. We've been told that the herd is, at least, maintaining its numbers and we see as many deer as we used to see, along with the other wildlife that live in the region.

But there's no getting around it. The look of the land has changed, but mostly, from what we can tell, everything that survived here for thousands of years, before they came to get the shale, is still surviving.

WHAT ABOUT OIL SHALE AND LAND DISRUPTION?

Count on it. A mature 1-million bbl/day oil shale industry including the towns that develop in the vicinity will occupy about 80,000 acres of land. This amounts to only about 1% of all the oil shale lands that have been explored and evaluated in Colorado, Utah, and Wyoming. The way in which land is disturbed in oil shale development will be similar to that associated with any large mining and ore processing operation. What will be different is the scale of the disruption. Although only a small portion of all of the known shale areas will be affected at one time, a 1-million bbl/day industry will involve mining about 1.8 million tons of oil shale per day.

Two tons of oil shale fill a volume about the size of an office desk.

Mining the oil shale, building roads and plants and towns, and storing spent shale will have a number of local impacts, other than aesthetic. These activities will cause increased erosion and sedimentation, removal or burial of vegetation, and changes in the mix of native trees, shrubs, and grass species. Grazing land will be reduced for range cattle and wild herds.

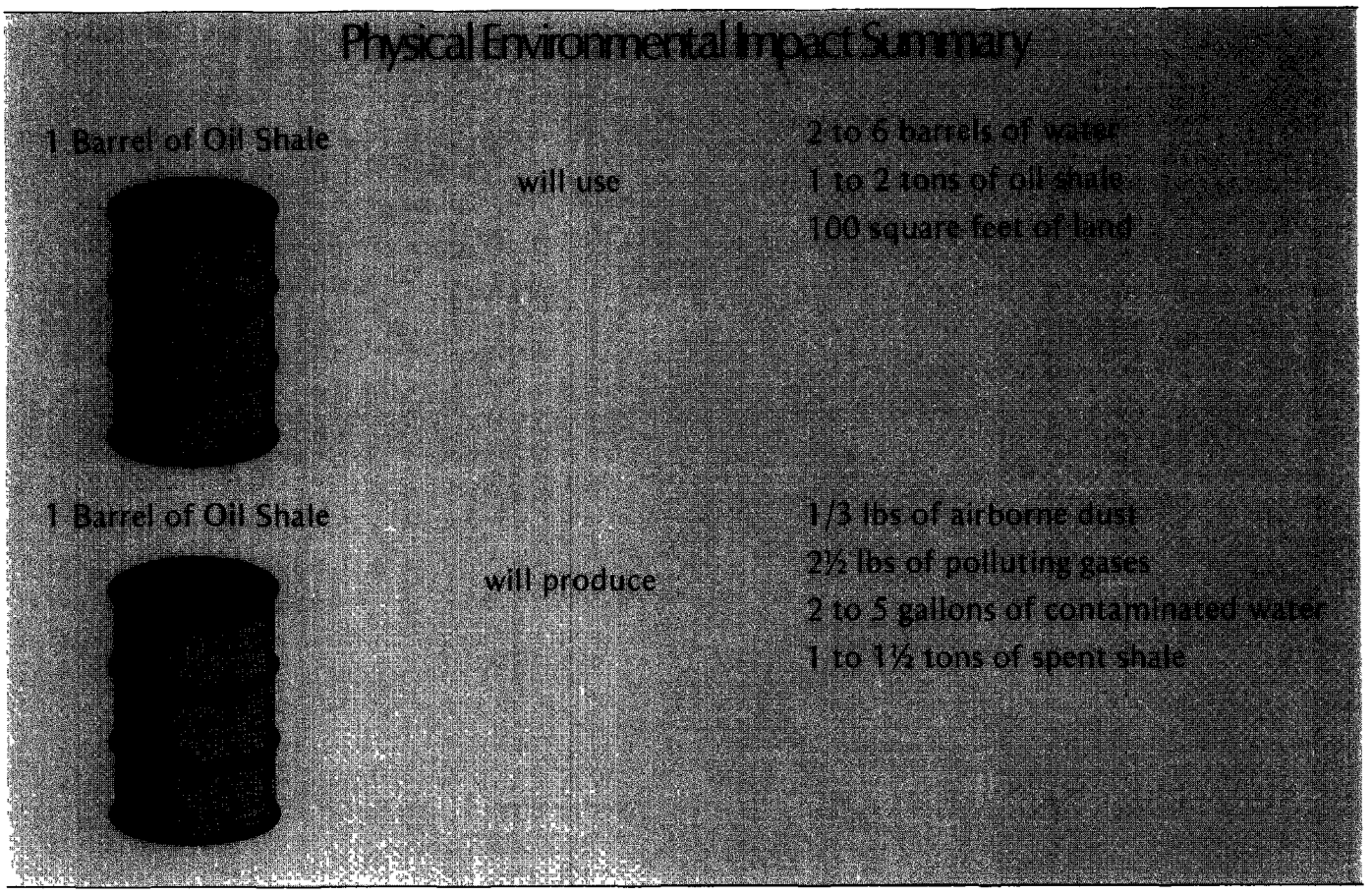
In the Piceance Basin, development will destroy critical winter range in the river valleys for deer, antelope, and elk in the White and Colorado River regions. The availability of winter range determines the size of the herd that can be supported by the available habitat. Destruction of winter range has a far more severe effect on herd size than similar destruction of the more abundant summer range.

