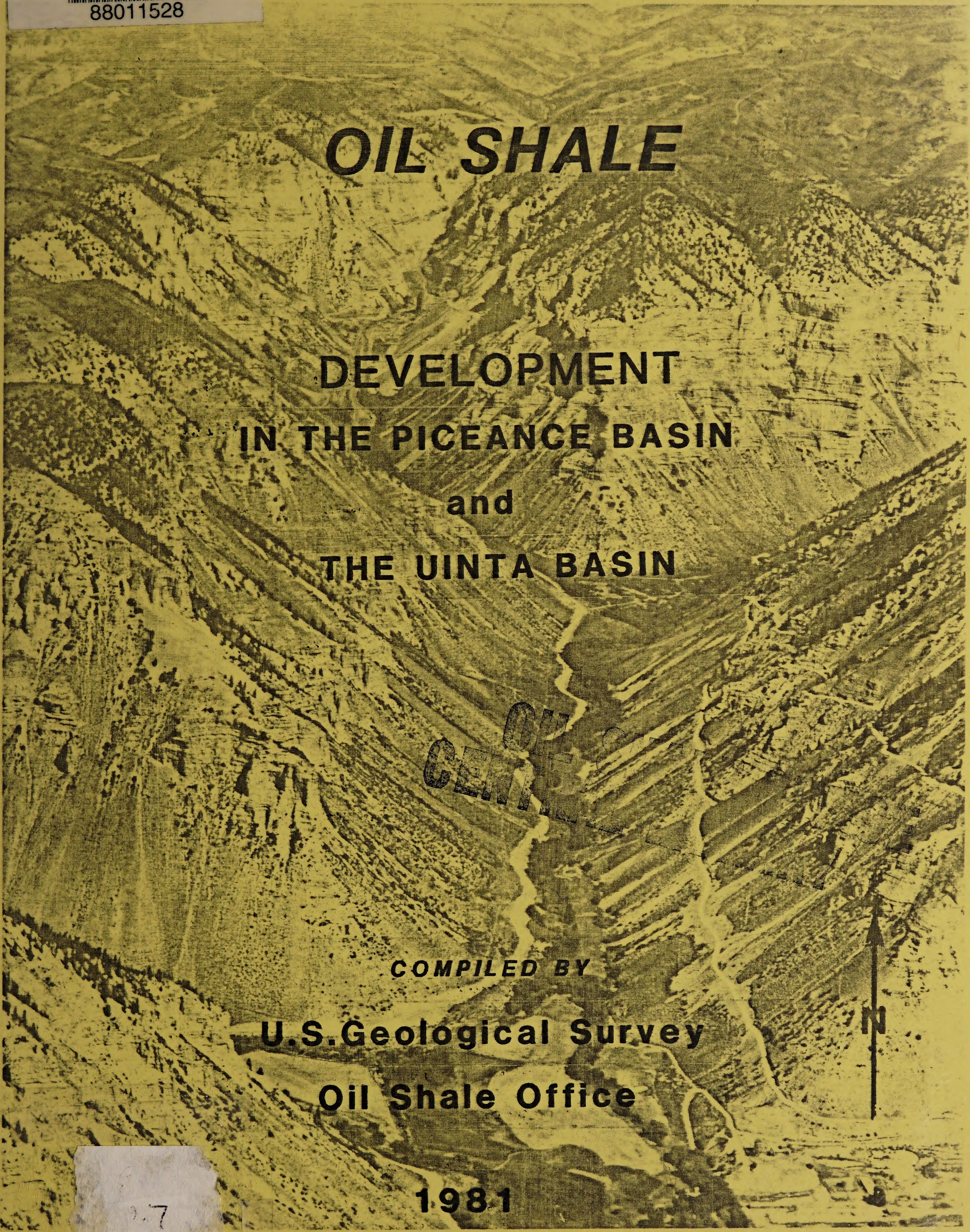

# OIL SHALE

## DEVELOPMENT IN THE PICEANCE BASIN and THE UINTA BASIN

COMPILED BY

U.S. Geological Survey
Oil Shale Office

1981

BACKGROUND

# PROTOTYPE OIL SHALE LEASING PROGRAM

## SUMMARY

Oil shale is a fine-grained sedimentary marlstone containing approximately 14 weight percent or more solid organic matter (kerogen) that can be converted to synthetic crude oil and gas by heating. Oil shales of the Eocene Green River Formation contain an estimated 1.8 trillion equivalent barrels ($3.0 \times 10^{11}$ $m^3$) of oil and vast quantities of valuable sodium and aluminum carbonate minerals (64 billion tons ($58 \times 10^9$ mt) of trona - a source of soda ash, 29 billion tons ($26 \times 10^9$ mt) of nahcolite a source of industrial stack gas scrubbing agent, and 19 billion tons ($17 \times 10^9$ mt) of dawsonite - a source of alumina). This fuel and mineral wealth can be recovered by either open-pit or underground mining and by surface or in situ retorting and processing for recovery of oil, gas, and associated minerals.

Oil shale retorts were being built in Colorado and Utah beginning in the early 1900's, but it has only been during the past decade that the national energy situation and evolving oil shale retorting technologies have appeared economically favorable for commercialization. Within the tri-corner area of Colorado, Utah, and Wyoming, 80 percent of the high grade oil shale lies beneath Federal land. In 1973, the Federal government took the initiative for evaluating the feasibility of commercial shale oil production by initiating and documenting the Prototype Oil Shale Leasing Program (POSLP) in a six volume environmental impact statement, and by BLM competitively leasing four 5,120 acre tracts in 1974 (two each in Colorado and Utah).

Administration of the lease then became the responsibility of the Geological Survey, Area Oil Shale Office (AOSO) in Grand Junction, Colorado, together with carrying forth four programmatic goals to: (1) provide a new source of energy; (2) develop safeguards to insure environmental integrity; (3) permit equitable return on resource development; and (4) develop management expertise for lease administration. To carry out these actions, the 20 member, multidisciplinary staff of the AOSO has through 1979 completed 466 environmental/development inspections, approved 157 development actions, conducted 17 public hearings, amended lease stipulations three times, and evaluated nearly 300,000 pages of environmental and development monitoring data. The AOSO is assisted in its environmental responsibilities by a Departmentally convened Oil Shale Environmental Advisory Panel which has held 28 public meetings.

In accord with lease terms, each lessee has gathered two years of baseline environmental data on and about each tract against which to assess development impacts from data gathered by monitoring programs that will be implemented throughout the operating life of each tract. Lessees' schedule and method of tract development are described in lease-required Detailed Development Plans (DDP's) that had to be approved by the Area Oil Shale

Supervisor prior to implementation. DDP's for the two Colorado tracts were approved in the summer of 1977 following public hearings and concurrence of the Assistant Secretary of Interior. Development work on the two Utah tracts is currently enjoined by Federal District Court ruling pursuant to Utah's in lieu land selection suit and conflicting prior mining claims.

To encourage development, the leases contain economic incentives which allow the last two of the five bonus bid installments and a portion of initial production royalty payments to be offset by actual development expenditures approved by the Area Oil Shale Supervisor. Better than $448 million were bid for the four tracts leased. By the close of 1979, approximately $196 million in bonus payments had been made by the lessees of the two tracts in Colorado. Approximately 37½ percent of this amount has been returned to the State for use in mitigating socioeconomic impacts. Bonus offsets for $145 million have been granted to the Colorado lessees subject to audit and actual use payback agreements. Approximately $72 million in bonus payments (not including interest) for the two leases in Utah are being held in escrow pending final court ruling on the State's land selection suit.

To ensure compliance with lease terms and approved DDP's, AOSO staff conduct weekly inspections of development, monitoring, and reclamation operations. Lessees have also been required to establish reclamation bonds and to comply with all other applicable regulations. Due to the complex lease terms and the first-of-a-kind nature of the POSLP, it has proved beneficial to hold regular development and monitoring coordination meetings with the lessees and to establish working level contacts with concerned Federal, State, and local agencies. To effectively evaluate the wealth of operational and environmental data compiled by the lessees, the AOSO has developed a number of formalized inspection, plan, and report review processes. A development/perturbation matrix analysis method has been designed to identify potential environmental impacts.

In-house data management is achieved by encoding all documents to a computer indexed central file according to a numerical system that reflects document subject and disposition. Computer facilities are also used to track bonus payments and offsets, verify royalty calculations, and soon to evaluate environmental monitoring data for trends and impacts. All major plans and actions before the AOSO are tracked by a Management by Objective system.

This report includes listings of Prototype Oil Shale Leasing Program milestones, location and description of each tract, and major on-site facilities. To date, 460 acres have been disturbed by development work on the two Colorado tracts. Approximately 80 percent of this area has been permanently or temporarily reclaimed. Bringing the tracts to commercial operation will require each lessee to obtain nearly 100 different types of permits from more than 20 separate agencies.

The lessees have established a network of biotic and abiotic treatment and control environmental monitoring stations and transects on and about each tract to measure the nature of development impacts on air and water quality, meteorology, surface and ground water, wildlife, vegetation, and geotechnical conditions. Monitoring data and the results of the lessees'

Department prior to implementation. Utah's and the two Colorado tracts were approved in the summer of 1977 following public hearings and [illegible] of the Assistant Secretary of Interior. Development work on the Utah tracts is currently enjoined by Federal district court ruling [illegible] to Utah's in lieu land selection suit and conflicting [illegible] mining claims.

To encourage development, the [illegible] government agreed to provide each lessee the first [illegible] of the five bonus bid installments and a portion of [illegible] production royalty payments to be offset by certain [illegible] expenditures [illegible] at the time the State Government [illegible]. [illegible] that bonus bids [illegible] for the four tracts leased. By the close of 1977, [illegible] million in bonus payments had been made by the lessees of the two tracts in Colorado. Approximately [illegible] percent of this amount has been returned to the States for use in mitigating socioeconomic impacts. Bonus offsets for [illegible] million have been granted on the Colorado leases subject to audit and [illegible] agreements. Approximately [illegible] million in bonus payments [illegible] for the two leases in Utah are being held in escrow pending final court ruling on the State's land selection suit.

To ensure compliance with lease terms and approved DDP's, the staff conducts weekly inspections of development, monitoring, and exploration operations. Lessees have also been required to establish environmental baselines and to comply with all other applicable requirements. Due to the complex issues and the first-of-a-kind nature of the [illegible], it has proven beneficial to hold regular conferences and workshops, to maintain meetings with the lessees and to establish working level contacts with government, Federal, State, and local agencies. [illegible] the results of operations and environmental data required of the lessees. The [illegible] has developed a number of operational regulations, plans, and report review procedures. A [illegible] matrix analysis method has been developed to identify potential environmental impacts.

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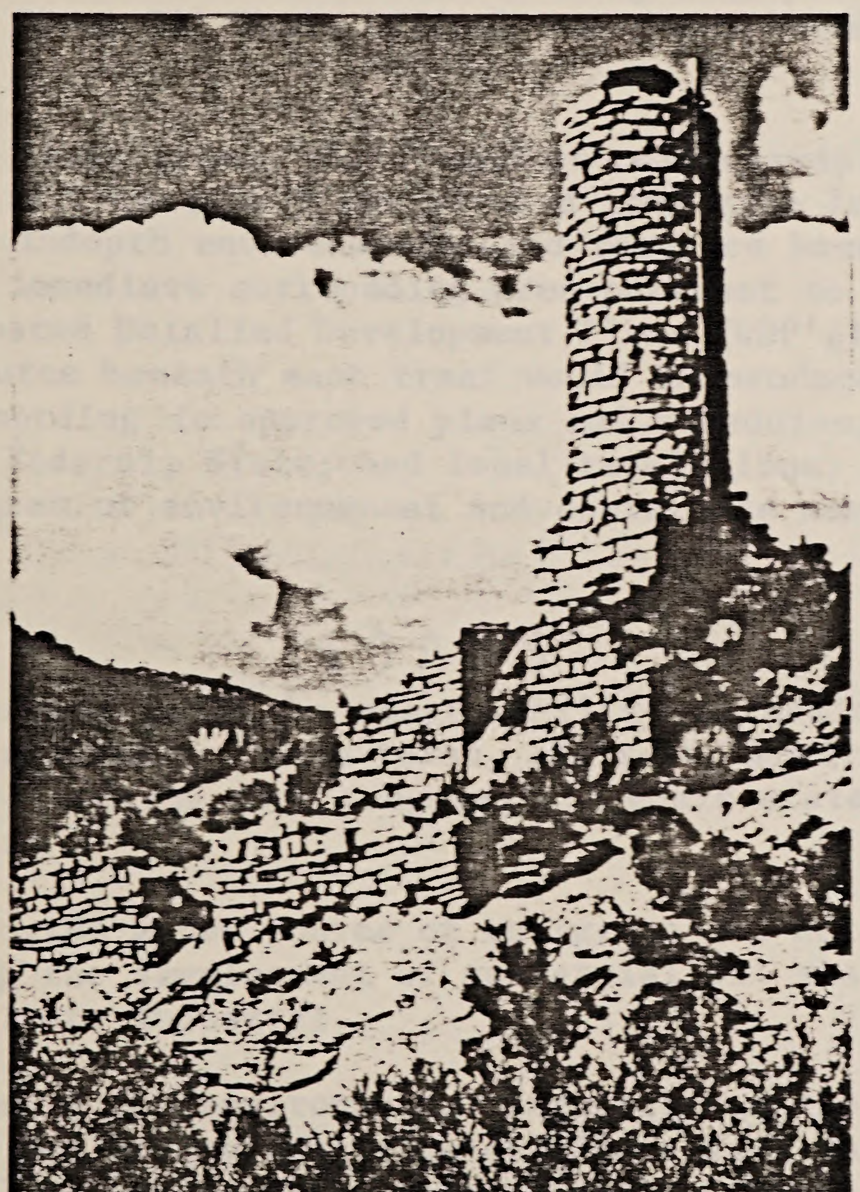
This [illegible] report includes listings of [illegible] for their [illegible] program [illegible], [illegible] and description of each tract, and [illegible] data. To date, 400 acres have been disturbed by development work on the two Colorado tracts. Approximately 50 percent of this area has been temporarily or permanently reclaimed. Bringing the tracts to commercial operation will require each lessee to obtain nearly 100 different types of permits from more than 20 separate agencies.

The lessees have established a network of [illegible] and [illegible] stations [illegible] each tract to measure the impacts of development [illegible] on air and water quality, [illegible], surface and ground water, [illegible], vegetation, and geotechnical conditions. Monitoring data and the results of the lessees' analyses are reported semi-annually to the AOSO. Major aspects of the monitoring programs are described in this report together with findings to date. These findings suggest that development impacts have been largely limited to areas directly disturbed by construction, the cone of ground water depression from mine dewatering, flow patterns and channel erosion in adjacent drainages, habitat areas augmented to enhance forage production, increased highway traffic, and community growth.

Data is also routinely gathered on workforce community impacts, health and safety, and development/environmental costs. Combined workforce on both Colorado tracts averaged 525 persons during 1979. One on-tract fatal accident has occurred since the POSLP began through the end of 1979. Community growth has been assisted by lessee front-end financing of new housing, apartments, and trailer spaces; and by use of some of the oil shale lease bonus bid payments returned to the State. Employee bussing and van pooling is used extensively between surrounding communities and the tracts to minimize highway congestion and hazards to wildlife. Current development work on each tract is costing nearly $40,000,000 annually.



Early Hand Bricked Oil Shale Retort Built Around 1919 in Agency Draw, Utah (probably retorted less than 10 barrels of shale oil).

# HISTORY

In early 1970, a task force was established within the U.S. Department of the Interior to evaluate the prospects of domestic oil shale development. Based on the task group's affirmative recommendation and the President's energy policy of 1971, industry nominations were solicited for tract sites with commercial development potential, public hearings were held, and concurrence obtained from the governors of the three affected states. Detailed lease terms and a massive 3,200 page six-volume environmental impact statement were released in August 1973. In November 1973, the Secretary of the Interior announced implementation of the Prototype Oil Shale Leasing Program (POSLP). Competitive bonus bid lease sale of six selected tracts was begun by the Bureau of Land Management in early 1974 (two each in Colorado, Wyoming, and Utah). Bids were received for the tracts in Colorado and Utah totaling nearly $449 million dollars. No bids were received for the Wyoming sites.

Following leasing, administration of the tracts and lease terms became the responsibility of the U.S. Geological Survey, Conservation Division, in accord with Department of Interior management procedures. A special program office (Area Oil Shale Office) was established in Grand Junction, Colorado.

In accord with lease terms, the 20-member multidisciplinary staff of the Area Oil Shale Office (AOSO) has ensured that each lessee: (1) carried out a two-year indepth environmental and resource baseline assessment of the tracts and immediate surrounding area pursuant to approved exploration plans; (2) prepared Detailed Development Plans (DDP's) describing how the oil shale resource beneath each tract would be produced; (3) implemented development according to approved plans and schedules; (4) complied with all applicable Federal, State, and local regulations; and (5) established an ongoing program of environmental and operations monitoring and reporting.

# GOALS

The AOSO is charged with the responsibility to administer the POSLP within regulatory bounds, lease terms, and sound environmental management practices toward meeting four programmatic goals stated by the Secretary of the Interior:

1. To provide a new source of energy to the Nation by stimulating the development of commercial oil shale technology by private industry;

2. To insure the environmental integrity of the affected areas and at the same time develop a full range of environmental safeguards and restoration techniques that will be incorporated into the planning of a mature oil shale industry;

3. To permit an equitable return to all parties in the development of this public resource; and

4. To develop management expertise in the leasing and supervision of oil shale development in order to provide the basis for future administrative procedures.

# LEASE ADMINISTRATION

## Leasing

Authority for leasing under the POSLP comes from the Mineral Leasing Act of 1920 (41 Stat. 437), as amended (30 U.S.C. §. 181-263), subject to regulations in 30 CFR 231 and 43 CFR 23 and Group 3000. Together these provide for leasing of public lands containing valuable mineral or fuel deposits including extraction of oil shale and associated economic minerals.

A Notice of Sale was published in the Federal Register on November 30, 1973. The notice indicated that six tracts would be offered for lease through sealed competitive bonus bidding beginning on January 8, 1974. The successful bonus bid was due in five equal payments. The lease, contains a diligent development economic incentive permitting the last two bonus payments and initial production royalties to be offset by expenditures directly related to development of the leased tract. Four tracts (two in Colorado and two in Utah) were bid on and leases granted to the lessees shown in table .

## Role of Bureau of Land Management

Secretarial Order 2948 of October 6, 1972, sets forth the division of responsibilities between the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS) for the administration of onshore mineral leasing and operating activities, which includes oil shale.

The BLM is responsible for issuing mineral leases and is the office of record in leasing matters. Prior to issuance of the oil shale leases, the BLM represented the Secretary of Interior in issuing permits for oil shale exploratory drilling. After lease issuance and until they are terminated, the USGS is the sole representative of the Secretary in matters relating to supervision of oil shale operations. The BLM maintains responsibility for operations on public lands off the leases and for other non-oil shale activities (e.g., grazing) on the leases. The BLM is consulted on the adequacy of the surface use, environmental protection, and reclamation aspects of all exploration and development plans submitted by the lessees to the USGS for approval.

## Role of the U.S. Geological Survey, Conservation Division

The Conservation Division has two primary functions: (1) evaluation and classification of Federal lands for their mineral character and value prior to lease or land exchange; and (2) supervision of operations incident to the prospecting, development, and production of minerals on Federal, Indian lands. Both functions are concerned with discovery, evaluation, receipt of fair market value, efficient development and conservation of leasable minerals belonging to the United States, and restoration of the environmental quality of those lands affected by mineral operations. Lease supervision functions include the responsibility for determining applicable royalty charges and for collecting royalty income on all leased Federal and Indian lands.

# LEASE ADMINISTRATION

## Leasing

Authority for leasing under the [illegible] comes from the Mineral Leasing Act of 1920 (41 Stat. 437), as amended (30 U.S.C. 181-263), subject to regulations in [illegible] and Group 3000. Together these provide for leasing of public lands containing [illegible] deposits including [illegible] of oil shale and associated minerals.

A notice of [illegible] was published in the Federal Register on [illegible] 30, 1973. The notice [illegible] that six tracts would be offered for lease through sealed bonus bidding beginning on January 8, 1974. The successful bonus bid [illegible] in five equal payments. The lease contains a diligent development [illegible] permitting the lease. The lease [illegible] and [illegible] requirements to be [illegible] by [illegible] during development of the leased tracts. Four tracts (two in Colorado and two in Utah) were bid on and leases granted to the lessees shown in Table.

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## Role of the Area Oil Shale Office

The Area Oil Shale Office, functioning within the Conservation Division's Central Region, has primary responsibility for enforcing lease terms and for carrying out programmatic goals set by the Secretary of the Interior. The organization scheme for the AOSO recognizes that maximum participation by other agencies and the public is essential. Attaining this participation is an important task in view of the diffusion of needed expertise throughout many Federal and State agencies. The AOSO is greatly assisted in carrying out its environmental management task by the Departmentally convened Oil Shale Environmental Advisory Panel.

The AOSO is organized on a team approach with coordinators for each leased tract using a management by objectives system. This management scheme has proven to be the most effective organization format for administration of POSLP. The AOSO staff structure is illustrated in figure. Personnel shown on the chart serve both in a regulatory capacity for lease operations and equally important, in a coordination/liaison capacity to bring needed outside expertise into the program. Members of the AOSO staff come from many different agencies including the U.S. Bureau of Mines, NOAA, U.S. Forest Service, BLM, Soil Conservation Service, and in one case, from the U.S. Fish and Wildlife Service attached to the staff by interagency agreement. To supplement permanent staff capabilities, temporary personnel details have been used from time to time. Contract studies for specific projects are often used.

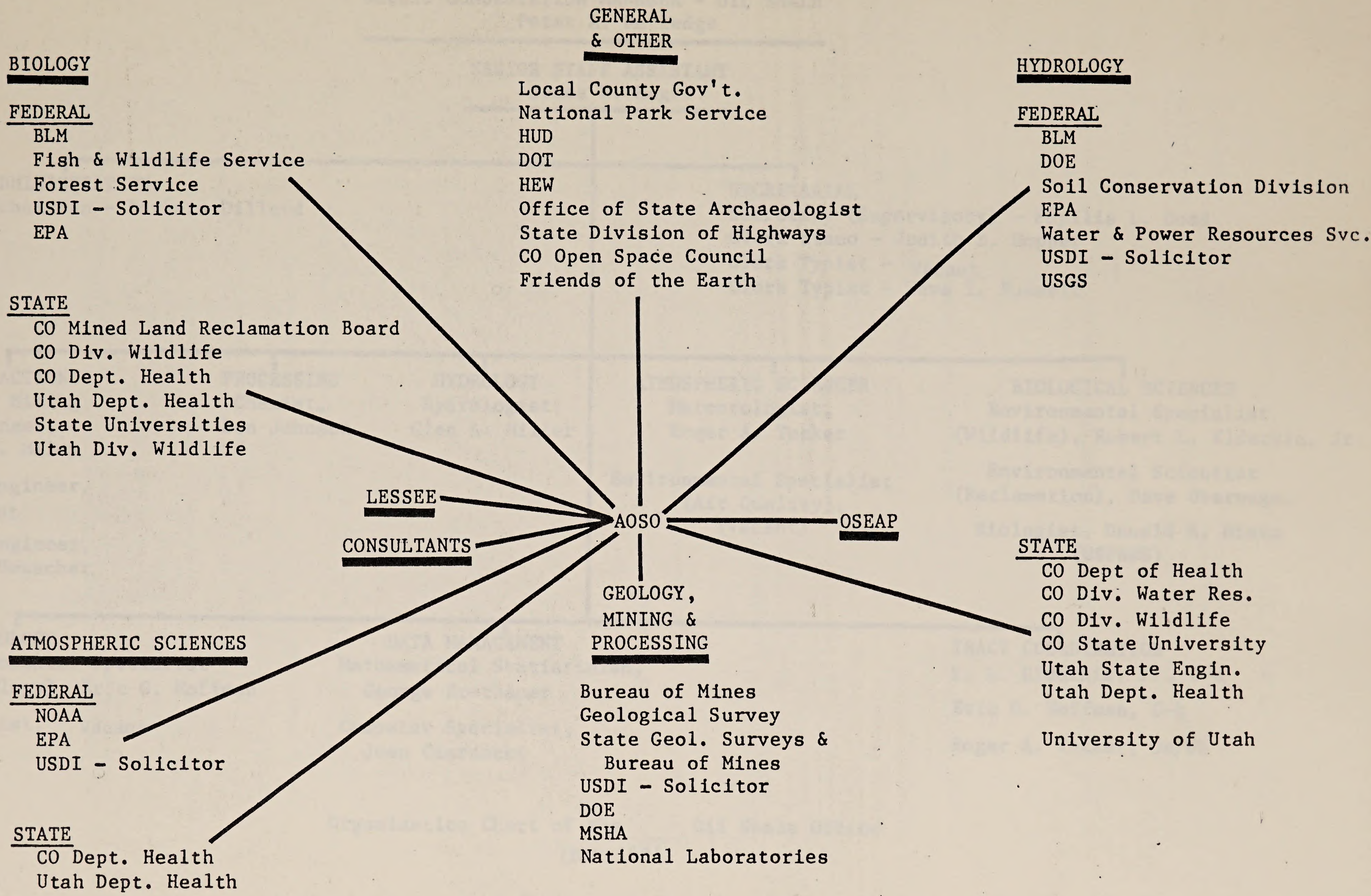
Management responsibilities of the AOSO in response to lease terms and programmatic goals include:

1. Supervision of on-tract activities in accord with lease terms, applicable regulations, and experience gained. To date, more than 466 inspections have been made of tract environmental monitoring and development activities.

2. Continuous evaluation of DDP implementation on premise that much can be learned to the benefit of current and future oil shale development, and that knowledge gained should be promptly applied. More than 157 changes or revisions were approved during the exploration/ baseline and development phases of the POSLP including three revisions of lease environmental Stipulations.

3. Compilation and analysis of information from the leased tracts to assist in Departmental decisions on oil shale policy and leasing. This has required the AOSO to review and archive nearly 300,000 pages of environmental and development data.

4. Continuing development and implementation of management expertise needed for effective lease supervision. This has involved completion of 12 management guidelines, 9 environmental analyses, 15 public notices, 17 public hearings, 564 bonus credit actions, active participation in 28 Oil Shale Environmental Advisory Panel meetings, and officiating at more than 200 interagency coordination meetings with the lessees.




U.S.G.S., Area Oil Shale Office Coordination with Other Agencies

## DEPUTY CONSERVATION MANAGER - OIL SHALE
Peter A. Rutledge

### SENIOR STAFF ASSISTANT
James W. Hager

**ADMINISTRATION**
Admin. Technician - Barbara Dillard

**SECRETARIAL**
Secretary (Supervisory) - Phyllis L. Goad
Clerk Steno - Judith B. Hopper
Clerk Typist - Vacant
Clerk Typist - Wava I. Russell

**EXTRACTION**
Senior Mining Engineer, John E. Miley
Mining Engineer, Vacant
Mining Engineer, Randy Heuscher

**PROCESSING**
Chemist, Don Johnson

**HYDROLOGY**
Hydrologist, Glen A. Miller

**ATMOSPHERIC SCIENCES**
Meteorologist, Roger A. Tucker
Environmental Specialist (Air Quality), (Vacant)

**BIOLOGICAL SCIENCES**
Environmental Specialist (Wildlife), Robert L. Elderkin, Jr.
Environmental Scientist (Reclamation), Dave Oberwager
Biologist, Donald R. Dietz (USF&WS)

**GEOLOGY**
Environmental Specialist (Geology), Eric G. Hoffman
Geologist, Vacant

**DATA MANAGEMENT**
Mathematical Statistician, George Brethauer
Computer Specialist, Joan Czarnecki

**TRACT COORDINATION**
R. L. Elderkin, Jr., C-a
Eric G. Hoffman, C-b
Roger A. Tucker, Ua/Ub

Organization Chart of the Oil Shale Office
(May 1981)

Prototype Oil Shale Program Lessees and Bonus Bid Payments

| Lease | Lessee | Lease Effective Date | Bonus Bid | Bonus Paid through 1979 | Bonus Offset through 1979 |
|---|---|---|---|---|---|
| **Colorado Tracts** | | | | | |
| C-a | Gulf Oil Corp. Standard Oil of Indiana (Rio Blanco Oil Shale Company) | 3/1/74 | $210,305,600.00 | $126,183,360.00 | $ 95,964,093.68 4/ |
| C-b 1/ | Occidental Oil Shale Inc. Tenneco Oil Co. (Cathedral Bluffs Shale Oil Company) | 4/1/74 | $117,788,000.36 | $ 70,672,800.21 | $ 49,417,826.89 4/ |
| **Utah Tracts** | | | | | |
| U-a | Phillips Petroleum Co. Sun Oil Co. | 6/1/74 | $ 75,596,800.00 | $ 45,358,080.00 3/ | 0.00 5/ |
| U-b | Sohio Petroleum (Utah tracts to be jointly developed by White River Shale Project) | 6/1/74 | $ 45,107,200.00 | $ 27,064,320.00 3/ | 0.00 5/ |
| **Wyoming Tracts** | | | | | |
| W-a | — | 2/ | — | — | — |
| W-b | — | 2/ | — | — | — |
| Totals: | | | $448,797,600.36 | $269,278,560.21 | $145,381,920.57 |

1/Original lessees of Tract C-b were Ashland Oil, Inc; Atlantic Richfield Co.; Shell Oil Co.; and The Oil Shale Corporation.

2/The Wyoming leases received no bids probably because of the restricted resource base for which an adequate return on investment was not then apparent.

3/Bonus bid payments from the Utah tracts are being held in escrow pending U.S. Supreme Court ruling on State in-lieu land selection suit.

4/Totals for "Bonus Paid" and "Offset" exceed the amount bid. Only the amount of offset equalling the last two bonus payments will actually be credited. The excess will be used to cover credit denied during audit, or can be applied against production royalties due during the sixth through the tenth lease years.

5/Application for bonus offsets have not been received from the Utah lessees, because of lease suspension under court injunction pending settlement of State in lieu land selection suit.

# Other Applicable Regulations

| P = Permits<br>R = Regulations<br>C = Clearance or Review | Mines & Process | Power Plants | Transmission | Pipelines | Railroads | Roads |
|---|---|---|---|---|---|---|
| **FEDERAL GOVERNMENT** | | | | | | |
| **Department of Interior** | | | | | | |
| Bureau of Indian Affairs | P | P | P | P | P | P |
| U.S. Geological Survey | P | C | C | C | C | C |
| Mining Enforcement & Safety | R | | | | | |
| Bureau of Land Management | P | P | P | P | P | P |
| Bureau of Reclamation | P | P | P | P | P | P |
| National Park Service | C | C | P | P | P | P |
| Fish & Wildlife Service | C | C | C | C | C | C |
| **Department of Agriculture** | | | | | | |
| Forest Service | P | | P | P | P | P |
| Soil Conservation Service | C | C | C | C | C | C |
| Rural Electric Administration | | P | P | | | |
| **Environmental Protection Agency** | | | | | | |
| Water Quality | P | P | R | R | R | R |
| Air Quality | P | P | | | | |
| Solid Waste Disposal | R | R | | | | |
| Hazardous Materials | R | R | | R | | |
| **Department of the Army** | | | | | | |
| Corps of Engineers | P | P | P | P | P | P |
| **Department of Labor** | | | | | | |
| Occupational Safety & Health | R | R | R | R | R | R |
| **Department of Transportation** | | | | | | |
| Federal Aviation Administration | P | P | P | | | |
| Federal Highway Administration | C | C | C | C | C | C |
| Materials Transportation Bureau | R | | | R | R | |
| **Federal Power Commission** | | P | P | | | |
| **Federal Communications Commission** | P | P | P | P | P | P |
| **Interstate Commerce Commission** | | | | P | P | P |
| **Nuclear Regulatory Commission** | P | P | | | | |
| **STATE OF COLORADO** | | | | | | |
| **Department of Health** | | | | | | |
| Air Pollution Control Div'n. | P | P | | | | |
| Water Pollution Control Div'n. | P | P | | | | |
| Engineering & Sanitation Div'n. | P | P | | | | |
| **State Historical Society** | C | C | C | C | C | C |
| **Department of Highways** | | | | | | |
| Division of Highways | P | P | P | P | P | P |
| Highway Safety Division | R | R | R | R | R | R |
| **Department of Labor** | | | | | | |
| Co. Occupational Safety & Health | R | R | R | R | R | R |
| **Department of Natural Resources** | | | | | | |
| Div'n of Water Resources (State Eng) | P | P | | | | |
| Geological Survey | C | C | | | | |
| Co. Groundwater Commission | P | P | | | | |
| State Board of Land Commissioners | P | P | P | P | P | P |
| Division of Mines | R | | | | | |
| Oil & Gas Conservation Comm. | P | | | | | |
| Mined Land Reclamation Section | P | | | | | |
| Co. Soil Conservation Board | C | C | C | C | C | C |
| Co. Water Conservation Board | C | C | C | C | C | C |
| Division of Wildlife | C | C | C | C | C | C |
| Div'n of Parks & Recreation | C | C | C | C | C | C |
| **Public Utilities Commission** | | P | P | P | P | |
| **Land Use Commission** | C | C | C | C | C | C |
| **LOCAL GOVERNMENTS** | | | | | | |
| **County** | | | | | | |
| Land Use | P | P | P | P | P | P |
| Air Quality | P | P | | | | |
| Water Quality | P | P | | | | |
| Health | R | R | | | | |
| Fire | R | R | R | R | R | R |
| Flood | R | R | R | R | R | R |
| Building Codes | P | P | | | | |
| Roads | R | R | P | P | P | P |
| **Municipal & Special Districts** | | | | | | |
| Land Use | P | P | P | P | P | P |
| Air Quality | P | P | | | | |
| Water | P | P | | | | |
| Sanitation | R | R | | | | |
| Health | R | R | | | | |
| Fire | R | R | R | R | R | R |
| Flood | R | R | R | R | R | R |
| Building Codes | P | P | | | | |
| Streets | R | R | P | P | P | P |

Compendium of federal, state and local permits (P), clearances (C) and reviews (R) required for shale oil development. Prepared by A. Novak (1976) as reproduced in Colorado Energy Research Institute Report on Oil Shale in Colorado, 1979.

# RESOURCE & PROCESSING

Oil shale is a fine-grained sedimentary dolomitic marlstone containing solid organic matter (kerogen) which can be heated to produce synthetic crude oil and gas. Composition of 25 gallon/ton (104 L/mt) shale is shown in table . While domestic oil shale deposits are widespread, the richest defined oil shale resource occurs in the Green River Formation of Colorado, Utah, and Wyoming , The kerogen within this shale consists of the remains of aquatic organisms, algae, and pollen grains which settled to the bottom of ancient lakes that covered the tri-state area some 50-60 million years ago. These deposits are estimated to contain more than 1.8 trillion equivalent barrels ($2.9 \times 10^{11} m^3$) of oil, or about 50 times known conventional domestic crude oil reserves. It is currently estimated that approximately 80 billion barrels ($1.3 \times 10^{10} m^3$) can be extracted with available technologies.

Vast quantities of valuable sodium-carbonate minerals are associated with the deep, rich oil shales. There is an estimated in-place resource of 64 billion tons ($5.8 \times 10^{10}$ mt) of trona ($Na_2CO_3$) - a source of soda-ash in the Green River basin of Wyoming; 29 billion tons ($2.6 \times 10^{10}$ mt) of nahcolite ($NaHCO_3$) - a potential industrial stack gas scrubbing agent; and 19 billion tons ($1.7\ 10^{10}$ mt) of dawsonite ($NaAlCOH_3CO_2$) - a potential source of alumina, both of the latter in the Piceance Creek basin of Colorado.

Synthetic crude oil and gas are produced from oil shale by a process called "retorting" which heats the shale to pyrolysis temperature of 400° to 1000°F (400° to 600° C.), causing the solid kerogen to decompose to oily vapors and gas and leaving behind a carbonaceous residue of petroleum coke on the inorganic fraction of the shale. Retorting can be carried out either in surface facilities or in the ground (in situ).

There are two basic types of surface retorts: (1) direct-heated retorts, where pyrolysis heat is provided by combustion of the carbonaceous residue within a moving bed of crushed oil shale; and (2) indirect-heated retorts, which uses a working medium heated external to the retort vessel and mechanically mixed with the raw shale.

There are also two basic in situ retorting methods: (1) true in situ which involves fracturing or dissolving out soluable minerals associated with the in-place shale between a pattern of boreholes and either directly combusting the shale or circulating a working medium heated on the surface; and (2) modified in situ (MIS) which involves removal of 20 to 40 percent of the in-place volume of the oil shale deposit by conventional mining methods and explosive rubblization of the remaining shale into the mine voids followed by ignition to achieve pyrolysis temperature.

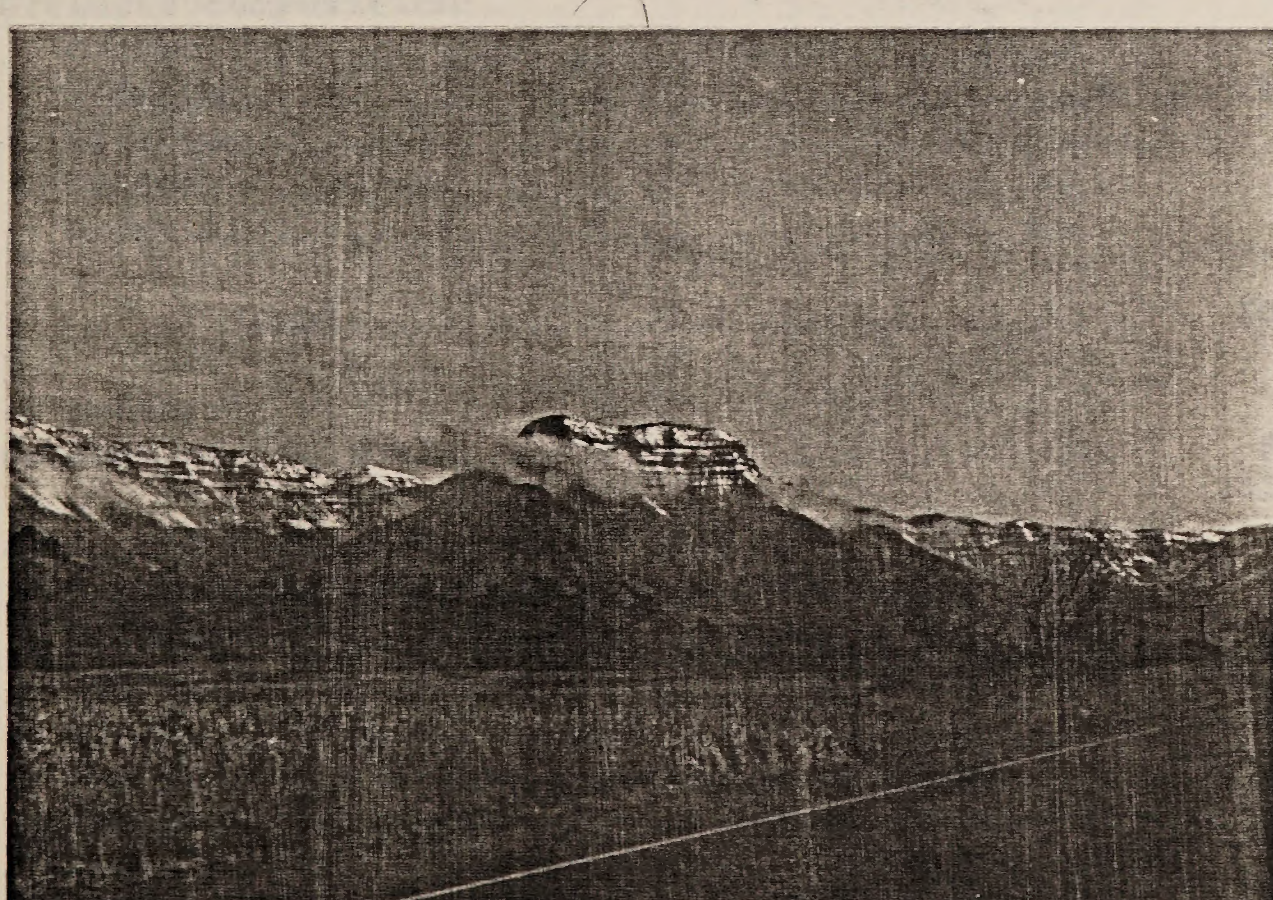
Combustible gases as well as petroleum liquids are produced during retorting. Indirect heated retorts usually produce a high BTU gas, which can be sold as a synthetic natural gas. Direct heated retorts produce a medium to low BTU gas due to dilution by combustion induced nitrogen and carbon

dioxide. The low BTU gas has potential value on-site where it can be burned in special boilers to make steam needed in the retorting process or in low BTU gas turbines to generate electricity.

Oil shale retorts were being built in Colorado as early as 1917 and in Utah by 1919 . By 1925, more than two dozen small oil shale plants were operating. Shale for these operations was obtained from small pits and mine adits located where the oil shale outcropped. None of these ever produced more than a few thousand barrels of shale oil before being economically driven out of business by discovery of conventional oil and gas fields. Major research for domestic commercial shale oil production began in 1945 at the U.S. Bureau of Mines' Anvil Points experimental mine and retort facility in response to fuel shortage during the closing years of World War II. Figure shows the location of current oil shale research and development operations. Table lists the current status of these projects. A synopsis of oil shale mining and retorting techniques is presented in the AOSO report entitled, "Mineral Property Economics of Oil Shale," by Ray A. Brady, 1978.

The current national energy situation together with evolving shale-oil extraction technology have convinced many that now is the time to begin commercial production of shale oil - approximately 50,000 bbls/day/plant (92 $dm^3/s$).

About 72 percent of the 11 million acres (4.5 x $10^6$ ha) of oil shale land potentially suitable for commercial development in Colorado, Utah, and Wyoming are Federal lands. These lands contain about 80 percent of the high-grade oil shale resource. In 1974, the Bureau of Land Management leased four 5,120-acre Prototype Tracts (C-a and C-b in the Piceance basin of Colorado, and U-a and U-b in the Uinta basin of Utah). Figure shows the location of these tracts. Two tracts offered for lease in Wyoming received no industry bids, probably due to thin low-grade resource.



Roan Cliffs along the Colorado River.
Upper portion formed by Green River Formation

Mahogany. The low BTU gas has potential value on-site where it can be burned in special boilers to make steam needed in the retorting process or in low BTU gas turbines to generate electricity.

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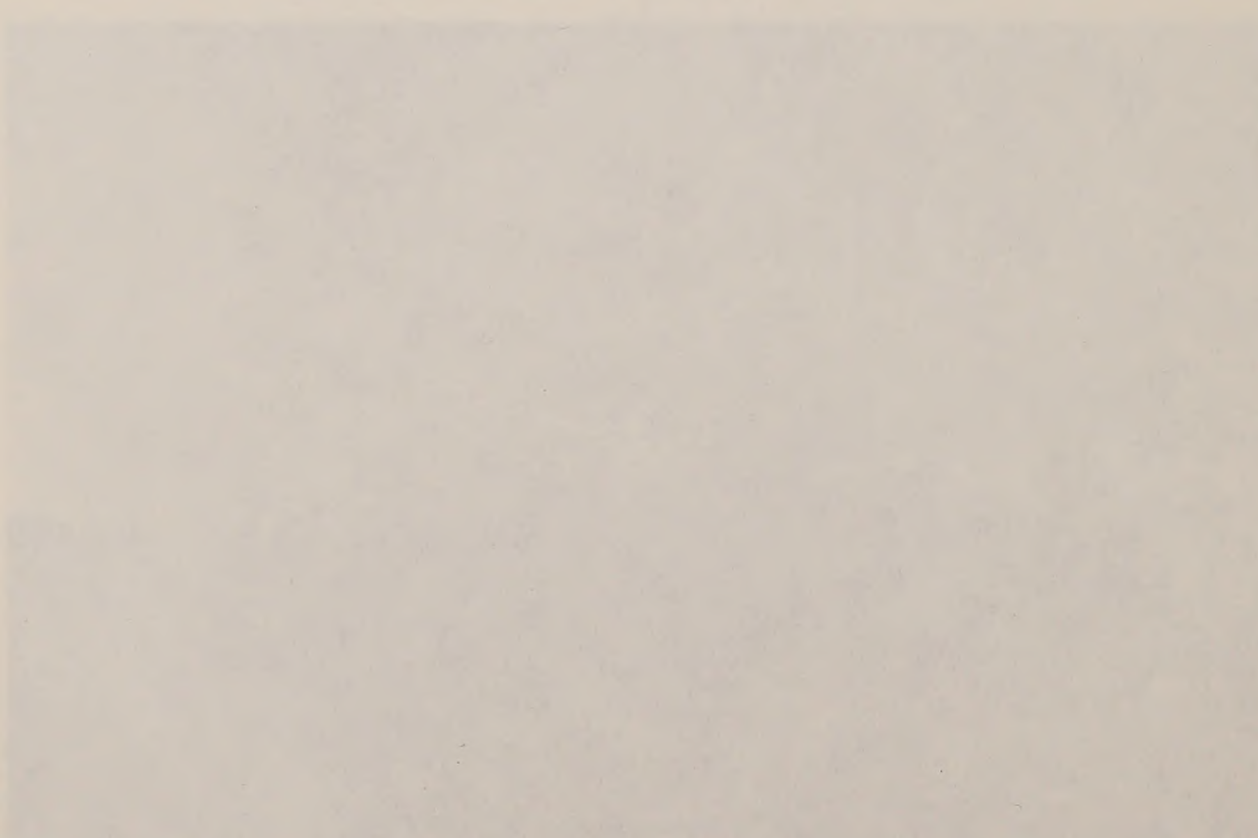
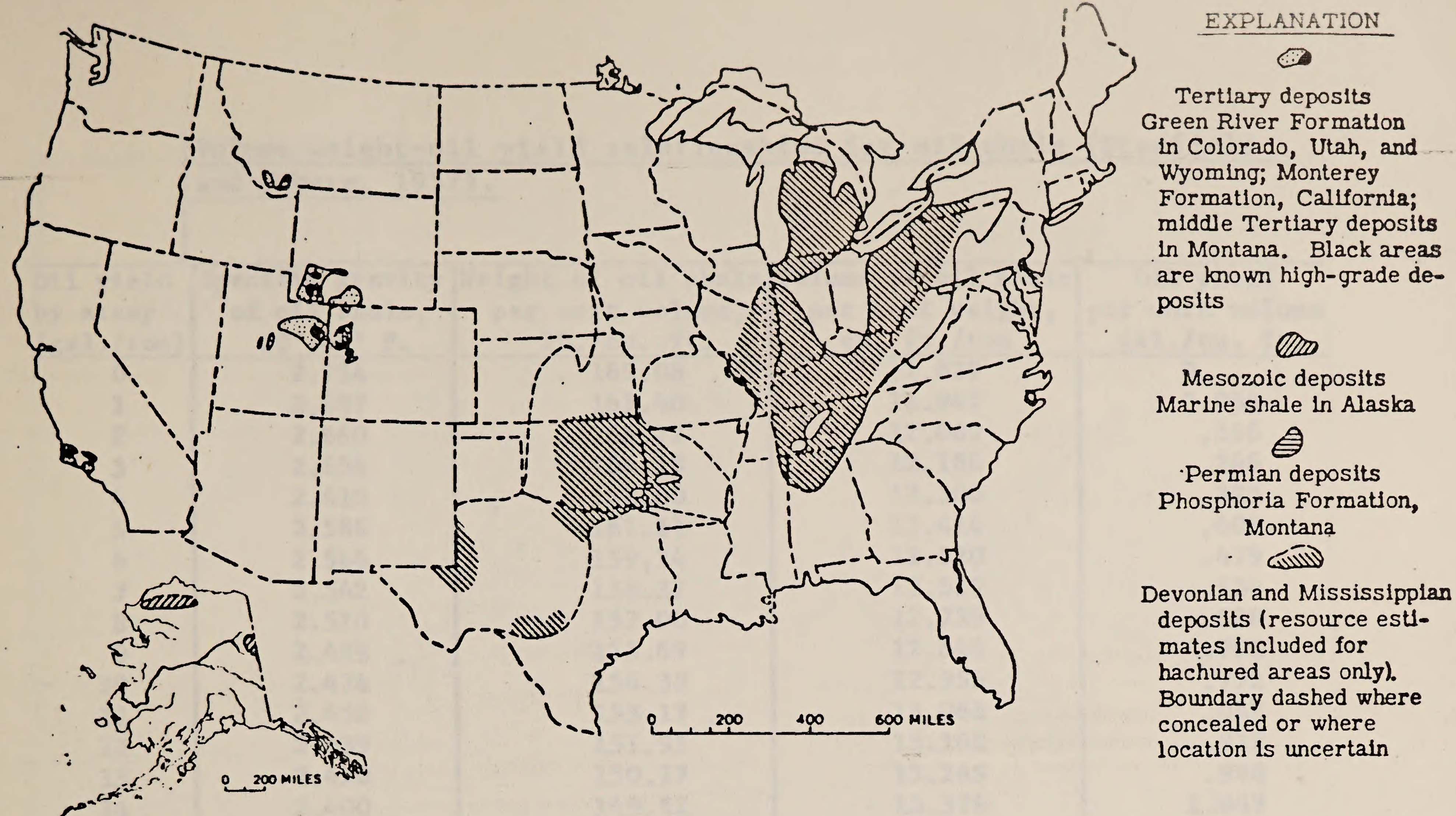


Sand Castle along the Colorado River.
Upper portion formed by Green River Formation




Principal reported oil-shale deposits of the United States

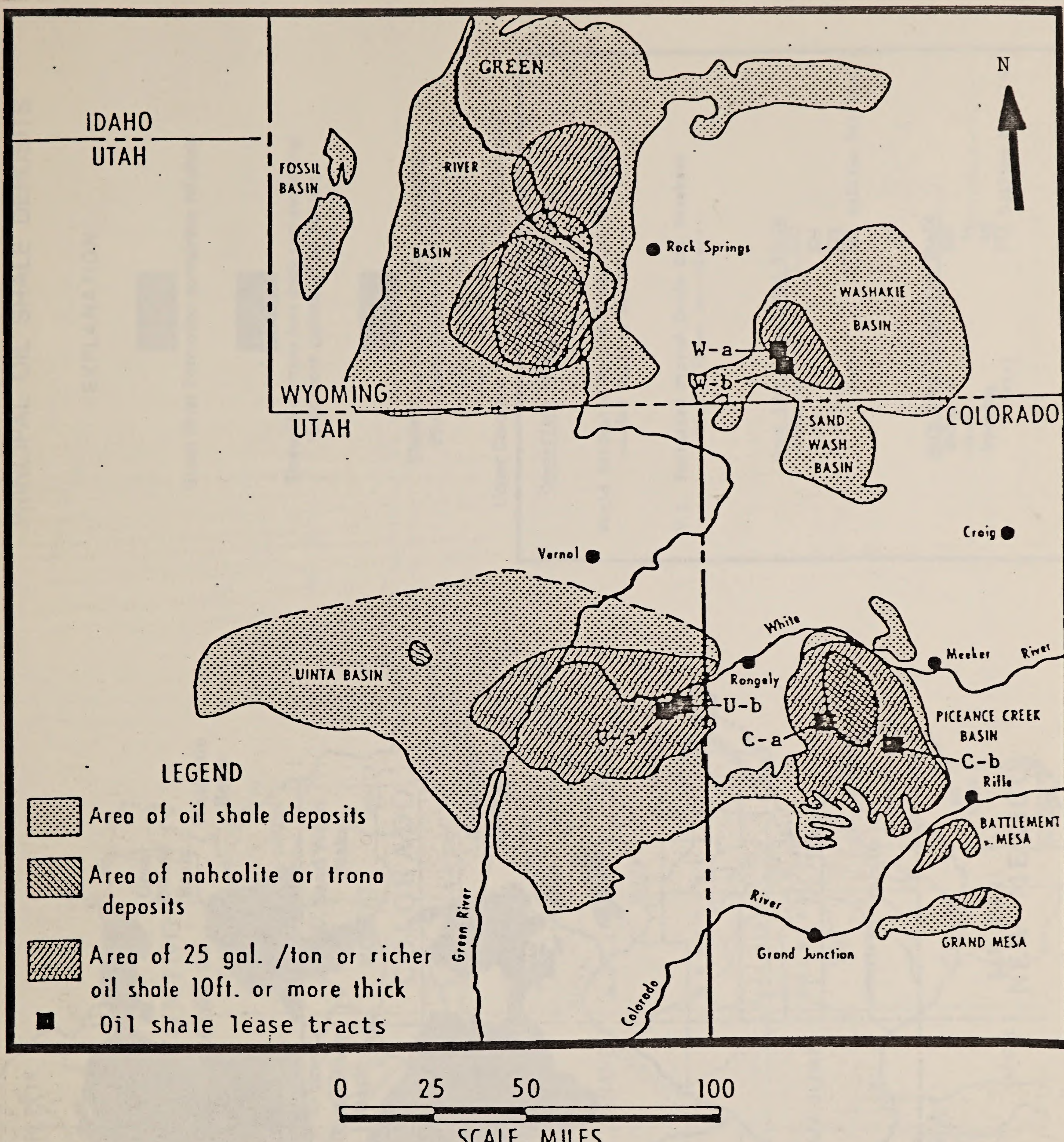
Typical composition of 25 gallon per ton oil shale

| | Weight-percent |
|---|---|
| Organic matter: | |
| Content of raw shale | 13.8 |
| Ultimate composition: | |
| Carbon | 80.5 |
| Hydrogen | 10.3 |
| Nitrogen | 2.4 |
| Sulfur | 1.0 |
| Oxygen | 5.8 |
| Total | 100.0 |
| Mineral matter: | |
| Content of raw shale | 86.2 |
| Estimated mineral constitutents: | |
| Carbonates; principally dolomite | 48 |
| Feldspars | 21 |
| Quartz | 13 |
| Clays, principally illite | 13 |
| Analcite | 4 |
| Pyrite | 1 |
| Total | 100 |

Source: Prototype Oil Shale Leasing Program EIS, U.S. Dept. Interior

Volume-weight-oil yield relationships for oil shale (Stanfield and others, 1957).

| Oil yield by assay (gal./ton) | Specific gravity of oil shale, 60°/60° F. | Weight of oil shale per unit volume, lb./cu. ft. | Volume of oil shale per unit weight, cu. ft./ton | Oil yield per unit volume gal./cu. ft. |
|---|---|---|---|---|
| 0 | 2.714 | 169.08 | 11.829 | 0 |
| 1 | 2.687 | 167.40 | 11.947 | 0.084 |
| 2 | 2.660 | 165.72 | 12.069 | .166 |
| 3 | 2.634 | 164.10 | 12.188 | .246 |
| 4 | 2.610 | 162.60 | 12.300 | .325 |
| 5 | 2.586 | 161.11 | 12.414 | .403 |
| 6 | 2.564 | 159.74 | 12.520 | .479 |
| 7 | 2.542 | 158.37 | 12.629 | .554 |
| 8 | 2.520 | 157.00 | 12.739 | .628 |
| 9 | 2.499 | 155.69 | 12.846 | .701 |
| 10 | 2.478 | 154.38 | 12.955 | .772 |
| 11 | 2.458 | 153.13 | 13.061 | .842 |
| 12 | 2.439 | 151.95 | 13.162 | .912 |
| 13 | 2.420 | 150.77 | 13.265 | .980 |
| 14 | 2.400 | 149.52 | 13.376 | 1.047 |
| 15 | 2.383 | 148.46 | 13.472 | 1.113 |
| 16 | 2.364 | 147.28 | 13.580 | 1.178 |
| 17 | 2.347 | 146.22 | 13.678 | 1.243 |
| 18 | 2.330 | 145.16 | 13.778 | 1.306 |
| 19 | 2.313 | 144.10 | 13.879 | 1.369 |
| 20 | 2.297 | 143.10 | 13.976 | 1.431 |
| 21 | 2.280 | 142.04 | 14.081 | 1.491 |
| 22 | 2.264 | 141.05 | 14.179 | 1.552 |
| 23 | 2.248 | 140.05 | 14.281 | 1.611 |
| 24 | 2.233 | 139.12 | 14.376 | 1.669 |
| 25 | 2.218 | 138.18 | 14.474 | 1.727 |
| 26 | 2.203 | 137.25 | 14.572 | 1.784 |
| 27 | 2.188 | 136.31 | 14.672 | 1.840 |
| 28 | 2.173 | 135.38 | 14.773 | 1.895 |
| 29 | 2.159 | 134.51 | 14.869 | 1.950 |
| 30 | 2.145 | 133.63 | 14.967 | 2.004 |
| 31 | 2.130 | 132.70 | 15.072 | 2.057 |
| 32 | 2.117 | 131.89 | 15.164 | 2.110 |
| 33 | 2.103 | 131.02 | 15.265 | 2.162 |
| 34 | 2.089 | 130.14 | 15.368 | 2.212 |
| 35 | 2.076 | 129.33 | 15.464 | 2.263 |
| 36 | 2.063 | 128.52 | 15.562 | 2.313 |
| 37 | 2.050 | 127.72 | 15.659 | 2.363 |
| 38 | 2.037 | 126.91 | 15.759 | 2.411 |
| 39 | 2.024 | 126.10 | 15.860 | 2.459 |
| 40 | 2.012 | 125.35 | 15.955 | 2.507 |
| 41 | 1.999 | 124.54 | 16.059 | 2.553 |
| 42 | 1.986 | 123.73 | 16.164 | 2.598 |
| 43 | 1.974 | 122.98 | 16.263 | 2.644 |
| 44 | 1.961 | 122.17 | 16.371 | 2.688 |




Oil shale areas in Colorado, Utah, and Wyoming showing areas offered for leasing in 1974 under the Prototype Oil Shale Leasing Program. Bids were received only for the Colorado and Utah tracts.

Source: Prototype Oil Shale Leasing Program EIS, U.S. Dept. Interior

# PRINCIPAL OIL SHALE DEPOSITS


EXPLANATION

Green River Formation containing oil shale

Shale 15 or more feet thick and averaging 15 or more gallons of oil per ton

Shale 10 or more feet thick averaging 25 or more gallons of oil per ton

Upper Colorado River drainage basin boundary

**Comparison of Oil Shale Resources**

World Estimated Proved Crude Oil Reserves
---642 billion barrels---

U.S. Estimated Proved Crude Oil Reserves
---26.5 billion barrels---

| More than 15 gal/ton Shale | |
|---|---|
| Colorado | 1,200 |
| Utah | 321 |
| Wyoming | 321 |
| Total | 1,842 billion barrels |

| More than 25 gal/ton Shale | |
|---|---|
| Colorado | 607 |
| Utah | 64 |
| Wyoming | 60 |
| Total | 731 billion barrels |

| More than 30 gal/ton Shale | |
|---|---|
| Colorado | 355 |
| Utah | 50 |
| Wyoming | 13 |
| Total | 418 billion barrels |

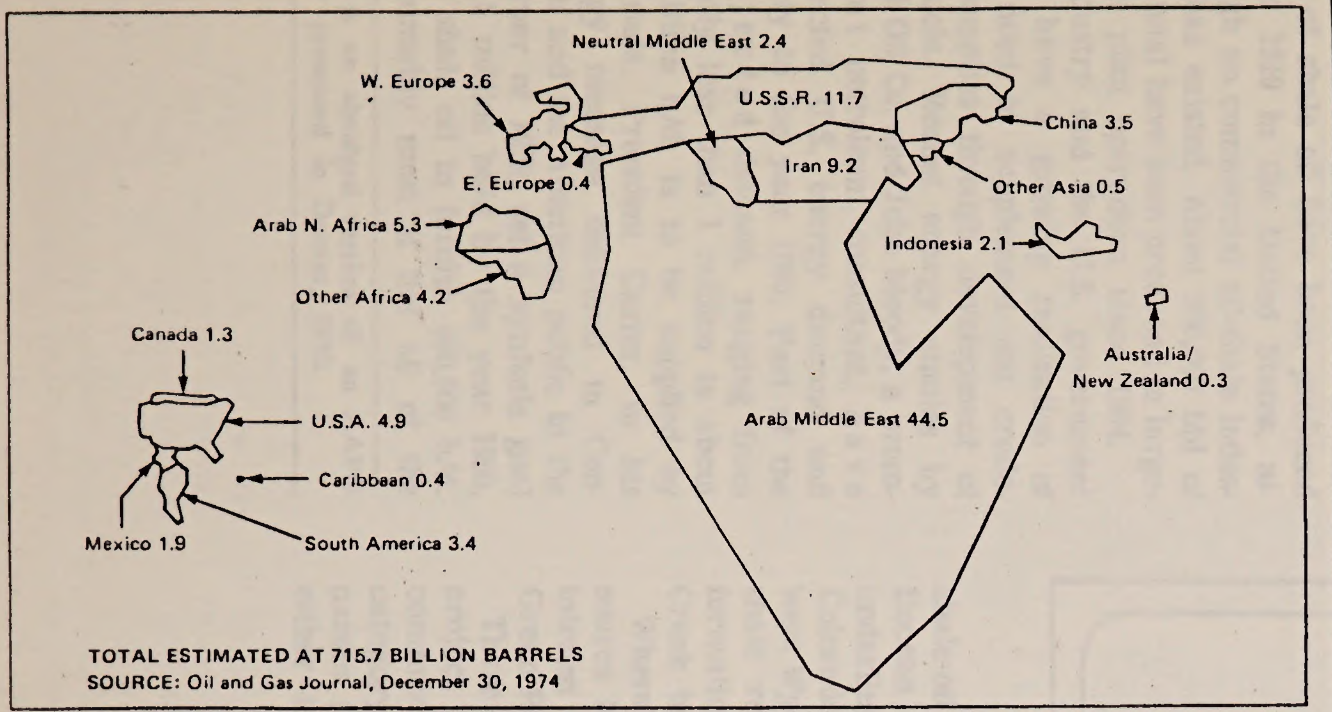



**Figure 1**—World Recoverable Crude Oil

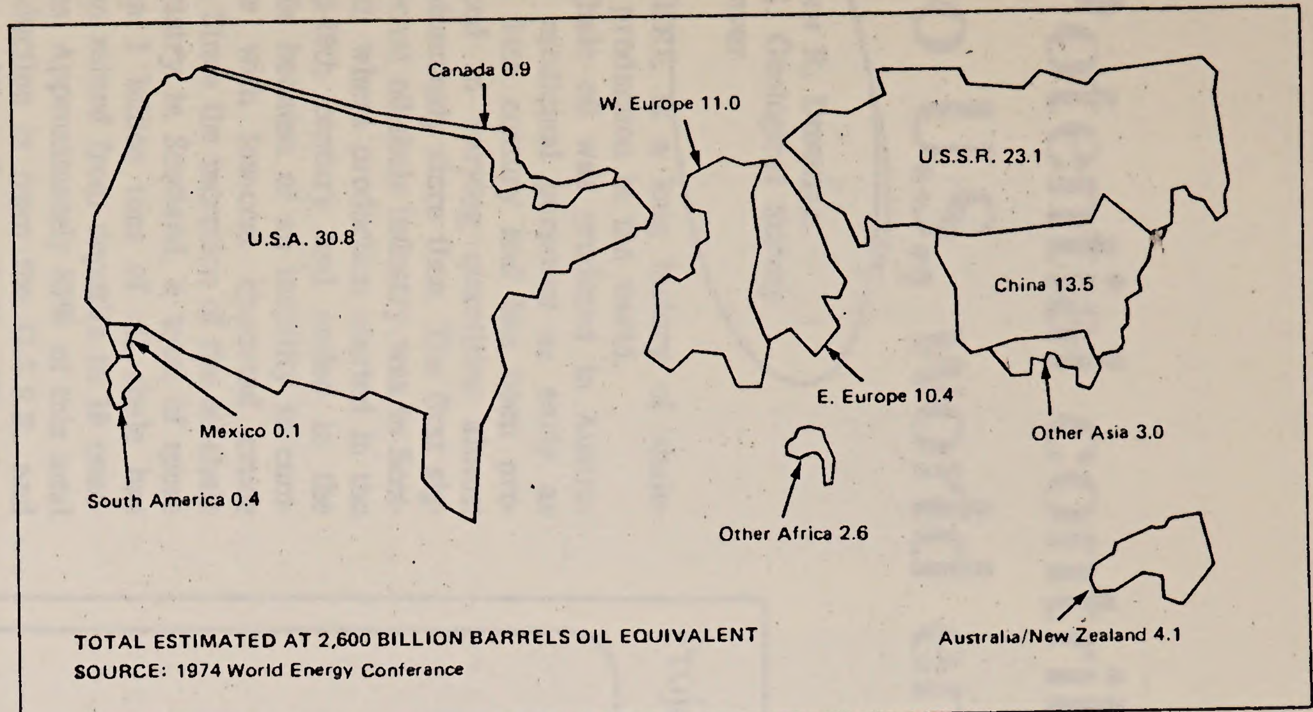



**Figure 2**—World Recoverable Coal

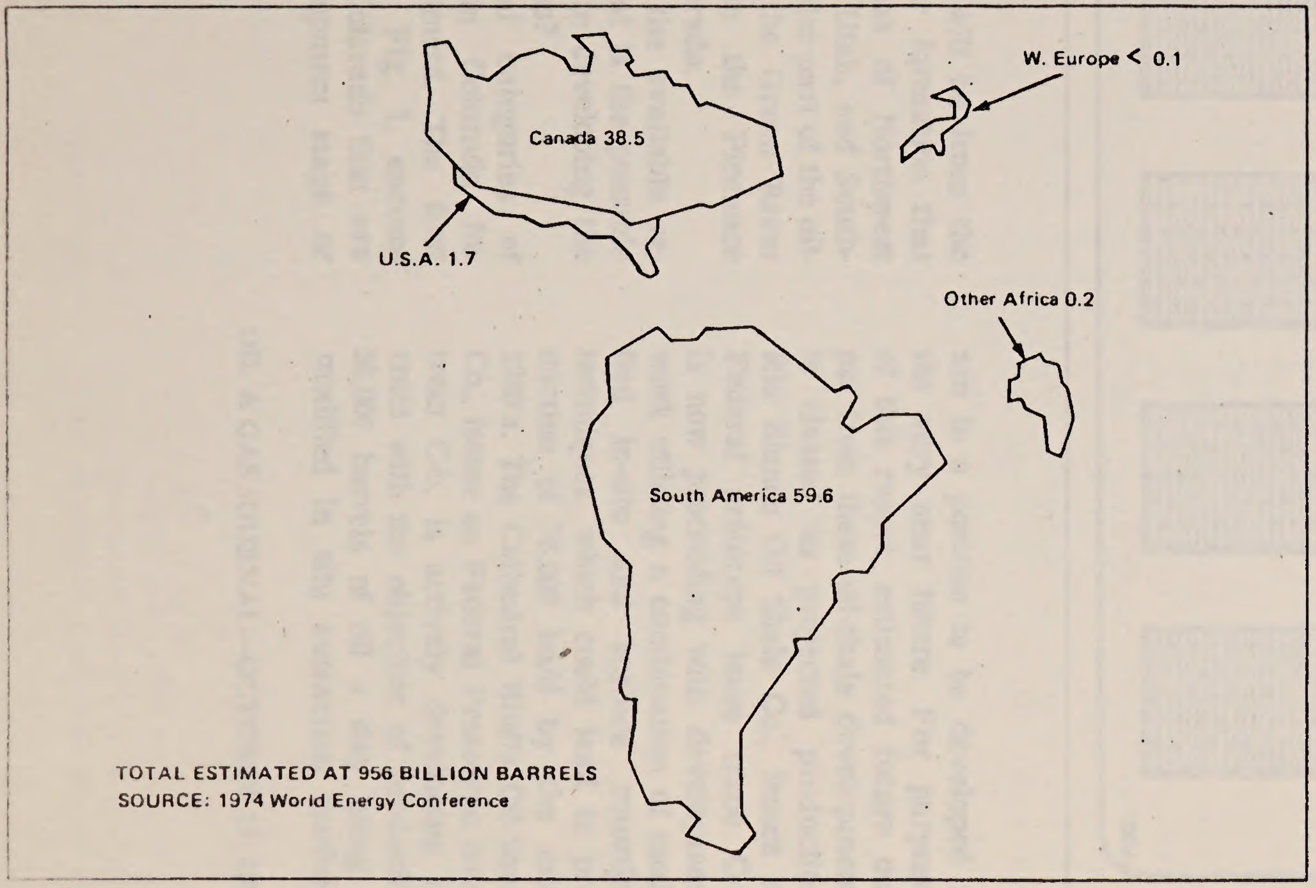



**Figure 3**—World Recoverable Tar Sands

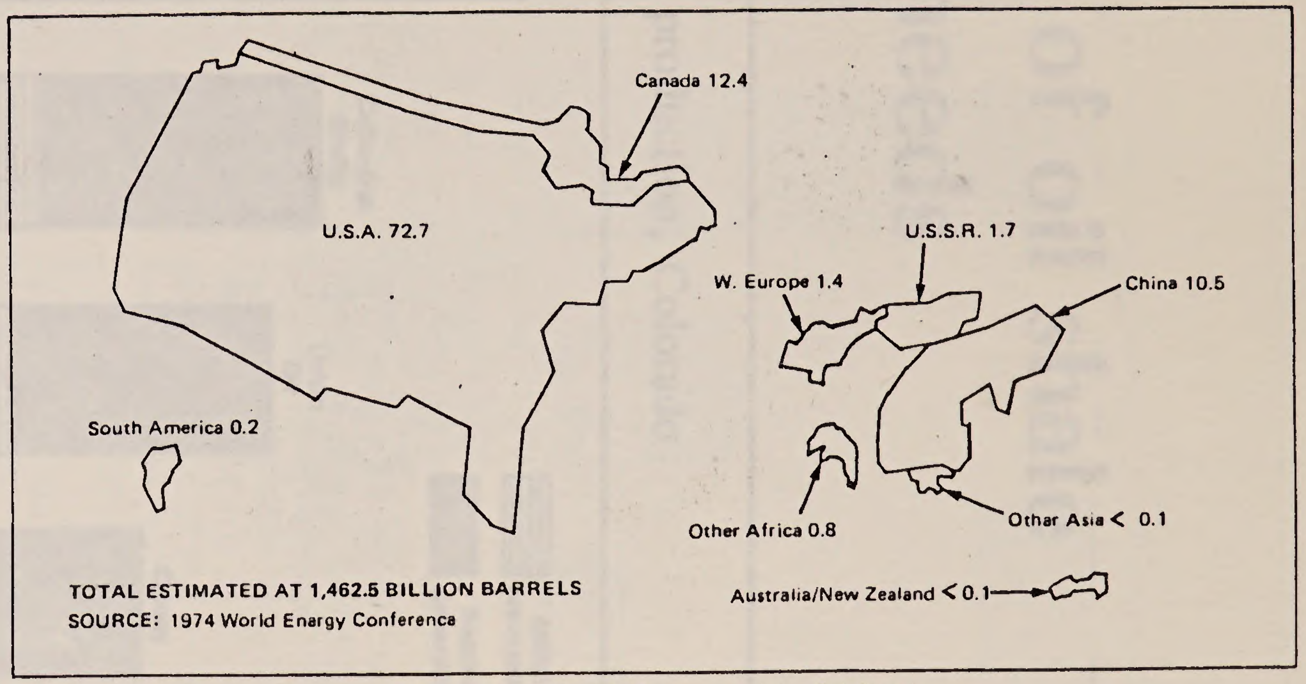



**Figure 4**—World Recoverable Oil Shale

# Potential contribution of oil shale to U.S., world energy needs

John R. Donnell
U.S. Geological Survey
Denver

There is a long history of shale-oil production in the world.

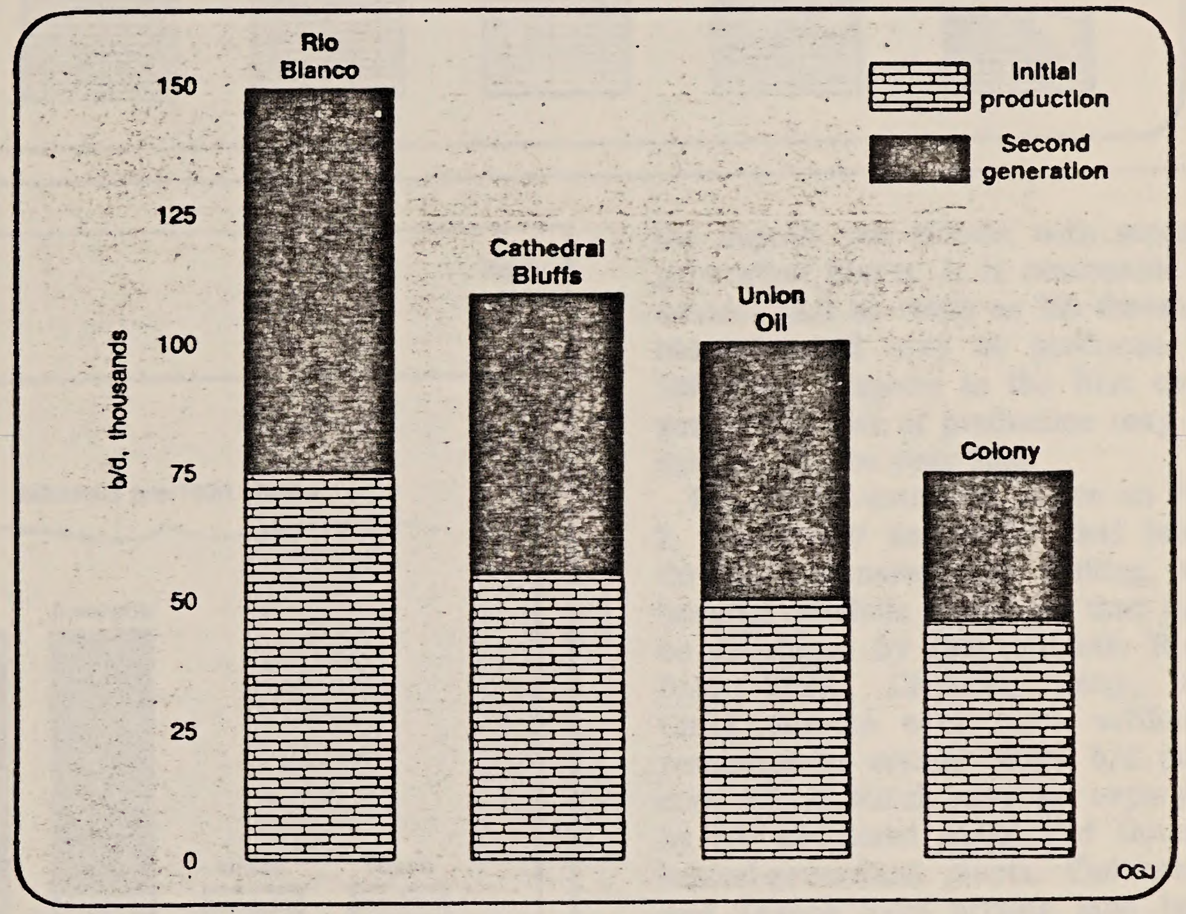
Shale oil was produced in Austria for medicinal purposes as early as the 14th century and has been produced in varying quantities almost continuously since then. The first significant oil-shale industry was in Scotland, where production started in the mid-19th century and ended in the 1960s because of an inability to compete with low-cost imported crude oil. Since the inception of the oil-shale industry in Scotland, a total of more than 1 billion tons of oil shale has been mined from deposits in 19 countries. Approximately 80% of this total production is from the U.S.S.R. and China. More than a half million barrels of shale oil have been produced since 1919 in the United States, although no commercial oil-shale industry has existed. About 350,000 bbl of this total have been produced in large-scale pilot operations since 1964.

Industry and the U.S. government now have a growing realization of the need to supplement our crude-oil supplies through development of synfuels. Recent energy studies by Shell Oil Co. and John Moody, a prominent petroleum consultant, have projected U.S. energy demand and supply to the year 1990. Part of the projected demand, ranging from slightly less than 1 million to about 2 million b/d, is to be supplied by syncrude. President Carter, in his energy message delivered to Congress and the American public in the summer of 1979, set a synfuels goal of 1.5 million bo/d by the year 1990, with shale oil to furnish 400,000 b/d. Presumably most if not all of the shale-oil production will be from the Eocene Green River formation that underlies large areas of Northwest Colorado, Northeast Utah, and Southwest Wyoming. A major part of the oil-shale resources of the Green River formation occurs in the Piceance Creek basin of Colorado.

This is an abridged version of an AAPG paper presented in Denver, 1980.

Fig. 1

Projected oil-shale production, Colorado




Where? Where is the available resource base and what is the possible interest of industry in developing the Green River oil shales?

There are several categories of project readiness in Colorado for commercial development. The first category, shown on Fig. 1, encompasses projects in Colorado that are either in the development stage or are in a position to be developed in the very near future. For purposes of this report, estimated future output from these oil-shale developments is classed as projected production. Rio Blanco Oil Shale Co., lessee on Federal prototype lease trace C-a, is now proceeding with development work utilizing a combination of modified in-situ and surface retorting techniques, which could lead to production of 76,000 bo/d by the mid-1980's. The Cathedral Bluffs Oil-Shale Co., lessee on Federal Prototype lease tract C-b, is actively developing its tract with the objective of producing 56,000 barrels of oil a day using a modified in situ extraction method.

Fig. 2

## Possible oil-shale projects on fee lands, Colorado

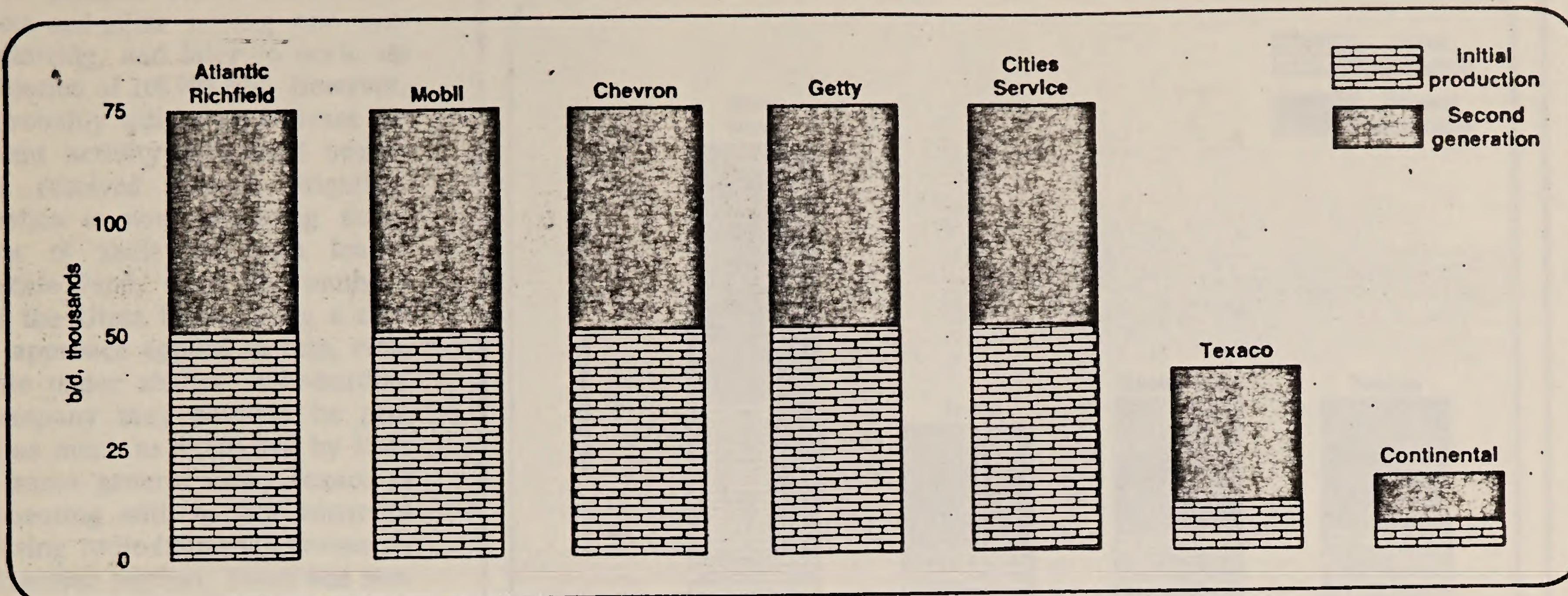
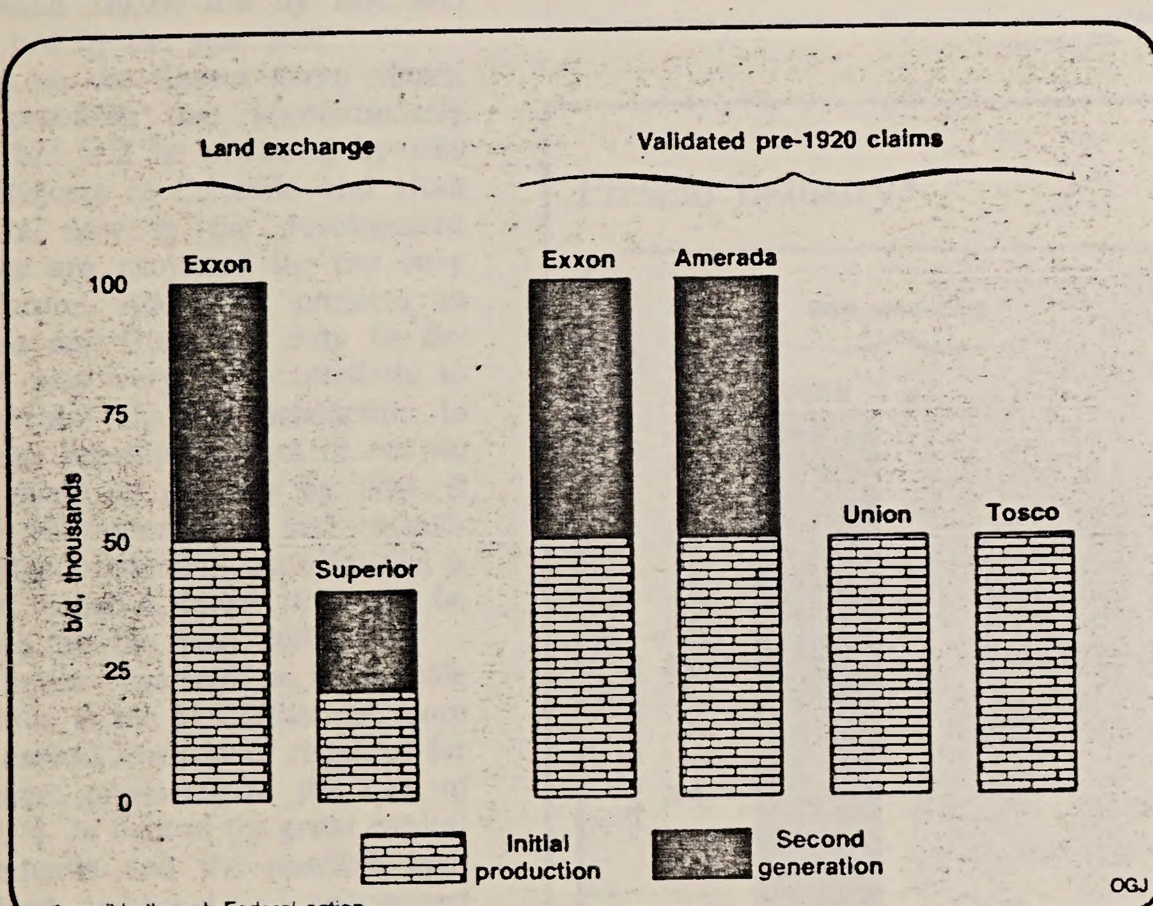



Fig.3

## Colorado oil-shale projects*




*possible through Federal action

Union Oil Co. and Colony Development have extensive private oil-shale holdings in the southern part of the Piceance Creek Basin.

Both companies have developed pilot mines and demonstrated the technical feasibility of their surface retorts at a semiworks scale. With proper incentives each company has indicated that it could be producing between 40,000 and 50,000 bo/d by the mid-80s using conventional room-and-pillar mining and surface-retorting methods. With the exception of Colony, all category-one projects have sufficient high-grade resources to justify a doubling of production through development of second-generation plants. Colony may achieve the goal of doubled production through mining a thicker sequence of lower grade shale in the Mahogany zone or by mining additional lower grade shale in the R-6 zone underlying the mahogany.

The part of the bar graph dashed on Fig. 1 and succeeding figures indicates the amount of shale oil that is being produced now or presumably will be produced in an initial venture. Yellow indicates the additional amount of shale-oil production that the deposit can sustain with second-generation plants. It is reasonable to assume that as much as 230 thousand bbl-shale-oil/d may be produced by 1990 from projects in the first category. This rate of production may be doubled by the year 2000.

The second category, shown on Fig. 2, consists of companies that have, through extensive core drilling, delineated oil-shale resources that may be developed by 1990. Atlantic Richfield, Mobil, Chevron, Getty, and Cities Service each have sufficient resources to sustain 50,000 b/d projects, all of which may be expanded by an additional 50,000 b/d through second-generation plants. Continental and Texaco have private land holdings underlain by thinner and leaner oil shale; therefore, production might initially be 5 and 10,000 b/d, respectively, and might possibly be expanded to a maximum of 15 and 40,000 b/d. The possibility exists that 265,000 bbl of shale oil a day may be produced from category-two projects by 1990, and that this may be expanded to an additional 290,000 b/d by the year 2000.

The third category (Fig. 3) consists of projects whose development is dependent on action by the federal government. Approval of requests by Exxon and Superior for oil-shale land exchanges and for patenting the pre-1920 oil-shale mining claims of Exxon, Amerada, and Tosco would add the potential for first-generation production of 270,000 b/d and an additional 170,000 b/d from second-generation plants by the year 2000.

The fourth category, shown on Fig. 4, encompasses projects in Utah and their projected and possible produc-

## Possible oil-shale projects on fee lands, Colorado

## Colorado oil-shale projects

[illegible]

tion. White River Oil-Shale Co., lessee of federal oil-shale lease tracts U-a and U-b, has stated that it plans initially to produce 50,000 bo/d utilizing room-and-pillar mining and surface retorting, and later to scale up to production of 100,000 b/d. However, there probably will be no on-tract development activity until land ownership is resolved through litigation. Geokinetics is now producing small amounts of shale oil from leased Utah state land, near the southern part of the Uinta basin, using a true in situ approach applied to thin, rich, oil shale under shallow over-burden. The company may possibly be producing as much as 50,000 b/d by 1990. In the same general area, Texaco is experimenting with in situ recovery of oil using radio-frequency waves as the extraction method. Tosco has several tracts of Utah state land that it intends to utilize in an eventual 45,000 b/d project using underground mining and surface retorting. Total production from Utah oil-shale deposits may reach 120,000 b/d by 1990 and 245,000 b/d by the year 2000.

Based on the figures given above, it is probable that approximately 350,000 b/d will be produced by 1990 from projects in Colorado and Utah that are now in the development stage or are projected for the very near future. Additional projects in Colorado and Utah that may be developed may very well contribute to enough total shale-oil production to meet the President's goal of 400,000 bbl of shale oil per day by 1990. If all the estimated first and second-generation production materializes, a total of about 1,700,000 b/d will be produced by the year 2000.

One major constraint on large-scale production is the $1.5 billion or more initial capital investment required for each plant producing at the rate of 50,000 b/d. In light of the great capital requirements and the possible lack of trained personnel and specialized equipment, a more realistic maximum production rate by the year 2000 might be 850,000 b/d.

**Foreign production.** Five foreign countries are either producing shale oil or actively working toward commercial development (Fig. 5). Two countries, Russia and China, are producing oil shale. Approximately 100,000 tons/day are being produced from the Baltic and Volga regions of Russia. Most of the shale is being used in the Estonia-Leningrad area as direct feed for the generation of electricity.

In China, a total of 50,000 bbl of shale oil a day is being produced from two localities. At Fushun, in Manchuria, oil is retorted from organic-rich shale in the overburden overlying an extremely thick coal bed. The other locality is near Maoming, in southern China. The production in China could very easily be doubled, and the oil-shale resources in Russia are of sufficient size to support an industry five times the present size. This could result in a total production of 600,000 b/d from the two countries by the year 2000.

Three other countries are actively progressing toward commercial development of their oil-shale resources. All three, Brazil, Australia, and Morocco, are aiming for 50,000 bo/d by the mid-1980s. Brazil, with an oil-shale deposit that parallels its east coast for a distance of 1,000 km, contains enough oil shale to expand the

Fig. 4

## Projected and possible*

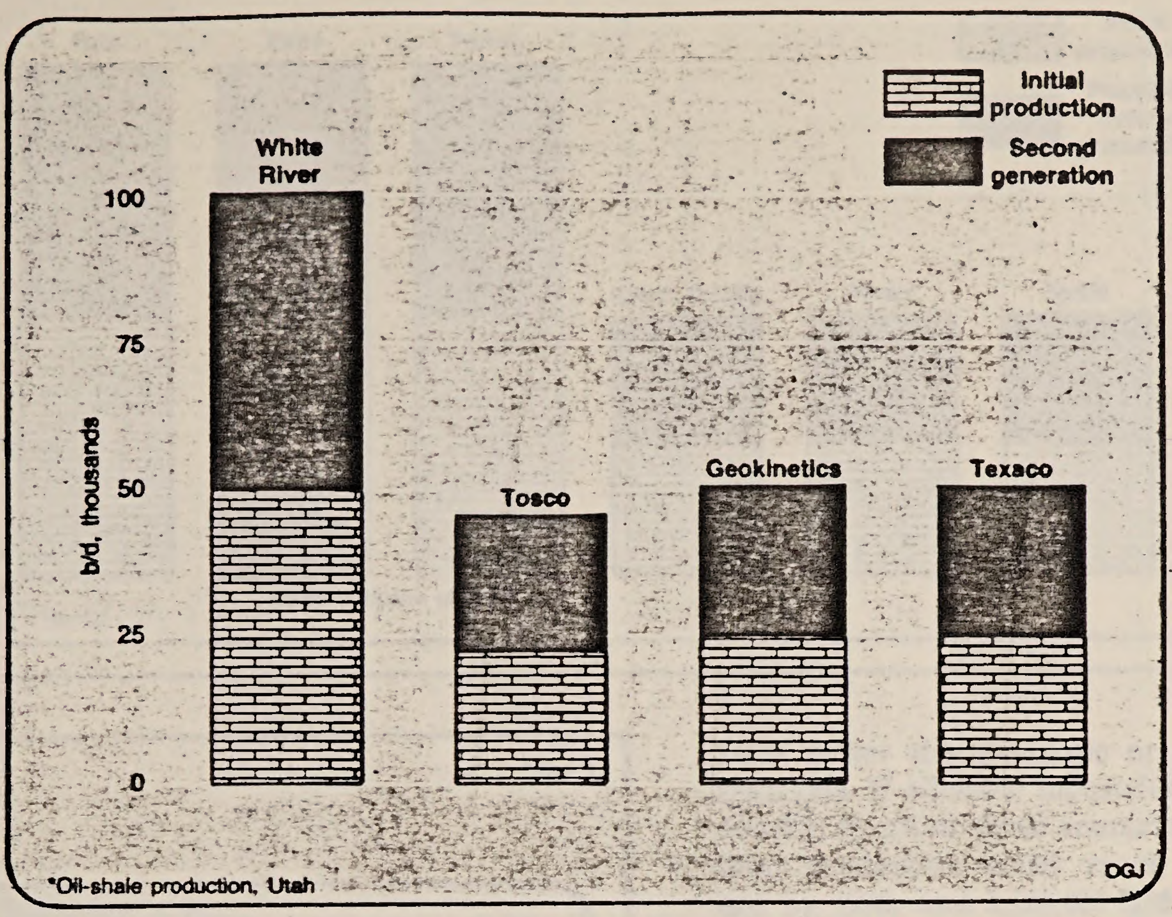
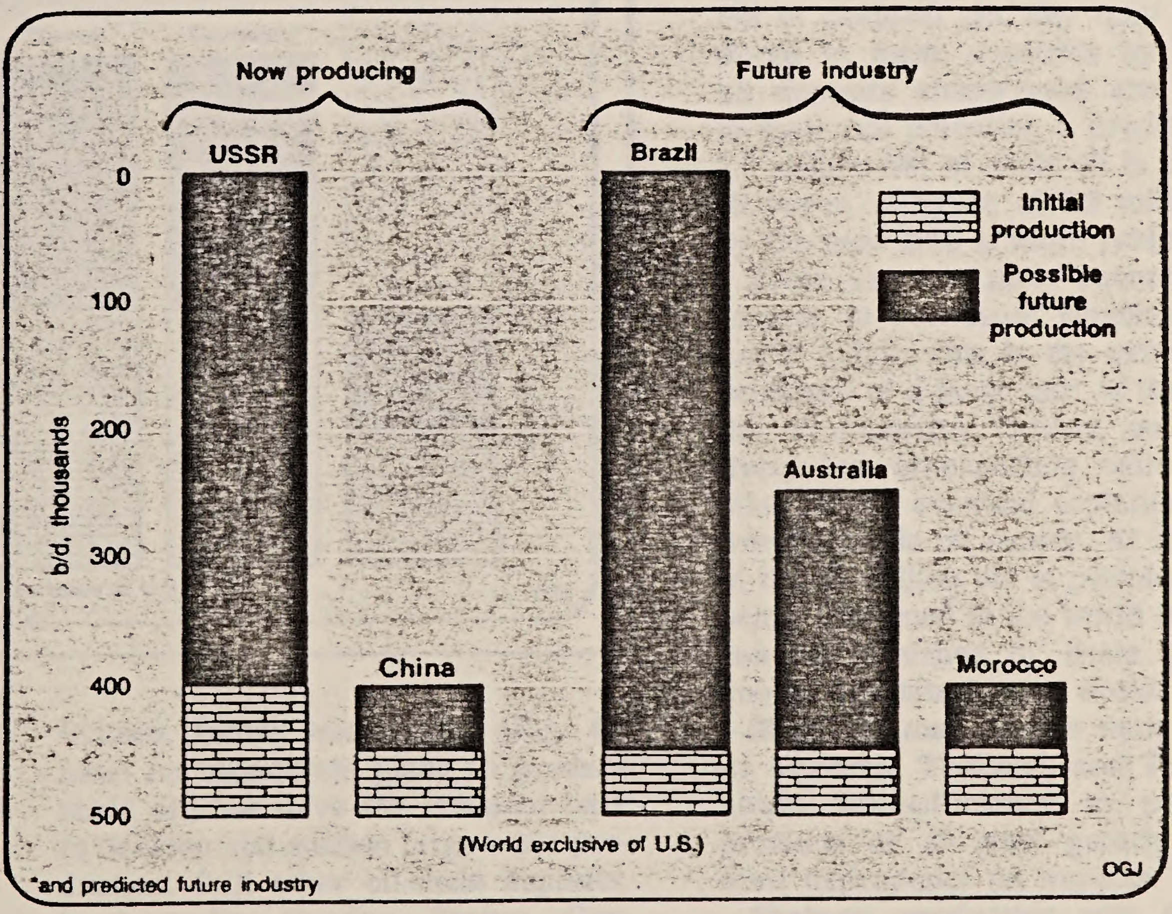



Fig. 5

## Present industry*



## Possible oil-shale projects

Fig 6

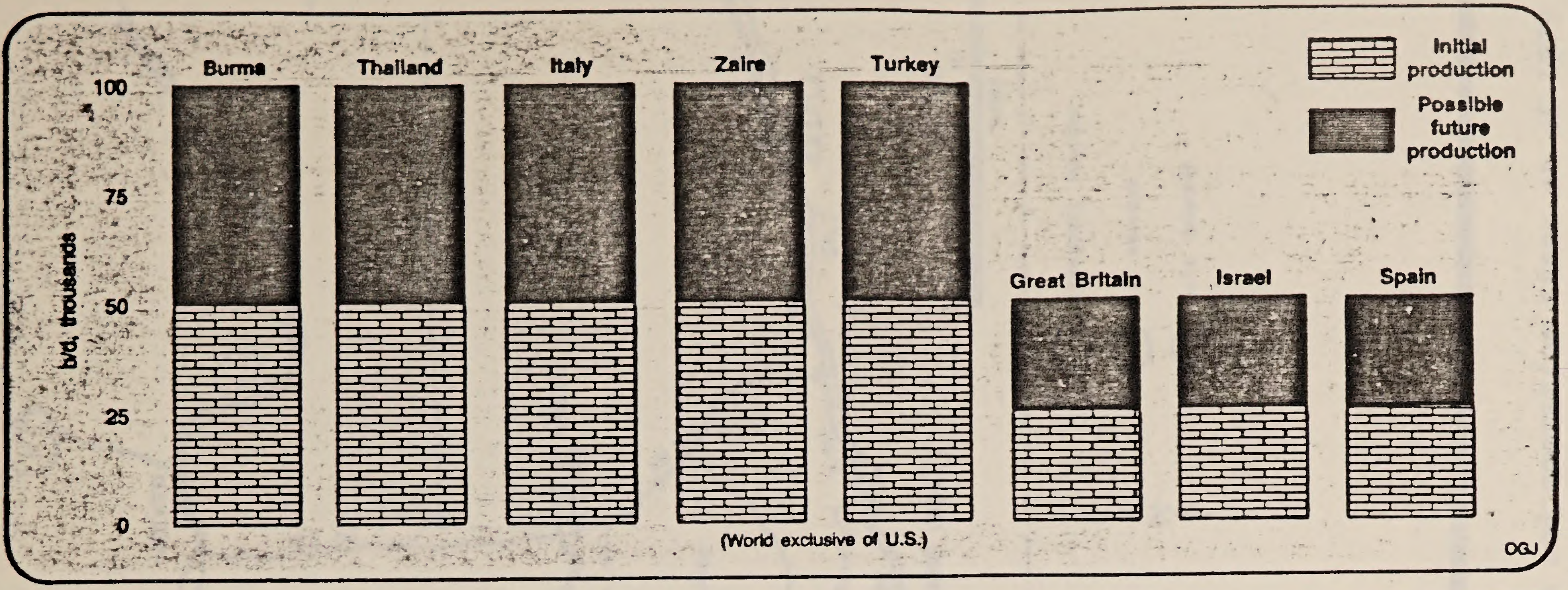
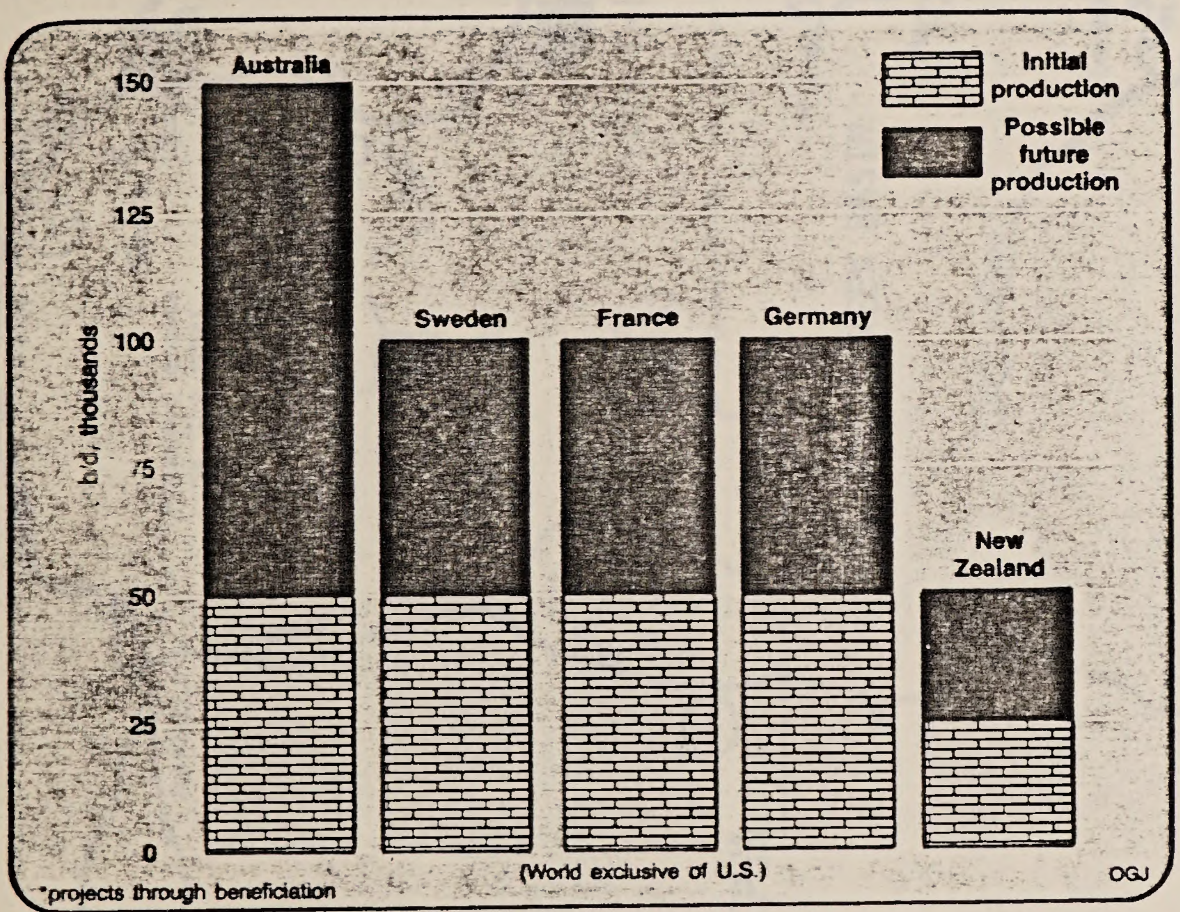



Fig. 7

## Possible oil-shale*




planned size of the initial industry 10 times. The ultimate aim of the Australian shale-oil industry is to expand to a production capacity of 250,000 b/d before 1990. Although Morocco will be self-sufficient in petroleum with the inception of a 50,000-b/d industry, enough resource base is available to double the production and allow Morocco to become a petroleum exporting country. The three countries combined have an initial potential of 150,000 b/d by 1990, and an ultimate capability of 850,000 b/d by the year 2000.