The major environmental disruption in surface mining will be the disturbance of the area being mined and the disposal of large quantities of overburden. Although the overburden will eventually be returned to the mined-out area for reclamation, as much as 2000 acres could be disturbed before any reclamation would take place.

Underground mining will cause the least ecosystem disruption. The major surface disturbance will be the construction of roads for mine access. Properly placed pillars left in the mine will keep severe depressions from developing on the ground surface.

In-situ operations would also cause some land disruption: surface subsidence for one. And, since in some in-situ processes about 30% of the activity will be carried out at the surface, it shares the same problems of disruption with conventional mining/surface retorting operations.

Land disruption goes with oil shale development, as well as with any other industrial, agricultural, or residential development. But its effects can be minimized by returning disturbed areas as nearly as possible to their natural state. This will require careful, coordinated planning among industry and government, with recognition of the well-being of those who will live and work in the area.



From the Draft Environmental Impact Statement of the Proposed Development of Oil Shale Resources by the Colony Development Operation:

> *"The proposed Federal action is the consideration of a right-of-way permit for an oil shale products pipeline from a plant site in Colorado to Lisbon Valley, Utah. Directly related to this Federal action is the development of a 4,000 acre underground oil shale mine; mining of 61,000 tons per day of oil shale for 20 years; construction and operation of a 47,000 barrel a day oil shale plant; construction of two dams – Davis Gulch processed oil shale disposal catchment and Middle Fork flood control; disposal of processed oil shale on 800 acres; construction of a 194-mile, 16-inch shale oil pipeline from the plant site on Roan Plateau to Lisbon Valley, Utah; development of a 15-mile-long service corridor in the Parachute Creek valley; construction of a 75-acre terminal site in Grand Valley; construction of two 230 kv powerlines to the plant site; a 337-acre exchange of land between BLM and Colony Development Corporation; and diversion of 12.5 cubic feet per second of water from the Colorado River."*

GREENVILLE, COLORADO, September 1988

There were major stories in the mid-1970s about mine safety, about the possible cancer-causing effects of the byproducts of shale mining and retorting. In the ten years since shale came to town, we've had one major mining mishap.

And cancer? The death rate has stayed pretty much what it's been. But there's always next year's figures to worry about — and the year after.

WHAT ABOUT OIL SHALE AND HEALTH EFFECTS?

It is too soon to tell.

There will be the risk of physical injury to workers in the mines and in processing plants, just as there is in any major mining and refining operation. This risk will be minimized by industry compliance with regulations governing such operations. Many of the safety procedures and much of the necessary technical data for estimating the dangers of an oil shale operation can be inferred from other energy industries — coal mining, oil refining.

What is not clear cut is how much of a health hazard air and water pollution from an oil shale industry will pose for humans — those directly involved in shale mining and processing, and those who live nearby. So little is known about the ways in which pollutants are transported through the environment and so little is known about how the human body resists or adapts to different concentrations of pollutants that no realistic estimate can be made of how these effects will ultimately affect the health of the surrounding populace.

There is also concern about a more subtle problem — the potential cancer-causing polycyclical hydrocarbons contained in oil shale. This concern stems from the high incidence of cancer that appeared among British cotton mill workers who had direct contact with spinning machines that were lubricated with shale oil. Workers in the Estonian oil shale industry, however, have no history of occupational cancer. This suggests that only certain types of shale and shale products are potentially carcinogenic.

The danger of exposure to crude shale oil is primarily a localized industrial health problem. Exposure of the general public to refined oil shale products on the commercial market poses a more universal problem. But without a developed American shale industry, it is very difficult to determine what cancer-causing risks are to be faced. This entire question is under study by the federal government, the academic sector, and the oil companies.

However, as research into this subject has intensified, it has become clear that there are no good, rapid tests for carcinogenicity. Tests currently used are only approximations to the effects of shale oil on humans and really measure genetic effects. Also, carcinogenicity may only be present when two or more compounds — by themselves not carcinogenic — are combined. Thus, it is not a simple matter of isolating carcinogenic compounds, but of testing the combinations of substances found in the many different products of shale oil.

The cancer question also arises regarding spent shale. The proper management of this waste is particularly important because of the volume of matter and because spent shale will contain organic compounds with known carcinogenic as well as toxic effects. These hazardous compounds could reach the public via airborne particulates, runoff water, as intake by plants and animals, and as organic vapors. The quantities will probably be small but, as with the refined oil shale products, the health effects are not known. This problem, like the others, is under study to define its severity and its solution.

GREENVILLE, COLORADO, September 1988

Well, the environment suffered and survived, as promised. The money eventually came, as promised, especially to the merchants, the land speculators, the builders. And the jobs came for those who would train for them in industry sponsored programs. And with the jobs, came the salaries, the fringe benefits – life insurance, credit unions, cars, and appliances.

But it all came too fast. In less than two years Greenville was Colorado's largest thriving slum. Shantytowns sprang up and trailers arrived and parked in the middle of open fields. The sewers were anywhere where people dumped their waste. Laundry hung from shanty to shanty, turning black from the early dust.

Greenville's small medical clinic was obsolete in a month. The few diners, restaurants, and markets couldn't stock foodstuffs fast enough. Schools filled to capacity; all the town facilities became woefully inadequate. The government sent us aid money but it was either too little or too late. And they talked a lot about Greenville in the legislature, but not much came of it. They told us we were a boom-town. And I guess we felt about that the way the Indians must have felt when they were told Columbus discovered America. We were hostile, angry, disappointed. We felt disenfranchised. They even dug up our graveyard and made a new one.

Prices skyrocketed – thirty thousand dollars a shanty, two dollars for a dozen eggs. The profiteers ran amuck, everyone tried to sell us something, we locked our doors at night; then locked our doors during the day. The oil shale we had been sitting on for years blew right up in our faces.

But give it time, many said. That was the talk then, for those who decided to stay. So we did. A few years passed, and Greenville finally caught up with the flow of money generated out of our own backyards. A lot of that money stayed in Greenville; a lot more of it came back in the form of federal and state tax revenues. Schools, roads, utilities, hospitals, sewers were built.

Services were upgraded. After the shantytown burned down one night, luckily taking the lives of only the rats that ran through them with abandon, the buildings that went up in their place were solid single-family dwellings that people built to live in, to settle in.

In the early stages of settlement, engineers and middle and upper management would commute from as far away as Aspen, or even Denver, to avoid living in booming Greenville. Now, with better facilities and a stabilized population growth, a number of them are building on a slight rise above the town suddenly called Greenville Heights. There's even a club under construction with a dozen tennis courts and an olympic-sized pool to be filled, we're told, with recycled water from the plants. And around the pool, no doubt there'll be talk about Greenville culture – once only a picture show, already a music group, a library, and an arts and crafts center, run by one of the companies for workers and their wives to ease the stresses caused by the crazy boom-town phenomenon.

Now most of those early problems are past. And today in Greenville, population 30,000, we've got new problems, but believe me, they're no longer the problems of a sleepy country town. Nor are they the problems of a wild boom-town. Today they're the problems of any small city in the United States. Plus, we've got oil shale to worry about, and to be thankful for.

WHAT ABOUT OIL SHALE AND BOOM-TOWNS?