A number of other countries, Burma, Thailand, Italy, Zaire, Turkey, Great Britain, Israel, and Spain, (Fig. 6), have no immediate plans to produce shale oil, but have the resource base to develop and sustain large-scale production. Still other oil-shale deposits, in Australia, Sweden, France, Germany, and New Zealand, (Fig. 7), that at present are considered submarginal may be upgraded to commercial ore deposits through a beneficiation process that will separate the mineral fraction from the organic fraction. Some of these deposits contain abnormally high concentrations of uranium, vanadium, molybdenum, and zinc that may be recovered as byproducts from either the inorganic or organic fractions. If oil-shale industries should develop in all of these countries, their total production could reach 550,000 b/d by 1990, and 1,150,000 b/d by the year 2000.

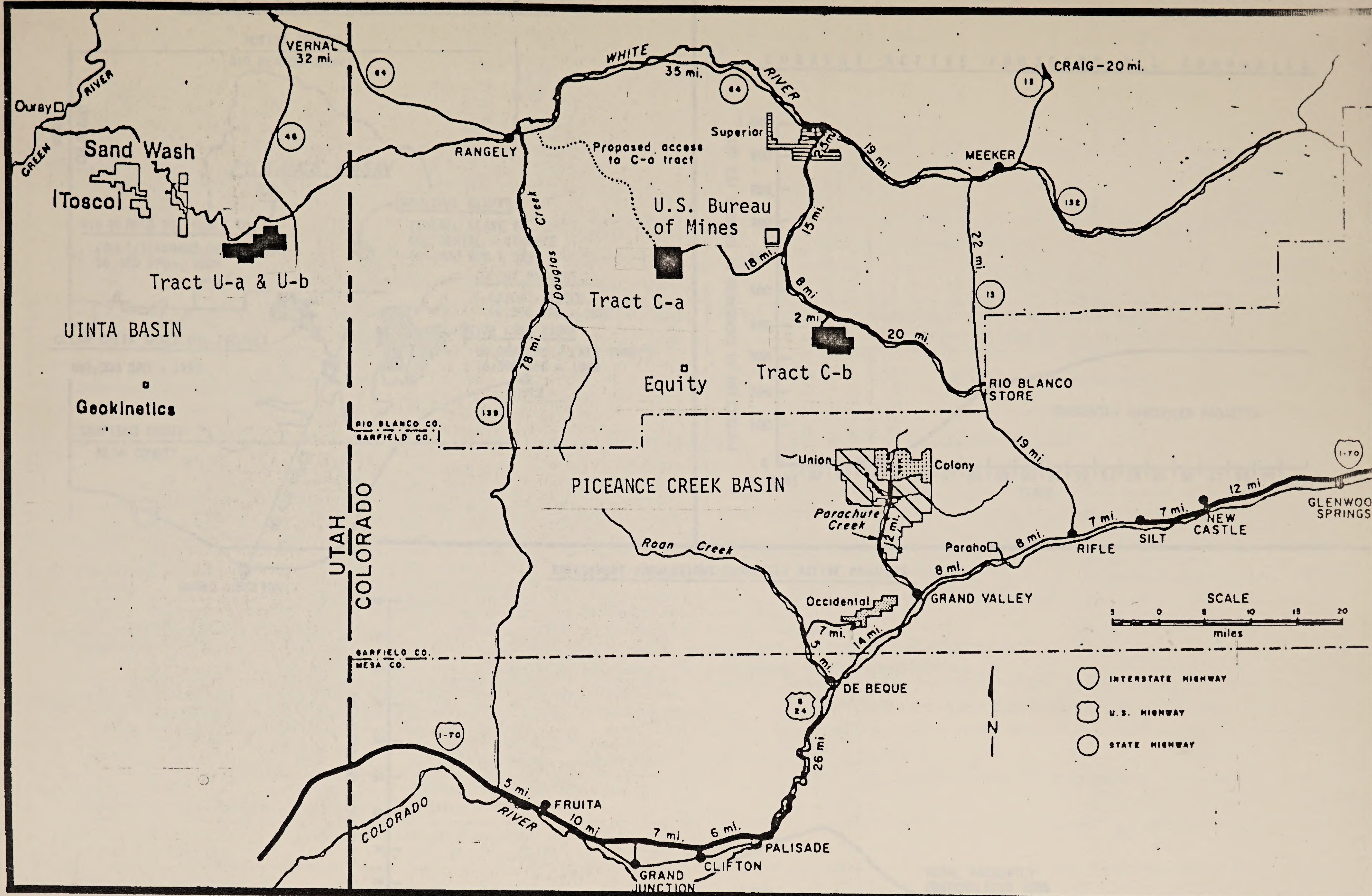
If present production continues in Russia and China and projected plans reach fruition in Brazil, Australia, and Morocco, a minimum of 300,000 bbl and possibly as much as 500,000 bbl of shale-oil per day may be produced in these countries by 1990. If all deposits enumerated are utilized to their full potential, a production of 2.6 million bbl of shale oil is possible. However, a figure of 2.2 million b/d by the year 2000 is more realistic.

There are two main concerns with respect to petroleum supplies in the world today: One is the extreme dependence of a large part of the world, the oil-importing nations, on a relatively few oil-exporting nations. The other is the eventual depletion of the world's crude oil supply. At least 5% of the 60 million bbl of petroleum now being consumed in the world each day can be furnished by shale oil from known deposits in the world.

Shale oil may enable nations such as Morocco, Thailand, and Turkey to attain self-sufficiency in petroleum products or at least greatly reduce their dependence on imports.

Shale-oil production will decrease the reliance of many oil importing countries on what in recent years has proven to be an unstable source of oil and will enable them to develop a more favorable balance of trade.

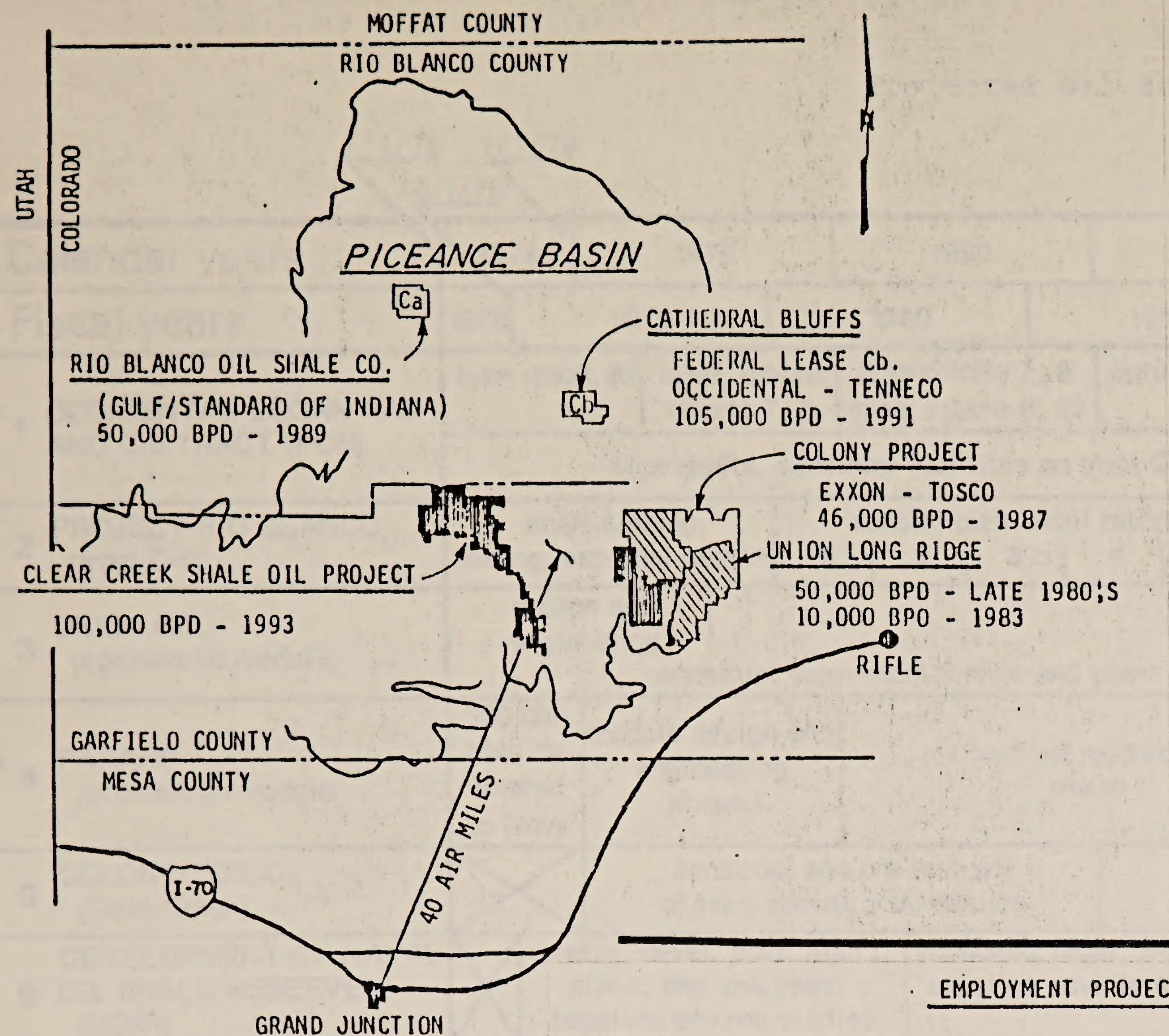
Lastly, shale-oil supplies and syncrude production from coal and tar sands, will in conjunction with crude oil supplies, assure us of a plentitude of petroleum for years to come. END



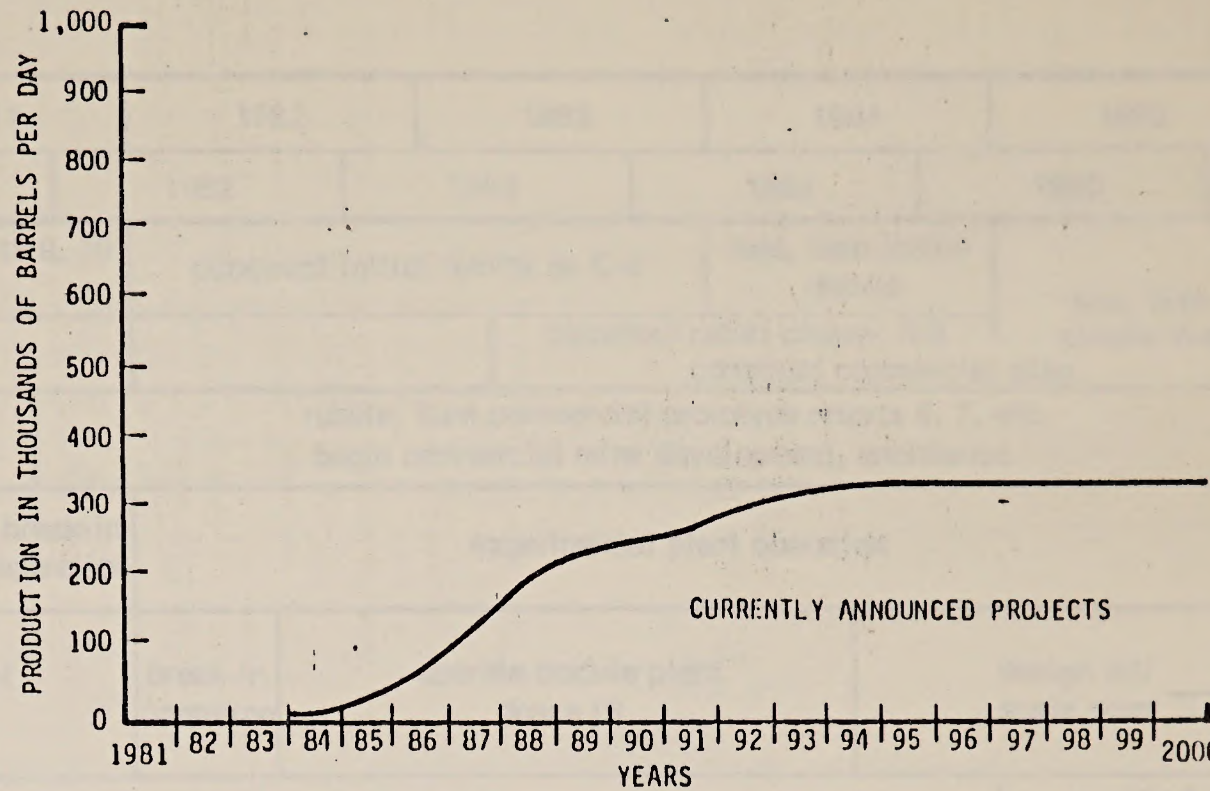

Location of Federal Oil Shale Tracts and other oil shale research and operation sites as of 1979

Source: Oil Shale Mining - Plans and Practices (Crockston and Weiss), 1979.

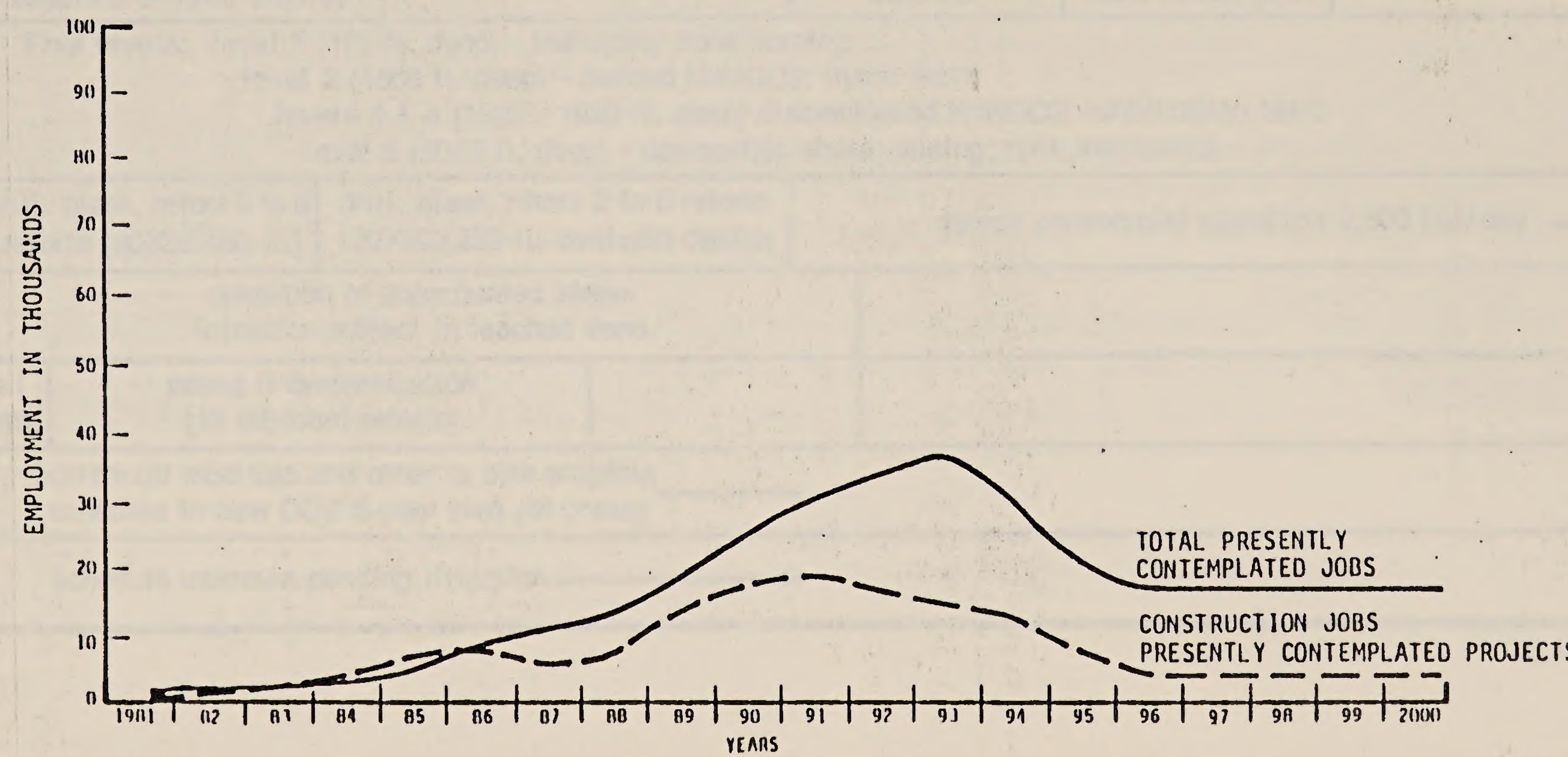
## CURRENTLY ACTIVE PROJECTS




## CURRENT ACTIVE PROJECTS ALL COMPANIES




## EMPLOYMENT PROJECTIONS CURRENTLY ACTIVE PROJECTS



## Projected oil shale activities

7/1/78 1/1/79
10/1/78

| | | Activities |
|---|---|---|
| | Calendar years | 1978 \| 1979 \| 1980 \| 1981 \| 1982 \| 1983 \| 1984 \| 1985 |
| | Fiscal years | 1978 \| 1979 \| 1980 \| 1981 \| 1982 \| 1983 \| 1984 \| 1985 \| 1986 |
| * 1 | OCCIDENTAL LOGAN WASH AND C-b TRACT (PON) | burn retort #6 \| mine, rubble retorts 7, 8 \| burn retorts 7, 8 mine, rubble 9, 10 \| burn retorts 9, 10 \| construct initial retorts on C-b \| test, burn initial retorts<br>sink shafts, construct facilities on tract C-6 \| construct retort cluster A-2 \| test, burn cluster A-2<br>construct commercial mine |
| 2 | PROJECT RIO BLANCO (tract C-a) | shaft sinking mining, experim. retorts \| rubble, burn small retorts 1 \| 2 \| 3 \| 4 \| 5 \| rubble, burn commercial prototype retorts 6, 7, etc. begin commercial mine development, ancillaries |
| 3 | UNION OIL (commercial module) | design and engineering \| construct experimental mine and plant \| break-in operation \| experimental plant operation |
| * 4 | PARAHO (commercial module) | 100,000 bbls delivered to Navy \| module design and engineering phase I \| construct module plant phase II \| break-in operation \| operate module plant phase III \| design full scale plant → |
| 5 | COLONY-TOSCO (Dave Gulch) | X \| construct and pre-test one or more commercial modules \| operate commercial modules, construct full scale plant \| operate full scale plant → |
| 6 | DEVELOPMENT OF NAVAL OIL SHALE RESERVES (NOSR) | X \| prelim. devel. plan; mgm't plans; eng analyses; baseline environ studies \| economic, legal, S-I studies; baseline environ studies — \| analyze technical data; E-SF environ studies \| complete EIS; tech studies; costs; mod. devel. plan \| initiate actual development of NOSR (schedule unknown) → |
| 7 | USBM EXPERIMENTAL DEEP MINE | X \| Five levels: level 1 (199 ft. deep) - Mahogany zone burning<br>level 2 (1660 ft. deep) - bedded NaHCO3; hydro tests<br>levels 3 & 4 (1820 - 1920 ft. deep) disseminated MaHCO3; rubblization tests<br>level 5 (2055 ft. deep) - dawsonitic shale; mining; rock mechanics |
| * 8 | GEOKINETICS, INC. (Uinta Basin) (PON) | small retorts \| drill, blast, retort 6 to 8 retorts (80X30X80 ft.) \| drill, blast, retort 2 to 5 retorts 120X50X250 ft. evaluate design \| design commercial operation 2,500 bbl/day → |
| * 9 | EQUITY OIL (PON) (Piceance Basin) | site prep'n \| operation of superheated steam injection project in leached zone |
| * 10 | TALLEY ENERGY SYSTEMS (PON) — Wyo | phase I (prelim) \| phase II demonstration (16 adjacent retorts) |
| * 11 | LETC-DOE (other field projects) | horizontal modified and other in situ projects schedule in new DOE 5-year plan (in press) → |
| 12 | WHITE RIVER SHALE PROJECT (tracts UaUb) | schedule unknown pending litigation → |

*DOE Interagency Involvement

C.H. PRIEN EPA/IPA 6/5/78

# PREDICTED SHALE OIL PRODUCTION LEVELS FROM WESTERN OIL SHALE RESOURCES 1980 — 1996

(BARRELS PER CALENDAR DAY)

NOV. 1979

| | OIL SHALE PROJECTS | | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ① | OCCIDENTAL OIL SHALE LEASE TRACT C-b | a | PILOT OPERATION, ENGR. / PERMITTING, CONSTRUCTION → | | | | 6,250 | 30,000 | 50,000 | 50,000 | 87,500 | 140,000 | 200,000 | COMMERCIAL OPERATION → | | | | | |
| ② | PROJECT RIO BLANCO LEASE TRACT C-a | b | PILOT OPERATION, ENGR. / PERMITTING, CONSTRUCTION → | | | | 19,000 | 45,600 | 76,000 | COMMERCIAL OPERATION / ENGR, PERMITTING, CONSTRUCTION → | | | | | 90,800 | 111,600 | 135,000 | COMMERCIAL OPERATION → | |
| ③ | GEOKINETICS, INC UINTA BASIN | c | SAME AS ABOVE → | | 5,000 | 5,000 | 10,000 | 15,000 | 25,000 | 40,000 | 50,000 | → | | | | | | | |
| ④ | EQUITY OIL PICEANCE BASIN | d | PILOT OPERATION | | PLANS DEPEND UPON OUTCOME OF PILOT OPERATIONS → | | | | | | | | | | | | | | |
| ⑤ | NAVAL OIL SHALE RESERVE PICEANCE BASIN | e | FEASIBILITY STUDY → | | | | DESIGN PERMITTING → | | CONSTRUCTION → | | | | 28,000 | 41,500 | 50,000 | COMMERCIAL OPERATION → | | | |
| ⑥ | DEMONSTRATION OF ABOVE GROUND RETORTING (DOE-PON) | f | MODULE DESIGN | MODULAR PLANT CONSTRUCTION → | | 8,000 | 4,000 | END PROJECT | | | | | | | | | | | |
| ⑦ | DEMONSTRATION OF ADVANCED RETORT TECHNOLOGY (DOE-PON) | g | RESEARCH → | | | | PILOT TESTS, ENGINEERING, PERMITTING / MODULE CONSTRUCTION → | | | | | | 8,000 | 8,000 | END PROJECT | | | | |
| ⑧ | UNION OIL LONG RIDGE, PICEANCE BASIN | h | CONSTRUCTION | | 9,500 | MODULE OPER. / CONSTRUCTION | | 30,000 | 50,000 | COMMERCIAL OPERATION SCALE UP → | | | | | | | 75,000 | 100,000 | → |
| ⑨ | COLONY/TOSCO PARACHUTE CREEK, PICEANCE BASIN | i | DESIGN, CONSTRUCTION → | | | | 25,900 | 38,400 | 46,200 | COMMERCIAL OPERATION → | | | | | | | | | |
| ⑩ | TOSCO SAND WASH UINTA BASIN | j | | | | | | PERMITTING, CONSTRUCTION → | | | 23,100 | 46,200 | → | | | | | | |
| ⑪ | WHITE RIVER PROJECT LEASE TRACTS Ua, Ub, UINTA BASIN | k | EXACT SCHEDULE WILL DEPEND UPON OUTCOME OF LITIGATION → | | | | | | | | | | | | | 45,000 | 90,000 | → | |
| ⑫ | CHEVRON OIL PICEANCE BASIN | l | ENGR., PERMITTING, PILOT / MODULE CONSTRUCTION → | | | | 7,000 | 15,600 | 24,200 | 32,800 | 41,400 | 50,000 | 66,600 | 83,200 | 100,000 | → | | | |
| ⑬ | SUPERIOR OIL PICEANCE BASIN | m | PERMITTING, CONSTRUCTION → | | | | | 6,700 | 10,000 | 12,000 | COMMERCIAL OPERATION → | | | | | | | | |
| ⑭ | MOBIL OIL PICEANCE BASIN | n | ENGINEERING, PERMITTING, CONSTRUCTION → | | | | | | 6,000 | 6,000 | 30,600 | 42,500 | 50,000 | COMM. OPERATION SCALE UP → | | | 78,000 | 91,500 | 100,000 |
| ⑮ | CARTER OIL | o | ENGINEERING, PERMITTING, CONSTRUCTION → | | | | | | 16,800 | 24,900 | 30,000 | 45,000 | 60,000 | COMMERCIAL OPERATION → | | | | | |
| ⑯ | CITIES SERVICES | | NO DEFINITE PLANS AT THIS TIME | | | | | | | | | | | | | | | | |
| | TOTAL PROJECTS | | 0 | 0 | 14,500 | 22,500 | 81,650 | 181,300 | 304,200 | 337,900 | 446,800 | 557,900 | 693,000 | 723,100 | 755,200 | 821,000 | 942,400 | 980,900 | 989,400 |

C.H. Prien, EPA/IPA 6/5/78

## DIRECT EMPLOYMENT ESTIMATES
### PROJECTED OIL SHALE DEVELOPMENT
### WESTERN OIL SHALE RESERVES 1980-1996

DEC. 1979

| | | | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | OCCIDENTAL OIL SHALE C-b | a | 220 | 259 | 516 | 875 | 954 | 936 | 905 | 905 | 1669 | 2670 | 500 | 0 | → | → | → | CONSTR. → | → |
| | | | 150 | 481 | 959 | 1625 | 1771 | 1739 | 1680 | 1680 | 3100 | 4955 | 10,400 | 10,300 | 9700 | 9100 | 8490 | OPER. → | → |
| (2) | RIO BLANCO C-b | b | 220 | 220 | 452 | 1055 | 3317 | 3317 | 3317 | 0 | CONSTRUCTION → | → | 354 | 826 | 2596 | 2596 | 2596 | 0 | → |
| | | | 0 | → | → | → | 452 | 754 | 1660 | → | OPERATION → | → | → | → | 1943 | 2245 | 2948 | → | → |
| (3) | GEOKINETICS, INC. UINTA BASIN | c | 0 | → | 125 | 125 | 250 | 300 | 450 | 720 | 800 | CONSTRUCTION & OPERATION COMBINED → | → | → | → | → | → | → | → |
| (4) | EQUITY OIL PICEANCE BASIN | d | DEPENDING ON OUTCOME OF PILOT OPERATIONS | | | | | | | | | | | | | | | | |
| (5) | NAVAL OIL SHALE RESERVE PICEANCE BASIN | e | 0 | CONSTRUCTION → | → | → | → | → | 600 | 1800 | 2000 | 2225 | 2225 | 2000 | 465 | 0 | → | → | → |
| | | | 0 | OPERATION → | → | → | → | → | → | → | → | → | 110 | 322 | 1100 | 1100 | → | → | → |
| (6) | UNION OIL LONG RIDGE, PICEANCE BASIN | f | 400 | 663 | 478 | 478 | 478 | 1395 | 0 | CONSTRUCTION → | → | → | → | → | → | 1530 | 1530 | 0 | → |
| | | | 0 | 0 | 265 | 265 | 265 | 837 | 1395 | OPERATION → | → | → | → | → | → | → | 2093 | 2790 | → |
| (7) | COLONY/TOSCO PARACHUTE CREEK, PICEANCE BASIN | g | 0 | → | → | 850 | 2100 | 2100 | 682 | 0 | CONSTRUCTION → | → | → | → | → | → | → | → | → |
| | | | 0 | → | → | → | 110 | 332 | 1040 | 1040 | OPERATION → | → | → | → | → | → | → | → | → |
| (8) | TOSCO SAND WASH UINTA BASIN | h | 0 | CONSTRUCTION → | → | → | → | → | → | 850 | 2100 | 682 | 0 | → | → | → | → | → | → |
| | | | 0 | OPERATION → | → | → | → | → | → | → | 100 | 1040 | → | → | → | → | → | → | → |
| (9) | WHITE RIVER U-a, U-b | i | 0 | CONSTRUCTION → | → | → | → | 400 | 700 | 475 | 0 | 0 | 700 | 3000 | 3400 | 2000 | 1100 | 0 | → |
| | | | 0 | OPERATION → | → | → | → | 100 | 230 | 300 | 450 | 450 | 500 | 675 | 1000 | 1800 | 2100 | 2300 | → |
| (10) | CHEVRON OIL PICEANCE BASIN | j | 0 | → | → | 337 | 414 | 414 | 414 | 414 | 414 | 800 | 800 | 810 | 0 | CONSTRUCTION → | → | → | → |
| | | | 0 | → | → | → | 158 | 351 | 545 | 738 | 932 | 1125 | 1486 | 1873 | 2251 | OPERATION → | → | → | → |
| (11) | SUPERIOR OIL PICEANCE BASIN | k | 0 | → | 155 | 274 | 442 | 790 | 711 | 0 | CONSTRUCTION → | → | → | → | → | → | → | → | → |
| | | | 0 | → | → | 45 | 251 | 375 | 425 | 686 | OPERATION → | → | → | → | → | → | → | → | → |
| (12) | MOBIL OIL PICEANCE BASIN | l | 0 | → | → | 200 | 450 | 450 | 450 | 900 | 1900 | | | | | | | → | 0 |
| | | | 0 | → | → | → | → | → | 108 | 108 | 551 | 765 | 900 | → | → | → | 1404 | 1647 | 1800 |
| (13) | CARTER OIL UINTA BASIN | m | 0 | CONSTRUCTION → | → | → | → | 809 | 390 | 390 | 722 | 722 | 0 | → | → | → | → | → | → |
| | | | 0 | OPERATION → | → | → | → | → | 378 | 560 | 675 | 1013 | 1350 | 1350 | → | → | → | → | → |
| | TOTAL | CONSTRUCTION | 840 | 1,142 | 1,601 | 4,069 | 8,155 | 10,611 | 8,169 | 5,734 | 8,805 | 8,999 | 6,479 | 8,536 | 8,361 | 8,026 | 7,126 | 1,900 | 0 |
| | | OPERATION * | 150 | 481 | 1,349 | 2,060 | 3,257 | 4,788 | 7,911 | 8,887 | 11,389 | 14,929 | 21,367 | 22,041 | 23,025 | 23,707 | 25,302 | 26,442 | 26,595 |
| | TOTAL | | | | | | | | | | | | | | | | | | |

C.H. Prien, EPA/IPA 6/5/78

* OPERATION TOTALS INCLUDE COMBINED CONSTRUCTION & OPERATION FIGURES GEOKINETICS.

## COLORADO POPULATION ESTIMATES
for Oil Shale Construction & Operation Workforce
("*" denotes actual workforce)

| | 1981 | | | 1982 | | | 1983 | | | 1984 | | | 1985 | | | 1986 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total |
| Cathedral Bluffs (Oxy/Tenneco) | 147 | 216 | 363 | 420 | 560 | 980 | 610 | 1,410 | 2,020 | 890 | 2,030 | 2,920 | 1,040 | 3,230 | 4,270 | 1,190 | 3,330 | 4,520 |
| Rio Blanco (Gulf Stand. of Ind.) | 200 | (May thru Dec) -0- | 200 | 274 | 143 | 417 | 150 | 248 | 398 | -0- | 248 | 248 | -0- | 248 | 248 | -0- | 248 | 248 |
| Colony (Exxon/Tosco) | 600 | 100 | 700 | 1,500 | 559 | 2,059 | 2,400 | 994 | 3,394 | 2,400 | 1,696 | 4,096 | 2,400 | 2,052 | 4,452 | 400 | 2,052 | 2,452 |
| Chevron (1) | 30 | | 30 | 30 | 20 | 50 | 200 | 20 | 220 | | | | | | | | | |
| Union Long Ridge (2) | 200* 680 | 17* 25 | 705 | 1,750 | 90 | 1,840 | 110 | 375 | 485 | 800 | 390 | 1,190 | 2,025 | 390 | 2,415 | 4,200 | 450 | 4,650 |
| ARCO Coal Company O.S. Development | | | *4 | | | *4 | | | *4 | | | *4 | | | *4 | | | |
| Logan Wash (Oxy) | -0- | 193 | 193 | -0- | 158 | 158 | -0- | 4 | 4 | -0- | 4 | 4 | | | | | | |
| Cities Service | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Conoco | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Mobil (3) | | | | | | | | | | | | | 600 | 50 | 650 | 675 | 417 | 1,092 |
| Multi-Mineral (4) | 62 | 0 | 62 | 112 | 0 | 112 | 37 | 215 | 252 | 0 | 418 | 418 | 0 | 440 | 440 | 0 | 440 | 440 |
| Phillips Petroleum Co. | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Sun Company | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Texaco | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Equity Oil | | | | | | | | | | | | | | | | | | |
| Marathon Oil | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Getty Oil | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |

| | 1987 | | | 1988 | | | 1989 | | | 1990 | | | 1995 | | | 2000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total |
| Cathedral Bluffs (Oxy/Tenneco) | 1,410 | 3,550 | 4,960 | 1,140 | 3,830 | 4,970 | 610 | 4,150 | 4,760 | 230 | 4,430 | 4,660 | -0- | 4,430 | 4,430 | -0- | 4,430 | 4,43 |
| Rio Blanco (Gulf Stand. of Ind.) | | | | | | | | | | | | | | | | | | |
| Colony (Exxon/Tosco) | -0- | 2,052 | 2,052 | 0 | 2,052 | 2,052 | 0 | 2,052 | 2,052 | 0 | 2,052 | 2,052 | 0 | 2,052 | 2,052 | 0 | 2,052 | 2,05 |
| Chevron (1) | | 550 | 650 | | | | | | | | 1,800 | 1,900 | | | | | | |
| Union Long Ridge (2) | 1,250 | 1,075 | 2,325 | 0 | 1,100 | 1,100 | 0 | 1,110 | 1,110 | 0 | 1,110 | 1,110 | | | | | | |
| ARCO Coal Company O.S. Development | | | | | | | | | | | | | | | | | | |
| Logan Wash (Oxy) | | | | | | | | | | | | | | | | | | |
| Cities Service | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Conoco | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Mobil (3) | 75 | 417 | 492 | 75 | 417 | 492 | 1,800 | 421 | 2,221 | 200 | 919 | 1,119 | (1991) -0- | 919 | 919 | | | |
| Multi-Mineral (4) | 0 | 440 | 440 | 0 | 440 | 440 | 0 | 440 | 440 | 0 | 440 | 440 | 0 | 440 | 440 | 0 | 440 | 440 |
| Phillips Petroleum Co. | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Sun Company | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Texaco | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Equity Oil | | 7 | 7 | | 7 | 7 | | | | | | | | | | | | |
| Marathon Oil | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |
| Getty Oil | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |

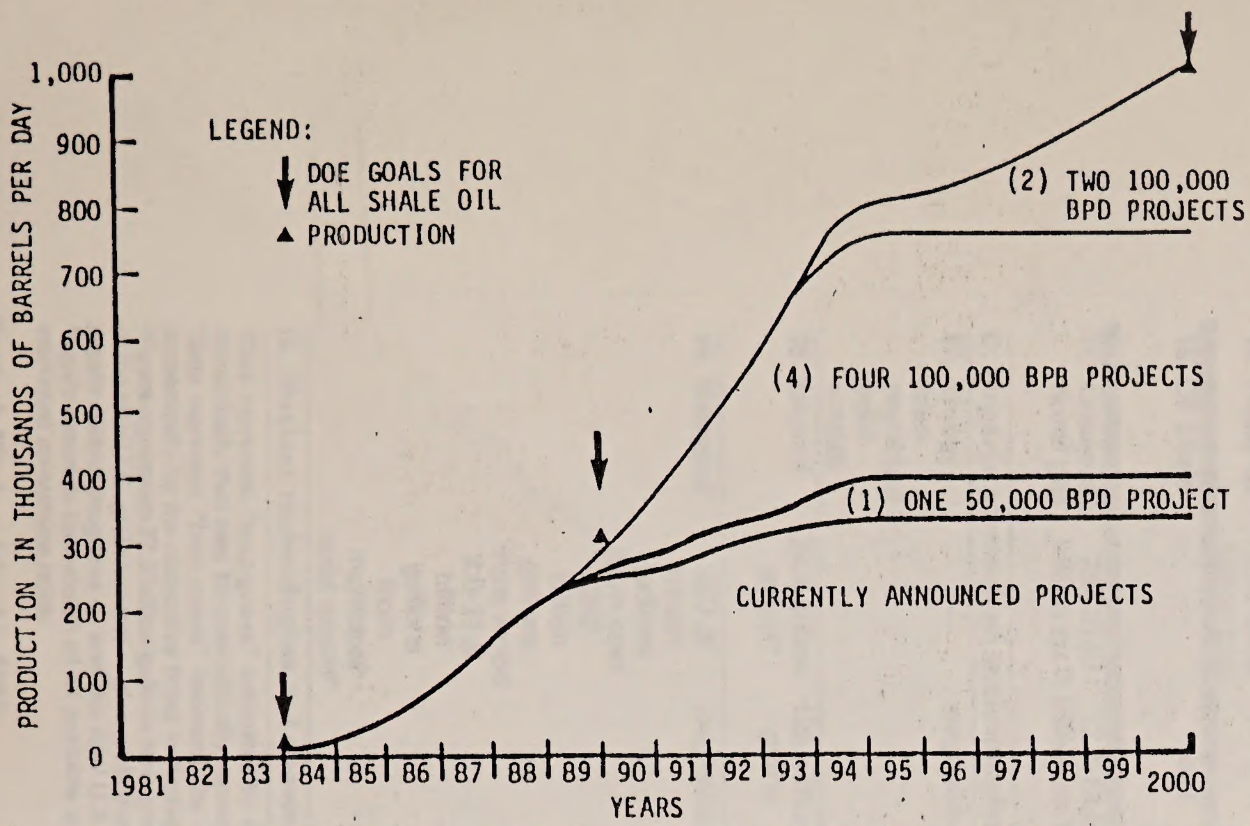
## UTAH POPULATION ESTIMATES
for Oil Shale Construction & Operation Workforce
("*" denotes actual workforce)

| | 1981 | | | 1982 | | | 1983 | | | 1984 | | | 1985 | | | 1986 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total |
| Tosco Sand Wash | | | | | | | | | | | | | | | | | | |
| Geokinetics (1) | | *28 | *28 | | 37 | 37 | | 50-100 | 50-100 | | 100-200 | 100-200 | | 150-300 | 150-300 | | 200-400 | 200-400 |
| Paraho | 0 | 0 | 0 | 800 | 0 | 800 | 1,100 | 0 | 1,100 | 1,300 | 200 | 1,500 | 900 | 900 | 1,800 | 600 | 1,200 | 1,800 |
| White River (Sun, Phillips, Sohio) | 200 | 200 | 400 | 900 | 200 | 1,100 | 625 | 200 | 825 | -0- | 175 | 175 | -0- | 450 | 450 | 800 | 450 | 1,250 |
| Gulf | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |

| | 1987 | | | 1988 | | | 1989 | | | 1990 | | | 1995 | | | 2000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total | Constr. | Operat. | Total |
| Tosco Sand Wash | | | | | | | | | | | | | | | | | | |
| Geokinetics (1) | | 250-500 | 250-500 | | 300-600 | 300-600 | | 350-700 | 350-700 | | 400-800 | 400-800 | | 500-1,000 | 500-1,000 | | 500-1,000 | 500-1,00 |
| Paraho | 0 | 1,300 | 1,300 | 0 | 1,300 | 1,300 | 0 | 1,300 | 1,300 | 0 | 1,300 | 1,300 | 0 | 1,300 | 1,300 | 0 | 1,300 | 1,30 |
| White River (Sun, Phillips, Sohio) | 3,200 | 600 | 3,800 | 3,400 | 700 | 4,100 | 2,200 | 900 | 3,100 | 2,200 | 1,100 | 3,300 | -0- | 1,600 | 1,600 | -0- | 1,600 | 1,60 |
| Gulf | NO CONTRIBUTION AT THIS TIME | | | | | | | | | | | | | | | | | |