Almost a certainty.

Development of natural resources in the west has a history of boom-towns. Recent experience in the boom-town phenomenon, and what it causes, comes from Sweetwater and Campbell counties in Wyoming. Between 1960 and 1970, these counties went through an industrial boom stemming from the production of petroleum and minerals. During this period, the population of these counties doubled – in Gillette, the county seat of Campbell county, the population rose from 3600 people to 7200 people.

To put this type of growth into perspective, consider:

- An annual population growth rate of 5% is said by some sociologists to be the maximum tolerable for the timely provision of housing, schools, health facilities and other community services necessary to a population's well being.
- Growth rates between 7% and 10% cause boom-towns that stress services and people alike.
- Beyond a 10% growth rate, the labor market and local government structures often falter and fail to accommodate the new population, which creates chaotic conditions.

Today, about 160,000 people live and work in the tri-state oil shale region. A 1-million bbl/day oil shale industry could double that population. An initial 250,000 bbl/day industry will create 13,000 new jobs — in construction, mining, trucking, and retorting and refining trades. This would draw about 35,000 people to the region, with the bulk of the new population finding employment in new commercial enterprises established to serve the communities that develop around the industry.

Shale country population — 1977

Colorado	*90,600*
Utah	*23,800*
Wyoming	*48,900*
	163,300

What Happens in Boom-Towns?

New jobs and high wages offer a bright outlook, but there is a painful tradeoff — the cost of living curves sharply upward, particularly in housing — especially rental units. As new people arrive, available housing quickly dwindles. Trailer towns and shanties spring up on the fringes of older communities, often with no water or sewage facilities.

Shortages of supplies develop in all areas. Food and recreation prices rise as a result, but salaries of local, old-time residents do not. For these people, prosperity is a price, not a larger paycheck. Discontent among long-term residents and resentment of newcomers flare to disrupt community spirit and cohesiveness.

As the boom accelerates, those who think it will be temporary worry about a bust. This means that investment in local businesses lags, creating unemployment and making it difficult to entice new employees into crafts and professions. Boom-inflated wages draw workers out of municipal jobs to industrial jobs, which also leaves an employment vacuum.

Health cases overload local hospitals, and new types of health problems appear, most of them psychological, fostered by the stresses that go along with boom-towns leading to alcoholism, broken homes, school dropouts, and down and outs. These factors lead to personnel problems in the new industry and in local business causing high employee turnover and lowered productivity.

Sweetwater County, Wyoming:
Mental health case load increased tenfold in 3 years while population doubled.

Ratio of population to physicians
Sweetwater County: 3300 to 1
Colorado: 660 to 1

Can Boom-Towns Be Avoided?

Well, maybe.

But it will take thoughtful planning, money to carry out the plans, and most important of all, perhaps, it will take the wholehearted support of those who live in shale country.

A 1-million bbl/day oil shale industry plus its urban population will require about $4 billion over a 10-year period to provide facilities and services to adequately take care of the population influx.

The money needed to provide those facilities and services will come mainly from taxes — local, state,

and federal. This could amount to a substantial fund that communities could draw on. For example, local tax revenues of $33 million per year, state revenues of about $22 million per year, and federal revenues of about $135 million per year are predicted to accrue from the Department of the Interior's Prototype Oil Shale Leasing Program.

Local communities get much of their revenue from property taxes, but they also receive money through state severance taxes levied on resource developers, reclamation fund taxes, and mining and corporation license taxes.

Different states have different tax money allocation policies. Some money stays in state treasuries, and some is earmarked for specific purposes. States can also require developers to post bond money that can be used for reclamation and to finance expanded services in particualr regions.

Federal tax money returns to the development regions in the form of bonus bid money and royalty revenues, general revenue sharing, adverse impact grants, and front-end loans. Under the Mineral Leasing Act of 1920, a certain percentage of bonus bid money from federal leases returns to states in which the leased land is located to be used for schools and roads. In general revenue sharing, a percentage of federal tax revenue can be designated for states that are experiencing adverse impacts of development. States also can apply for adverse impact grants on the basis of demonstrated costs associated with development. And, low-cost front-end loans are available to finance public facilities and services needed to keep up with resource development.

Bonus bid money is the money paid to the federal government by the oil companies for the rights to mine oil shale on federal land. It runs into hundreds of millions of dollars.