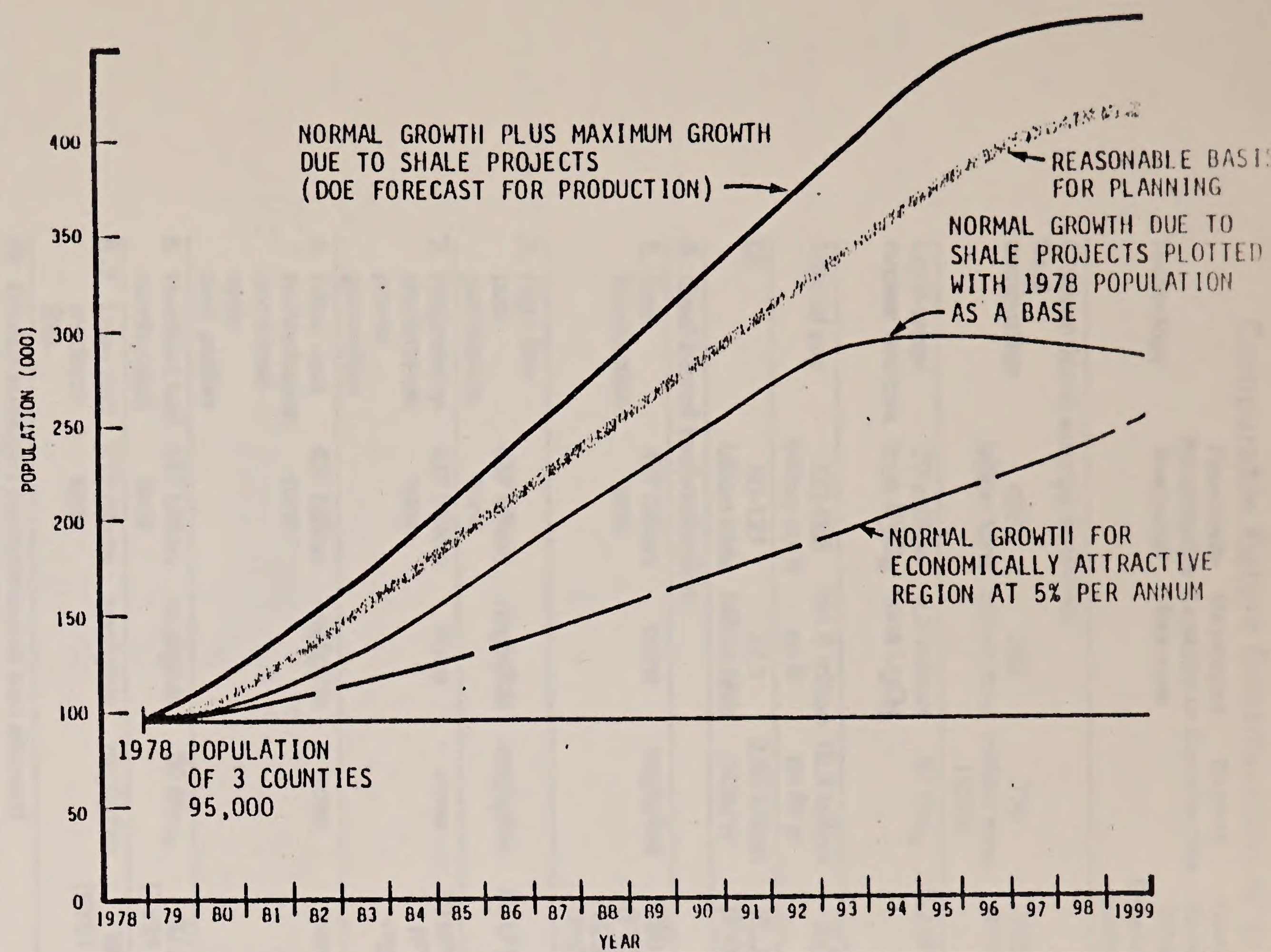
(1) Please note that our construction & operating force is the same

## PRODUCTION FORECASTS DOE OBJECTIVES

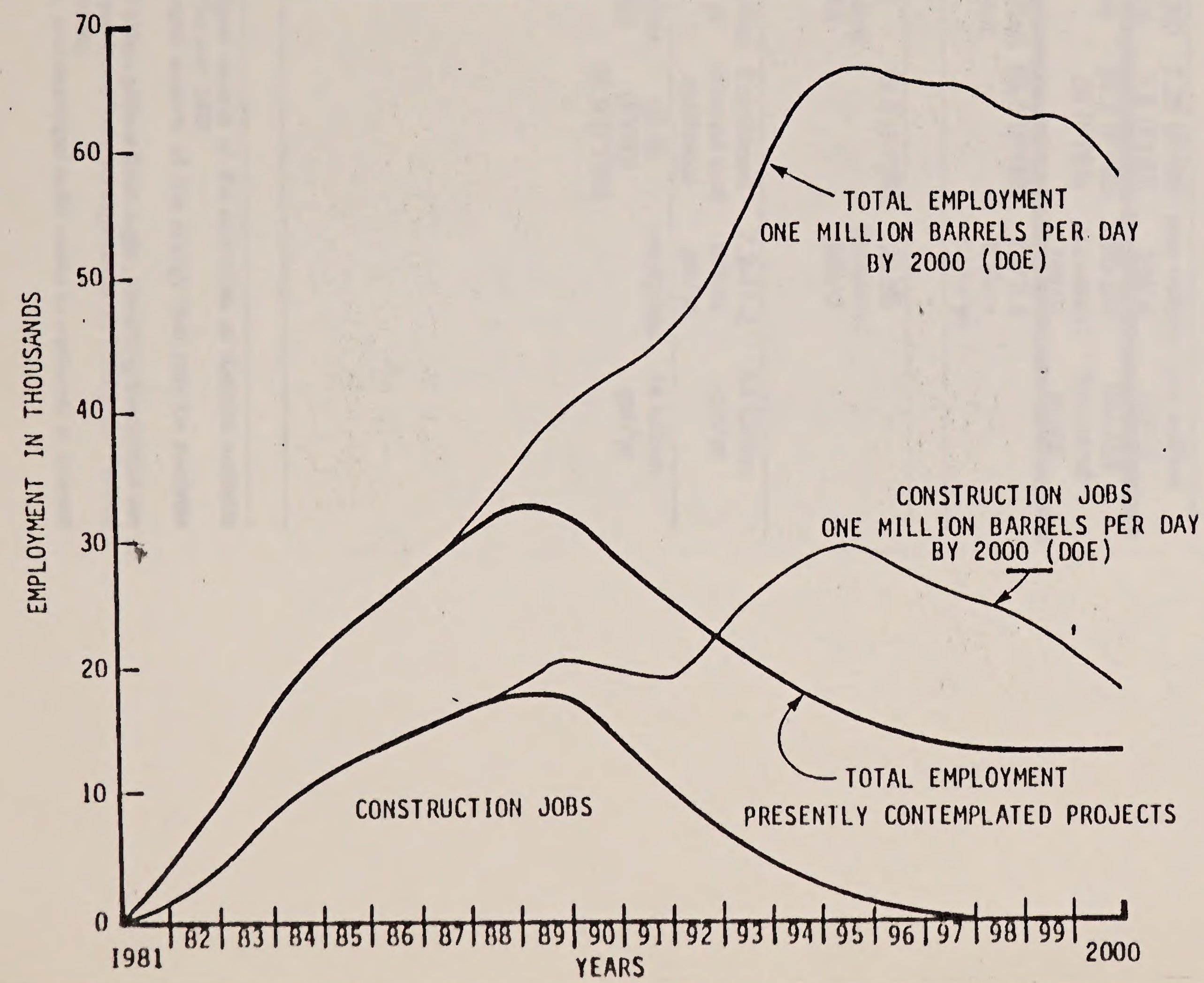



## ESTIMATED POPULATION GROWTH

WESTERN COLORADO "SHALE COUNTRY"




## EMPLOYMENT PROJECTIONS (DOE) OBJECTIVES




## Community Facility Cost Summary

(1981 dollars)

| Employment | Chevron (100,000 bpd) | Active Projects 350,000 pbd | DOE Goals 1,000,000 bpd |
|---|---|---|---|
| Construction | 5,000 | 17,500 | 52,000 |
| Super & Oper | 3,000 | 10,500 | 30,000 |
| **Subtotal** | **8,000** | **28,000** | **82,000** |
| Secondary | 2,500 | 8,800 | 25,000 |
| **Total** | **10,500** | **36,800** | **107,000** |
| **Total Resultant Population** | **27,000** | **91,800** | **270,000** |
| **Housing Units** | | | |
| Single Family | 6,100 | 21,400 | 61,400 |
| Multi-family | 1,300 | 4,400 | 13,000 |
| Mobile Homes | 1,400 | 5,000 | 14,000 |
| RV's | 200 | 700 | 20,000 |
| **Total** | **9,000** | **31,500** | **90,000** |
| **School Facilities** | | | |
| Elementary Classrooms | 100 | 350 | 1,000 |
| Elementary Buildings | 5 | 20 | 50 |
| Junior High Classrooms | 50 | 180 | 500 |
| Junior High Buildings | 2 | 10 | 20 |
| Senior High Classrooms | 50 | 180 | 500 |
| Senior High Buildings | 1 | 5 | 10 |
| Water Supply, G.P.D. | $5.4\times10^6$ | $19\times10^6$ | $54\times10^6$ |
| Sewage Disposal, G.P.D. | $4\times10^6$ | $14\times10^6$ | $40\times10^6$ |
| Hospital Beds | 100 | 350 | 1,000 |
| Fire Protection, Manpower | 40 | 140 | 400 |
| Police Protection, Manpower | 60 | 200 | 600 |

## Comparable Future Contributions of Energy Te...

| Technology | Potentially Recoverable Resource[1] | Developed Capacity or Reserves | Current Contribution | Current Federal RD&D Expenditure (millions) | Estimated Potential Contribution[2] 1990 | 2000 |
|---|---|---|---|---|---|---|
| **Conventional energy sources:** | | | | | | |
| Coal combustion | 437 billion tons | 283 billion tons | 770 million tons (1979) | 102.5 (FY81) | 1.1-1.2 billion tons | 1.2-1.7 billion tons |
| Light-water nuclear reactors | 77 million tons $U_3O_8$ | 2.5 million tons $U_3O_8$ | 52 $Gw_e$ | 412 (FY80) | 131-182 $Gw_e$ | 131-300 $Gw_e$ |
| Natural gas | 322-655 trillion cu ft | 194.9 trillion cu ft | 19.9 trillion cu ft/yr | 2.37 | 17.1 trillion cu ft/yr | — |
| Oil | 50-127 billion bbls | 27.1 billion bbls | 2.96 billion bbls/yr | 21.77 (FY80) | 2.2 billion bbls/yr | — |
| **A. Coal-based technologies:** | | | | | | |
| 1. Coal liquefaction | 437 billion tons | none | negligible | 250.3 (FY80) 523.9 (FY81) | 100-200 thousand bbl/d | 0.5-1.2 million bbl/d |
| 2. High-Btu coal gasification | 437 billion tons | negligible | negligible | 85 (FY80) | 0.5-1 billion cu ft/day | 3.3 trillion cu ft/day |
| 3. Magnetohydrodynamic power generation | 437 billion tons | none | none | 80 (FY79) 71 (FY81 req) | 500 $Mw_t$ | 1-3 $Gw_t$ |
| 4. Other coal technologies: combined-cycle coal gasifier | 437 billion tons | negligible | none | none | 0.1 Q | 3 Q |
| 5. Fluidized bed combustion | 437 billion tons | negligible | 60 $Mw_e$ | 37.2 (FY81 req) | 0.8 Q | 6.0 Q |
| 6.-7. Low- and medium-Btu | 437 billion tons | negligible | negligible | 19 (FY81 req) | 0.16-0.2 Q | 1 Q |
| **(B. Direct-sunlight technologies not shown)** | | | | | | |
| **C. Fluid hydrocarbon technologies:** | | | | | | |
| 14. Heavy oil | 7.47-20.5 billion bbls | — | 500,000 bbl/d | 7.25 (FY80) 7.9 (FY81) | one million bbl/d | one million bbl/d |
| 15. Oil Shale | — | none | none | 28.2 (FY80) 36 (FY81) | 60-250 thousand bbl/d | 180-450 thousand bbl/d |
| 16. Unconventional gas | 782-3140 trillion cu ft | 12.7-13.5 trillion cu ft | 1.1 trillion cu ft/yr | 66.5 (FY81) | 2.1-9.6 trillion cu ft/yr | — |
| **D. Organic conversion technologies:** | | | | | | |
| 17. Energy from municipal solid wastes | — | negligible | 10 thousand bbl/d | 13.5 (FY80) | 20.85 thousand bbl/d | — |
| 18. Ethanol | 28.8 billion gal/yr[3] | 120 million gal/yr | 120 million gal/yr | Combined ethanol and methanol | 7.2-41.2 billion gal/yr | 54 billion gal/yr |
| 19. Methanol | 447.3 trillion gallons from coal 250 billion gallons from wood 8.0-11.8 billion gallons from municipal solid waste[4] | negligible | negligible (FY80) | 18.45 (FY80) 24.9 (FY81) | negligible | 14 billion gal/yr |
| **(E. Nuclear technologies not shown)** | | | | | | |

[1]Data represent "best-guess" estimates by acknowledged experts of the quantities of material available domestically that may be economically recoverable by the year 2000.

[2]Data represent "best-guess" estimates by acknowledged experts of the energy that may be available domestically by the respective times indicated.

[3]Figure represents 27.8 billion gallons from grain and 1.0 billion gallons from sugar, assuming theoretical use of the total U.S. grain harvest — plus grain that could be produced from acreage currently idled under Federal supply control programs — and the total U.S. sugar harvest.

[4]Figure assumes conversion of all available coal, wood, and municipal solid waste to methanol at present estimated conversion rates.

*Synfuels Week — May 11, 1981*

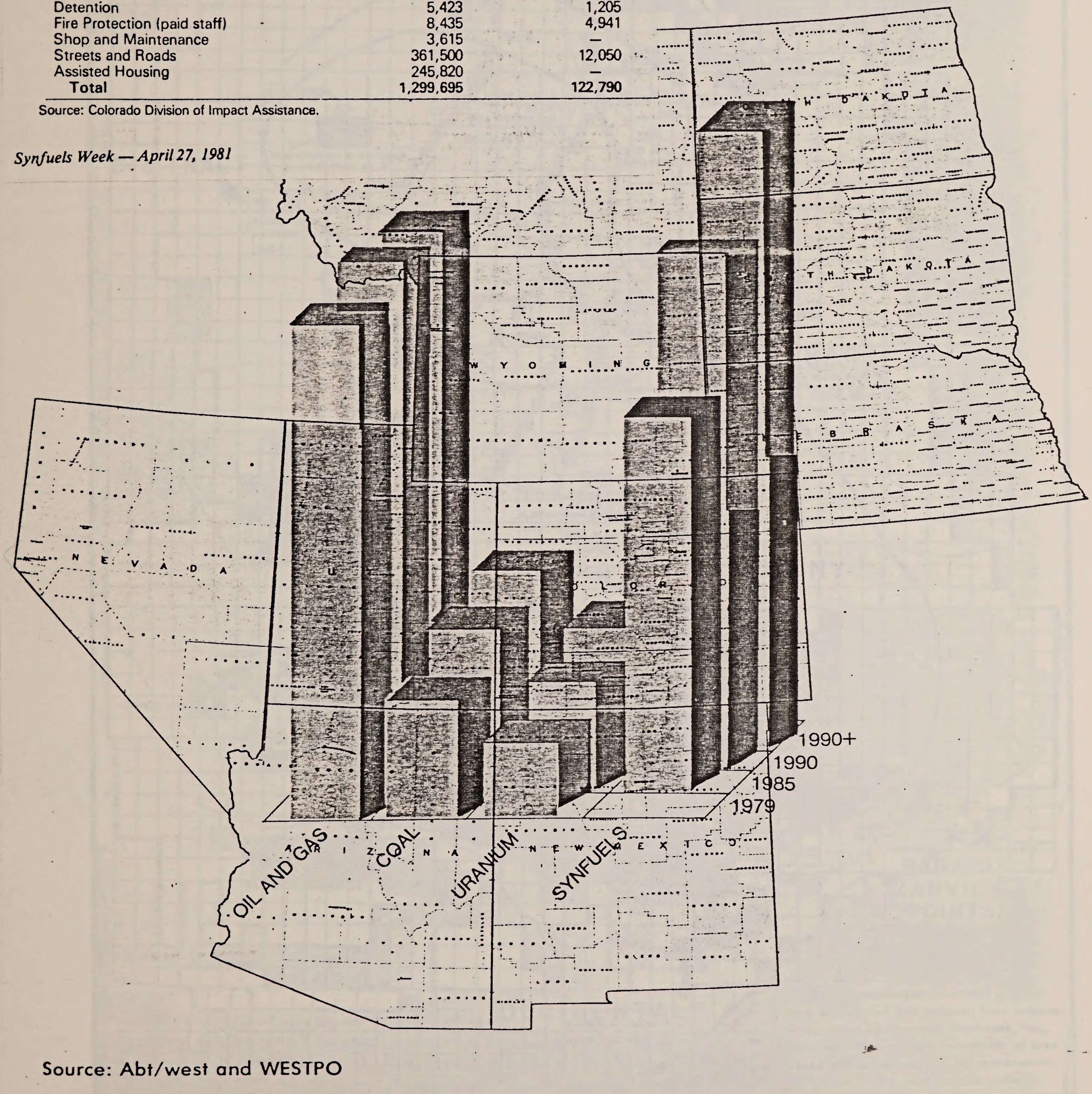
1990 Capital and Operating Costs Incurred by Energy Employment in Colorado Jurisdictions
(Employment = 24,212; Population 119,123; 1980 dollars)

| | Capital (000's) | Operations (000's) |
|---|---|---|
| Sewer | 120,000 | 3,013 |
| Water | 150,625 | 7,230 |
| Schools | 289,200 | 50,610 |
| Libraries | 8,435 | 723 |
| Administration | 6,025 | 12,050 |
| Parks and Recreation | 51,815 | 2,410 |
| Hospitals | 28,920 | — |
| Ambulance Service | 2,410 | 1,205 |
| Health, Mental Health, Social Services | 12,050 | 14,460 |
| Solid Waste | 1,205 | 3,254 |
| Public Safety | 4,218 | 9,640 |
| Detention | 5,423 | 1,205 |
| Fire Protection (paid staff) | 8,435 | 4,941 |
| Shop and Maintenance | 3,615 | — |
| Streets and Roads | 361,500 | 12,050 |
| Assisted Housing | 245,820 | — |
| **Total** | **1,299,695** | **122,790** |

Source: Colorado Division of Impact Assistance.

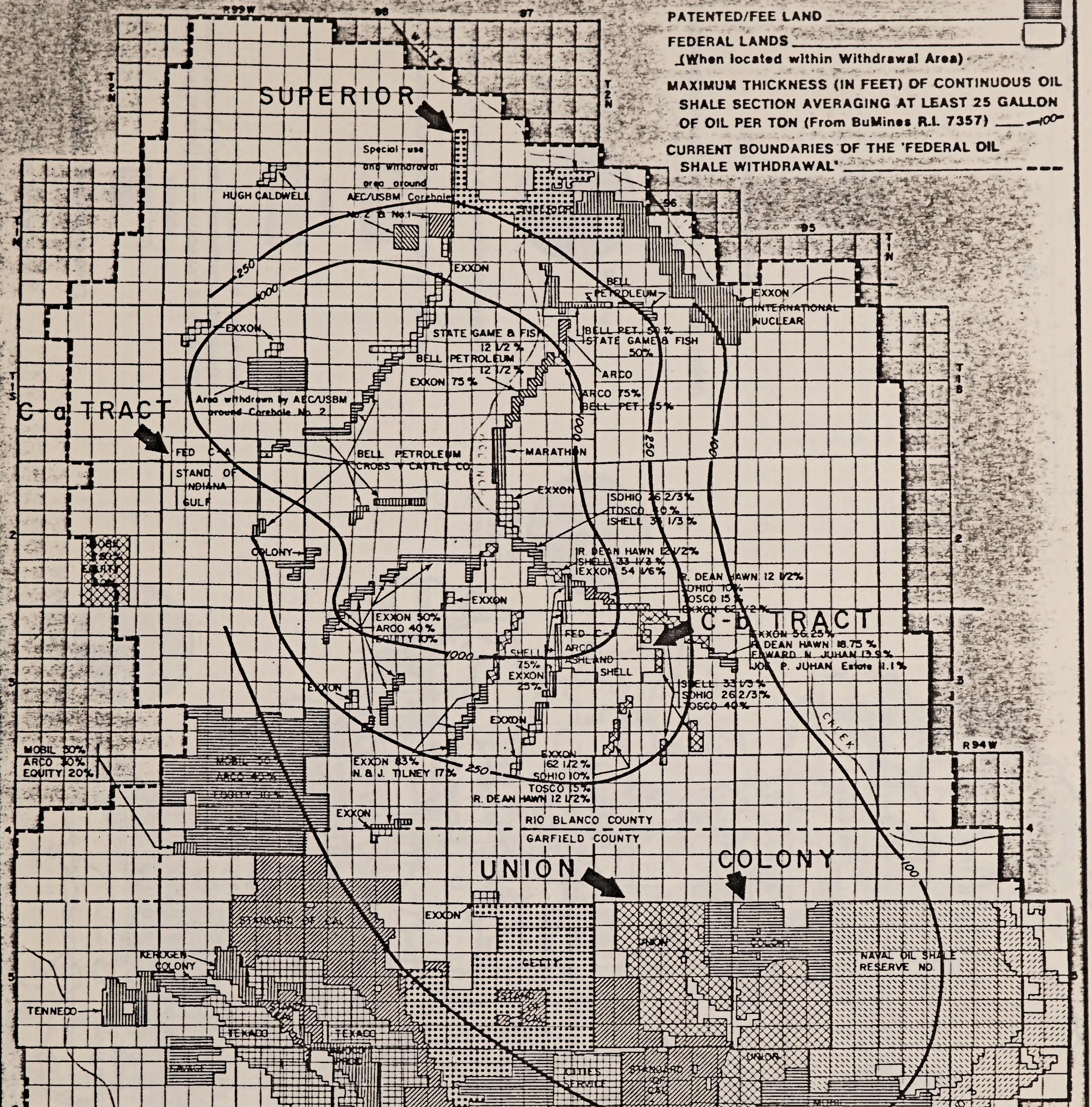
*Synfuels Week — April 27, 1981*

# REGIONAL EMPLOYMENT in the ENERGY INDUSTRY

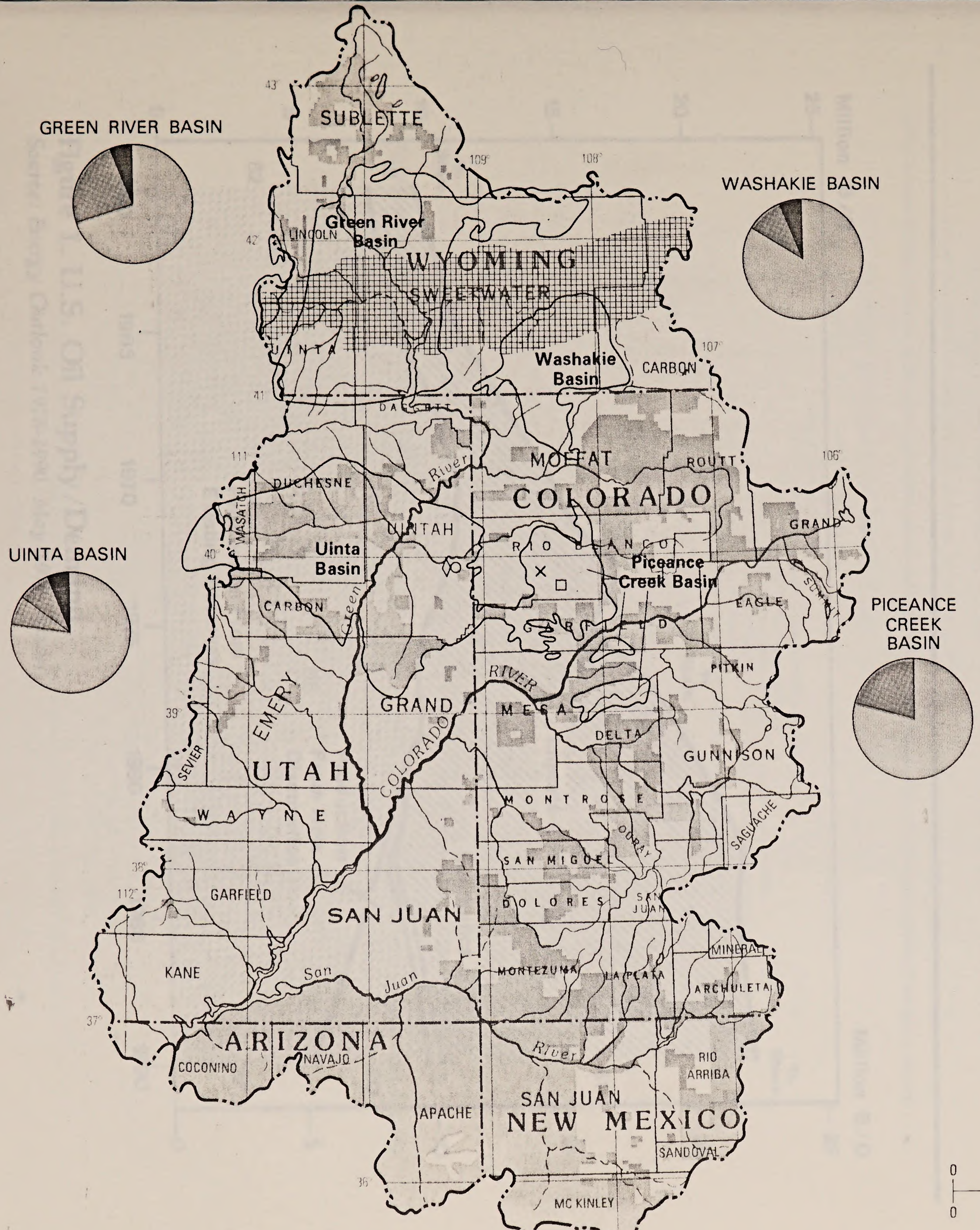



Source: Abt/west and WESTPO

# OIL SHALE MINERAL RIGHT OWNERSHIP
## PICEANCE CREEK BASIN, COLORADO



# OWNERSHIP OF OIL SHALE LAND AND MINERAL RIGHTS




## EXPLANATION

**Land ownership, 1970**

Federal

*Grid indicates predominately Federal land with numerous interspersed tracts of private, state, municipal, and county*

Indian

Private, state, municipal, and county

**Oil-shale mineral rights ownership, 1970**

State — Federal — Private — Indian

Upper Colorado River drainage basin boundary

**Federal lease tracts**

× C–a

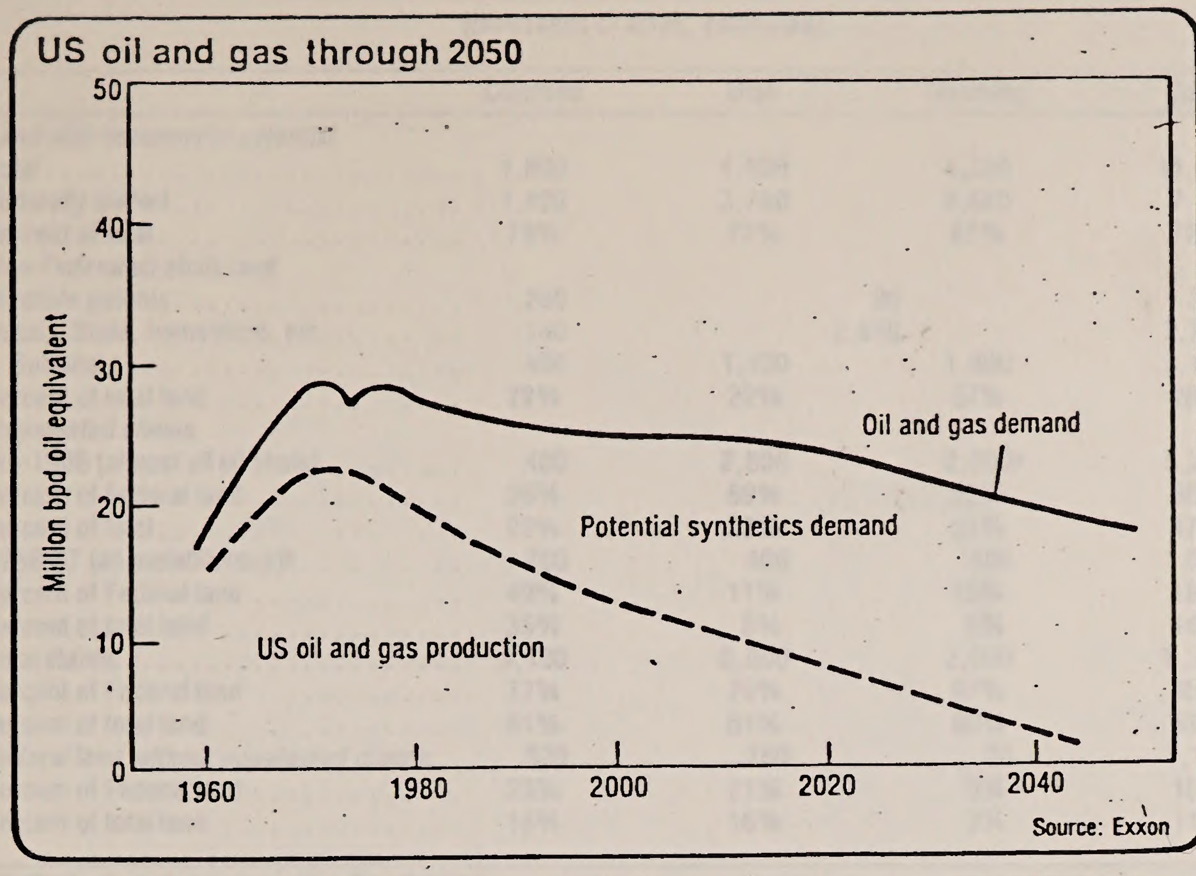
□ C–b

◊ U–a

○ U–b

0 — 100 — 200 MILES

0 — 100 — 200 — 300 KILOMETERS



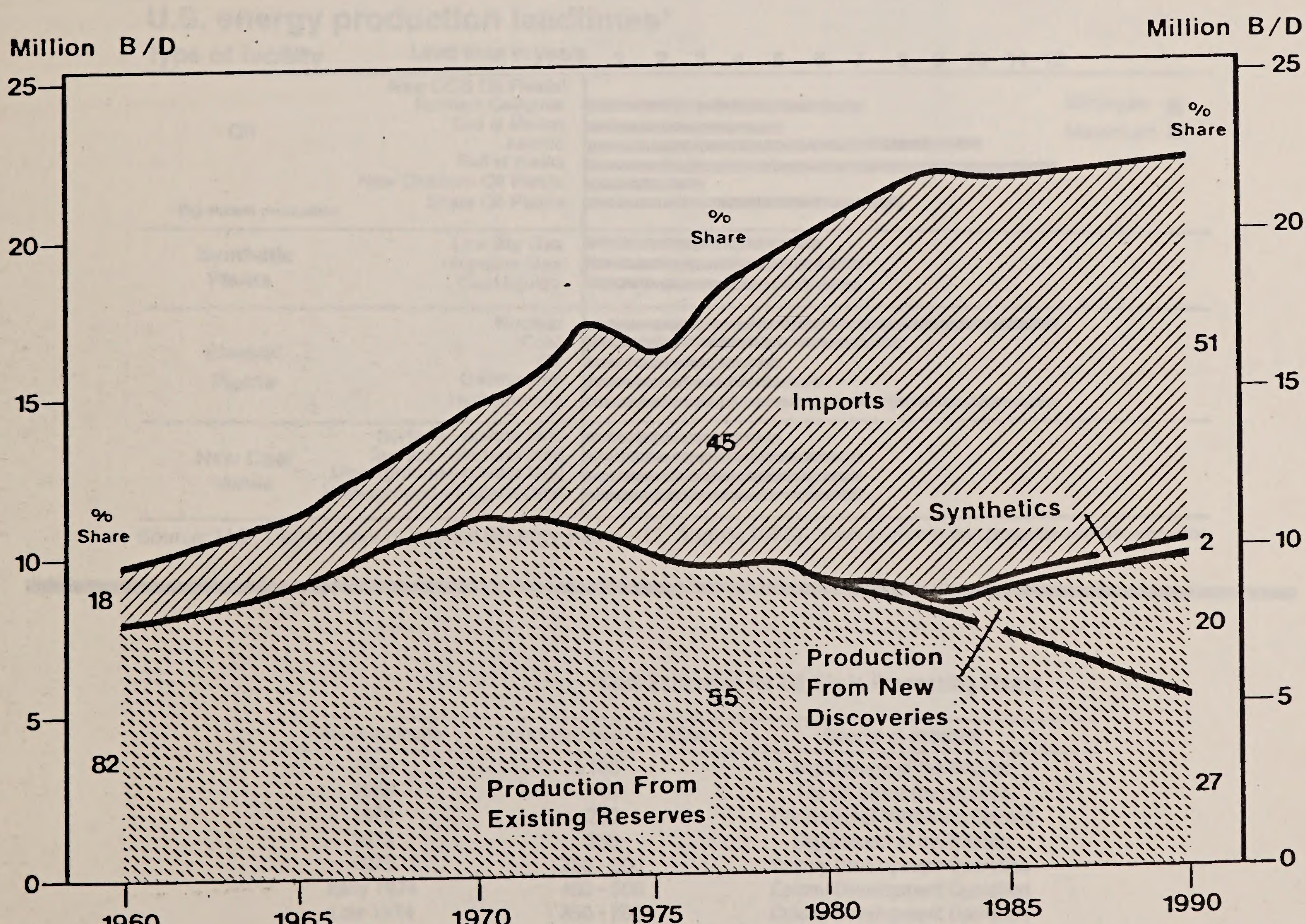




**Figure 1. U.S. Oil Supply/Demand.**

*Source: Energy Outlook 1978-1990, May 1978, Exxon*

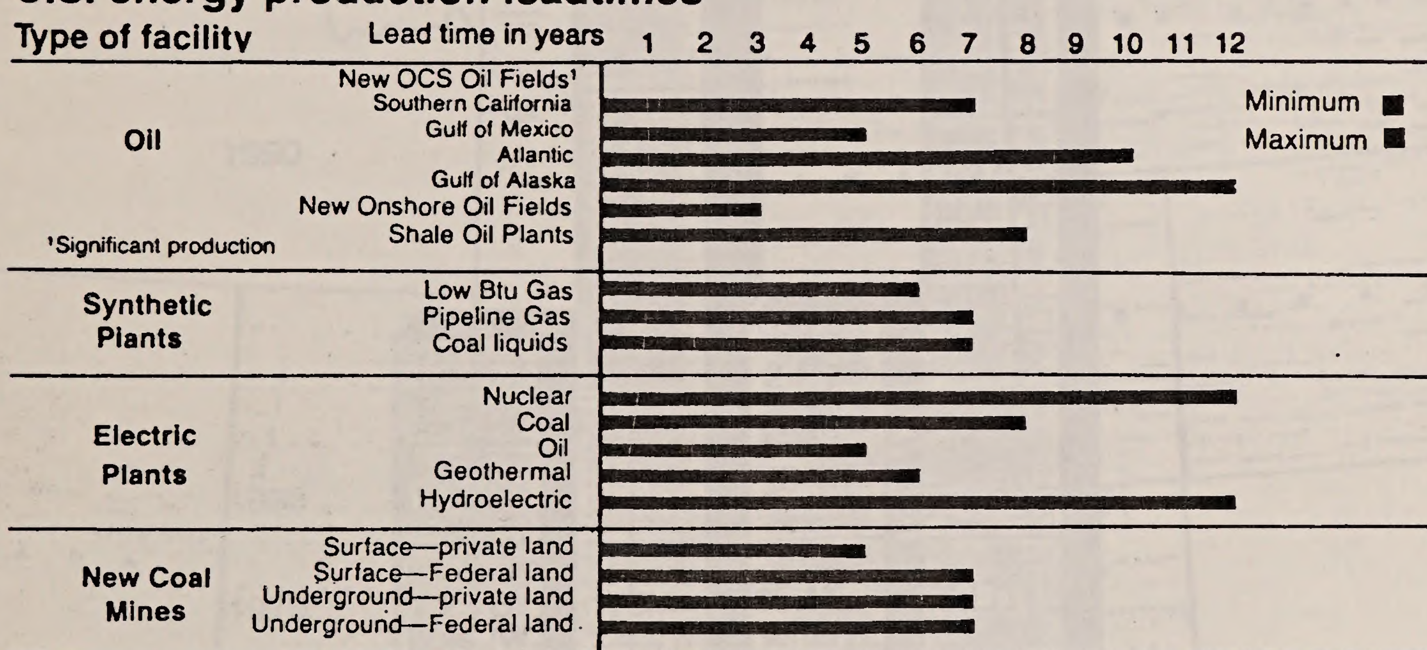
### Nature of Claims on Oil Shale Lands With Commercial Potential, 1968
(thousands of acres, estimated)

| | Colorado | Utah | Wyoming | Total |
|---|---|---|---|---|
| ***Land with commercial potential*** | | | | |
| Total | 1,800 | 4,900 | 4,300 | 11,000 |
| Federally owned | 1,420 | 3,780 | 2,670 | 7,870 |
| Percent of total | 79% | 77% | 62% | 72% |
| ***Non-Federal oil shale land*** | | | | |
| Oil shale patents | 260 | 90 | | 350 |
| Indian, State, homestead, etc. | 140 | 2,610 | | 2,750 |
| Subtotal | 400 | 1,100 | 1,600 | 3,100 |
| Percent of total land | 22% | 22% | 37% | 28% |
| ***Unpatented claims*** | | | | |
| Pre-1966 (almost all oil shale) | 400 | 2,600 | 2,200[a] | 5,200 |
| Percent of Federal land | 28% | 69% | 82% | 66% |
| Percent of total | 22% | 53% | 51% | 47% |
| 1966-67 (all metalliferous)[b] | 700 | 400 | 400 | 1,500 |
| Percent of Federal land | 49% | 11% | 15% | 19% |
| Percent of total land | 39% | 8% | 9% | 14% |
| Total claims | 1,100 | 3,000 | 2,600 | 6,700 |
| Percent of Federal land | 77% | 79% | 97% | 85% |
| Percent of total land | 61% | 61% | 60% | 61% |
| ***Federal land without unpatented claims*** | 320 | 780 | 70 | 1,170 |
| Percent of Federal land | 23% | 21% | 3% | 15% |
| Percent of total land | 18% | 16% | 2% | 11% |

[a]Unofficially reported to have been settled. See reference 5.
[b]In most cases canceled. See text.

SOURCE: Office of Technology Assessment, derived from Department of the Interior data.

## U.S. energy production leadtimes*




Source: U.S. Department of Interior (Energy Facts—11, August 1975). *From decision to start production until first production

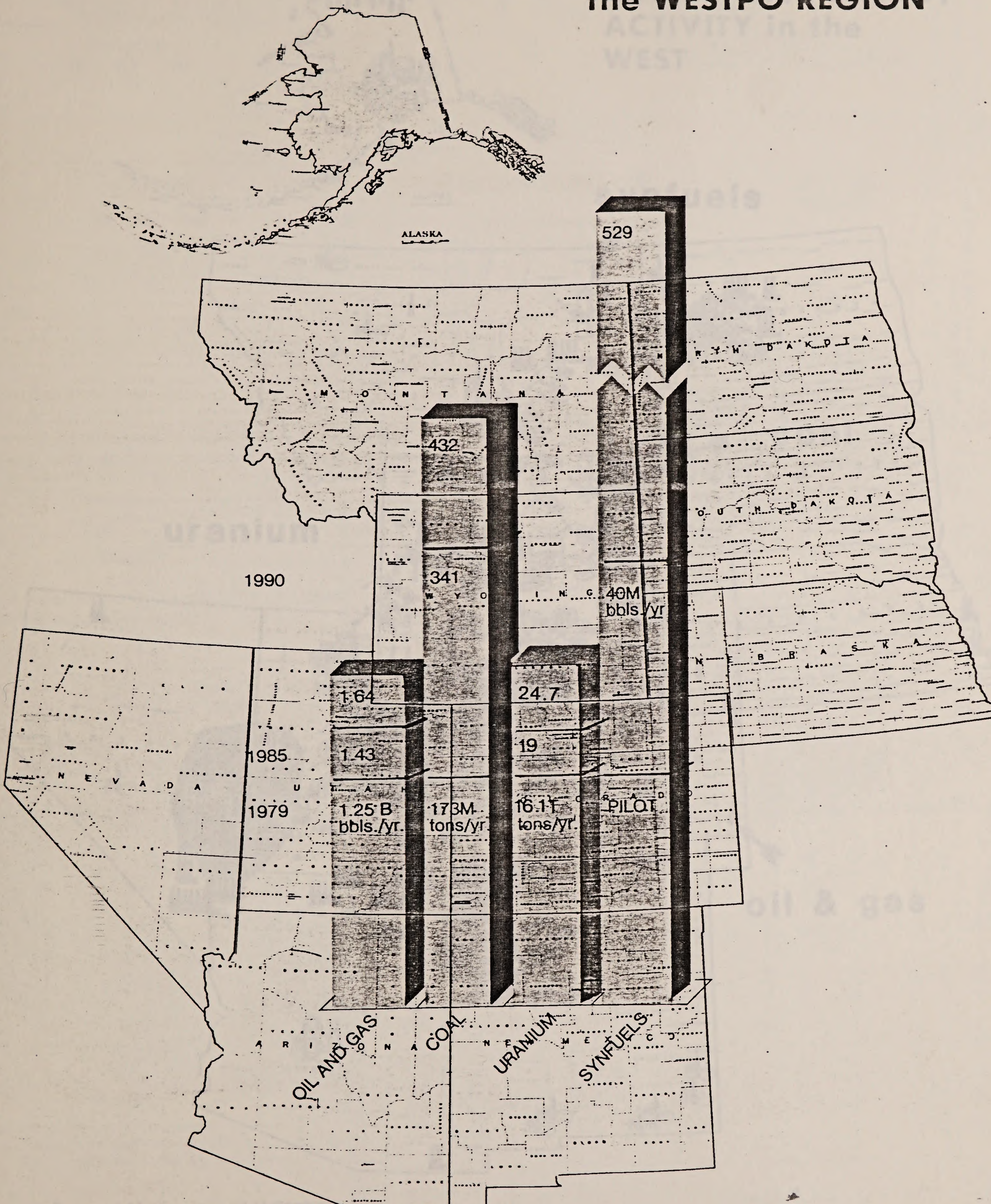
### Cost Estimates for Oil Shale Processing Plants

| Time of estimate | Estimated cost[a] $ million | Source of estimate |
|---|---|---|
| 1968 | $138 | Department of the Interior |
| 1968 | 144 | The Oil Shale Corporation |
| 1970 | 250 | The National Petroleum Council |
| 1973 | 280 | Department of the Interior |
| 1973 | 250 - 300 | Colony Development Operation |
| Early 1974 | 400 - 500 | Colony Development Operation |
| Late 1974 | 850 - 900 | Colony Development Operation |
| 1976 | 960 | The Oil Shale Corporation |
| 1977 | 1,050 | The Oil Shale Corporation |

[a]Plants use underground mining and aboveground retorting. Production capacities are approximately 50,000 bbl/d of shale oil syncrude.
[b]See reference list. The cost trends are analyzed in references 6 and 8.

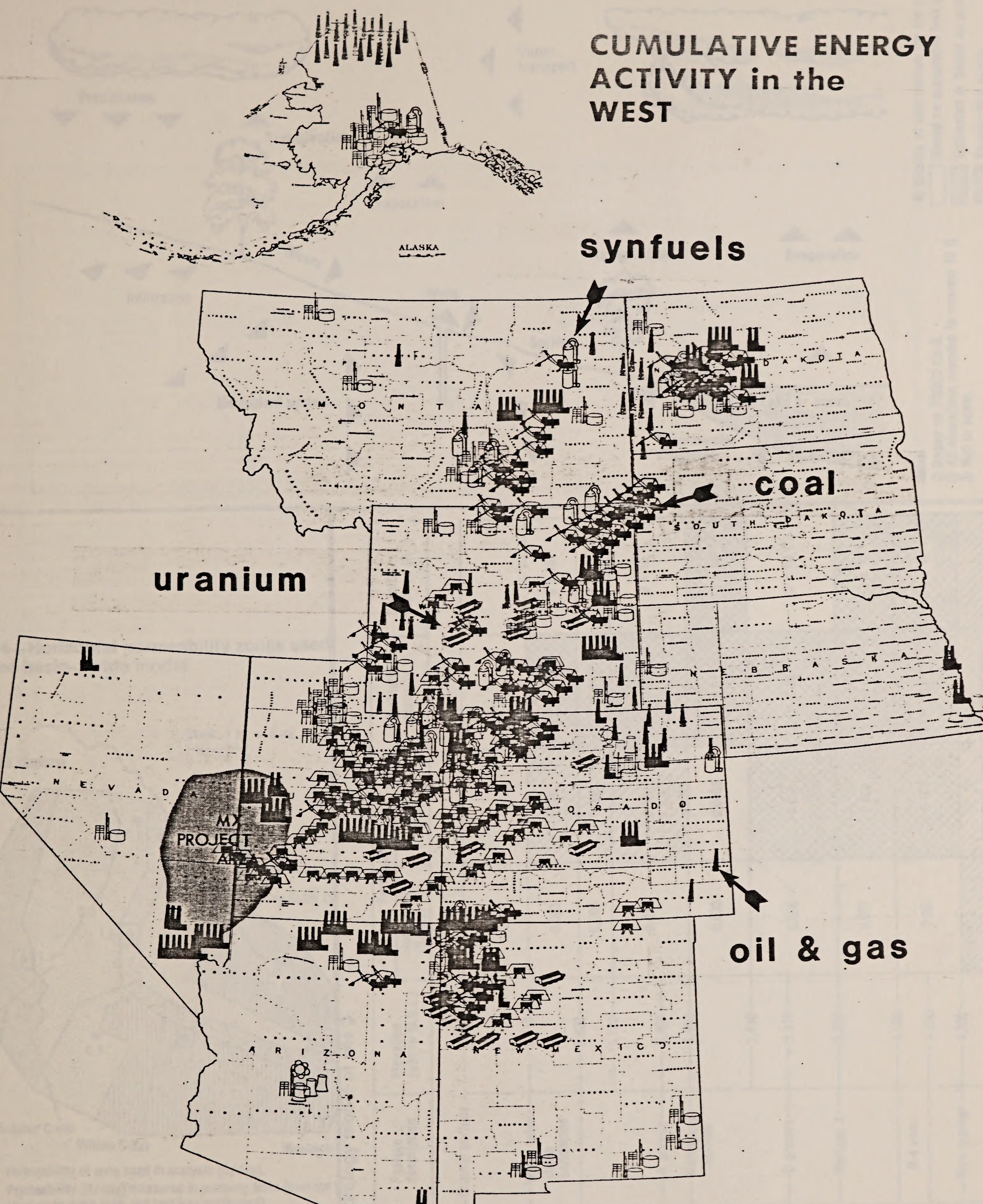
SOURCE: Office of Technology Assessment.

# ENERGY PRODUCTION in the WESTPO REGION




Source: Abt/west and WESTPO

# CUMULATIVE ENERGY ACTIVITY in the WEST




Source: Abt/west and WESTPO

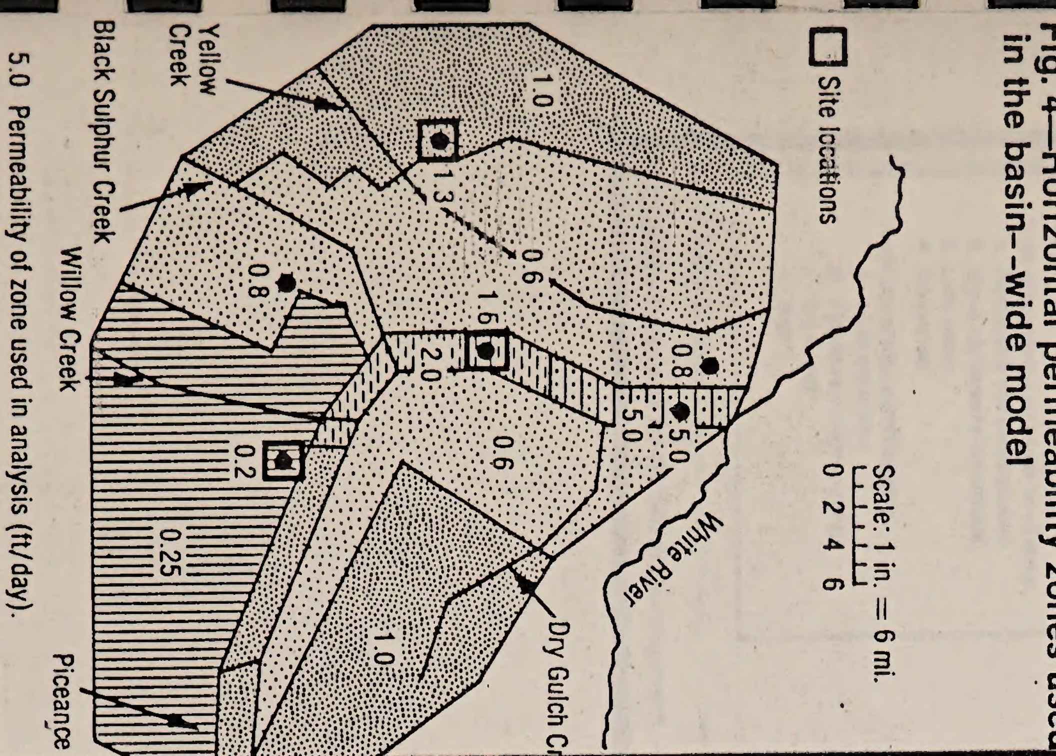



**Fig. 4—Horizontal permeability zones used in the basin-wide model**

5.0 Permeability of zone used in analysis (ft/day).
● 5.0 Permeability (ft/day) measured in pumping tests (average sites when more than one test was performed).