But, the fact that there are a number of sources of money does not mean that money is always immediately available. Research in the boom areas of Wyoming revealed that there is a 5- to 7-year lag before tax revenues from new industrial and commercial developments are returned to local communities. This puts restrictions on how quickly plans to accommodate accelerated growth can be carried out.

However, guidelines for planning and fund allocation are to be found in the ways in which Wyoming, and more recently Canada, in its tar sands petroleum project, sought means to overcome the stresses caused by resource development. Wyoming has become a model for legislation in western states faced with potential industrial booms to speed up the flow of needed money to areas that will be affected by a surge of population. A key force in alleviating boom-town conditions is the Western Governors Regional Energy Policy Office. This federation of state policy makers has adopted a number of policies aimed at ways to forestall adverse societal impacts of energy development. So, hopefully, by the time an oil shale industry gets under way mechanisms will be there to permit facilities and services to keep pace with growth to sustain an acceptable quality of life.

Boomtown Experience: Wyoming

Housing value (1970) Median

Gillette	*$20,700*
U.S.	*$17,000*

House price 3 bed/1000 sq ft (1970)

Gillette	*$45,000*
Kansas City, Mo.	*$25,000*

Mobile home housing (1965)

Gillette	
within city limit:	*30%*
outside city limit:	*70%*

Wage differentials:

City police, road maintenance crews
$500 – $700/month

Construction jobs for new industry
$1000 – $1200/month

GREENVILLE, COLORADO, September 1988

At first those of us who lived in Greenville were skeptical when they came finally to get the shale. Skeptical, and just a little scared. Air pollution was a problem, water pollution was a problem. So was solid waste, the look of the land, the health effects of the mining. Living itself seemed to be the biggest problem. But because of what were referred to as "control technologies" in the 1970s, most of these problems have worked themselves out. Or have been worked out by the oil companies, the federal and state governments, and the people of Greenville themselves.

As for the environment, it's impossible to pin down the change. Still, I'd say that we've sacrificed about 10% of what our physical life in Greenville used to be. I might add that our sacrifice was about 30% when it all first began, a surprise to those who spent millions to make sure it wouldn't happen that way. But fair is fair, and though in the midst of the initial crush of new men and machines, it seemed that promises had been made and not kept, those promises are being kept now.

The basic promise, incidentally, was this: America would swap us the "good life" for our shale. It would exact a piece of our environment, but it would be worth the cost.

Though we don't really feel it yet, we are told that because of the significant growth of our population, we are better represented in Washington and in Denver; more important, more and more people listen to Greenville County politicians.

They have to. Because Greenville is oil shale. And oil shale today is a major factor in America's energy market. There is, I'll have to admit, a certain civic pride in that, but more important, there is something that can't be that easily defined. Call it a feeling, if you like. Today in Greenville, among those of us who stayed for the money and the jobs, there is a feeling that after ten up and down years we finally do have some control over what happens to us. We've been partly led, partly dragged into the mainstream of American industry and power; and even on the individual level, the feeling is there that we are part of the action, on the edge of a special frontier.

So what's Greenville today. Environmentally: it's not what it was. Economically: it's a lot bigger, a lot wealthier. A changed town, one our parents would not recognize, a town that's survived and will, from all indications, continue to survive.

Research & Development

It makes sense environmentally, and economically, to develop environmental controls in tandem with oil shale processing technology. This will minimize environmental effects and it will prevent costly retrofits to oil shale facilities once commercial production is under way. This is the rationale for the structure of federally sponsored investigation of oil shale problems.

EPA funds research internally and to other government agencies through the Office of Energy, Minerals and Industry (OEMI). This research is divided into two basic programs: the Process and Effects Program and the Control Technology Program.

The Process and Effects Program looks at:

- Characterizing the types of pollutants that would be expected, measuring the magnitude of pollution discharged, and finding ways to monitor and detect the source of those pollutants.
- Tracing what happens to the pollution in the environment. Where does it go? How does it get there? Once it arrives at its final destination, has its form changed to become more or less toxic?
- Defining toxic characteristics. Is human health to be impaired? What part of the body is most susceptible to the types of pollution? What limits must be set to keep hazardous substances out of the environment?
- Determining the effects on the ecologies of the area that are disrupted by the industry. What are the atmospheric and terrestrial ecologies? What are their needs to sustain life? And what will the shale oil development impacts be?

Then . . .

- Combining all the consequences of the development into one total integrated assessment for the environment, social and welfare effects, costs/risks/benefits, and selection of alternatives.

In parallel with the Process and Effects Program, EPA Control Technology research evaluates and helps to develop techniques to limit the adverse impacts that shale development could cause. The Control Technology Program is:

- Investigating mining techniques to reduce the adverse effects of the extensive amount of mining that will accompany a commercial oil shale industry.

- Looking at ways to reclaim those areas that have been mined or used for spent shale disposal. This includes the research on revegetation of spent shale piles.
- Assessing the types of the technologies available to control of water, air, and solid wastes.
- Measuring effluents from the retorting processes.

Over $35 million has been earmarked for oil shale research over the next five years. From $10 to $20 million will come from the EPA/OEMI through the federal Interagency Energy/Environment Research and Development Program.

Not all of the work is being done by EPA scientists or in federal research laboratories. Private industry, universities, and independent research contractors are all part of finding answers to oil shale problems. These research programs cover many areas:

Oil shale and water pollution – about $3.7 million for research with over 30 different projects.

- Developing a groundwater monitoring model for oil shale and coal mining areas in Utah and Wyoming. By General Electric Company, due in 1981.
- Describing water-related impacts resulting from in-situ processes that may prove significant. By the University of California, Berkeley.
- Developing a computer model to predict hydrological effects of oil shale development. By the U.S. Geological Survey, due in 1977.
- Collecting specific hydrologic data in the Upper Basin of the Colorado River, identifying where more data are necessary and developing procedures to assess water quality. By Colorado State University, due in 1977.
- Determining toxicity of material released into the water by oil shale mining and conversion. By Colorado State University, due in 1978.
- Determining leaching rates of inorganic salts from spent shale. By Texas Tech University.
- Developing water control technology for oil shale mining. By Golder Associates, Vancouver, Canada, due in 1977.

Oil shale and air pollution – over $2.7 million in research funds to more than 20 separate projects.

- Collecting basic atmospheric data for the most likely oil shale development areas. By EPA, due in 1980.
- Establishing quality assurance of air monitoring programs for energy-related work. By Rockwell International, due in 1981.
- Studying reaction kinetics of complex organic sulfur and nitrogen compounds in shale oil to design more efficient methods to remove sulfur and nitrogen from shale oil so that when the oil is burned it will meet strict air emission standards. By Massachusetts Institute of Technology, due in 1978.
- Identifying the emissions from gasoline produced from oil shale. By Southwest Research Institute.
- Measuring the amounts of particulates, sulfur dioxide, and nitrogen oxides at Rifle, Craig, and Meeker, Colorado. By the State of Colorado, due in 1977.

Oil shale and human health – over 25 research projects with $3.8 million in federal funds and an additional $660,000 by industry.

- Studying human health dangers from pilot-plant shale operations. There will be joint U.S. – USSR research to take advantage of the experience in the Estonian oil shale industry. By National Institute for Occupational Safety and Health (NIOSH), due in 1978.
- Finding methods of detecting cell transformations and carcinogenic effects of substances involved in in-situ oil shale conversion. By the Lawrence Livermore Laboratory, due in 1977.
- Determining carcinogenic properties of oil shale products and byproducts: interrelated projects cover pulmonary cancer in laboratory animals, upper respiratory problems, epithelial cell damage, changes in lung cell cytology, etc. By EPA and Oak Ridge National Laboratory and Los Alamos Scientific Laboratory, due between 1977 and 1981.
- Developing new testing, screening, and evaluating procedures to assay the carcinogenic and co-carcinogenic potential of oil shale products. By Lawrence Livermore Laboratory and the University of California at Los Angeles, due between 1977 and 1980.
- Studying cell damage and cell recovery from exposure to hazardous oil shale materials. By the Department of Energy, due between 1977 and 1978.
- Determining the chronic inhalation toxicity of shale oil process products. A companion project is studying toxicity from other forms of exposure including oral, occular, and epidermal. By the American Petroleum Institute.
- Comparing potential carcinogenic effects from oil shale products and alternate energy sources including coal. By EPA and the Department of Energy, due in 1978.