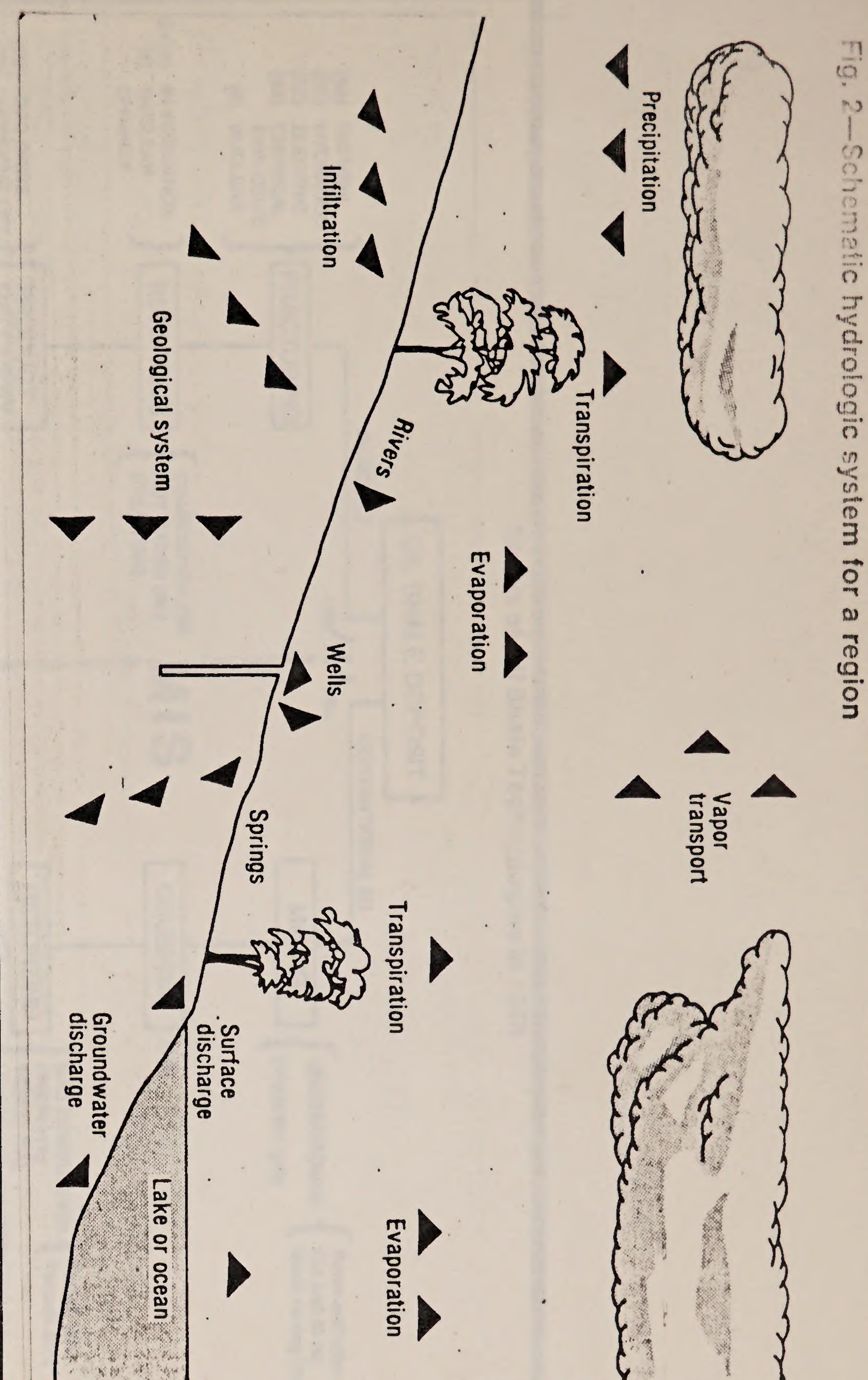


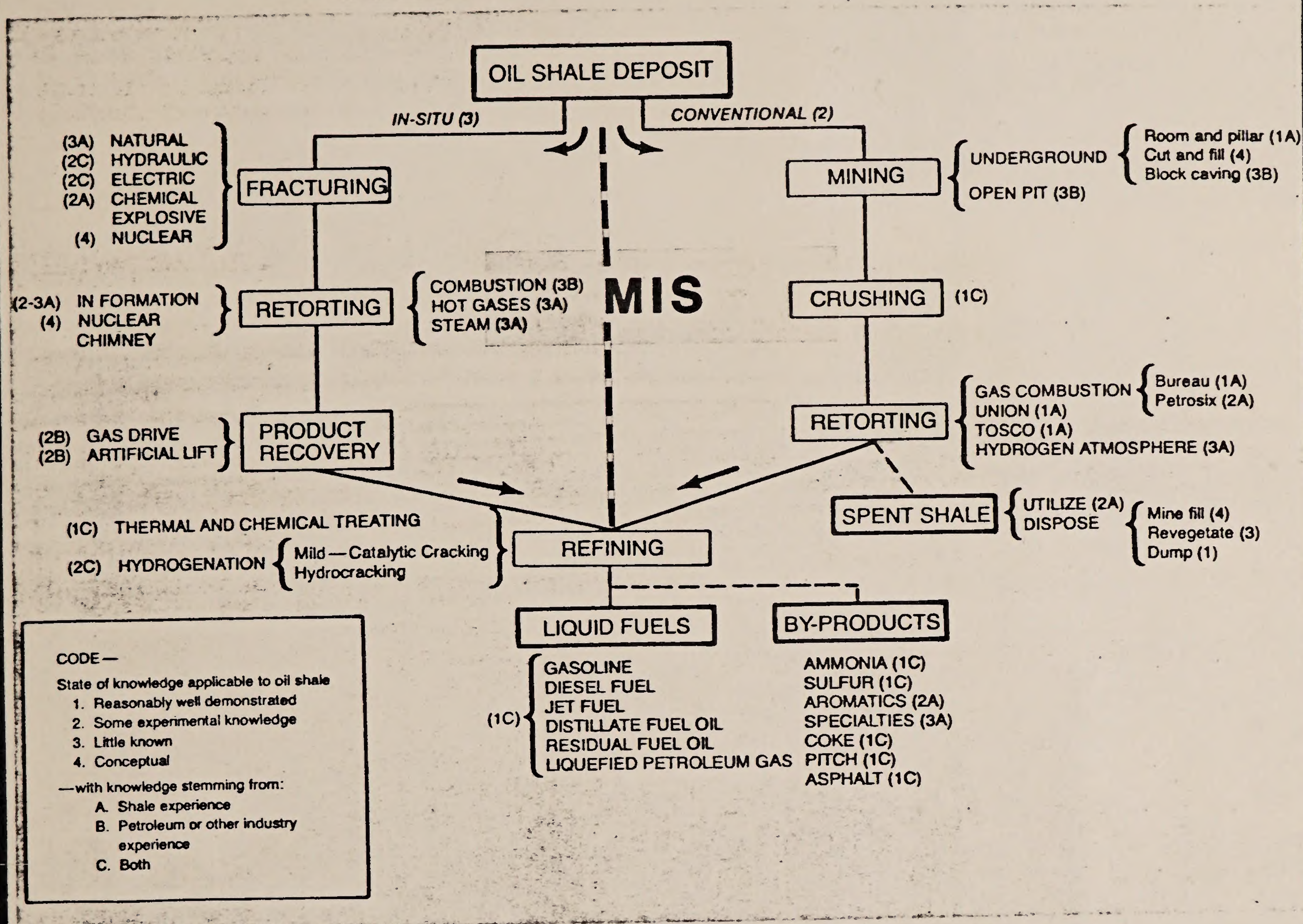

Fig. 2—Schematic hydrologic system for a region

## Fig. 5—Geohydrology model of site 3

| Geological unit | Feature description | Elevation (above M.S.L.) | Permeability Horizontal (ft/day) | Permeability Vertical (ft/day) | Drainable porosity | Specific storage ($ft^{-1}$) |
|---|---|---|---|---|---|---|
| Uinta formation | Ground surface | 6,740 | | | | |
| Uinta formation | Water table | 6,410 | | | | |
| Uinta formation | Uinta sandstone | | 0.093 | 0.03 | 0.10 | $3 \times 10^{-7}$ |
| Green River formation, Parachute Creek member | | 5,820 | 0.005 | 0.003 | 0.01 | $3 \times 10^{-7}$ |
| Green River formation, Parachute Creek member | | 5,720 | | | | |
| Green River formation, Parachute Creek member | A groove | 5,490 | 0.411 | 0.008 | 0.02 | $3 \times 10^{-7}$ |
| Green River formation, Parachute Creek member | Mahogany marker | 5,460 | 0.033 | 0.0003 | 0.01 | $3 \times 10^{-7}$ |
| Green River formation, Parachute Creek member | | 5,410 | | | | |
| Green River formation, Parachute Creek member | B groove | 5,310 | 0.586 | 0.058 | 0.02 | $3 \times 10^{-7}$ |
| Green River formation, Parachute Creek member | Horizon X | 5,260 | 0.077 | 0.008 | 0.01 | $3 \times 10^{-7}$ |
| Green River formation, Parachute Creek member | | 4,630 | | | | |
| Green River formation, Parachute Creek member | R-4 zone | 4,500 | 0.063 | 0.008 | 0.01 | $3 \times 10^{-7}$ |
| Green River formation, Parachute Creek member | Blue marker | 4,200 | | | | |
| Green River formation, Garden Gulch member | | | Assumed functionally impervious | | | |

**Notes:**
1) Based on TOSCO Cb-3.
2) All elevations rounded to nearest 10 ft.
3) Not to scale.
4) Quality of information for the purposes
- Based on acceptable test data
- Estimated or based on poor data
- Experiential guess

## Status of Oil Shale Technologies in 1968




SOURCE: *Prospects for Oil Shale Development — Colorado, Utah, and Wyoming*, U.S. Department of the Interior, May 1968, p. 47.

TRIP


Cedar Mtn
Craig
Breeze
Mtn

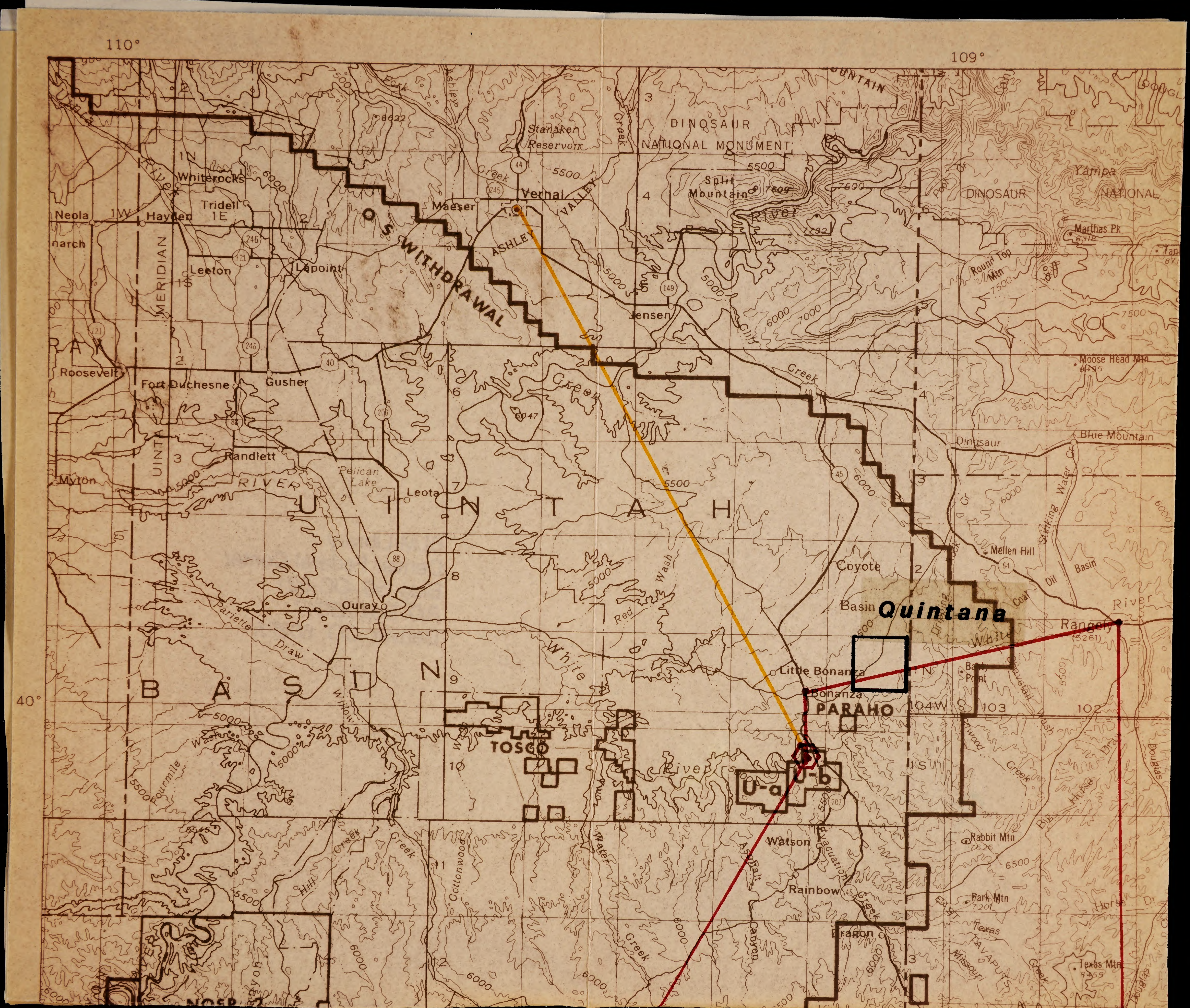



10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers

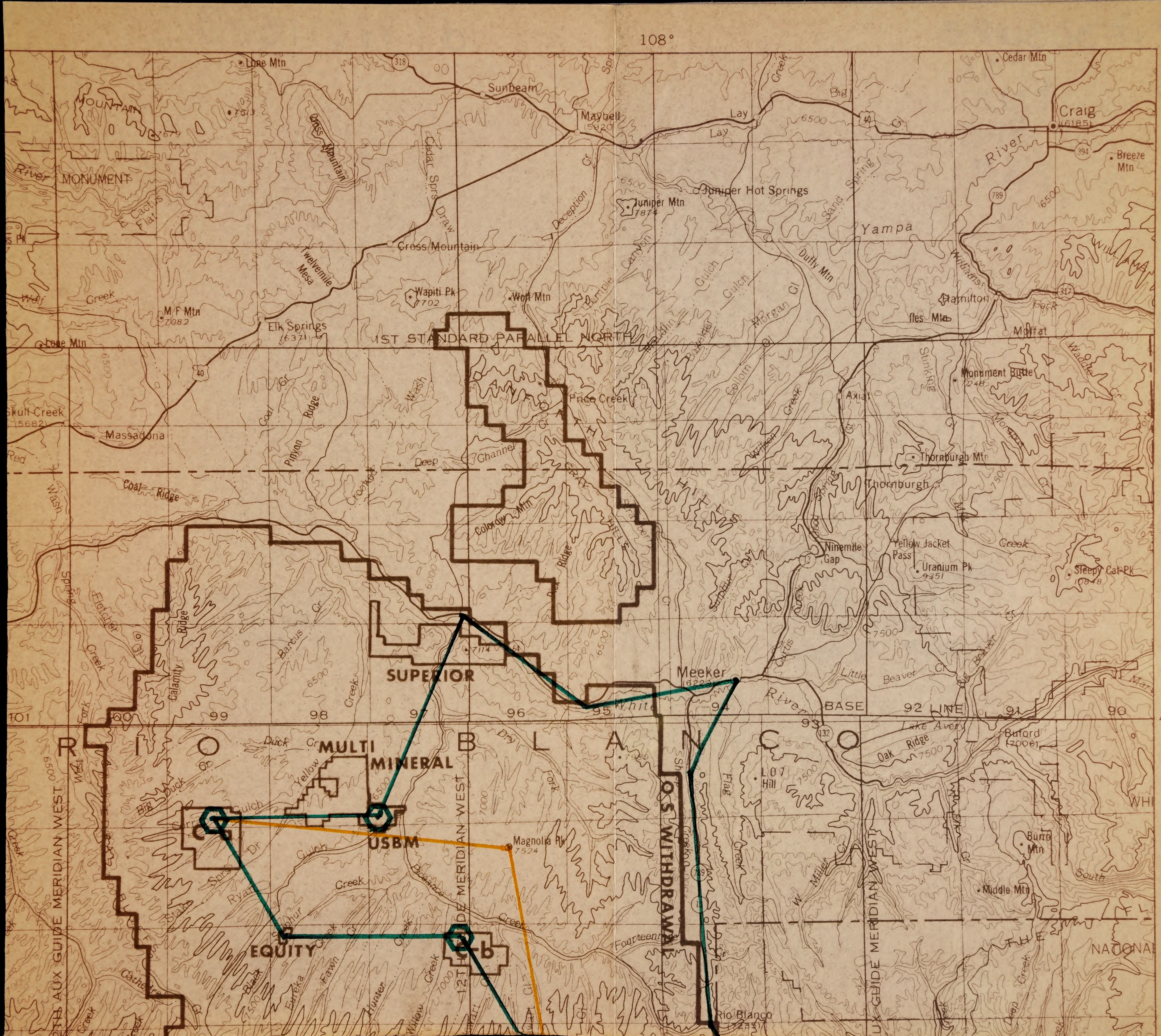
Contour interval 500 feet
Datum is mean sea level

⬡ Land
— Tues. 26th
— Wed. 27th
— Fuel runs

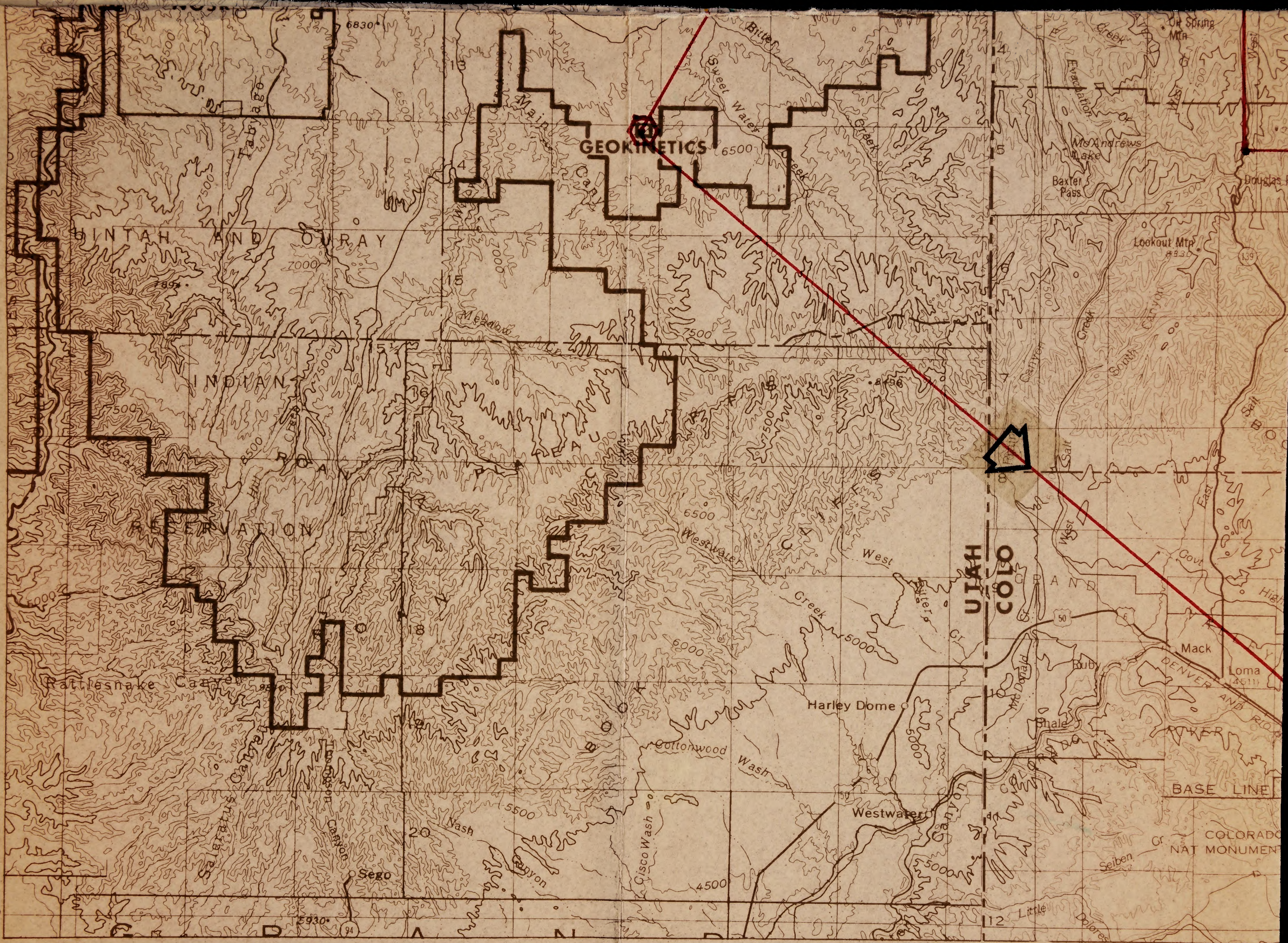
U. S. G. S.
AREA OIL SHALE OFFICE
SEPT 1980



110°
109°
40°
DINOSAUR
NATIONAL MONUMENT
DINOSAUR
NATIONAL
Stanaker Reservoir
Split Mountain
Vernal
Maeser
ASHLEY
VALLEY
WITHDRAWAL
Whiterocks
Neola
Hayden
Tridell
Leeton
Lapoint
MERIDIAN
UINTA
Jensen
Roosevelt
Fort Duchesne
Gusher
Randlett
Myton
RIVER
Pelican Lake
Leota
Green
U I N T A H
B A S I N
Ouray
Pariette
Draw
White
Red Wash
Coyote
Basin
Quintana
Little Bonanza
Bonanza
PARAHO
TOSCO
U-a
U-b
River
Dinosaur
Blue Mountain
Mellen Hill
Rangely
Moose Head Mtn
Round Top Mtn
Marthas Pk
Yampa
Watson
Rainbow
Dragon
Rabbit Mtn
Park Mtn
Texas Mtn
Evacuation
Cottonwood
Willow
Fourmile
NOSR 2
104W
103
102



108°
Lone Mtn
Sunbeam
Maybell
Lay
Craig
Cedar Mtn
Breeze Mtn
MONUMENT
Cross Mountain
Cedar Sprs Draw
Deception Cr
Juniper Mtn
Juniper Hot Springs
Yampa
River
Sand Spring
Duffy Mtn
Twelvemile Mesa
Wapiti Pk
Wolf Mtn
M F Mtn
Elk Springs
Lone Mtn
Hamilton
Iles Mtn
Moffat
1ST STANDARD PARALLEL NORTH
Price Creek
Morgan Gl
Axial
Monument Butte
Skull Creek
Massadona
Pinyon Ridge
Coal Ridge
Deep Channel
Thornburgh Mtn
Thornburgh
Colorow Mtn
Ninemile Gap
Yellow Jacket Pass
Uranium Pk
Sleepy Cat Pk
Calamity Ridge
Barcus Cr
SUPERIOR
Meeker
White
River
Little Beaver Cr
BASE
LINE
101
100
99
98
97
96
95
94
93
92
91
90
40°
RIO BLANCO
Lake Avery
Oak Ridge
Buford
Duck Cr
MULTI MINERAL
Yellow Cr
L O 7 Hill
Flag Creek
Big Duck
C-a
USBM
Magnolia Pk
Ryan Gulch
Creek
Burro Mtn
Middle Mtn
South
O S WITHDRAWAL
AUX GUIDE MERIDIAN WEST
6TH AUX GUIDE MERIDIAN WEST
12TH GUIDE MERIDIAN WEST
EQUITY
C-b
Fourteenmile
Black
Eureka
Fawn
Hunter
Willow Creek
Rio Blanco
NATIONAL

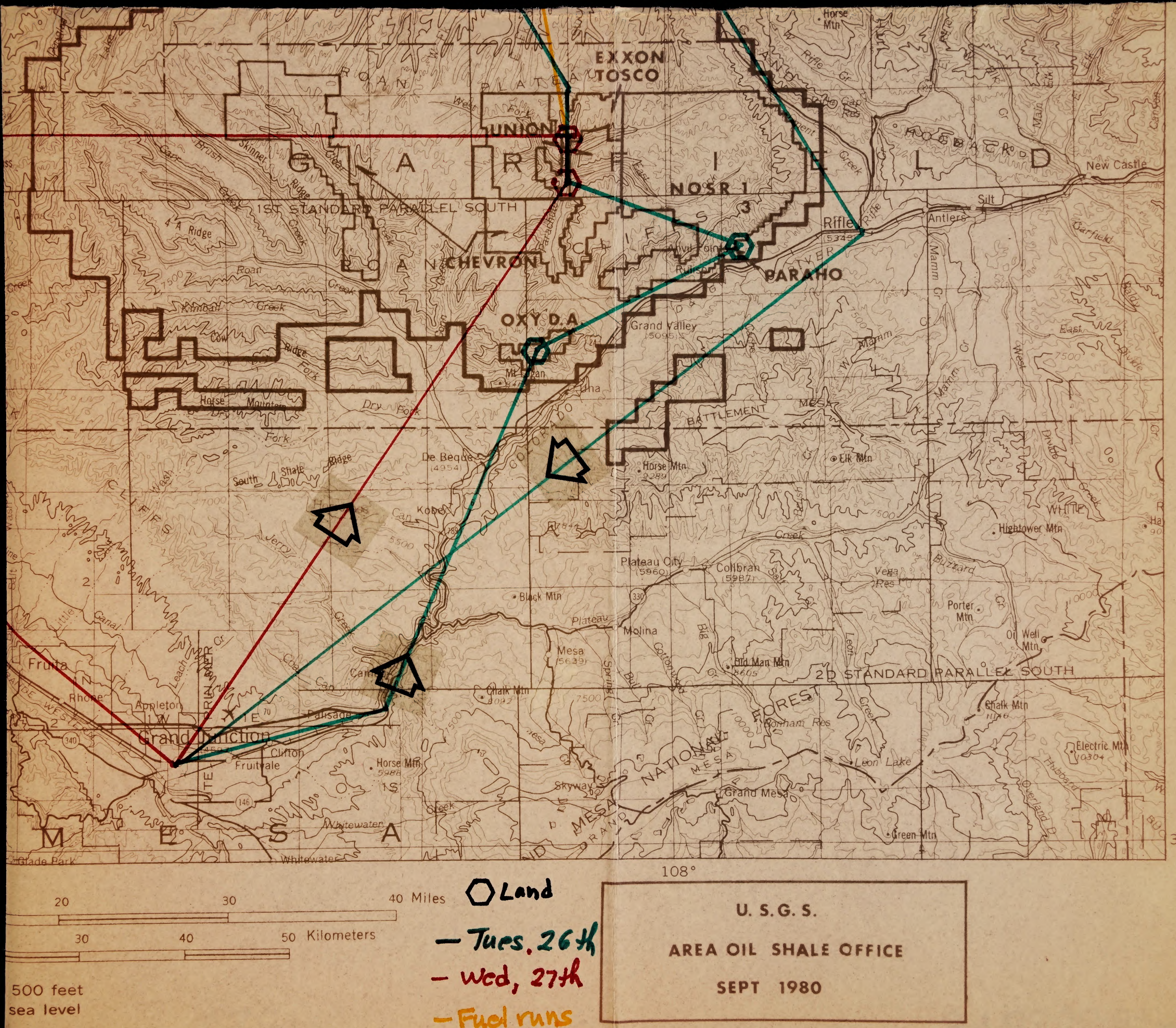



10 0 10

10 0 10 20

Contour interva

Datum is mean



EXXON
TOSCO
UNION
NOSR 1
NOSR 3
CHEVRON
PARAHO
OXY D.A.
G A R F I E L D
M E S A
1ST STANDARD PARALLEL SOUTH
2D STANDARD PARALLEL SOUTH
GRAND MESA NATIONAL FOREST
BATTLEMENT MESA
Rifle
Silt
New Castle
Antlers
Grand Valley
De Beque
Plateau City
Collbran
Molina
Mesa
Palisade
Grand Junction
Clifton
Fruitvale
Fruita
Appleton
Skyway
Whitewater
Grand Mesa
Leon Lake
108°
39°
20 30 40 Miles
30 40 50 Kilometers
500 feet
sea level
Land
— Tues. 26th
— Wed, 27th
— Fuel runs
U. S. G. S.
AREA OIL SHALE OFFICE
SEPT 1980

STATES
OF THE INTERIOR
CAL SURVEY

USINESS
ATE USE. $300

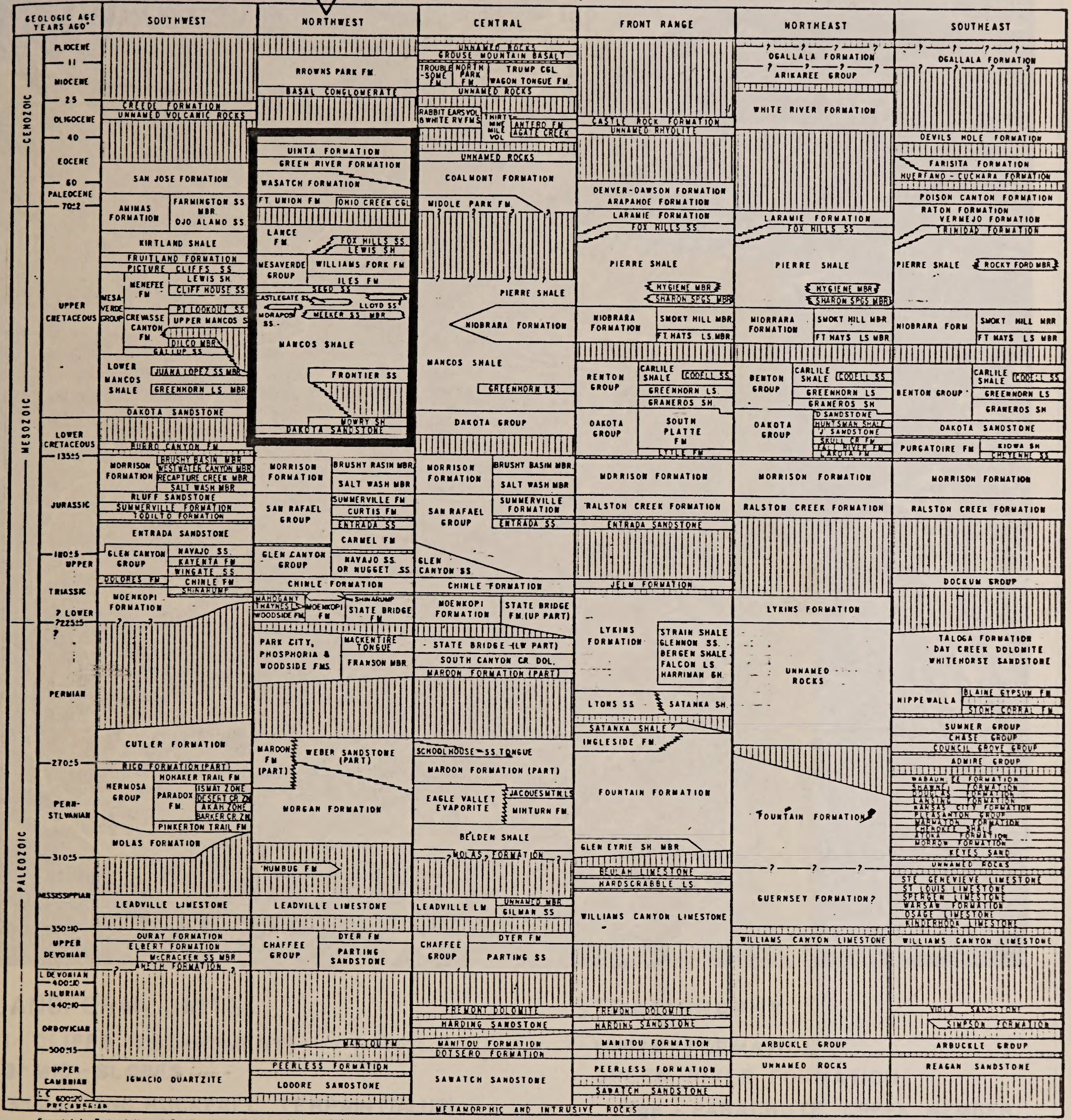
AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF THE INTERIOR
INT-413

U.S.MAIL

# COLORADO STRATIGRAPHIC CORRELATION CHART

## COLORADO GEOLOGICAL SURVEY




Compiled by Richard Howard Pearl and O Keith Murray (August 1974).
*Millions of years before present (Source: Geochron Laboratories, Inc.)

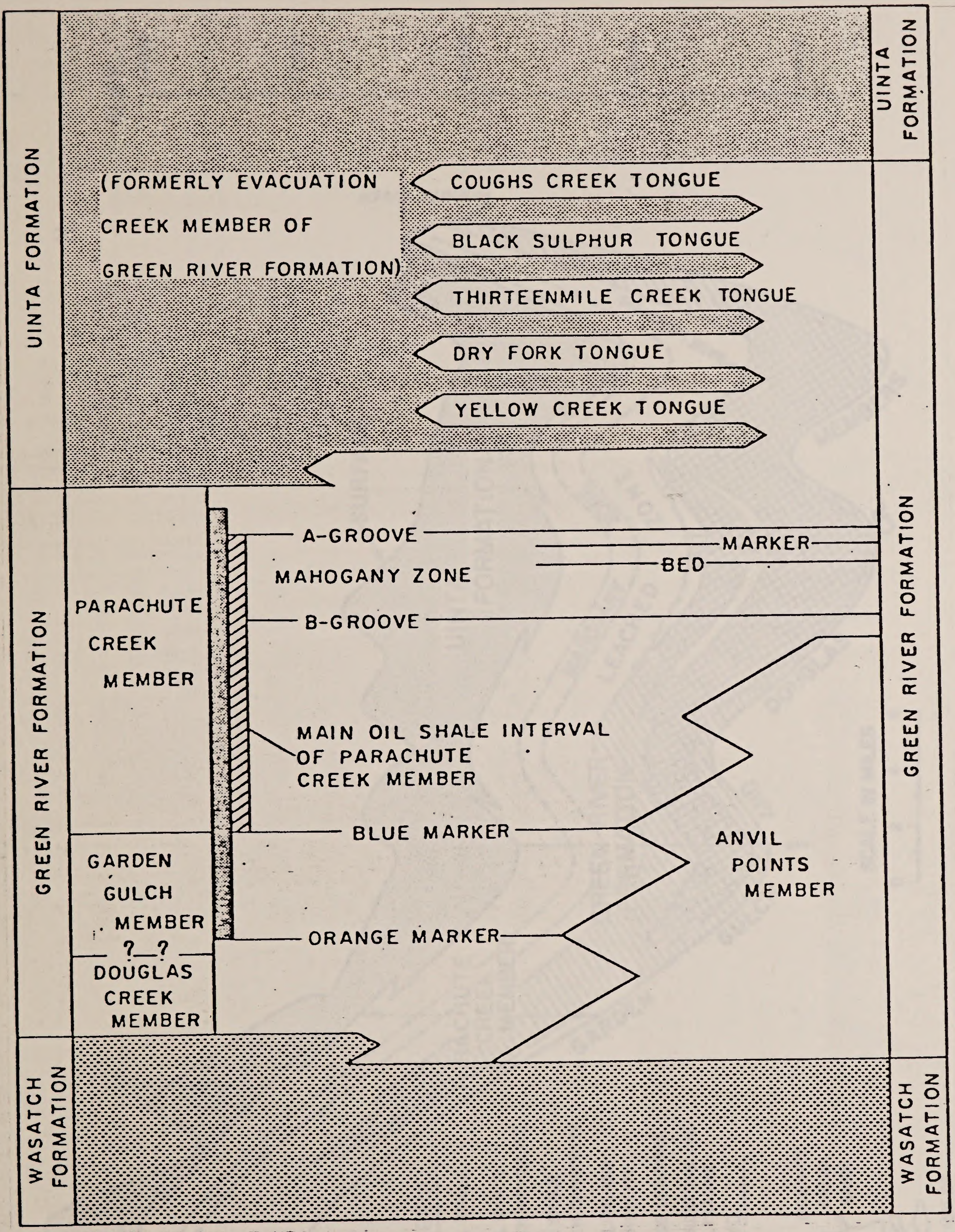
Source of data: Geologic Atlas of the Rocky Mountain Region (RMAG, 1972) and other publications. Reviewed by selected members of the RMAG


LANDFORM UNITS

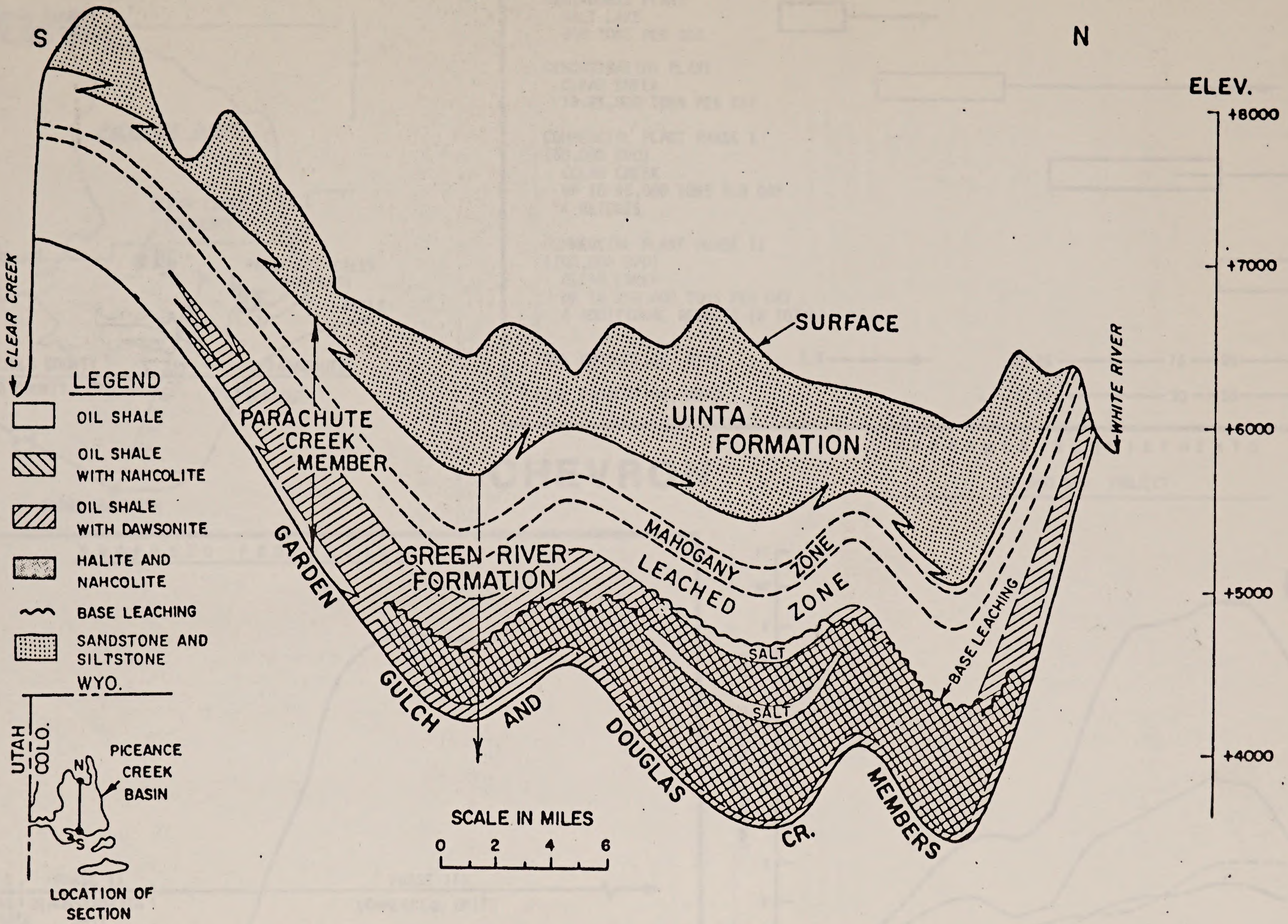
1- CLIFFS (ESCARPMENT)
2- MID-SLOPES
3- SLIP AND ROCKFALL TERRAIN (TALUS)
4- WASATCH FOOTSLOPES
5- ALLUVIAL FAN
6- CHANNEL LAND

STRATIGRAPHY

UINTA FORMATION
GREEN RIVER FORMATION
Tgp - PARACHUTE CREEK MEMBER
Tgg - GARDEN GULCH MEMBER
Tgd - DOUGLAS CREEK MEMBER
WASATCH FORMATION




Gradation between Uinta, Green River, and Wasatch formations and principal oil shale marker beds