General environmental research for oil shale development – 18 separate projects that deal with more than one element of the environment, funded at about $5.5 million.

- Studying the total environmental impact of oil shale development to compile all background data on industrial processes for oil shale, compare their environmental acceptability, and identify environmental control technologies for air, water, and solid waste emissions. By TRW and Denver Research Institute, due in 1978.
- Assessing the technologies for western energy resource development. This study will develop environmental control policies and strategies for mitigating adverse impacts of western energy sources. By the University of Oklahoma, due in 1978.
- Developing standardized methods for measuring environmental impacts. By the National Bureau of Standards, due in 1979.
- Analyzing environmental control technologies for oil shale development, especially those that have overlapping areas of development. By the University of Utah, due 1977.
- Simulating burning of shale oil in power plants to determine pollutants to be expected from commercial use of oil shale. By Laramie Energy Research Center and Pittsburgh Energy Research Center, due in 1977.
- Assessing the impacts of airborne pollutants from mining and spent shale disposal on forest, range, and freshwater ecosystems. By the U.S. Department of Agriculture, due in 1979.
- Assessing impacts of synthetic liquid fuels development. Examines resource requirements, net energy analysis, legal mechanisms, financing for the industry, government incentive policies and totally integrated socioeconomic and environmental impacts of oil shale development. By SRI International.

Miscellaneous research — over 40 projects covering such topics as oil shale characteristics and properties, process development, and socioeconomic studies. Almost $20 million in federal funds are allocated for these projects.

- Performing an integrated assessment of the socioeconomic consequences of coal and oil shale development, including resources used in coal and oil shale industries, in terms of agricultural economic implications and future resource competition. By the U.S. Department of Agriculture, due in 1979.
- Improving methods for converting shale oil to liquid and gaseous fuels and reducing sulfur, nitrogen, and oxygen in the oil as well as to produce pipeline quality gas from an in-situ process. By the Department of Energy, due in 1977.
- Demonstrating techniques and economic effectiveness of massive hydraulic fracturing of shale. By the Department of Energy and Columbia Gas System Service Corporation.
- Drilling a bore hole 2350 feet deep in the Piceance Basin for long range experiments in deep mining, and for the extraction of a 500-ton sample of dawsonite-rich shale for testing in an alumina removal project. By the U.S. Bureau of Mines, due in 1977.
- Evaluating methods of producing aviation fuel from oil shale and coal. By the U.S. Air Force and Exxon Research and Engineering.
- Producing 100,000 barrels of shale oil. A series of projects to mine, commission a retort, and an initial plant start-up, and build storage for 80,000 barrels of shale oil. This work will be carried out at the Anvil Points facility and may offer one of the best opportunities to study actual environmental consequences of an operating oil shale plant. By the U.S. Navy and Development Engineering Inc., Grand Junction, Colorado.

The Outlook

The oil shale industry of the future faces the present-day challenges of environmental restraints, socioeconomic problems, and uncertain financial burdens. Nevertheless, oil shale development is going forward — urged on by the high price of world oil, the potential for high profits, and decreasing U.S. supply of conventional energy sources. No one questions the amount of energy that could come from shale oil, and few doubt the need for increased national energy supplies. But many people are concerned about the environmental, health, and socioeconomic tradeoffs posed by oil shale development.

Thus, there is a natural conflict between energy profits and environmental purity — and standing squarely in the middle of this conflict is government.

Government is playing a large part in oil shale development. Less dependence on foreign oil is a stated national goal. Oil shale serves that goal. But it is also a national goal to maintain a clean environment and a high quality of life. Oil shale development will cause environmental degradation and it will change the way of life in the development areas. But if an adequate energy supply will sustain a high quality of life, then oil shale contributes to that on a national scale.

The federal government owns most of the land on which the richest shale deposits lie, and the government sets the environmental and regulatory standards with which the oil shale companies must comply. More important, perhaps, the price of oil products to the American public is controlled through complex government price structures. In fact, many agree that it is economics, not environment, that is keeping shale oil off the market.