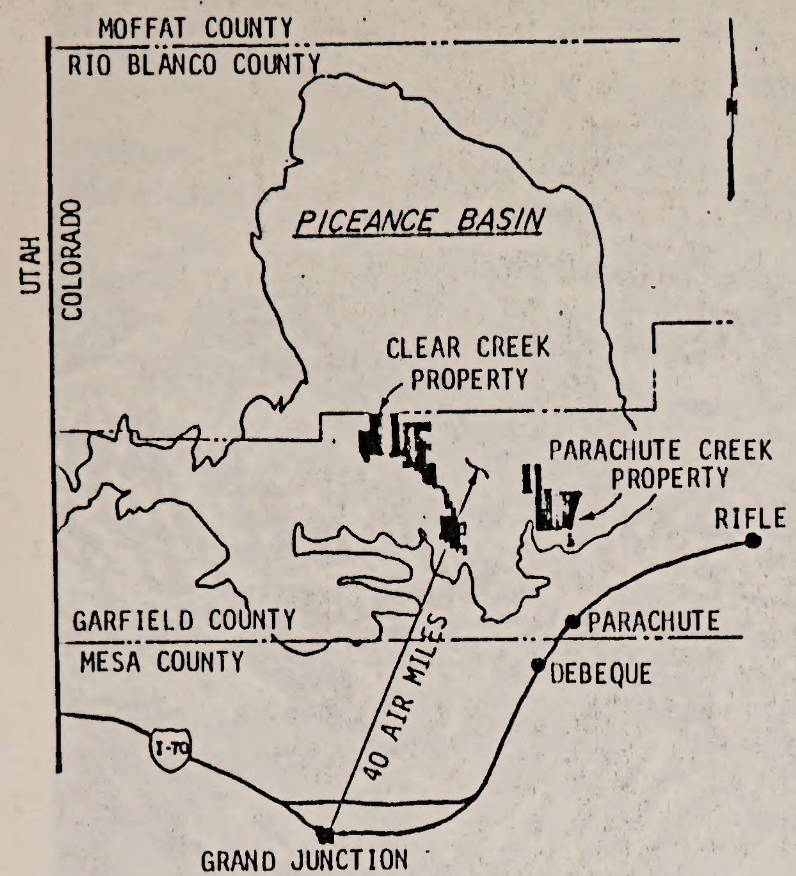



Diagrammatic geologic cross section through the Piceance Creek basin

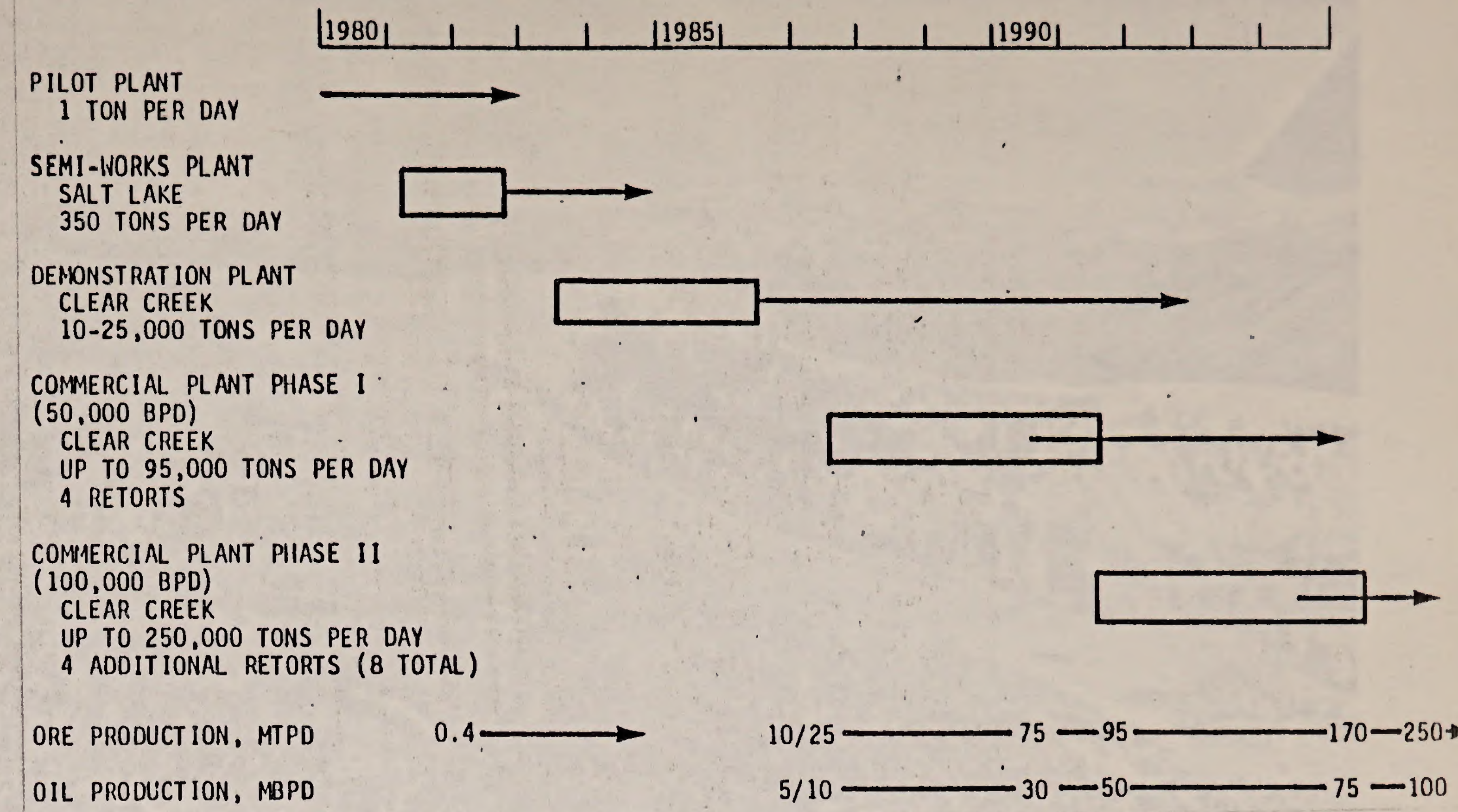
Source: Beard, Tait, and Smith, 1974

# Clear Creek Shale Oil Project

## LOCATION MAP

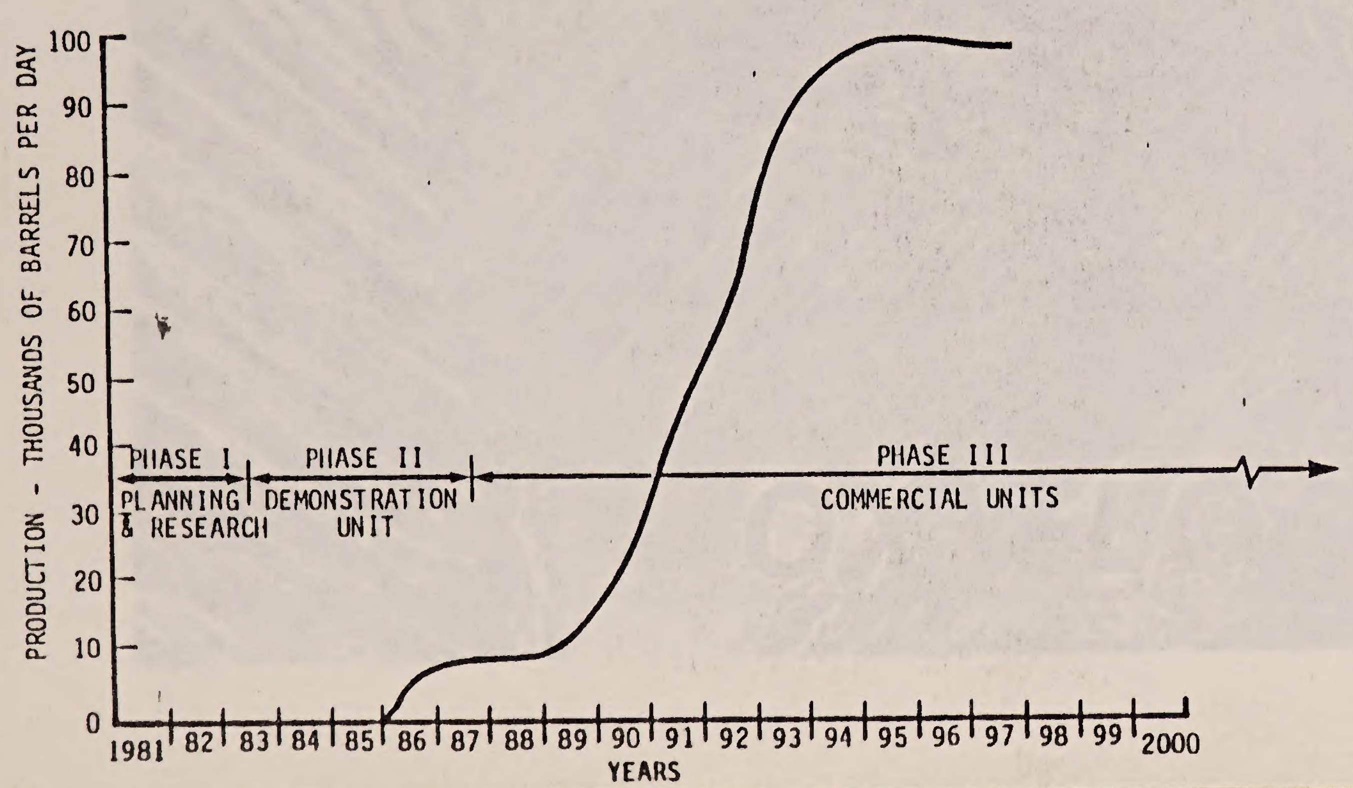



## RETORT DEVELOPMENT



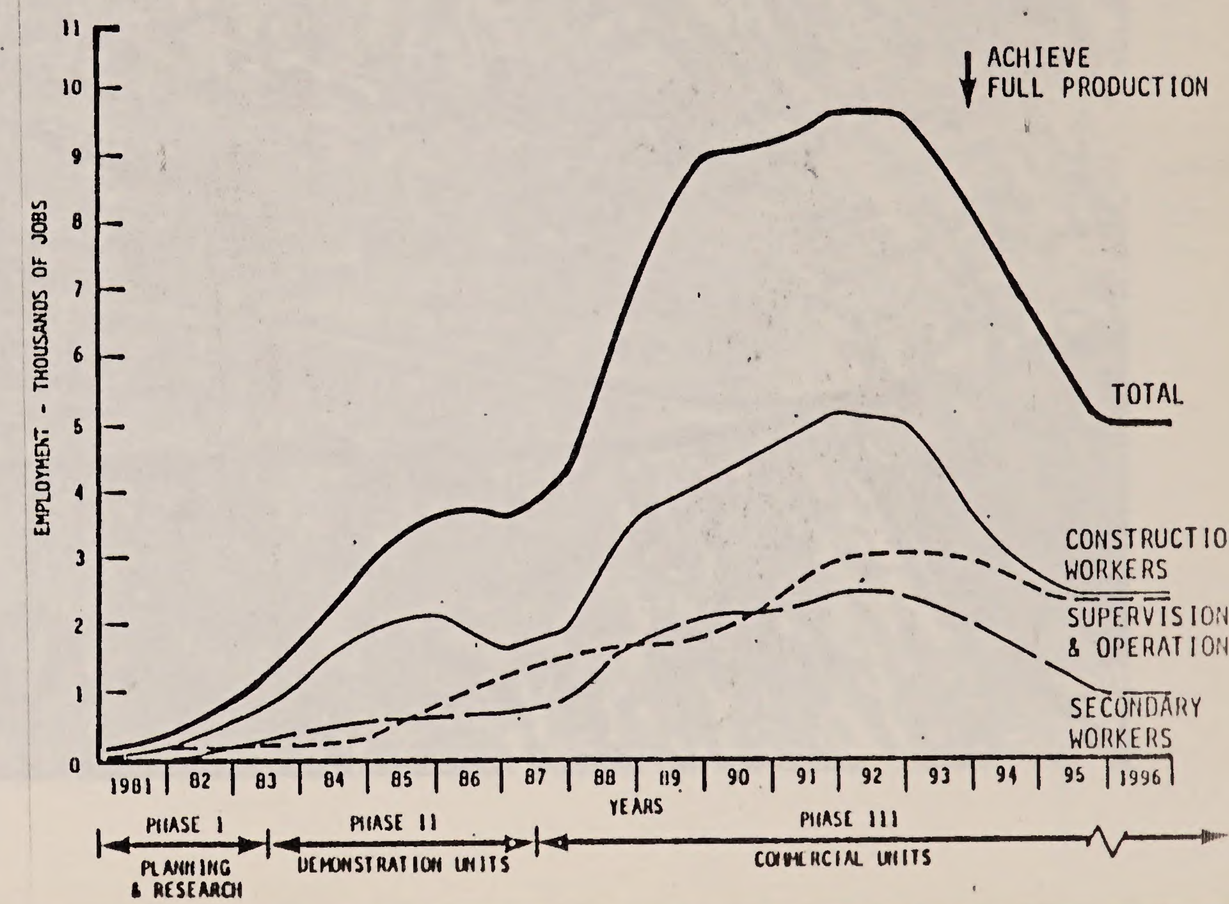

# CHEVRON

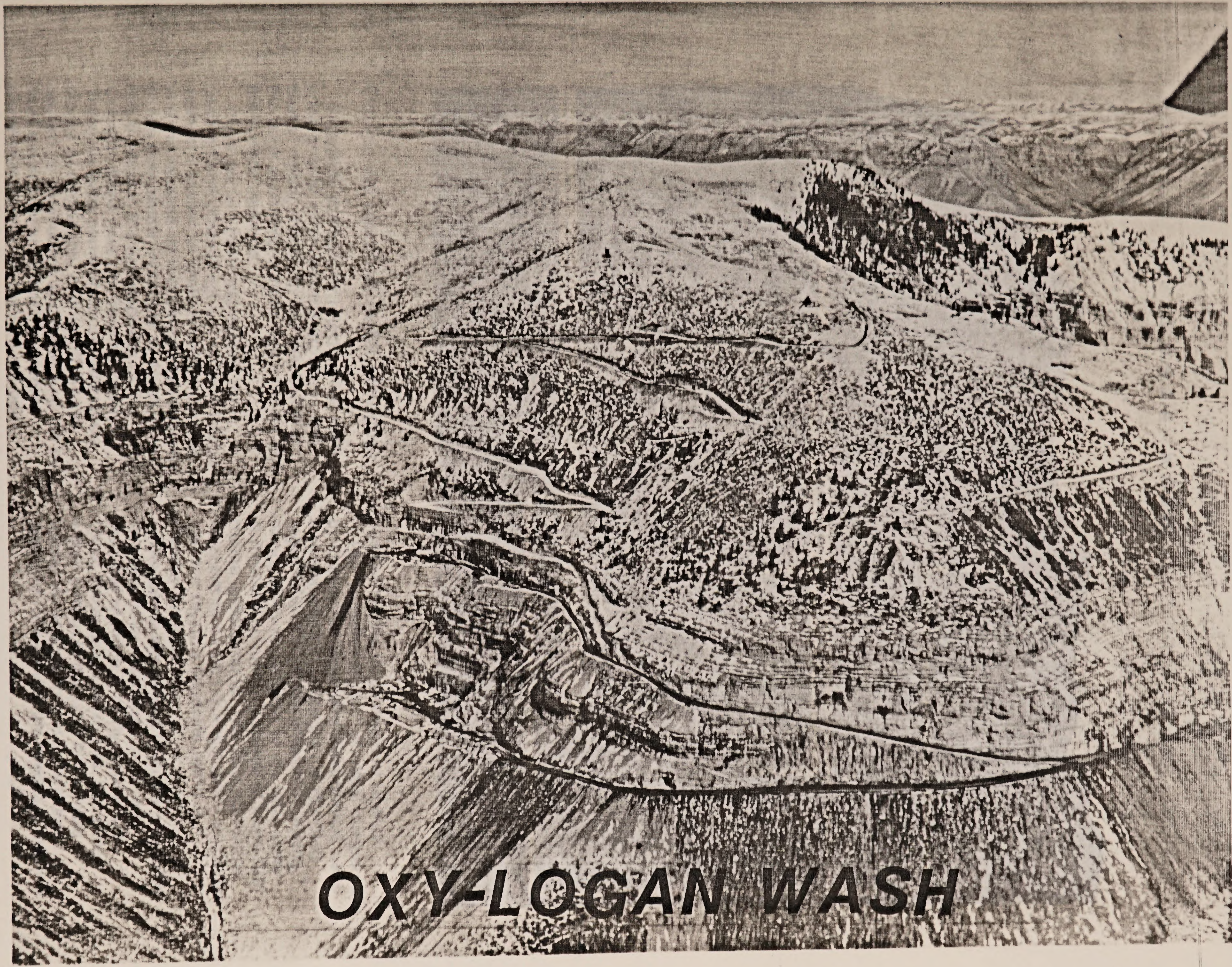
## PROPOSED PRODUCTION




## MANPOWER REQUIREMENTS

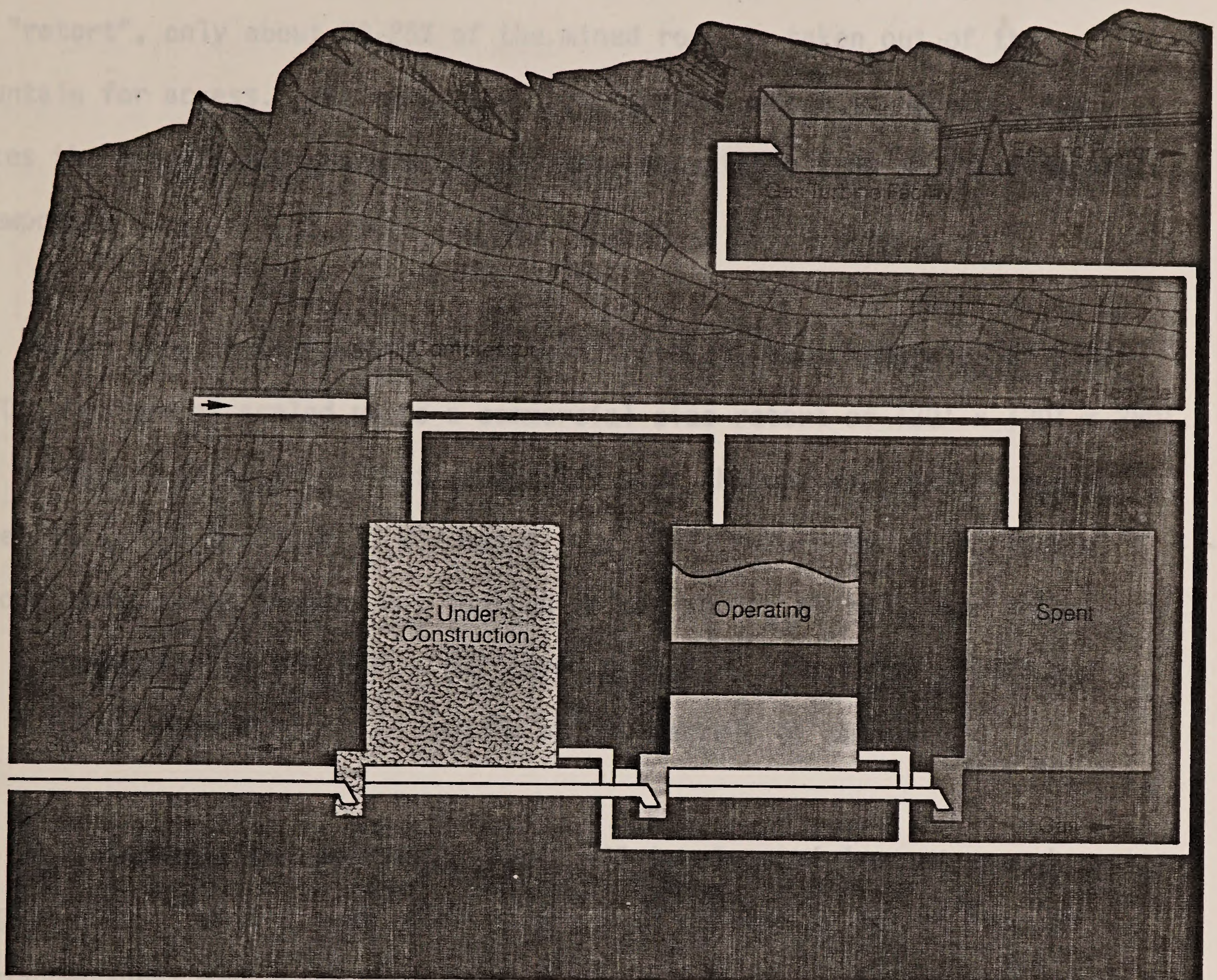
100,000 BPD PROJECT




OXY-LOGAN WASH

# OCCIDENTAL OIL SHALE INC

## LOGAN WASH




### Occidental Modified In-Situ Process

Extracting shale oil by retorting the shale *underground* minimizes the problems and cost of mining, handling and disposing of the large quantities of materials inherent in the surface methods.

There are two basic techniques for underground processing. In the "true in-situ" method, a section of shale is heated in place, and the released oil is collected by installed piping from below. Attempts to develop this method in the rich deposits of the Colorado Basin have not been successful. The shale lacks permeability and effectively blocks all circulation, cutting off the air needed for combustion and preventing the oil from seeping down. Efforts to develop a workable true in-situ method are being pursued by the Department of Energy.

The "modified in-situ" process, pioneered by Occidental Petroleum Corporation, uses a combination of underground retorting together with a limited amount of mining. About 20-to-25 per cent of the total shale is removed to create a series of individual rooms underground. The rock formation adjacent to a room is explosively expanded into the room; a separate retort is thereby formed.

The retorts are created in clusters, adjacent to one another. Each may be an acre in area and as much as thirty stories high. Using conventional explosives, the shale within a retort is fractured into a mass of rubble. Air spaces around the shattered pieces of rock provide the needed circulation.

In 1972 Occidental Petroleum Corporation began work on an in situ or "in place" method of extracting shale oil from the Rocky Mountains. Through a process which recovers oil from the shale rock in an underground chamber or "retort", only about 20-25% of the mined rock is taken out of the mountain for access. The rest stays underground, where it belongs, and makes the process more economical and more acceptable from an environmental viewpoint.

After experimenting with three small retorts, approximately 30' x 30' x 70', Occidental scaled up to a commercial size retort of 120' x 120' x 280'. In December, 1975, this first commercial size chamber was ignited and by June, 1976, had produced 30,000 barrels of oil. Retort No. 5, Occidental's second large-scale chamber was ignited in the spring of 1977; and Retort No. 6, measuring 162' x 162' x 337' was ignited in late summer, 1978 and had a total production run of nearly 52,000 barrels of shale oil.

Modified in situ recovery of shale oil involves mining out enough rock to gain access, development of an underground chamber or retort through use of conventional explosive, and finally, using a small amount of supplemental outside fuel such as shale oil, heating the top of the rubble pile to the required temperature of 900° F. After a predetermined amount of rubblized shale has been heated, the supplemental fuel burners are removed. Combustion continues by injection of air into the retort to keep the "burn" going. The retorted shale oil flows down the retort by gravity, ahead of the burn, and is collected in a sump at the bottom of the retort. From there the pipelines carry the oil to storage.

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In a commercial operation, many retorts or chambers would be created and burned. When each retort is completed and closed down, it remains inside the mountain, underground, minimizing surface subsidence. Considerably less water is used for retorting with the modified in situ process as compared to surface or aboveground retorting, and because the retorting takes place underground, there is no spent shale to dispose of. Rock that has been mined out for access readily supports new plant life.

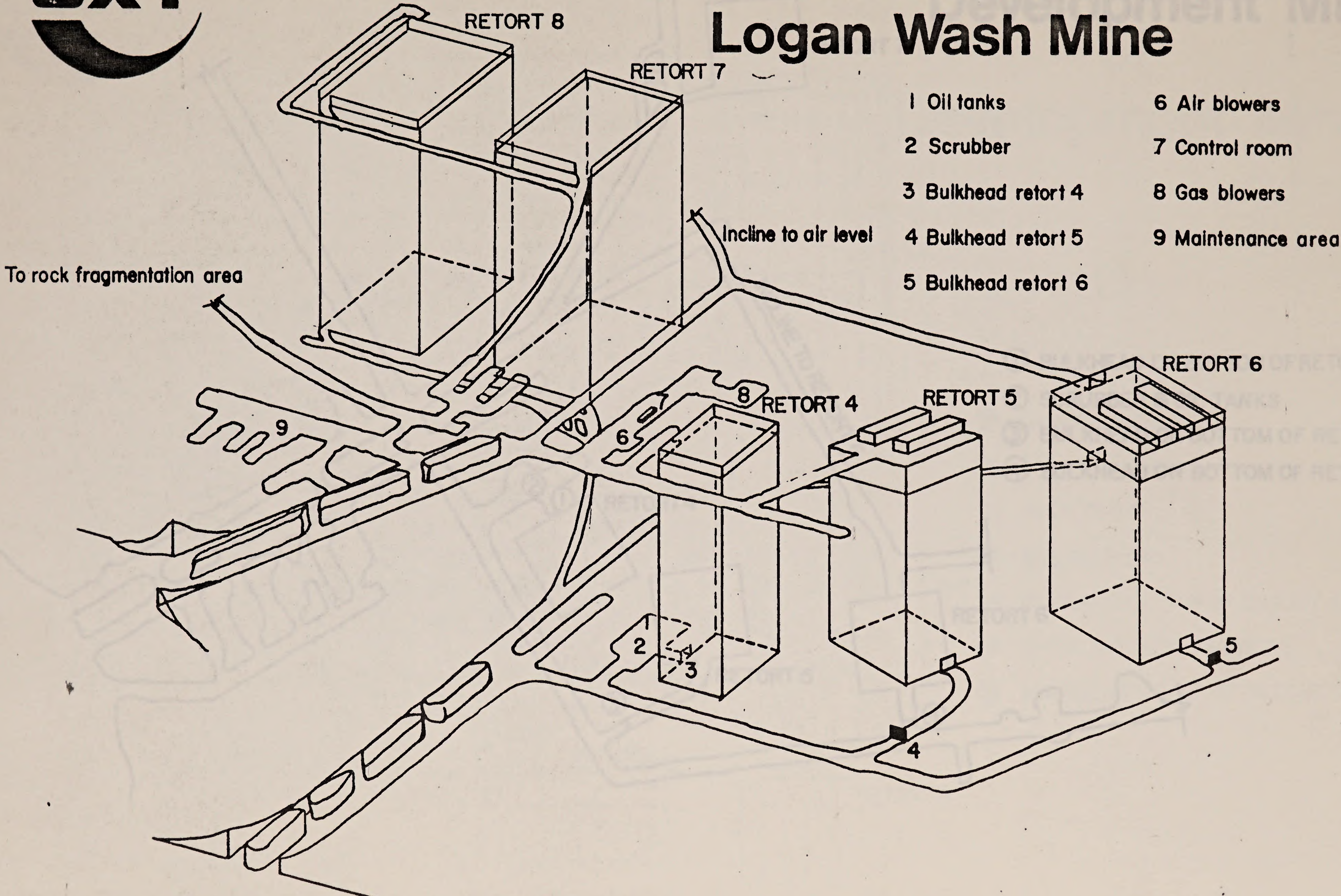
Occidental Petroleum Corporation has entered into an agreement with Tenneco Oil, Inc. as a 50/50 percent partner in the development of the 5,000 acre Federal C-b oil shale tract north of Rifle, Colorado. Occidental is the operator and is planning to use the modified in situ process to produce 55,000 barrels of oil per day from this tract by 1988. Cathedral Bluffs Shale Oil Company (Tract CB) is expected to have a capital cost of approximately $1 Billion plus, and has an anticipated production life of 50 years.

Underground retorts will be developed into "clusters" and each cluster will contain several retorts, all of which will be processed simultaneously. Site preparation for shaft sinking began in September, 1977. Five shafts are planned, three of which are currently being developed. Roads, water storage facilities and temporary construction facilities are included in the surface developments taking place during the shaft sinking period. It is expected that the first retort will be ready for processing by late 1985, and by 1988, the first commercial cluster will be ready for operation. From then on, spent clusters will be closed down and new clusters commenced so that design can be maintained over the life of the property.

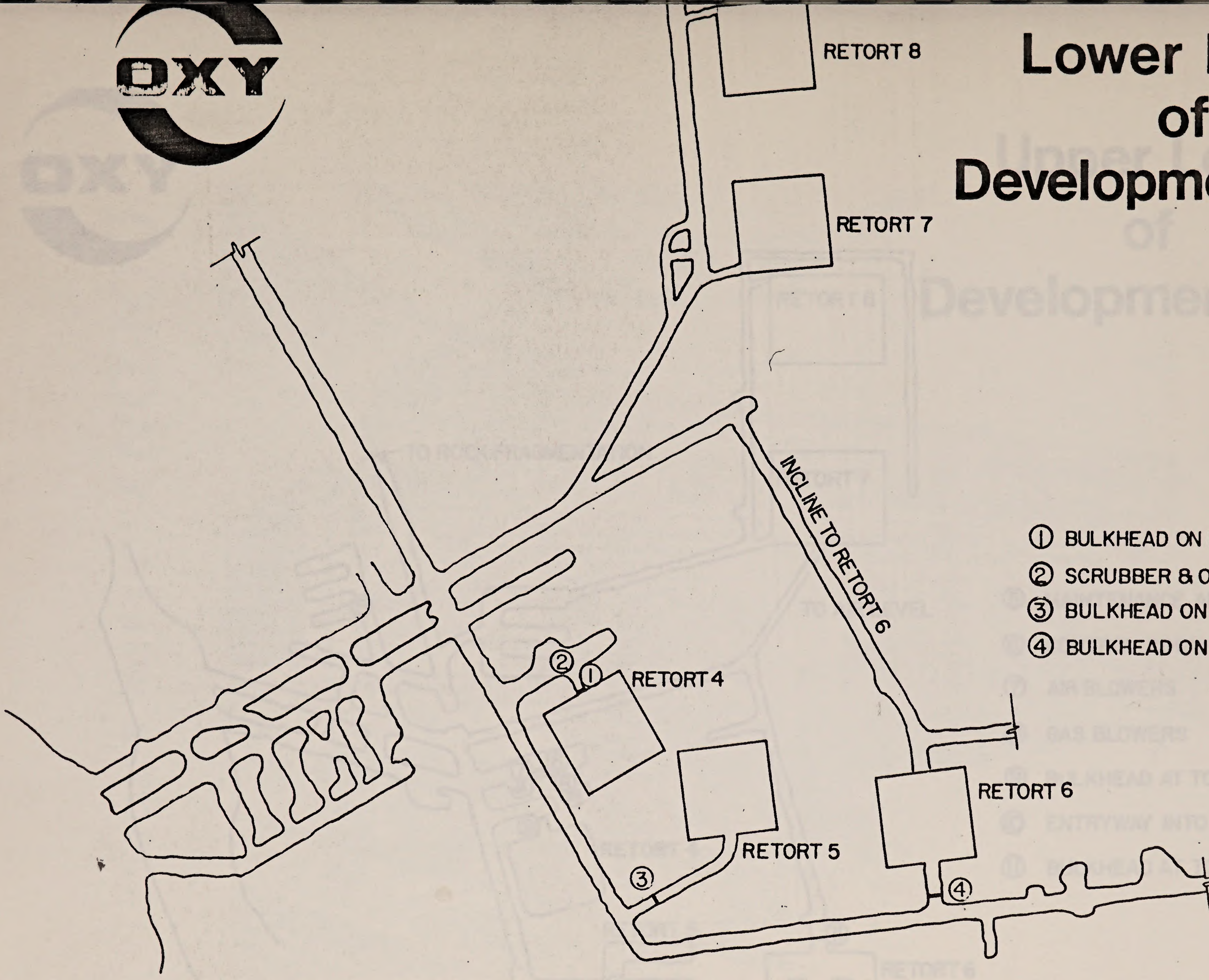
On the CB Tract, oil will be extracted from a 310 ft. shale interval. This interval contains approximately 3.0 billion barrels of oil in place and using Occidental's modified in situ method, approximately 1.2 billion barrels of this oil is recoverable. If it were determined to be feasible to surface retort the mined out shale, total recovery would be about 1.9 billion barrels of oil.

* * * *

# Schematic of the Logan Wash Mine

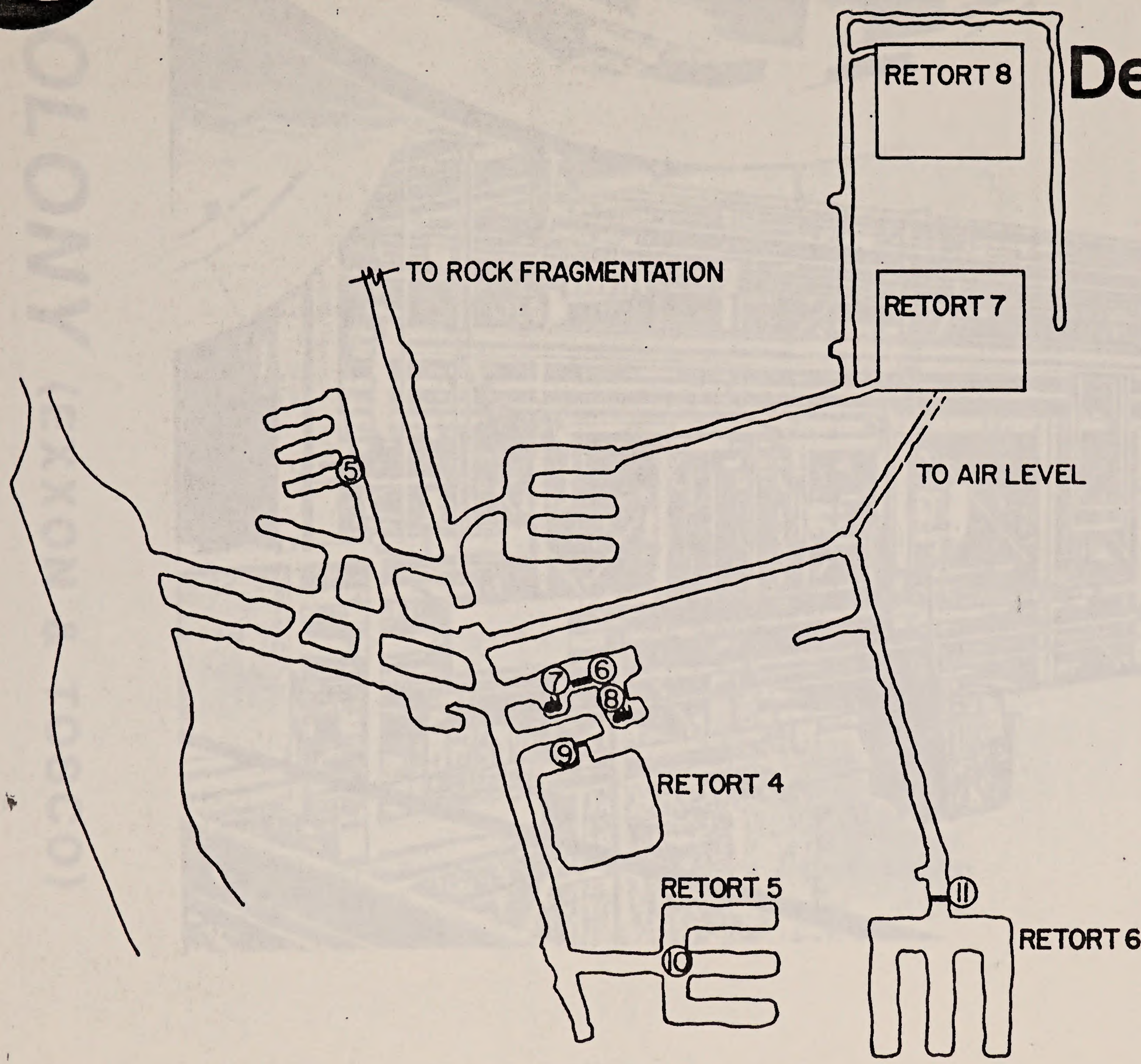


# Lower Level of Development Mine




① BULKHEAD ON BOTTOM OF RETORT 4
② SCRUBBER & OIL TANKS
③ BULKHEAD ON BOTTOM OF RETORT 5
④ BULKHEAD ON BOTTOM OF RETORT 6

# Upper Level of Development Mine




⑤ MAINTENANCE AREA

⑥ CONTROL ROOM

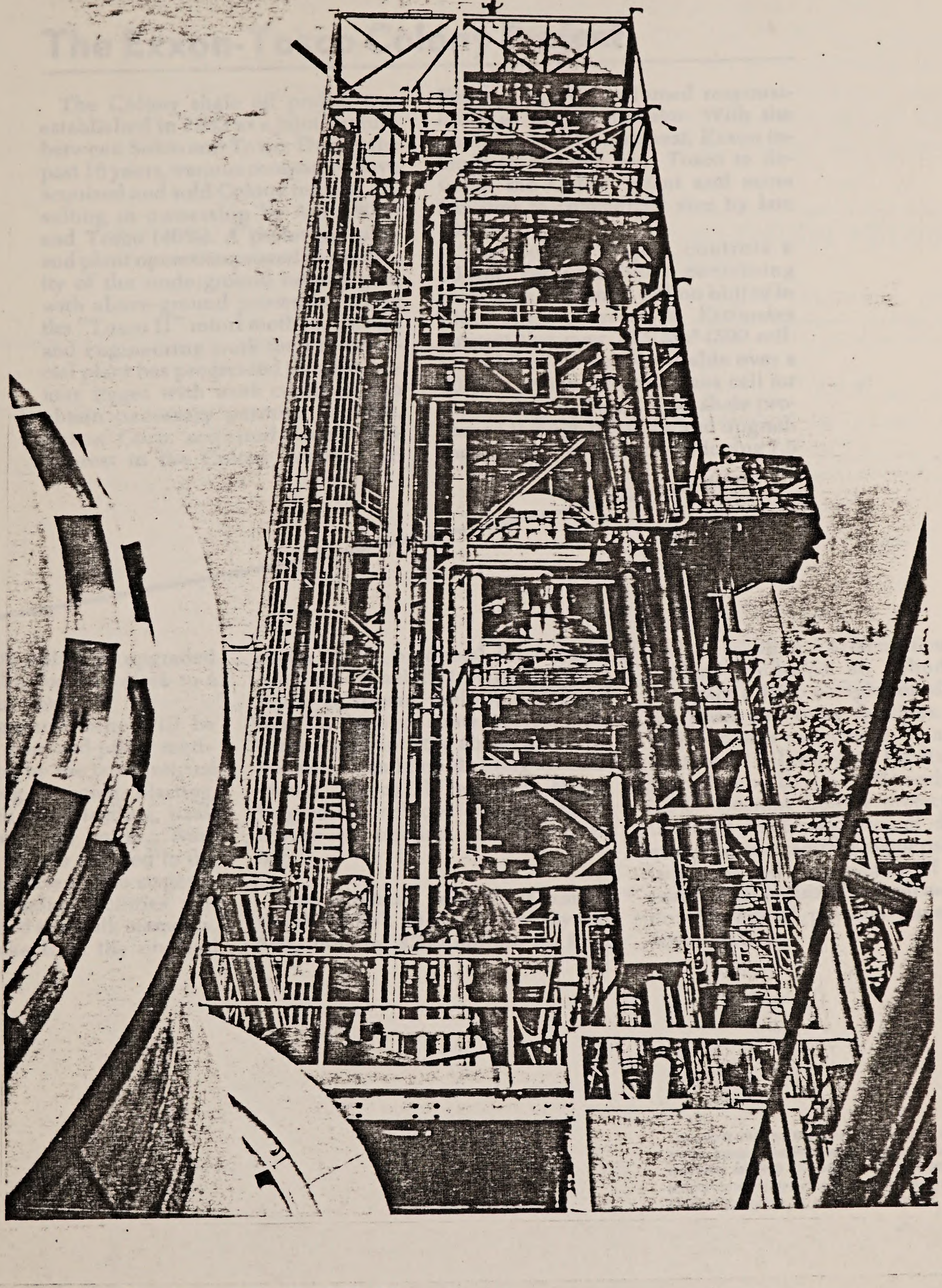
⑦ AIR BLOWERS

⑧ GAS BLOWERS

⑨ BULKHEAD AT TOP OF RETORT 4

⑩ ENTRYWAY INTO RETORT 5

⑪ BULKHEAD AT TOP OF RETORT 6



# *COLONY* (EXXON & TOSCO)

## The Exxon-Tosco Colony Project

The Colony shale oil project was established in 1963 as a joint venture between Sohio and Tosco. During the past 16 years, various companies have acquired and sold Colony interest, resulting in ownership by Arco (60%) and Tosco (40%). A prototype mine and plant operation proved the viability of the underground mining plan with above-ground processing using the "Tosco II" retort method. Design and engineering work for a commercial plant has progressed through various stages with work continuing to obtain necessary permits. In 1980, Exxon Corp. acquired Arco's 60% interest in the Colony venture and Exxon Co., USA, assumed responsibility as project operator. With the purchase of Arco's interest, Exxon intends to proceed with Tosco to develop the Colony plant and mine facilities to commercial size by late 1985.

The Colony Project controls a 35-km² resource block containing more than 159 hm³ (1 billion bbl) of in place shale oil reserves. Estimates suggest that over 79.5 hm³ (500 million bbl) of oil are recoverable over a 30-year period. Current plans call for the mining of 60 kt/d of oil shale processed through pyrolysis and upgrading facilities, capable of producing 7.5 dam³/d (47 000 bbl/d) of upgraded shale oil suitable for feed stock to a conventional refinery.

The underground mine will be worked with room-and-pillar methods, proceeding by the conventional cycle of drilling, charging, blasting, wetting of rock piles, loading, hauling, scaling, and roof bolting. Run-of-mine shale will be crushed to desired retort feed size in two stages.

Retorting/upgrading facilities will recover upgraded shale oil, ammonia, sulfur, and coke from the crushed shale. Fuels produced for internal combustion include treated fuel gas, a liquid $C_4$ stream, fuel oil, and diesel fuel. The kerogen content of raw shale is converted into the above hydrocarbon vapors and liquids using six individual "Tosco II" retorting trains. Upgrading includes coking, gas recovery and treating, and hydrotreating.

The purchase price for Exxon to acquire Arco's interest in Colony was $400 million, $300 million up front with an additional $100 million if the project produces on schedule—currently a 1985 completion date for the plant and mine facilities. Total project cost is expected to be approximately $2 billion with funding participation by Exxon (60%) and Tosco (40%). Current Colony project work includes finalizing project design, awarding contracts for major packages involved, and construction of access roads. Most required federal and state environmental permits have been acquired.□

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# COLONY OPERATIONS

Colony is a joint venture of Atlantic Richfield (60%) and the TOSCO Corporation (40%)--one a petroleum company and the other a technology company--and experiments date back to the mid-1960's. Colony probably has conducted more environmental and socio-economic studies than any other potential oil shale producer. To accommodate their projected maximum production level, Colony has discussed plans for a new, self-contained community at Battlement Mesa, which is close to their development area. Technologically, the TOSCO II oil shale process has a high yield, and the feedstock fines are handled in the same process, rather than separately as required by some other processes.

## MAXIMUM PRODUCTION 1990

50,000 barrels per day

(4,100 acres)

| | | |
|---|---|---|
| Mahogany Zone and above | | 2.5 billion barrels |
| R-6 zone | | 1 billion barrels |
| R-4 zone | | 0.5 billion barrels |
| Overburden to Mahogany | 0-1000 feet | |
| Mahogany Zone | 130 feet | 27 gpt |

## WATER

Usage: 7200 acre ft. per yr
Source: Colorado River

## EMPLOYMENT

| | Time | Workers |
|---|---|---|
| Const: | 4-5 yrs. | 1500-2000 |
| Operation: | | 1500-2000 |
| First production: | | 1986 |

## MINING OPERATION

Type: Underground, room and pillar
Tons per day: 66,000
Grade: 35 gallons per ton
Recovery: 70% - 75%
Fines: None

## PROCESS

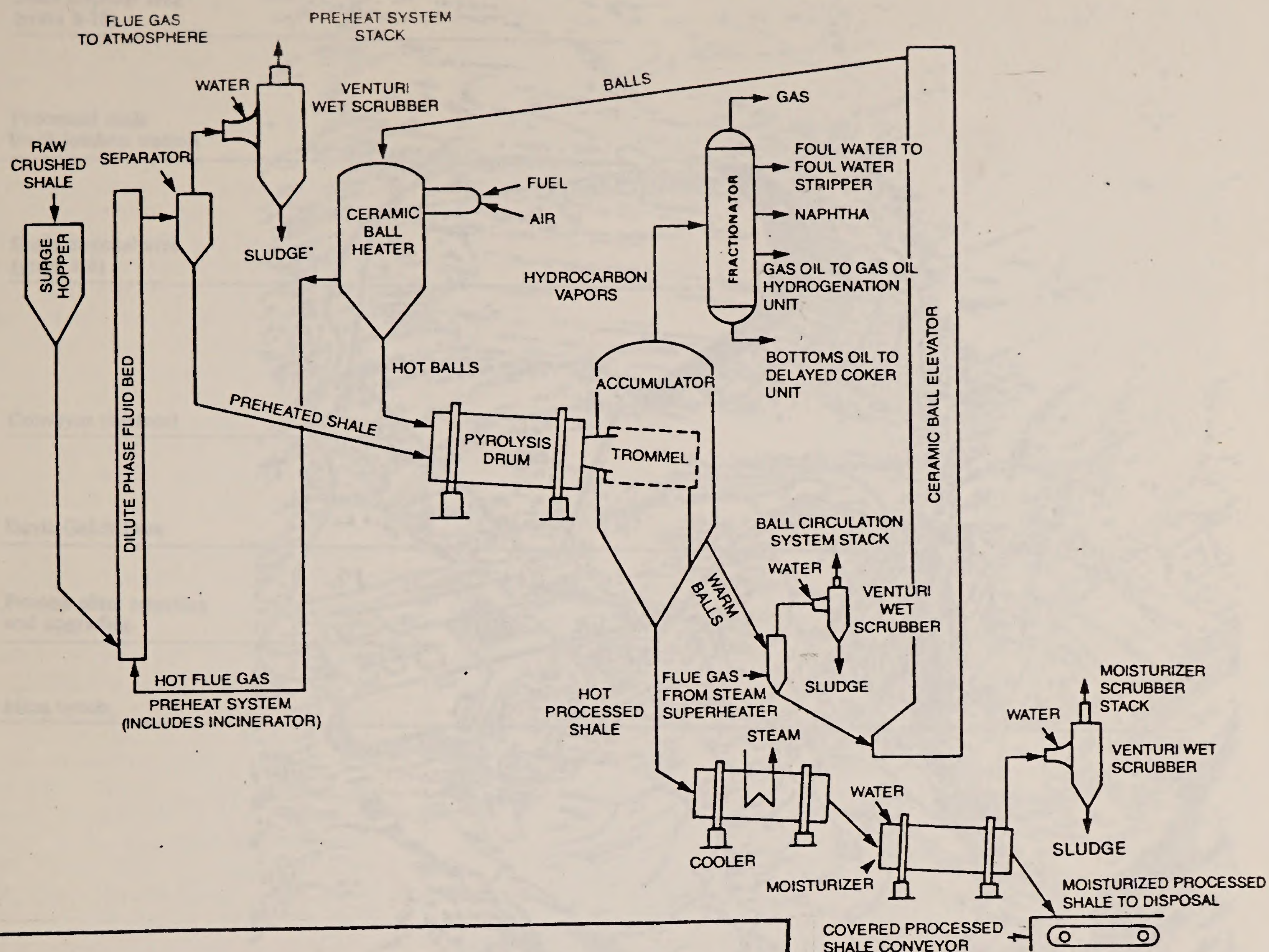
Type: Surface, horizontal retort, TOSCO II
Retorted shale: 53,200 tons per day (waste)
Oil yield: 100% of Fischer Assay

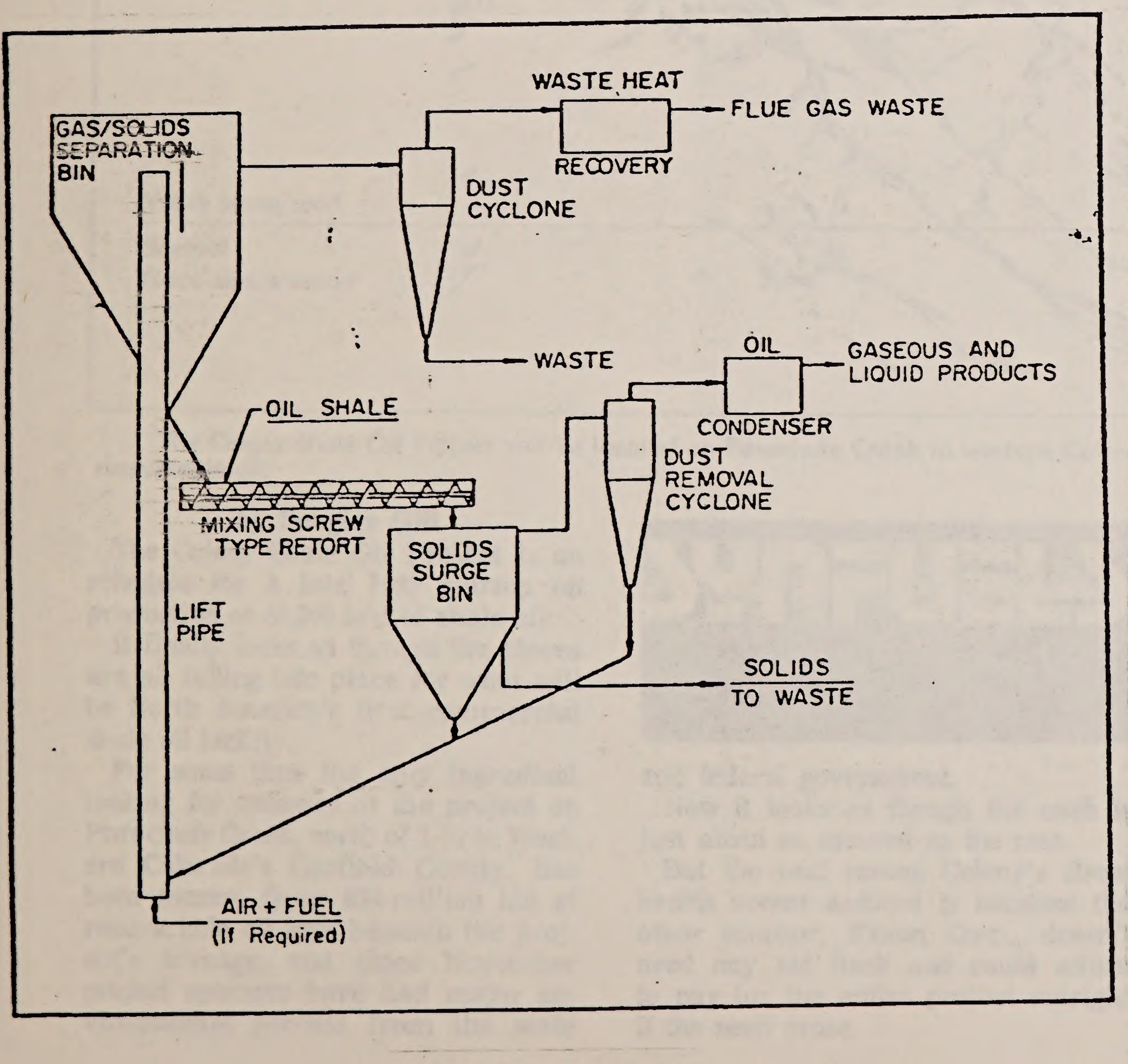
## WORK FORCE REQUIREMENTS & EXPECTED RESIDENCY

| | 1980 | '81 | '82 | '83 | '84 | '85 | '86 | '87 | '88 | '89 | '90 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Construction | 400 | 600 | 1000 | 1500 | 2000 | 2000 | 2000 | 2000 | 2000 | 1500 | 1000 |
| Operation | 150 | 300 | 500 | 800 | 800 | 800 | 800 | 1200 | 1500 | 1800 | 2000 |

In the absence of Battlement Mesa project, it is estimated that 50% of the work force would reside in Rifle, 10% in Silt, 30% in rural Mesa County, and 5% each in rural Grand County and rural Garfield County.

Figure 44.—The TOSCO II Oil Shale Retorting System




Lurgi-Ruhrgas Retorting Process

*The Lurgi process is a similar solid heat carrier process, but not planned for use at the Colony site. Shown here for comparison only!*

# Colony project on schedule for 1985 startup


The Colony Shale Oil Project will be located on Parachute Creek in western Colorado's Garfield County above 634 million bbl of recoverable oil.

**by Douglas Gill**

The Colony Shale Oil Project is on schedule for a late 1985 startup on production of 48,300 b/d of shale oil.

It finally looks as though the pieces are all falling into place for what will be North America's first commercial shale oil facility.

For some time the only ingredient lacking for sponsors of the project on Parachute Creek, north of 1-70 in Western Colorado's Garfield County, has been money. Some 634-million bbl of recoverable oil lays beneath the project's acreage, and since November project sponsors have had major environmental permits from the state and federal government.

SYNFUELS

Now it looks as though the cash is just about as assured as the rest.

But the real reason Colony's fiscal health seems assured is because the other sponsor, Exxon Corp., doesn't need any aid itself and could afford to pay for the entire project outright if the need arose.