So, what is the outlook for oil shale? Perhaps the best word is uncertain. The costs of production are uncertain, the sources for the large capital investments required are uncertain, the competition from foreign oil and even from new domestic supply is uncertain, and new energy sources may capture a significant share of the market. Moreover, the costs of protecting the environment are uncertain, there are uncertain "front-end" costs the industry may have to absorb to reduce social impacts in oil shale regions, and government's future role, ubiquitous now, is also uncertain.

The growth of an oil shale industry may not be as explosive as past oil booms. The approach is now more cautious; the gains and gambles being weighed more carefully. Nevertheless, oil shale development is not stagnant. Research into better and more efficient production processes is progressing, studies of environmental effects are underway, and, in general, there is guarded optimism in much of the industry. Perhaps, after being an "almost" industry for so long, oil shale will soon turn the corner into commercialization as a safe, and environmentally sound, industry.

For Further Reading

Interagency Energy/Environment Research and Development Program – Status Report III, EPA-600/77-032, prepared by Office of Energy, Minerals and Industry, Office of Research and Development/Environmental Protection Agency (April 1977)

A detailed status report of the Interagency Program including history, organization, and the basic rationale for the Program. Some cost figures are given for environmental control technologies being developed and for health and environmental effects studies of energy use.

A Practical Approach to Development of A Shale Oil Industry in the United States, prepared by Colorado School of Mines Research Institute, P.O. Box 122, Golden, Colorado 80401. Prepared for Gary Operating Company, Four Inverness Court East, Englewood, Colorado 80110. (October 1975)

A technically accurate and easily readable report concerning all phases of the oil shale industry. This study puts forth a well-reasoned proposal that the oil shale industry should be developed in a gradual, orderly manner instead of under a crash program. The idea has considerable merit from environmental and financial standpoints. The report was summarized as a Position Paper presented to the Committee on Science and Technology, U.S. House of Representatives regarding the 1976 ERDA Authorization Bill, H.R. 3474 (5.598)

Energy from Oil Shale: Technical, Environmental, Economic, Legislative and Policy Aspects of an Undeveloped Energy Source, The Science Policy Research Division, Congressional Research Service, Library of Congress. Prepared for The Subcommittee on Energy of the Committee on Science and Astronautics, U.S. House of Representatives (November 1973)

A somewhat dated but still pertinent report used by Congress for baseline data. Little technical discussion but a good overview of the major issues facing legislators who deal with energy resources in general and oil shale in particular, with a synopsis of behind-the-scene development of the Prototype Oil Shale Leases. An appendix contains correspondence with selected companies interested in oil shale development.

Synthetic Fuels – Oil Shale, Coal, Oil Sands
A Quarterly Report by Cameron Engineers, Inc., 1315 South Clarkson, Denver, Colorado 80210.

One of a series of highly professional surveys of the most current information regarding synthetic fuels development. The point of view is unabashedly pro-development and pro-industry. Still, in lieu of tracking industry proposals, reading the trade journals, and being in close contact with oil shale developers, these reports represent a good way to keep up-to-date on synthetic fuels. The March 1977 issue contains oil shale sections on land, water, corporations, environment, technology, and government.

Synthetic Liquid Fuels Development: Assessment of Critical Factors, ERDA 76-129/2, Stanford Research Institute, 333 Ravenswood, Menlo Park, California 94025. Prepared for the Office of Energy, Minerals and Industry of the Office of Research and Development/Environmental Protection Agency and for the Division of Transportation Energy Conservation/Energy Research and Development Administration. (May 1976)

The definitive study of the environmental, societal and institutional ramifications of synthetic fuels development. The study was organized as a technology impact assessment and called on a large team of experts to contribute in their specialty area. There are 23 separate chapters covering everything from the legal mechanisms for access to oil shale and financing the synthetic liquid fuels industry to the impact of industrial growth on rural society. Each chapter can stand alone for easy reading.

A Preliminary Assessment of the Environmental Impacts from Oil Shale Developments
EPA-600/7-77-069, prepared by the Industrial Environmental Research Laboratory, Office of Research and Development/Environmental Protection Agency (July 1977)

A thoroughly credible review of the potential environmental impacts of oil shale development. This report is a survey about what is, and is not, known regarding oil shale. The data were assembled from a wide variety of governmental and industrial data sources including Detailed Development Plans by the federal lease tract developers. An abundance of facts, figures and detailed information is assembled into a logical format for easy reference.