While spokesmen for Tosco and Exxon would not officially comment, the possibility remains that as a last resort, if Tosco fails to get federal aid, Exxon could take over the project's entire working interest and allow Tosco to "back in" for a carried share of the revenue interest in return for providing its patented Tosco II retorting technology.

Colony's financial health improved, not when Congress passed the Energy Security Act of 1980 last June, appropriating some $19 billion for synfuel development, but when Exxon, bought out Atlantic Richfield Co's 60% working interest last May.

Project officials have every expectation, however, that Exxon won't have to become the project's financial angel, since Tosco is asking for federal loan guarantees totaling only some 30% of the total cost, and both the Department of Energy and the Synthetic Fuels Corp. are allowed to guarantee loans up to 75%.

Key construction contracts have already been let: to Stearns-Roger Engineering Corp. for design, engineering procurement and construction liaison for the materials handling and mine support facilities; to C. F. Braun & Co., $300 million for similar work to construct the six 11,000 T/day Tosco II retorts; and to Foster-Wheeler Energy Corp. to construct the upgrading plant which would process the 48,500-b/d crude oil output of the retorts to make it ready for pipelining. This plant would be the first commercial-scale shale oil upgrading facility in the world.

Already, the road that will connect the mine in Parachute Valley with the retort complex on the mesa above is being built.

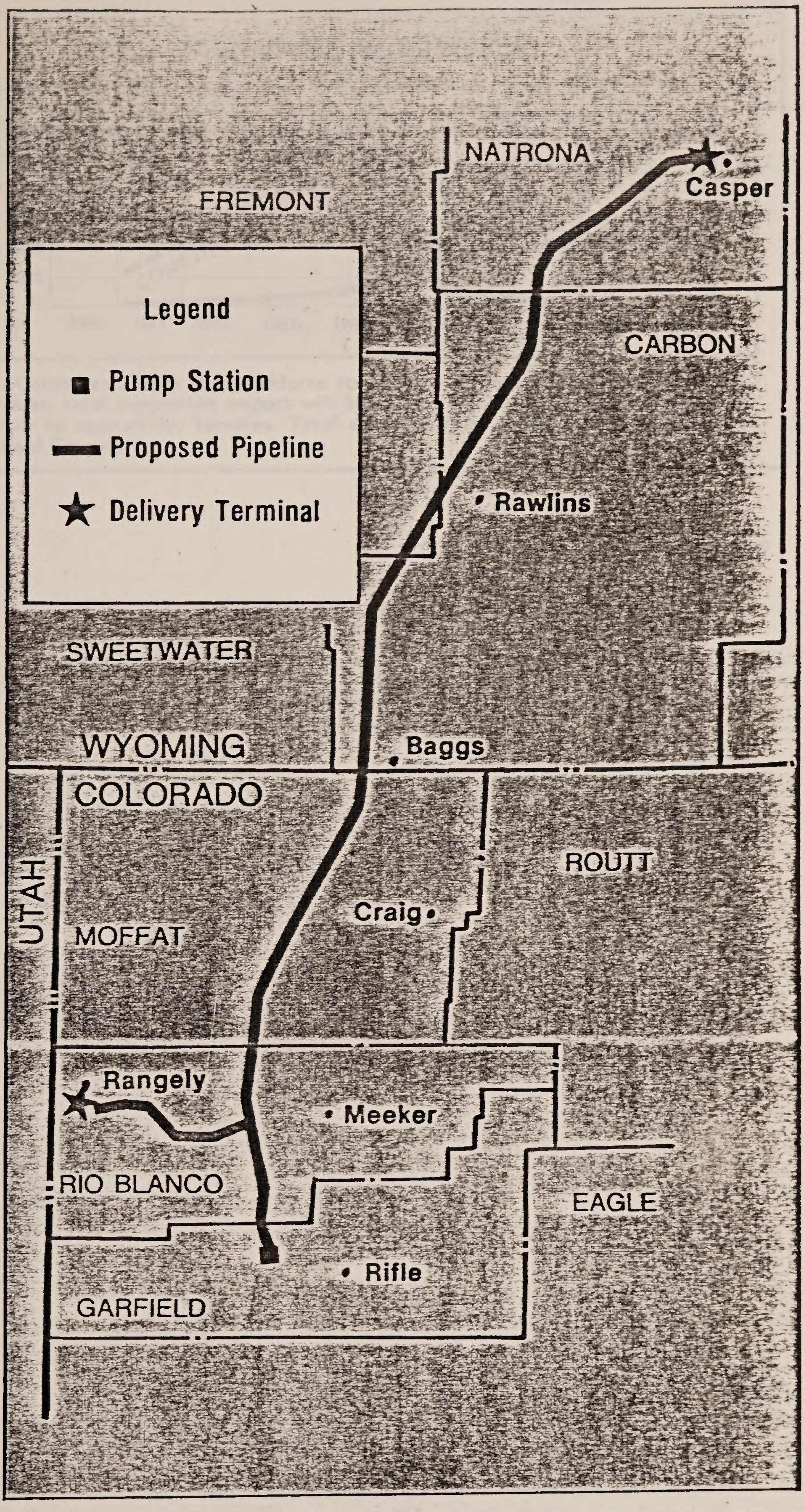
The project will involve mining and processing a 60-ft-thick section of Mahogany zone oil shale with an average richness of 34.7 gal/ton. The deposit underlies 4,763 acres of the 5,480-acre Colony property, and is covered by 500-1,000 ft of overburden. Access to the conventional room-and-pillar mine will be through adits where the zone outcrops at 7,100 ft elevation. Eventually the mine will occupy about 4,500 acres.

Over 22 years, it's estimated that 347 million bbl will be recovered. The raw shale oil, to be produced by six retorts at a rate of just over 8,000 b/d apiece, will be upgraded on the site by a hydrotreating and coking process which involves a straightforward adaptation of conventional refinery technology.

According to Colony, the hydrotreated product will be superior to any conventional crude oil as a refinery feedstock because it will contain no residual fraction that must be disposed of, it has a high naphtha content making it readily convertible to high octane unleaded gasoline, and the light fractions will be directly salable as No. 2 fuel oil or diesel fuel without further processing.

It's been estimated that operation of the mature plant will require water amounting to less than 1% of the average annual flow of the Colorado River. Further, a study completed in October 1979 by the Colorado Department of Natural Resources for the Water Resources Council concluded there is enough water available in the upper Colorado River Basin to support a synfuels industry of about 1.5 million b/d

LaSal's proposed pipeline



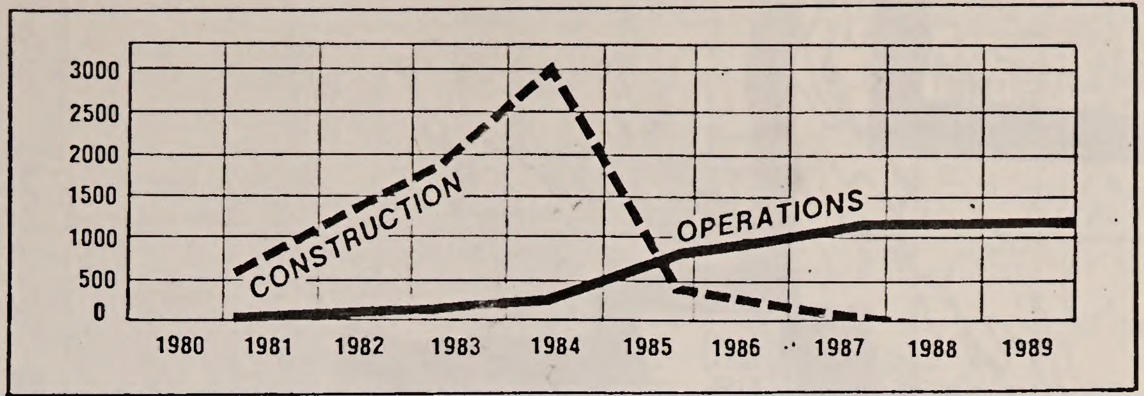

LaSal Pipeline Co., a Houston, Tex., subsidiary of the Exxon Co., USA, is seeking rights-of-way for a 16-in. pipeline to carry the crude shale oil output of the Colony project from the site in Garfield County, Colorado, 302 miles northeast to Casper refineries. The common-carrier pipeline also would be available to other customers. From Casper, crude can be moved through existing lines to the Midwest. A 12-in. spur would be built to the Rangely oilfield to gain access to existing lines to Salt Lake City. Construction will begin in 1984 if all permits are received when expected. Completion in 1986 will coordinate with the expected on-stream date of the Colony plant. Final environmental impact statement on the line is planned to be released in November, according to the Wyoming Bureau of Land Management. About 45% of the line's route follows existing pipeline and utility easements, the agency said.

without significantly altering other consumptive uses.

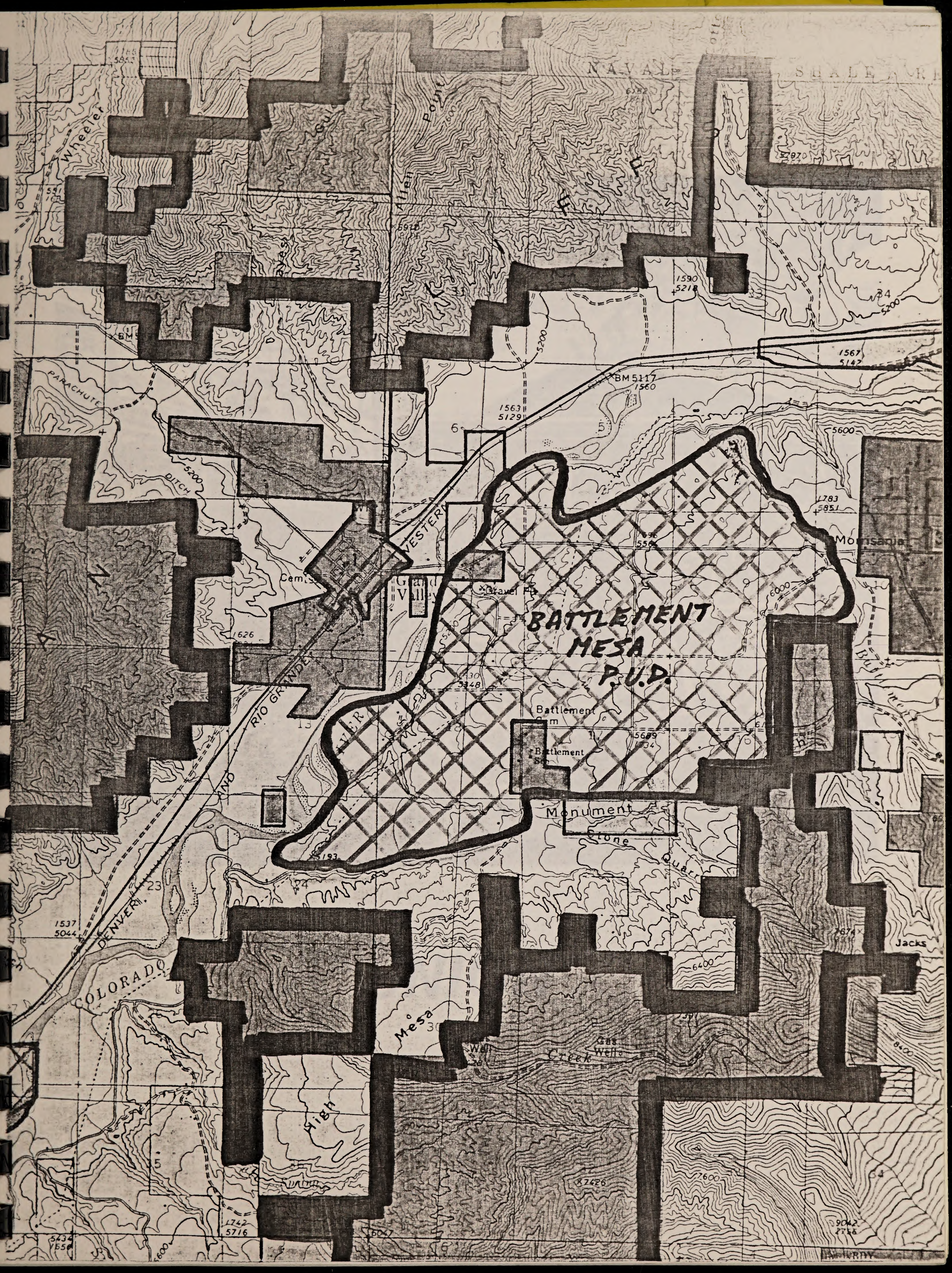
However, that estimate considered mostly direct water use by the processing plants themselves, and not the indirect demands that would be caused by the attendant population increases.

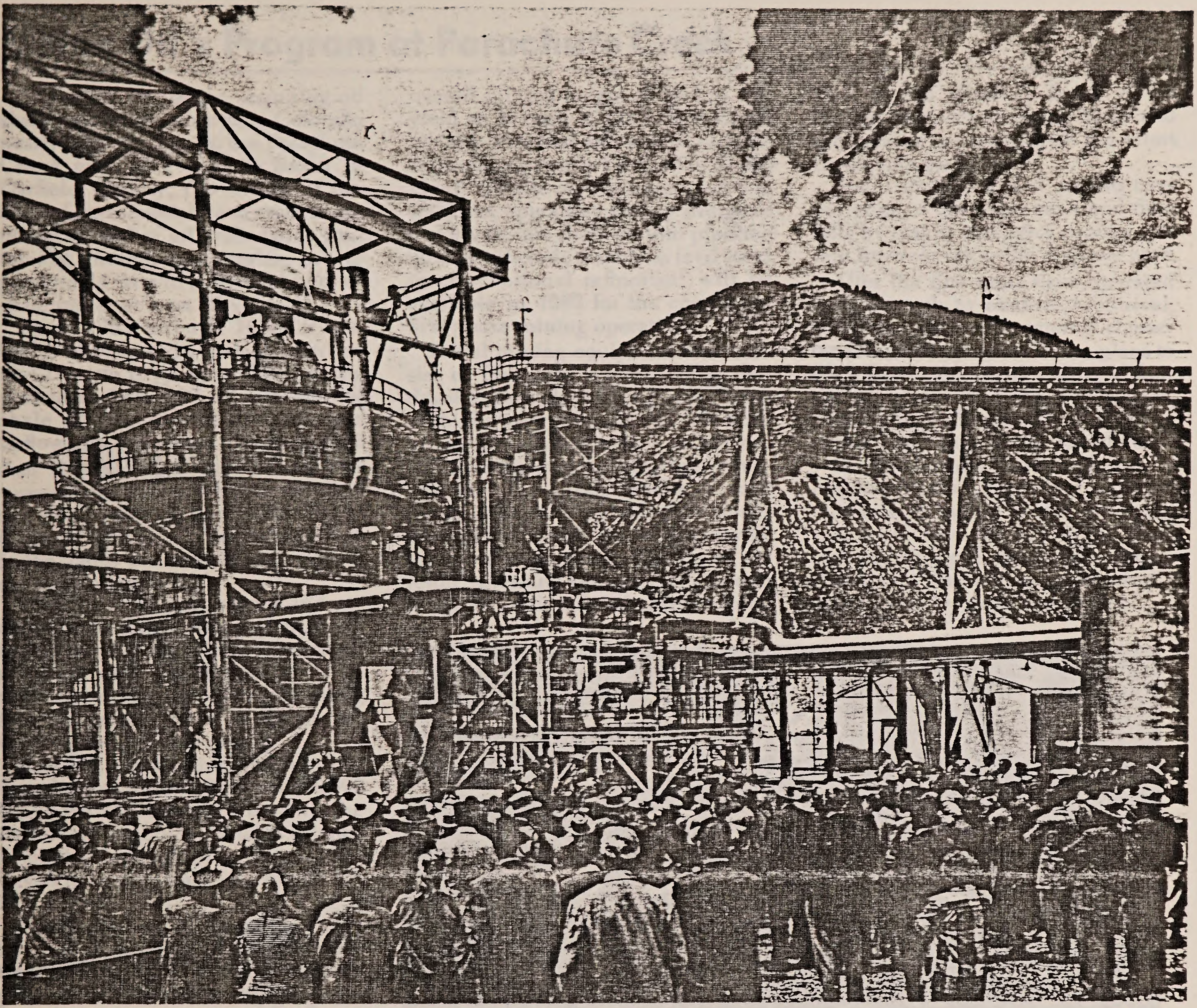
A June 1980 study done by the Denver Research Institute for the Colorado Energy Research Institute concluded, in fact, that under a case of extensive synfuel development, there would be a 100% population increase in the Colorado River Basin within Colorado, which would cause major dislocations in current water usage, with recreation and agriculture being the big losers. □

## Manpower requirements




Colony estimates the workforce to peak in 1984 at about 3,250 workers. However, total population impact will be about 13,000, multiplying each worker by four to account for families. Total effect is 57% of the entire population of Garfield County.


BATTLEMENT
MESA
P.U.D.
NAVAL
SHALE
Wheeler
PARACHUTE
DITCH
RIO GRANDE
DENVER
COLORADO
Morrisania
Monument
Stone
Gravel Pit
Battlement
Mesa
Creek
Gas Wells
Jacks
BM 5117



# UNION

# Union Oil's Program at Parachute Creek

Union Oil Co. began acquiring oil shale properties in western Colorado nearly 60 years ago. In the Parachute Creek area of Piceance Basin in Garfield County, CO (north of the town of Parachute), Union owns in fee nearly 81 $km^2$ of oil shale lands containing enough recoverable ore to produce 24 $dam^3/d$ (150 000 bbl/d) of shale oil for at least 25 years.

From 1955 through 1958, Union built and operated a surface retort on its Colorado properties. The facility produced about 127 $m^3$ (800 bbl) of shale oil per day using a unique upflow retort process. More than 2 $dam^3$ (13 000 bbl) of this shale oil was successfully processed into gasoline and other products at a Colorado refinery. However, low crude oil prices in the 1960s prevented further process development.

With the rapid rise in price and uncertain availability of foreign crude oil in the early 1970s, Union reactivated research and development in its upflow retorting process. Continuing improvements were made in efficiency and product quality.

Last fall, construction began on the first phase of Union's 8-$dam^3/d$ (50 000 bbl/d) oil shale facility despite the current absence of financial assistance from the federal government, believed to be obtainable for the $2 billion project.

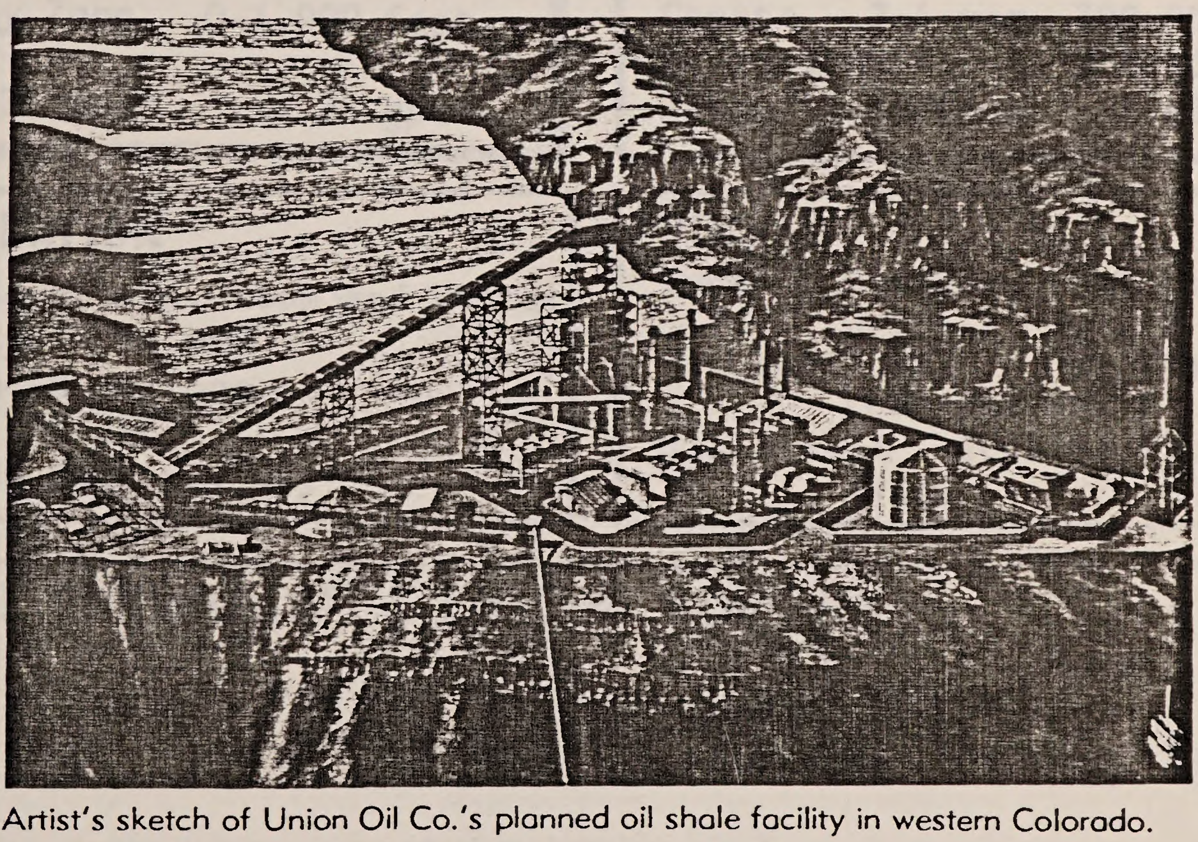
The first phase of the project calls for surface retorting of raw shale retrieved from an 11.4-kt/d room-and-pillar mine, situated to extract shale from the Mahogany zone of the Green River formation. Preliminary plans for the conventional room-and-pillar-mine call for spans of 16.8 m, supported by 30.5- × 15.2-m pillars. The overall mining height of 18.3 m will yield an average of 120 L of shale oil per ton. This first unit will be capable of producing nearly 1.6 $dam^3/d$ (10 000 bbl/d) of shale oil when completed in 1983. An upgrading facility designed to convert raw shale oil into pipeline quality syncrude (usable as feed stock in conventional refineries) will be available in 1983 for the completed first phase mining operation.

Initial mining equipment will consist of front-end loaders and/or hydraulic shovels loading into large off-highway type trucks that will carry ore to the crushing area. Crushed ore will then move to the retort feed chute and into the solids feeder or rock pump. A 3-m-diam piston then forces ore upward into the retort. Hot recycle gas is introduced into the top of the retort, releasing kerogen contained in the shale in liquid and gaseous form. The liquid product flows down through the cool incoming shale and the balance is carried from the retort by recycle gases.

Spent shale is forced up and over the edge of the retort cone and then falls by gravity through a cooling system for removal to the disposal area.

After the first units have operated long enough to confirm technical, economic, and environmental characteristics of the project, Union plans to open four more mines and build four additional retorts, along with accompanying upgrading facilities, to bring capacity to 8 $dam^3/d$ (50 000 bbl/d).

In the future, Union intends to examine various secondary recovery methods, including in situ mining, to recover oil from the 31% of the shale rock remaining as pillars, plus leaner shales that may not be economically recoverable by surface retorting.□



Artist's sketch of Union Oil Co.'s planned oil shale facility in western Colorado.

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# U N I O N

Of the current oil shale companies, Union is the oldest in terms of ownership of reserves and maturity of water rights. Its earliest processes date to the late 1950's. Union has completed the necessary state and federal permits to construct and operate a low-level commercial plant yielding approximately 10,000 barrels per day of crude oil from shale. This operation will likely produce the first commercial oil shale product from the State of Colorado. Union Oil Co. owns approximately 33,000 acres of oil shale property, making it the second largest private holder of the resource in Colorado.

## MAXIMUM PRODUCTION 1990

30,000 barrels per day

| (10,000 acres) | | |
|---|---|---|
| > 15 gal/ton | | 18 billion barrels |
| > 25 gal/ton | | 2 billion barrels |
| > 30 gal/ton | | 1.5 billion barrels |
| Overburden to Mahogany Zone | | 0-1,000 feet |
| Mahogany Zone | 120 feet | 26 gpt |

## WATER

Usage: 3000 acre ft. per yr.
Source: Wells, Colo. River

## EMPLOYMENT

| | Time | Workers |
|---|---|---|
| Const: | 2-4 yrs. | 700-800 |
| Operation: | | 400-700 |
| First Production: | | 1983 |

## MINING OPERATION

Type: Underground, room and pillar
Tons per day: 35,000
Grade: 30-40 gallons per ton
Recovery: 70-75%
Fines: 3500 tons per day

## PROCESS

Type: Surface, rock pump, vertical retort
Retorted shale: 25,200 tons per day (waste)
Oil Yield: 100% of Fischer Assay

## WORK FORCE REQUIREMENTS & EXPECTED RESIDENCY

| | 1980 | '81 | '82 | '83 | '84 | '85 | '86 | '87 | '88 | '89 | '90 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Construction | 300 | 800 | 700 | 200 | 800 | 700 | 200 | 0 | 0 | 0 | 0 |
| Operation | 100 | 250 | 400 | 400 | 400 | 400 | 550 | 700 | 700 | 700 | 700 |

It is estimated that 60% of the work force will reside in Rifle, 10% each in Silt and Grand Valley, and the remaining 20% in rural Mesa County.

## UNION RETORT B FLOW DIAGRAM

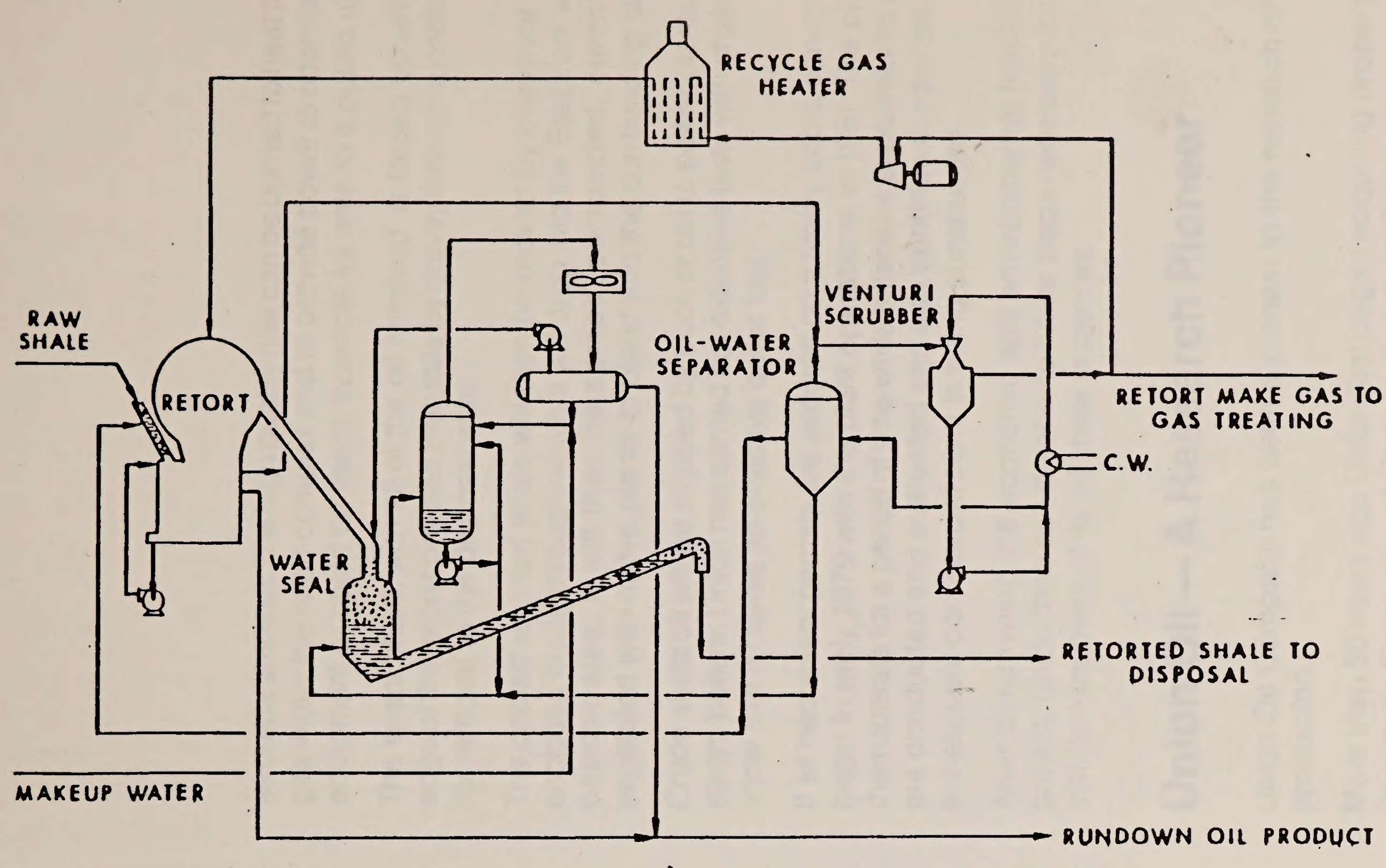
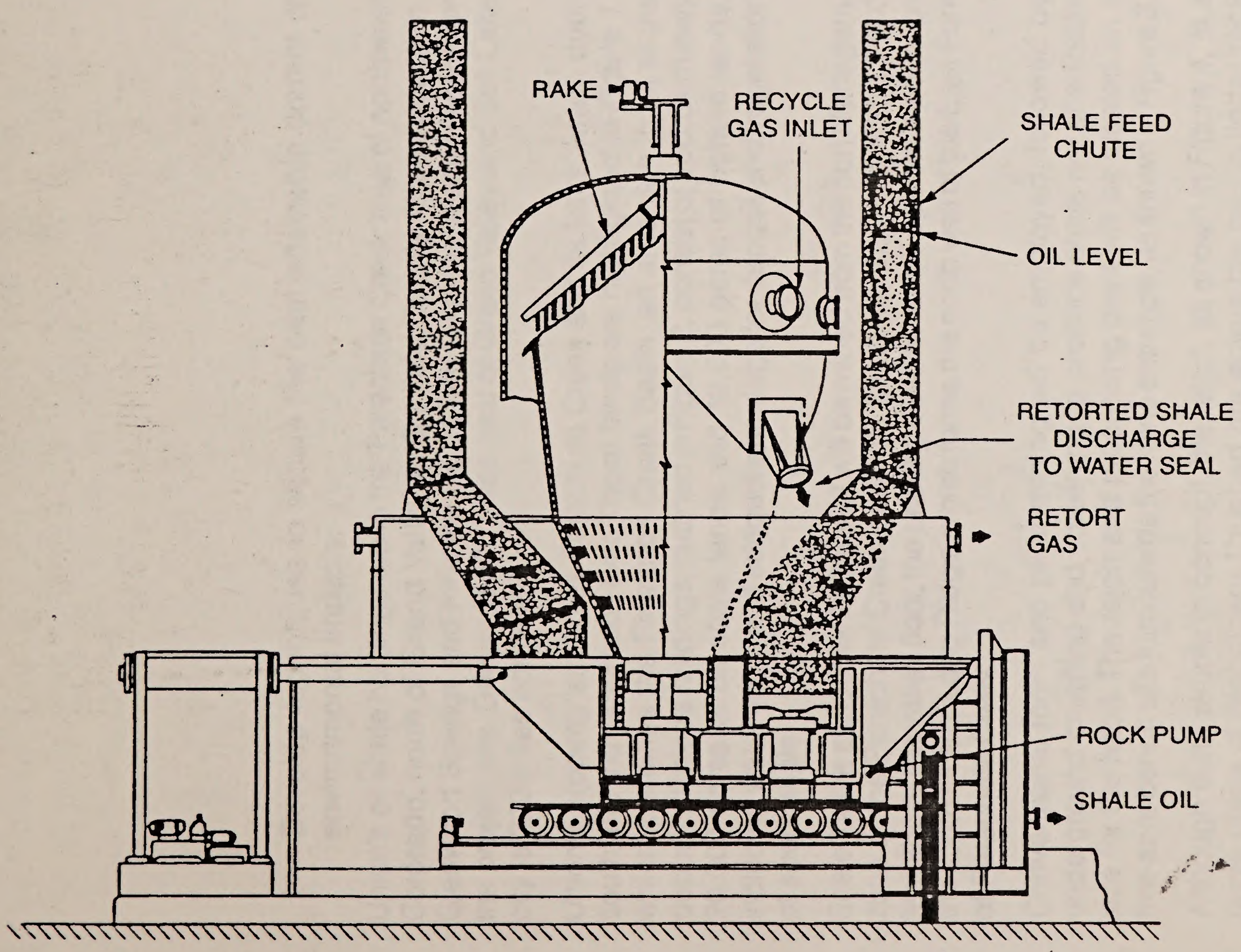



Figure 40.—The Union Oil "B" Retorting Process



- Develop techniques to secure the best attainable control of environmental impacts.

Union's oil shale holdings are in the Parachute Creek area of northwest Colorado, north of Grand Valley, in Garfield County. Grand Junction, Glenwood Springs and Rifle are 58, 54 and 28 miles, respectively, from the project site. Denver is 200 miles east of Grand Valley and Salt Lake city is 320 miles northwest.

Union's property straddles Parachute Creek and its forks, which drain south into the Colorado River. These lands are highlighted in *Figure 1*, which identifies the Piceance Creek Basin, an area rich in oil shale deposits. Union's holdings, outlined in *Figure 2*, consist of approximately 20,000 acres of oil shale lands and 10,000 acres of bottom lands, including water rights and adequate acreage for deposit and vegetation of spent shale.

Shale for the experimental project will be mined from the rich Mahogany zone of the Parachute Creek geologic formation. Located about 1,000 feet above the valley floor, the underground mine will open at a portal on the south side of Long Ridge, which forms the north wall of the East Fork of Parachute Creek.

Conventional room and pillar mining will be employed, followed by underground crushing and screening to produce shale ore of suitable size for the retort. The retort and processing plant will be located on a five-acre bench site just outside the mine entrance, as shown in *Figure 3*.

Although quite simple in concept, the retort, as shown in *Figure 4*, is a large piece of machinery. Crushed ore enters the two-cylinder rock pump through two feed chutes. The 10-foot diameter pistons then force the ore upward into the retort.

Heated gas enters the top of the retort releasing kerogen contained in the shale in a hot gaseous form. The hot vapor is cooled and condensed by contact with entering cold shale being forced upward in the retort. The shale oil liquid is separated from the gas and transferred to storage as crude shale oil. The high quality gas can be burned to heat the recycle gas within the retort complex and to provide power to operate the retort equipment or could be made available for sale to a public utility.

The spent shale, with all of the oil removed, is forced up and over the edge of the retort cone and then falls by gravity through a cooling system for removal to the disposal area.

The cooled retorted shale will then be moved by conveyor belt to an enclosed chute through which it will drop into the East Fork valley floor deposit area. It will then be spread, compacted, contoured and vegetated with native plants to blend into the surrounding landscape.

Crude shale oil will be shipped by truck or rail to power plants for use in steam boilers. Union has carried out extensive tests with shale oil which show that it makes an effective boiler fuel.

If all necessary permits are secured on a timely basis, construction will begin in early 1979 with the plant operational in 1981. The plant would then operate for a period of time while extensive experimental programs are conducted and evaluated and can continue to operate while the subsequent commercial plant is being constructed.

After determining the economic and environmental feasibility of the project, Union then can determine future steps necessary for commercial development of its oil shale resources.

## Union Oil—A Research Pioneer

Union Oil Company has been a pioneer in the research of shale oil production.

More than 50 years ago Union first began acquiring properties in the Parachute Creek area of Garfield County in Colorado.

The nearly 20,000 acres of oil shale lands Union owns contain some two


This sketch shows Union's experimental oil shale project during operations. Crushed and screened shale will move from the underground mine onto a five-acre bench site, then be fed into the retort to extract the shale oil. The shale oil flows into storage tanks and retorted shale moves by conveyor to the enclosed chute and down to the bottom of the valley for spreaoing and vegetation. A drainage pond (lower left) will capture runoff water from the spent shale deposits along with rain and snow for use in the retorting process. East Fork Parachute Creek (lower right) will be protected from recycled water and other contaminants.

## Union's Upflow Retort
## 10,000 Tons Per Day Capacity

Raw shale flows into the rock pump and is forced upward into the retort by two 10-foot diameter pistons. Hot gas enters the retort, releasing shale oil from the rock. Condensed shale oil flows to storage and the spent shale falls into the shale cooler and moves to the deposit area. A heater produces hot gas providing heat for the retorting process.

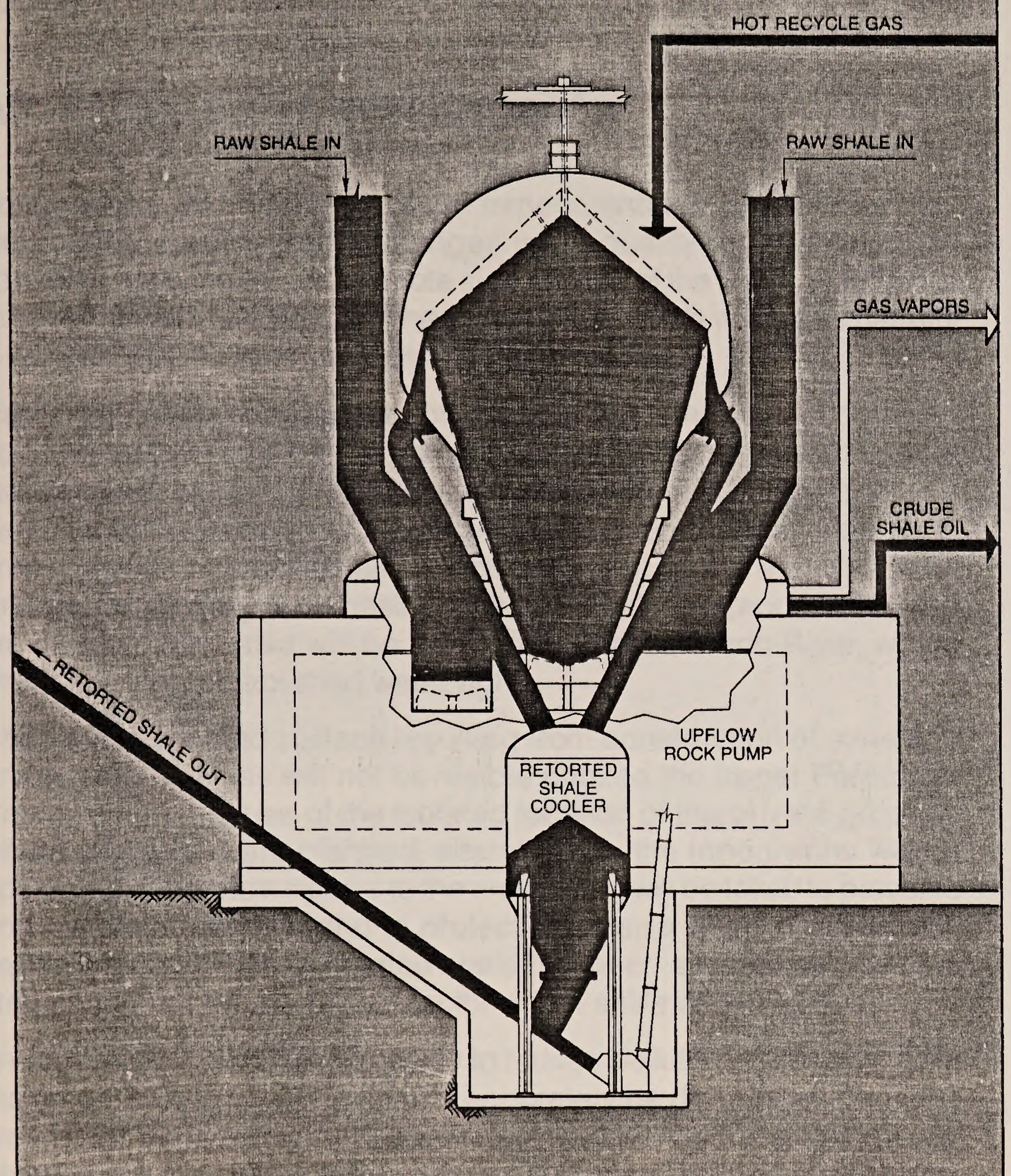



Figure 4

billion barrels of recoverable oil in the high-yield Mahogany zone alone. These reserves are large enough to produce 150,000 barrels of shale oil each day for at least 25 years. In addition, there are approximately two billion more barrels of reserves in adjoining lower quality zones.

Fully aware of the potential energy value of these holdings, Union's research scientists have conducted a wide variety of laboratory and field studies for more than 30 years. They have consistently sought technically, environmentally and economically feasible methods of extracting usable oils from shale.

Starting in the early 1940's and continuing into the early 1950's, Union built and operated a small, 50-ton-per-day pilot retort at its Los Angeles refinery.

From 1955 through 1958 Union built and operated a retort in Parachute Creek valley, processing up to 1,200 tons of ore per day, and producing about 800 barrels of shale oil per day. The company developed technology for treating the oil so that it could be processed in a crude oil refinery or utilized as boiler fuel in an electric generating plant. In the first commercial-scale refining of Colorado shale oil, over 13,000 barrels of shale oil were successfully processed into gasoline and other products at a refinery near Fruita, Colorado.

The low prices of world oil in the 1960's forced Union Oil to put the project on the shelf.

Following the 1973 oil embargo and the ensuing rapid rise in the world price of crude oil, Union reactivated its interest in developing a viable shale oil industry.

In addition to its own efforts, Union has engaged experienced Colorado engineering firms to evaluate the company's mining and retorting processes. This evaluation has convinced Union that it has a viable process for extracting oil from shale. With proper encouragement by the federal government and approval by the State of Colorado, Union is now

prepared to take the next steps in the development of an oil shale industry.

## Air, Water and Land Impacts

Construction and operation of the experimental shale oil plant may temporarily result in some changes in air quality in the immediate operating area, located in a remote side canyon of the valley. Exhaustive studies indicate, however, that the low emission levels will not be harmful to residents of the area, to vegetation or to wildlife.

Water required in the experimental project's operations will be taken from wells on Union's property and will be recycled to minimize water requirements. Union's water rights were secured many years ago as a part of the company's long-term plan for future shale development. Project design includes detailed plans to prevent contamination of local streams and underground basins. As future retorts and process facilities are added, water also will be drawn from the Colorado River, where Union has long-established water rights.

Changes in the land surface resulting from construction of mine and processing facilities will not be visible outside the upper Parachute Creek valley. Because of the isolated location of the private property where operations are planned, alterations in the topography will be apparent only to a few visitors to the area. Steps will be taken to preserve and restore vegetation and to protect the area's wildlife and wildlife habitat. Revegetation of retorted shale has been successfully demonstrated and will be carried out on the spent shale disposal areas.

The abatement facilities necessary to reduce pollutant emissions to the maximum extent possible cannot accurately be determined from the small pilot plant operations conducted to date. As the experimental plant begins operations, Union will continuously monitor all environmental factors. The company can then install the best controls dictated by actual operating results. This will permit development of new advanced technology as required to achieve an environmentally acceptable operation.

## Social and Economic Benefits

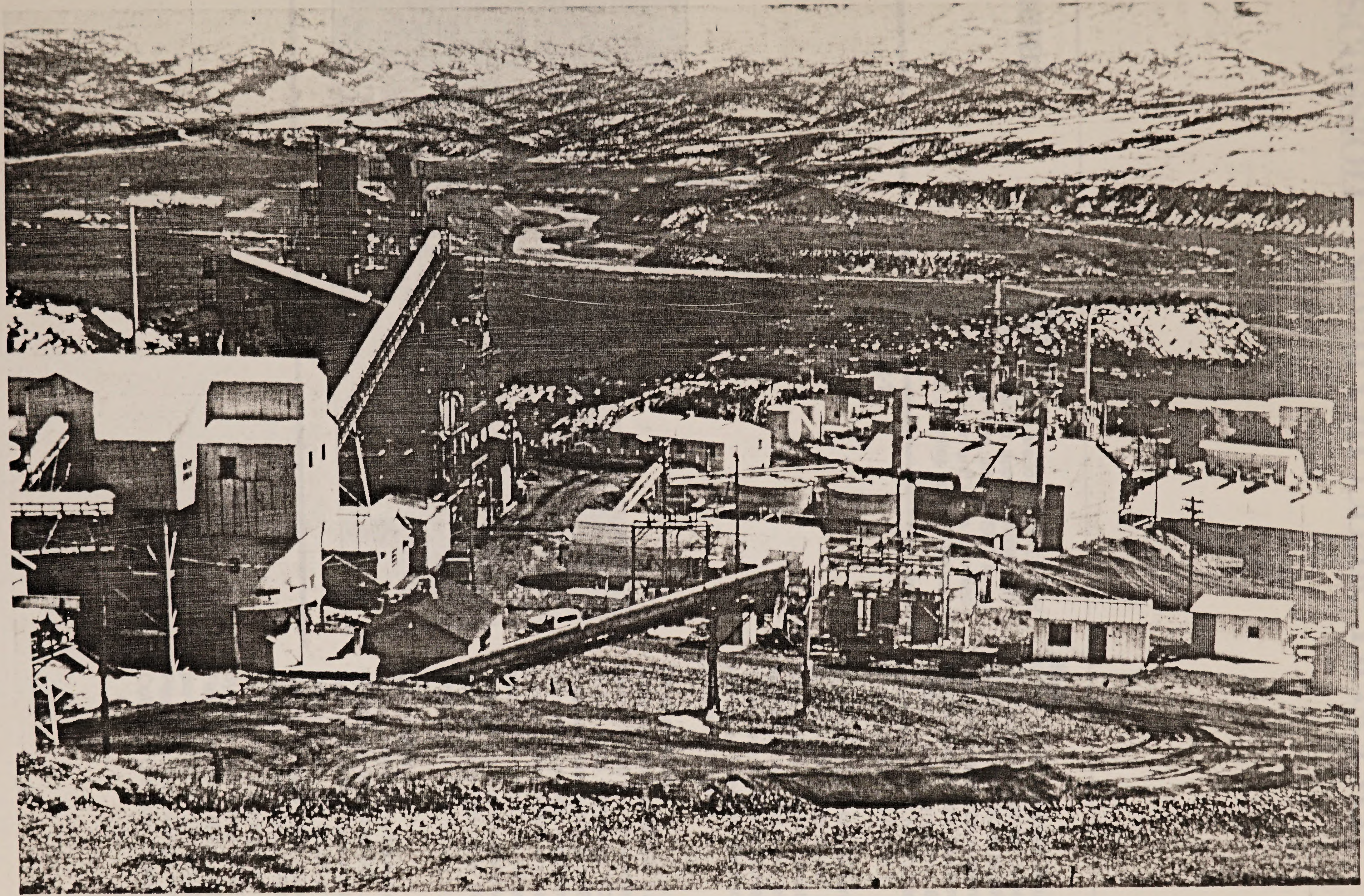
The project will have many economic and social benefits for area communities. Total payroll of the project during construction of the experimental plant will approach $12 million annually, most of which will be spent locally.

During the operating phase of the project, it is estimated it will provide annual local taxes of about $2 million, local purchases of $2.3 million, and a payroll of some $4 million to combine to produce a basic economic contribution of more than $8 million a year to the local area. Studies indicate that each dollar usually turns over at least 2½ times before leaving an area. Thus, Union's proposed oil shale development will contribute about $20 million annually to Colorado's economy. Most of these expenditures should take place in Western Slope communities. If results of Union's operations make further development feasible, the economic contribution would grow considerably.

The project will provide about 400 jobs during the construction phase and 200 during plant operations. Many of these jobs will be filled by local residents.

Union recognizes that local communities will need to expand housing and may experience some increase in public services for a growing population. Increased revenues from local taxes should more than offset the costs of additional community expenses. In addition, the company is prepared to work closely with local officials to help solve problems before they arise.

Union will work with the area communities to plan for population growth in an effort to preserve the life style enjoyed in western Colorado.

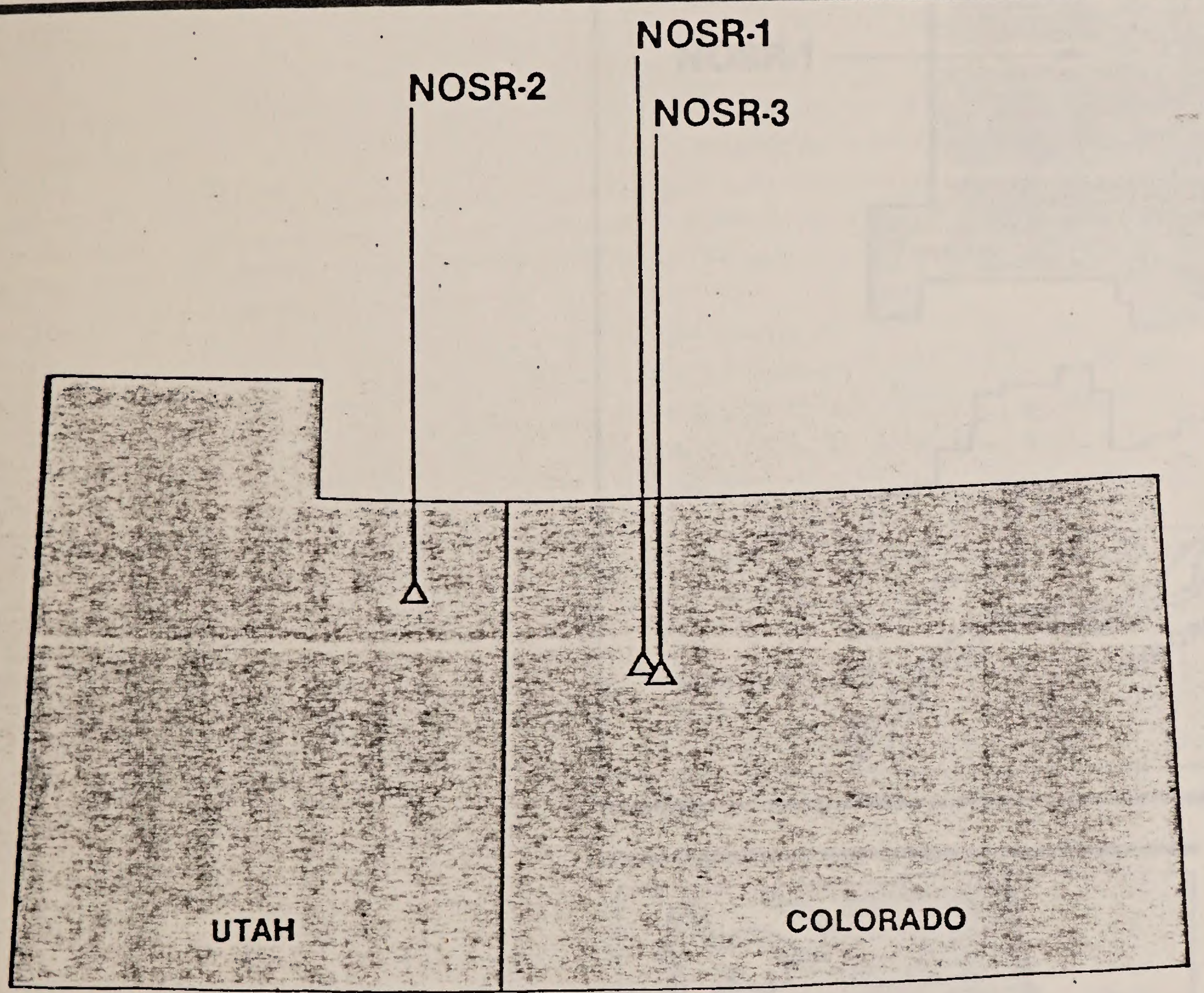


# ANVIL POINTS

# Discussion: Naval Oil Shale Reserves

## General

### Location
NOSRs 1 and 3 are located in Garfield County, Colorado, approximately eight miles west of Rifle, and NOSR 2 is located in Carbon and Uinta Counties, Utah, about 50 miles south of Vernal.

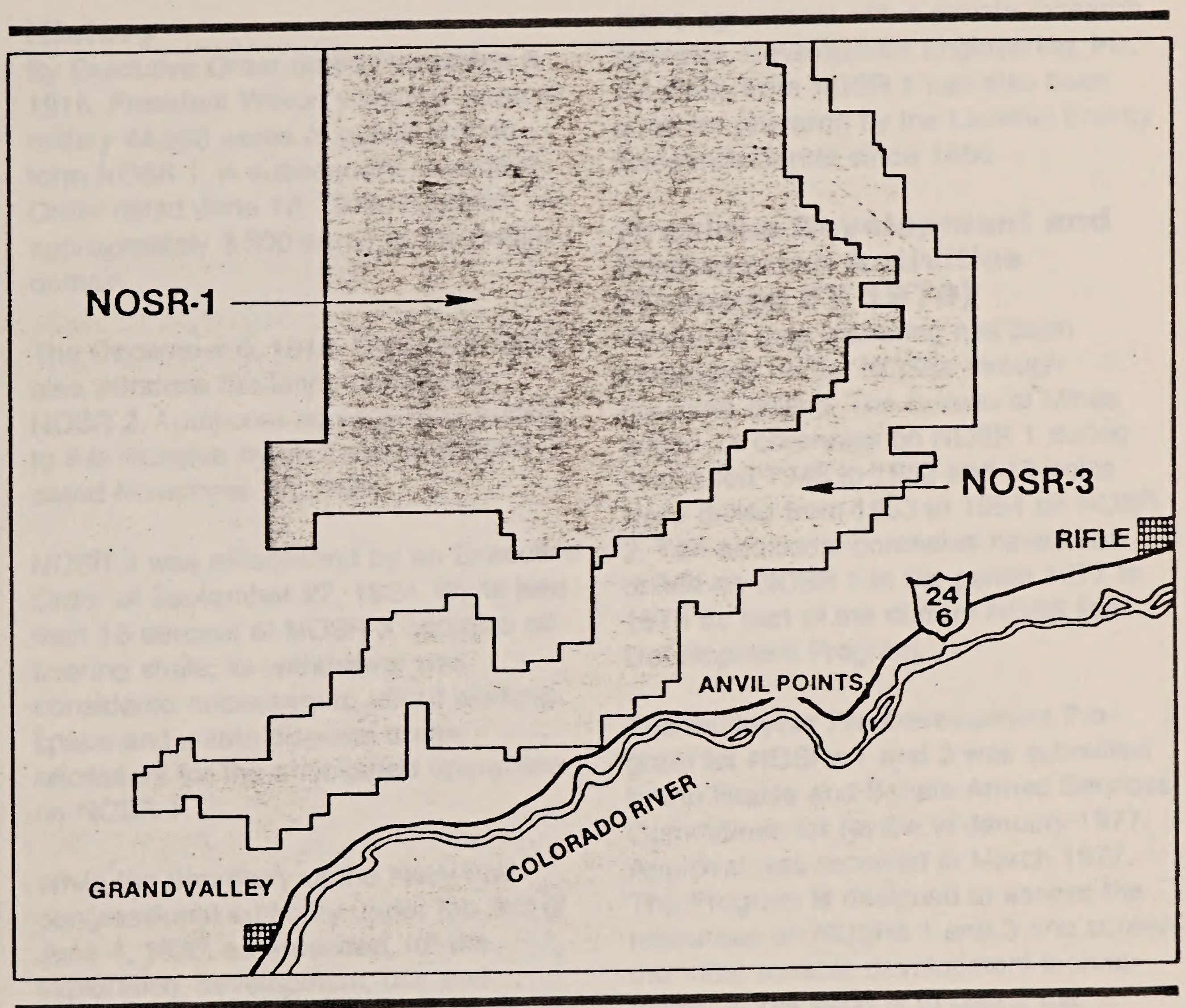


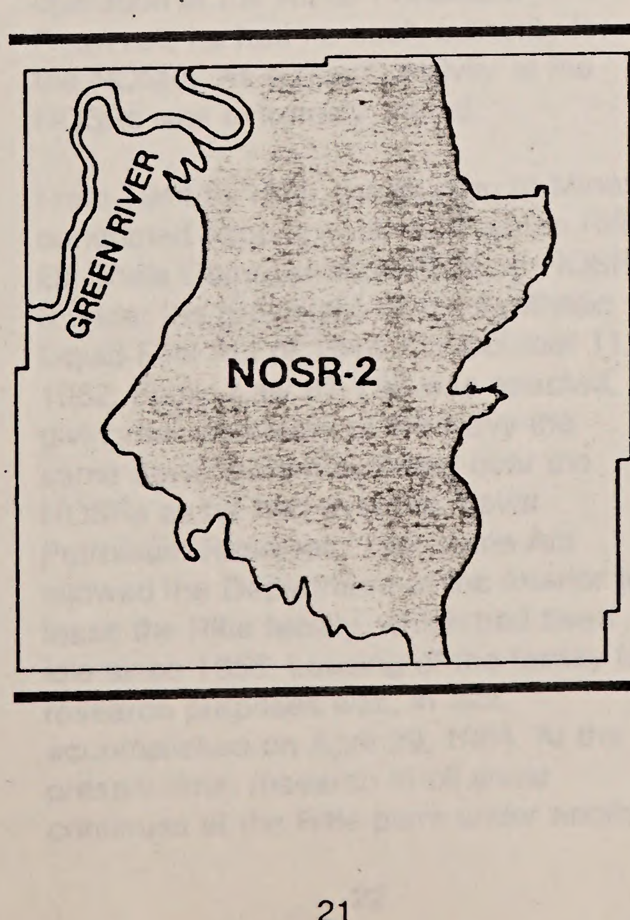

### Size
NOSR 1 is 40,760 acres of rugged highland country in western Colorado. NOSR 3, which adjoins NOSR 1 on the east, south, and west is approximately 14,130 acres in size. The elevation of NOSRs 1 and 3 range from 6,000 feet above sea level at NOSR 3 to 9,300 feet above sea level at NOSR 1.

NOSR 2 contains 90,440 acres of land characterized by flat topped uplands and steep walled canyons. Elevations vary from 4,600 feet above sea level in the Green River to slightly above 7,050 feet above sea level near the center and southern boundary.

### Ownership
All of the lands at NOSRs 1 and 3 are owned by the U.S. Government. Of the 90,440 acres comprising NOSR 2, 640 acres are state lands and 320 acres are homestead entries. Approximately 40 percent of the surface lands at NOSR 2 are part of the Uinta-Quray Indian Reservation. The mineral ownership on these lands is retained by the Government.

### Operator
Surface management functions on the NOSRs are funded by DOE and are managed by the Bureau of Land Management. The NOSR pre-development program is being implemented through the services of TRW, Inc. as the Government's Management Support and Systems Engineering (MSSE) contractor. Field supervision of the MSSE contract is performed by the Director, Naval Petroleum and Oil Shale Reserves in Colorado, Utah and Wyoming.


NOSR-1
NOSR-3
RIFLE
24
6
ANVIL POINTS
COLORADO RIVER
GRAND VALLEY


GREEN RIVER
NOSR-2

# Discussion: Naval Oil Shale Reserves

## Background

### History

By Executive Order dated December 6, 1916, President Wilson withdrew approximately 44,560 acres of public land to form NOSR 1. A subsequent Executive Order dated June 12, 1919, restored approximately 3,800 acres to the public domain.

The December 6, 1916, Executive Order also withdrew the lands comprising NOSR 2. Additional acreage was added to this Reserve by an Executive Order dated November 17, 1924.

NOSR 3 was established by an Executive Order of September 27, 1924. While less than 15 percent of NOSR 3 contains oil bearing shale, its withdrawal was considered necessary to afford working space and waste disposal areas necessary for the anticipated operations on NOSR 1.

While the Secretary of the Navy had congressional authority under the Act of June 4, 1920, as amended, for the exploration, development, use and operation of the Naval Petroleum Reserves, he had no such authority for the NOSRs. As a result, activity at the NOSRs was extremely limited.

From 1944 to 1956, the Bureau of Mines conducted experimental work at the Rifle Oil Shale Demonstration Plant on NOSR 3 under the provisions of the Synthetic Liquid Fuel Act of 1944. On October 11, 1962, Public Law 87-796 was enacted, giving the Secretary of the Navy the same development authority over the NOSRs as he had over the Naval Petroleum Reserves. That same Act allowed the Department of the Interior to lease the Rifle facility, which had been idle since 1956. Leasing of the facility for research purposes was, in fact, accomplished on April 29, 1964. At the present time, research in oil shale continues at the Rifle plant under another lease agreement with a private research operator, Development Engineering, Inc. Oil shale from NOSR 1 has also been used for research by the Laramie Energy Research Center since 1956.

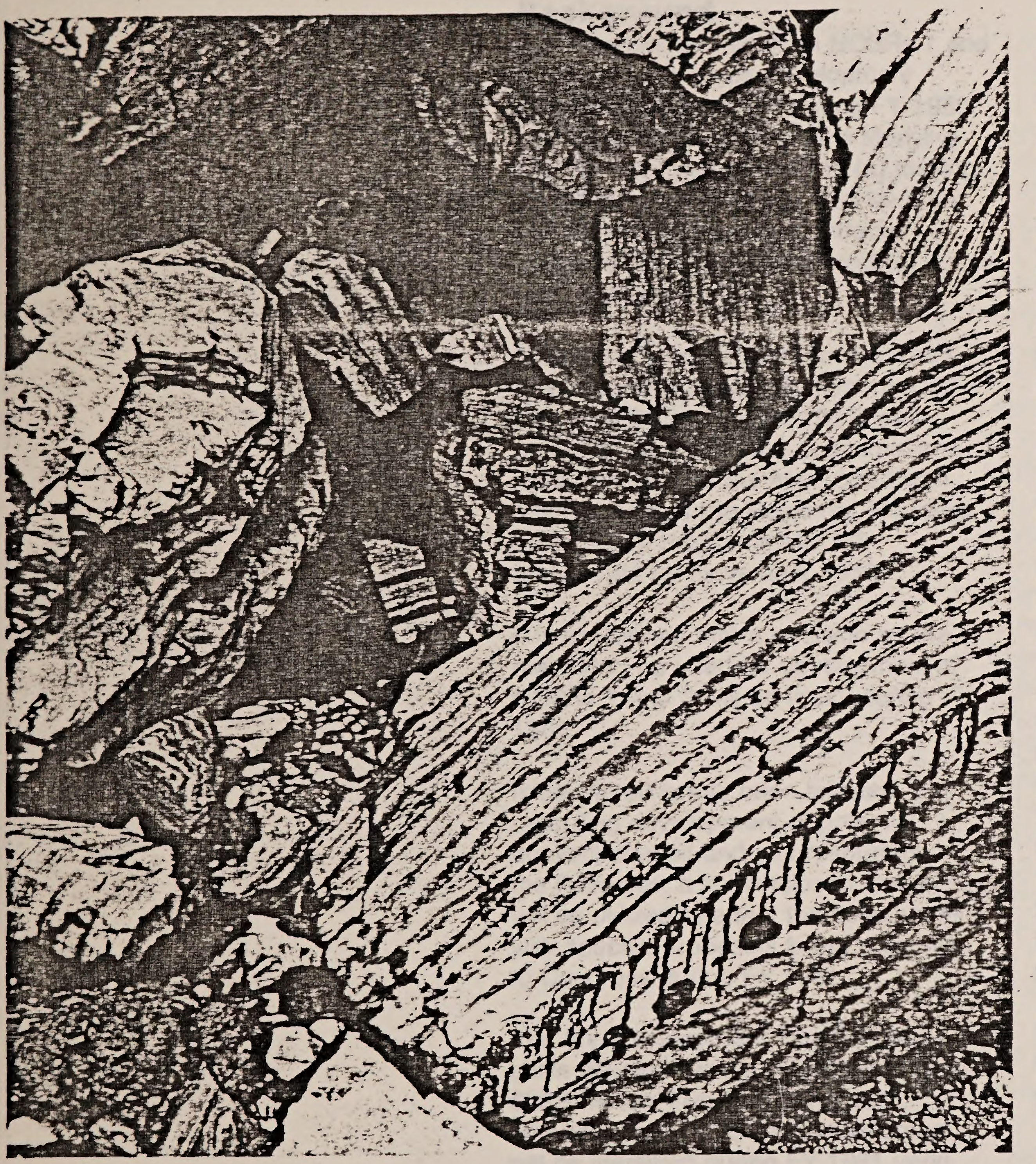
### Previous Development and Exploration Activities (Through FY 1979)

Resource data gathering has been completed on the NOSRs through corehole drilling. The Bureau of Mines drilled 14 coreholes on NOSR 1 during the period 1945 to 1952 and 18 holes were drilled from 1953 to 1954 on NOSR 2. Ten additional coreholes have been drilled on NOSR 1 in the period 1977 to 1978 as part of the current NOSR Pre-Development Program.

The multi-year Pre-Development Program for NOSRs 1 and 3 was submitted to the House and Senate Armed Services Committees for review in January 1977. Approval was received in March 1977. The Program is designed to assess the resources on NOSRs 1 and 3 and screen the most suitable development technologies. A key effort is to define the environmental (biological, meteorological, and hydrological) characteristics of the NOSRs, assess potential mitigation measures. This Program does not involve any development, but is intended to assess the developmental potential of the NOSRs. This data and analysis will be compiled in a NOSR Master Development Plan. A companion plan for NOSR 2 was completed in September 1977 and set-aside for future use.

The Pre-Development Program provides the Department of Energy with information concerning the optimum use of the NOSRs in pursuing its overall oil shale industrialization strategy.

# Current Fiscal Year (FY 1980): Naval Oil Shale Reserves



*Oil shale*

During FY 1977, the Government began to implement the NOSR 1 and 3 Pre-Development Program with a five-year study of the surface hydrology at NOSR 1. This surface hydrology program is being conducted under an Interagency Agreement with the U.S. Geological Survey.

In addition to the oil shale quality and geomechanical property tests performed on the recovered cores, from the FY 1977 and FY 1978 corehole program, extensive hydrology tests were conducted in the core holes. This data will be used as part of the environmental baseline data gathering effort. During FY 1979 hydrologic data was collected monthly from the ten holes drilled in 77 and 78. A 50-meter (160 feet) tower was erected in the fall of 1979 to collect meteorological data for the environmental baseline data report on NOSR 1.

## Production and Reserves

Production on the NOSRs has been limited to that associated with oil shale research at the leased Anvil Points Facility on NOSR 1 and 3. This work has been accomplished by a private contractor, Development Engineering, Inc., which has a lease from DOE for the Anvil Points facilities to conduct research in oil shale. The lease was entered into in 1972 and will expire in 1982. The lessee completed a major shale oil production program for the Department of Defense in 1978, during which approximately 100,000 barrels of shale oil was produced using the Paraho direct heating process. This shale oil has been refined and tested by the Department of Defense.

No production has occurred at NOSR 2.

In place reserves of 15 gallon per ton oil shale are estimated to be over 18 billion barrels for NOSR 1 and 3.8 billion barrels for NOSR 2. Conventionally recoverable shale oil at NOSR 1 is estimated to be approximately 2.5 billion barrels. No estimate of the recoverable reserves at NOSR 2 has been made.

The present Pre-Development Program will provide additional information on these reserves and thus allow for a refinement of the total oil shale resource figures as well as provide data on the quality and quantity of other minerals of interest.

# Current Fiscal Year (FY 1980): Naval Oil Shale Reserves

## Background

Pre-Development work on NOSRs 1 and 3 regarding oil shale development continued on schedule during FY 1980. The Department of Energy is studying four development scenarios: (a) leasing; (b) Government/industry joint venture; (c) Government owned contractor operated (GOCO) venture; and (d) quasi-utility venture.

During the year a Programmatic Draft Environmental Impact Statement (DOE/EIS-0068-D, September 1980) was published analyzing the economic and environmental issues associated with development of the Reserves. Hearings on the Draft Programmatic EIS areplanned for November 1980.

It is envisioned that a decision on the method to be used for development of NOSRs 1 and 3 will be made during FY 1981.

Initial planning has been initiated regarding development of potential conventional oil and gas resources on the Reserves. It is envisioned that leasing will be utilized to effect the development with specific proposals being presented to Congress during FY 1981.

The Pre-Development Program for oil shale development is projected to cost $26.3 million. Funds required for conventional oil and gas development will be identified during FY 1981 upon approval of the program.

## Development and Exploration

NOSRs 1 and 3 program tasks completed during FY 1980 are outlined below.

1. Environmental: Public scoping meetings were held in Grand Junction and Denver in February 1980 in preparation for the Programmatic Environmental Impact Statement, which was published in Draft form in September 1980. The Environmental Baseline Requirements for a site specific EIS were published in May 1980.

The summer field activities included hydrology, biology meterology and air quality measurements. The aquifiers identified in previous tests were tested individually by pump and injection tests. Biological inventories were performed for birds, mammals, fish and vegetation. The baseline Air Quality Monitoring Parameters were recorded by the TRW Air Quality Trailer.

2. Engineering: The Long Range Utilization Study was published in September 1980 in three parts: The geologic hazards study; an analysis of the mining hazards for NOSR 1 in which mine access, surface plant layouts, dam site, and shale disposal sites were identified. The Draft Conceptual Design of Shale Oil Production Systems for NOSR 1 was published in August 1980.

Figure 27.
NOSR Program
($ millions)

| | ORIGINAL Oil and Gas | ORIGINAL Oil Shale | CURRENT Oil and Gas | CURRENT Oil Shale |
|---|---|---|---|---|
| NOSR 1 and 3 | 7.4 | 28.4 | 0 | 26.3 |
| NOSR 2 | 4.5 | 29.6 | 3.0 | 0 |
| Subtotal | 11.9 | 58.0 | 3.0 | 26.3 |
| Program Total | 69.9 | | 29.3 | |

## Production and Reserves

There has been no significant production from the leased, Anvil Points Facility located on NOSR 3 during FY 1980. No production has occurred at NOSR 1 or NOSR 2. The reserves of shale oil have remained untapped.

## Revenues and Expenditures

DOE does not realize any revenue during the execution of the NOSR oil shale Pre-Development Program. The total cost of the program for NOSR 1 and 3 is estimated to be $26.3 million through FY 1984. This is within the industry accepted range of costs to complete the resource assessment, environmental, socio-economic and preliminary engineering work needed on a site before commercial scale development can proceed. Actual expenditures for the NOSR Program during FY 1980 were $3.9 million.

# Current Fiscal Year (FY 1980): Naval Oil Shale Reserves

**Legal Issues**
Water Rights for the Naval Oil Shale Reserves in Colorado. The Executive Orders which set aside the NOSRs failed to specifically provide water rights for development of the Reserves. Recent U.S. Supreme Court decisions have affirmed a federal reserved right doctrine but have held that the Federal Government must proceed through State courts to perfect these water rights. These decisions have also required that the water claimed be appurtenant to the Federal reservation, a serious obstacle to be overcome if water from the Colorado River is to be used on the NOSRs. The United States is currently pursuing rights for the National Forests in the Colorado Water Courts. **In the Matter of the Application For Water Rights of the United States of America, et al.** The courts have expressed a willingness to entertain the matter of a water right for the NOSRs at the conclusion of that case.

In cooperation with the U.S. Geological Survey, DOE and the MSSE Contractor have been gathering and analyzing data on surface and ground water on the NOSRs. Technological advances in the retorting of oil shale have resulted in reduced water requirements. It is hoped that these technological developments and the availability of water on the NOSRs will provide a solution to this vexing problem.

At the request of R. D. Langenkamp, Deputy Assistant Secretary, Resource Development and Operations, DOE, and Anvil Points fact-finding committee was formed and met at the Anvil Points facility August 4-5, 1980, with the Director, Naval Petroleum and Oil Shale Reserves in Colorado, Utah and Wyoming as Chairman. The purpose of this Committee was to review, inconjunction with other segments of DOE, the current use of these facilities and to make recommendations regarding a proposed course of action for the present and future use of Anvil Points.

# Paraho Development: From Anvil Points to Paraho-Ute

Paraho Development Corp. is currently completing final designs for its "Paraho-Ute" oil shale facility that, if completed on schedule, will be the first commercial shale oil facility in the US, according to the company. The proposed operation, located 64 km southeast of Vernal, UT, calls for the production of 1.6 dam³/d (10 000 bbl/d) in 1984 and 4.8 dam³/d (30 000 bbl/d) by 1986.

Paraho utilizes a surface retorting technique that was first demonstrated in the mid-1970s at the government-owned Anvil Points oil shale facility near Rifle, CO. During a three-year, industry-sponsored, $10 million demonstration program, two Paraho oil shale retorts were used: a 0.8-m inside diameter pilot plant with a nominal capacity of about 3.2 m³/d (20 bbl/d), and a larger unit having a 32 m³/d (200 bbl/d) capacity. These units, like other Paraho retorts, process oil shale sized from 6 mm to −89 mm. Crushed shale is fed into the top of the retort and flows downward by gravity as a continuous moving bed.

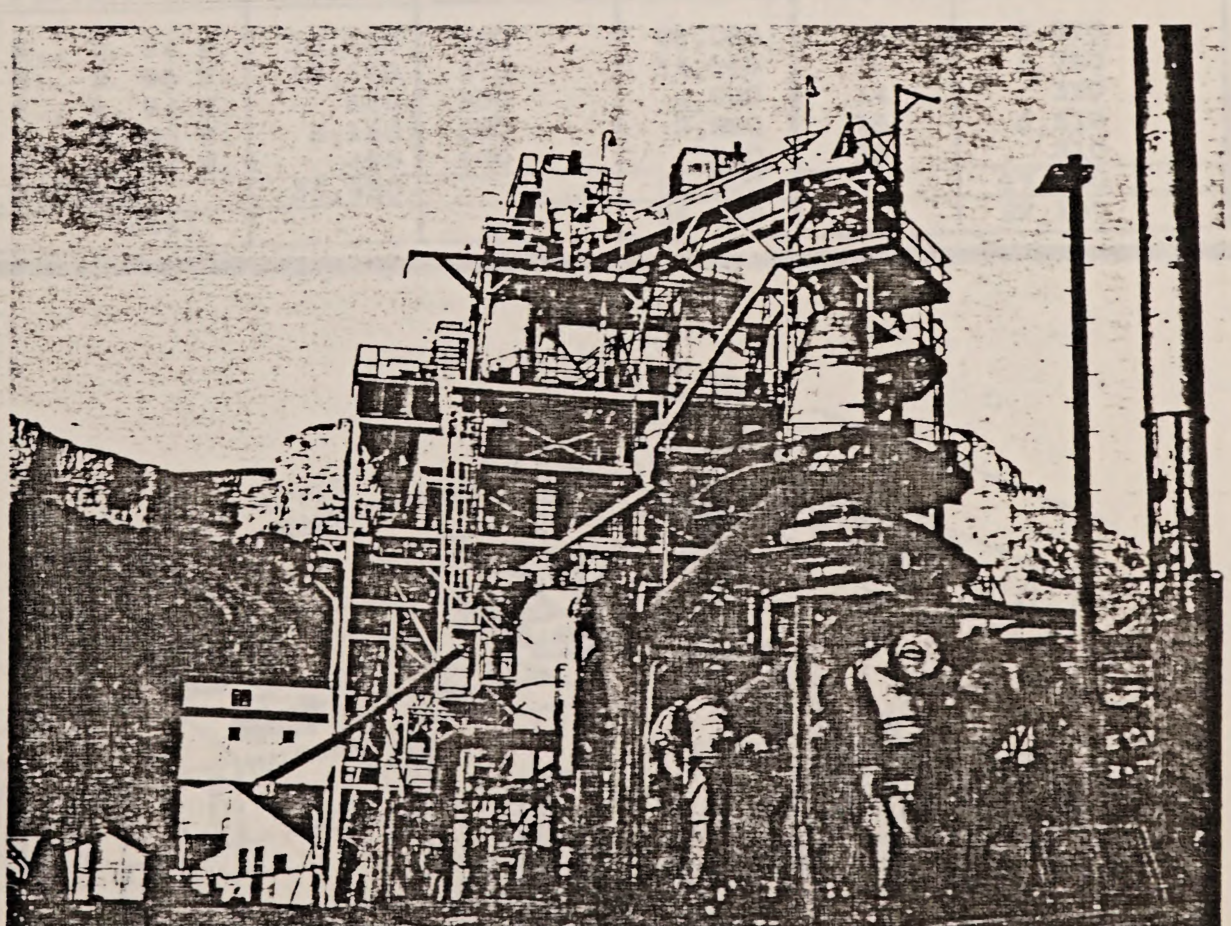
As the shale moves downward in the retort, it passes through four zones: a mist formation zone; a retorting zone; a combustion zone; and a retorted shale cooling zone.

Following the demonstration program, DOE and the US Navy's Office of Naval Research selected Paraho for a large-scale production and shipping operation, which also involved refining the recovered shale oil at a Standard Oil Co. of Ohio refinery. Over 14 dam³ (88 000 bbl) of shale oil were successfully refined into fuel products meeting strict military specifications.

In addition to Paraho's success in producing relatively large amounts of crude shale oil in long, continuous operations, the Paraho process has met environmental standards. The company says that there are no fugitive dust problems, no expansion or "popcorn" effects with retorted shale, and, perhaps most importantly, no water problems. Paraho says its retort requires no water. However, on a commercial basis, nearly one-half barrel of water will be required for every barrel of oil produced.

The most recent Paraho venture, the Paraho-Ute oil shale facility, began when DOE selected Paraho for an 18-month program to design and demonstrate a commercial, full-size oil shale retort or module. The module will consist of a mine, retort, and all supporting equipment. DOE and 12 industry sponsors* will share the cost of the $9-million program, and Paraho will manage the operation.

Last fall, DOE awarded Paraho a $3.2-million grant for preparing a commercial feasibility study covering the expansion of the single module retort to a commercial facility producing over 4.7 dam³/d (30 000 bbl/d). Successful completion of the module design and engineering effort and the commercial feasibility study could lead to construction and operation of a Paraho retort as early as 1984. The company is presently siting both studies on a state oil shale lease in Utah. Paraho said that its work, along with others, should lead to the development of an oil shale industry that may produce as much as 477 dam³/d (3 000 000 bbl/d).□



Paraho's semiworks retort (at right) has produced over 17.5 dam³ (110 000 bbl) of crude shale oil.

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# NAVAL OIL SHALE RESERVE, ANVIL POINTS, PARAHO OPERATION

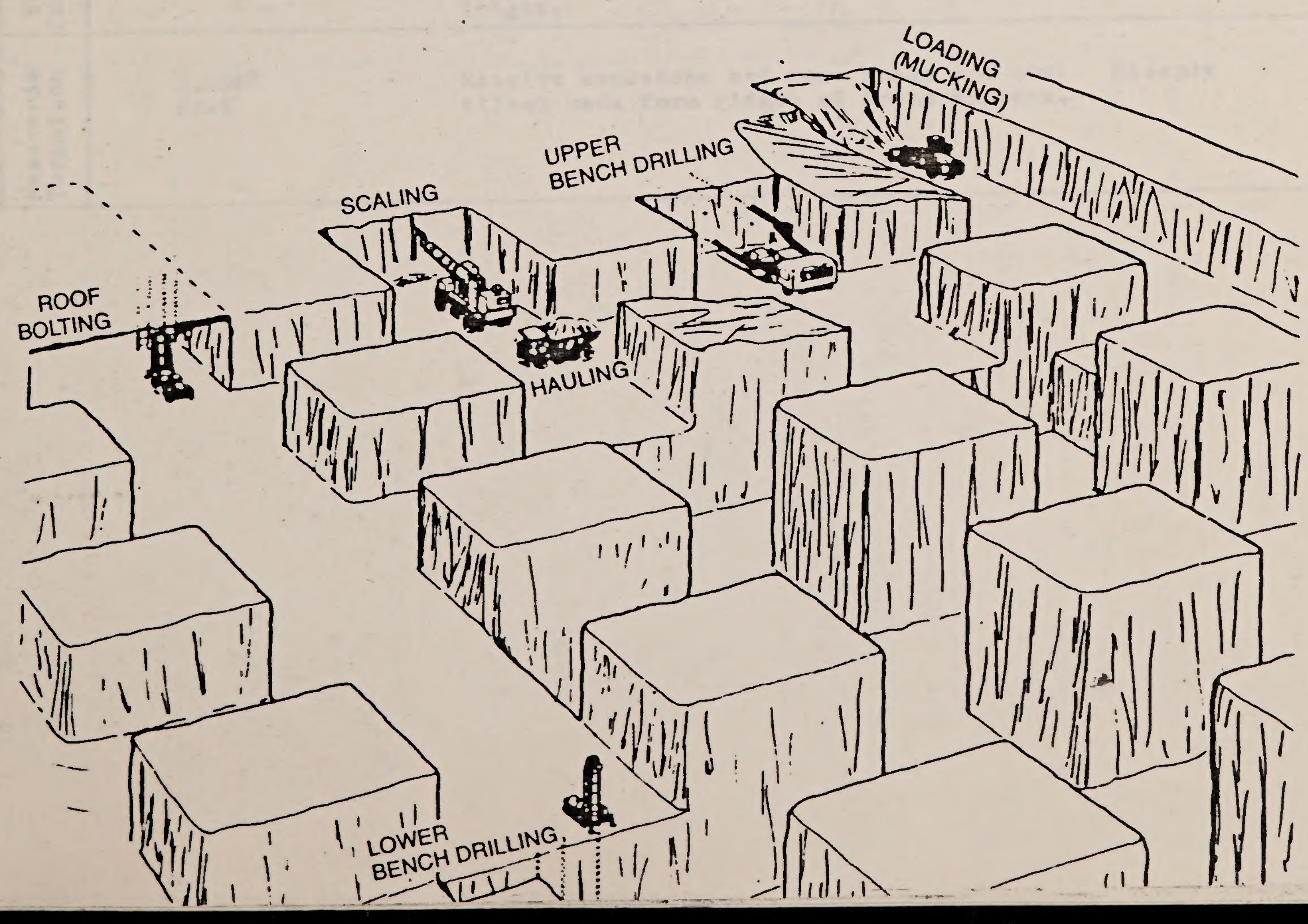
(36,500 acres)

| | |
|---|---|
| > 15 gal/ton | 18 billion barrels |
| > 25 gal/ton | 5 billion barrels |
| > 30 gal/ton | 4 billion barrels |
| Overburden to Mahogany | 0-1,000 feet |
| Mahogany Zone | 120 feet 25 gpt |

Estimate of tonnage of oil shale and estimate of amount of oil yield in the lower, middle, and upper oil-shale zones in the Naval Reserves 1 and 3

Area of Naval Reserves 1 and 3

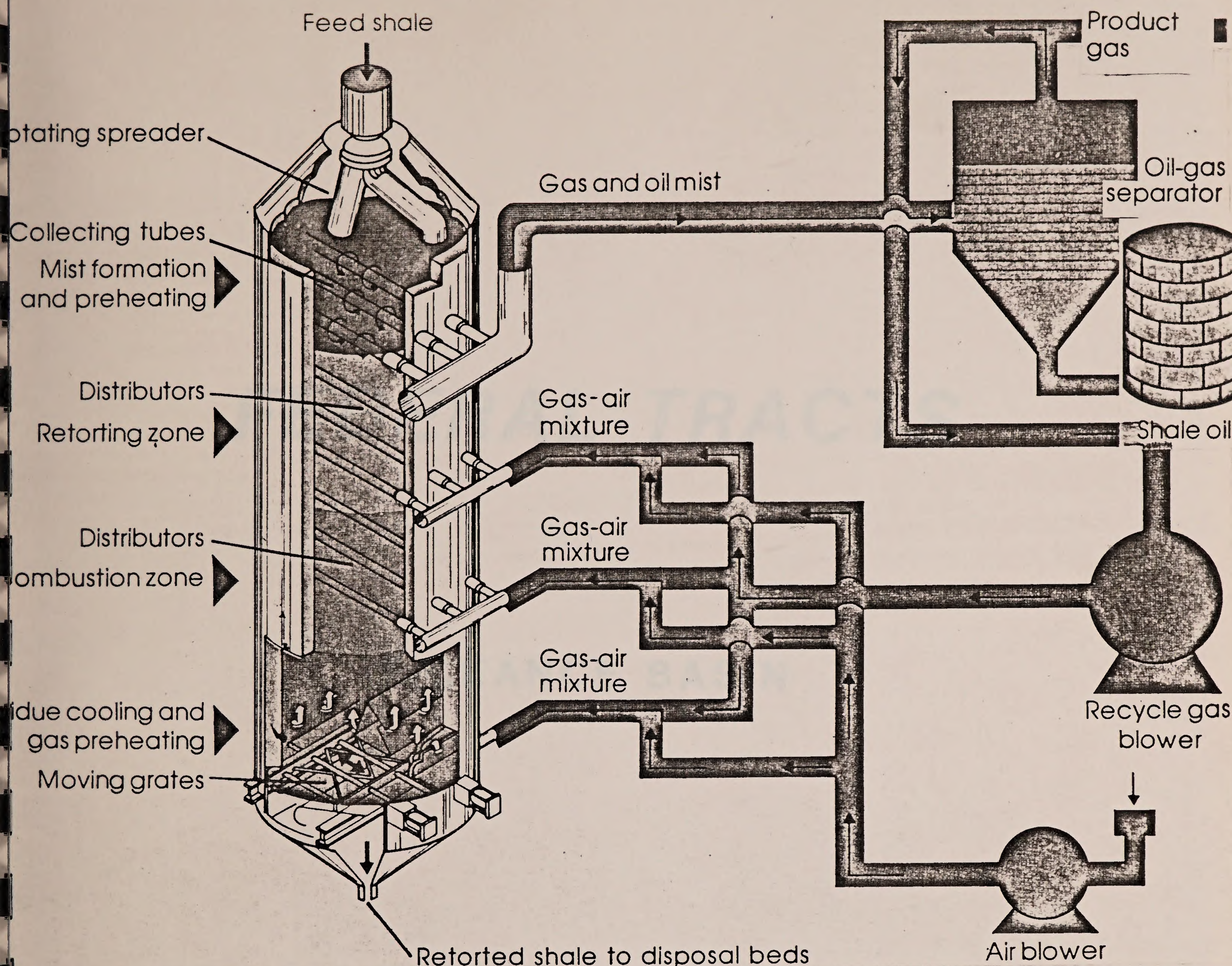
| Zone | Tract | Area in acres | Average thickness in feet | Short tons in millions | Estimated oil yield: Gallons per ton | Estimated oil yield: Total barrels (42 gals.) in millions |
|---|---|---|---|---|---|---|
| Lower oil-shale zone | T. 5 S., R. 95 W. | 5,920 | 200 | 3,430 | 10 | 820 |
| | T. 6 S., R. 95 W. | 620 | 200 | 360 | 10 | 86 |
| | T. 6 S., R. 96 W. | 409 | 200 | 240 | 10 | 57 |
| | Subtotal | 6,949 | | 4,030 | | 963 |
| Middle oil-shale zone | T. 5 S., R. 94 W. | 5,130 | 120 | 1,790 | 10 | 430 |
| | T. 5 S., R. 95 W. | 10,390 | 225 | 6,780 | 15 | 2,420 |
| | T. 6 S., R. 95 W. | 3,265 | 120 | 1,140 | 10 | 270 |
| | T. 6 S., R. 96 W. | 490 | 250 | 360 | 11 | 94 |
| | Subtotal | 19,275 | | 10,070 | | 3,214 |
| Upper oil-shale zone | T. 5 S., R. 94 W. | 16,350 | 550 | 26,080 | 13 | 8,070 |
| | T. 5 S., R. 95 W. | 10,340 | 475 | 14,240 | 17 | 5,760 |
| | T. 6 S., R. 94 W. | 650 | 530 | 1,000 | 14 | 330 |
| | T. 6 S., R. 95 W. | 6,150 | 550 | 9,820 | 15 | 3,510 |
| | T. 6 S., R. 96 W. | 490 | 600 | 850 | 15 | 310 |
| | Subtotal | 33,980 | | 51,990 | | 17,980 |
| | Total | | | 66,090 | | 22,157 |



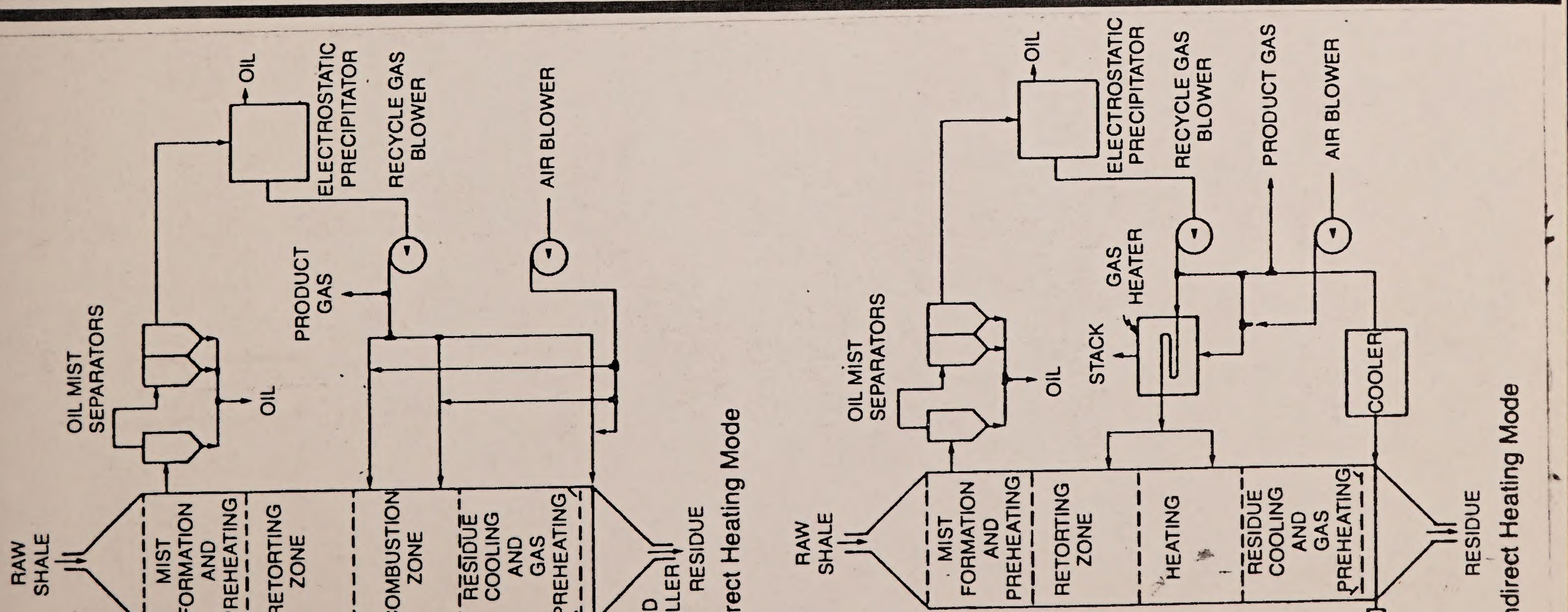
Generalized description of the rocks exposed in or near Naval Oil Shale Reserves 1 and 3

| System | Series | Formation | Member | Thickness of unit | Character of rock |
|---|---|---|---|---|---|
| Tertiary | Eocene | Green River formation | Evacuation Creek member | 1,000± feet | Fine, gray and brown sandstone with interbedded gray marlstone and a few thin beds of oil shale. Upper 200 feet contains massive sandstones that may belong in the lower part of the Bridger formation. Member weathers to rounded slopes. |
| Tertiary | Eocene | Green River formation | Parachute Creek member | 700-1,230 feet | Black, brown, and gray marlstone including principal oil-shale units. Few thin key beds of altered tuff, analcite, and chert. Tongues of sandstone near base. Member weathers to light-gray and light-brown cliffs. |
| Tertiary | Eocene | Green River formation | Garden Gulch member | 630-720 feet | Gray marlstone with some gray and brown shale and a few thin oil shales. Weathers to smooth steep slopes. |
| Tertiary | Eocene | Green River formation | Douglas Creek member | 430-470 feet | Brown sandstone and gray shale, and a few thin beds of oolites and algae beds. Weathers to buff slopes and low cliffs. |
| Tertiary | Eocene | Green River formation | Lower sandy member | 1,100-1,600 feet | Brown and gray sandstone and gray shale, and a little gray marlstone near top. Unit interfingers with Douglas Creek Garden Gulch, and lower part of Parachute Creek members. Weathers to slopes and low cliffs. |
| Tertiary | Eocene | Wasatch formation | | 4,000-5,200 feet | Red, drab, gray, and maroon shale, and irregularly distributed lenticular sandstones. Weathers to varicolored slopes with discontinuous sandstone ledges. |
| Cretaceous | Upper Cretaceous | Mesaverde formation | | 5,000± feet | Massive sandstone and some shale and coal. Steeply tilted beds form ridges of Grand Hogback. |

# PARAHO RETORT




The Paraho Oil Shale Retorting System




A. Direct Heating Mode

B. Indirect Heating Mode

SOURCE: C. C. Shih, et al., *Technological Overview Reports for Eight Shale O[il] Recovery Processes*, report prepared for the U.S. Environmental Protection Agency by TRW under contract No. EPA-600/7-79-075, March 1979, pp. 20 and 23.

# FEDERAL TRACTS

## PICEANCE BASIN


U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849
PROTOTYPE TRACT C-a
OCT 31 1980
AREA OIL SHALE OFFICE
1879 CENTENNIAL 1979
U.S. GEOLOGICAL SURVEY

# The Rio Blanco Project at Tract C-a

In 1974, Gulf Oil Corp. and Standard Oil Co. of Indiana leased Federal Prototype Oil Shale Tract C-a from the Department of Interior for $210.3 million. C-a was the first federal tract to be leased as part of Interior's program to test environmental and economic feasibility of oil shale development. Gulf and Standard later formed the Rio Blanco Oil Shale Co., a 50-50 general partnership, to develop the 21 km² tract. Cost of the C-a project is estimated at $1 billion. By fall 1980, RBOSC expenditures, including lease payments, totaled about $250 million.

Originally, Tract C-a was to be developed as an open-pit mine. However, Interior was unable to make additional federal land available for off-tract disposal of processed shale and overburden. There were also air quality problems and other constraints with the pit mining concept. After a one-year suspension of operations, RBOSC decided to develop the tract by underground modified in situ (MIS) methods. In February 1979, the company purchased Occidental Oil Corp.'s MIS technology.

Tract C-a is located in Rio Blanco County at the head of Yellow Creek on the western edge of the Piceance Creek Basin. The tract has estimated shale oil reserves of 1.4 km³ (9 billion bbl), depending on the extraction methods used. Open-pit production could produce more than 795 hm³ (5 billion bbl) of oil; MIS, about 318 hm³ (2 billion bbl). In the commercial phase, current plans call for shale oil to be transported to existing Gulf or Standard refineries.

Tract C-a is a one-level operating mine with driftwork essentially complete for three underground demonstration retorts. A conventionally sunk production shaft is 4.6 m in diameter and 298 m deep. The 3-m-diam vent shaft is 76 m away. There is also a 3-m-diam service shaft about 137 m from the production shaft.

In addition to the MIS program, RBOSC is planning to demonstrate surface retorting technology. The company has an agreement with Lurgi Co. of Germany for its Lurgi-Ruhrgas technology. RBOSC hopes to start construction of a 4-kt surface retort on or adjacent to Tract C-a in spring 1981. The retort, capable of processing about 320 m³/d (2000 bbl/d), is scheduled to go onstream in 1983. RBOSC thinks the surface retort is about half the size needed for a commercial production unit. The surface retort will process oil shale removed and brought to the surface prior to burning the underground retorts. Due to the greater efficiency of surface retorting, it will produce about as much shale oil as the underground retort.

In October 1980, RBOSC ignited the first of three demonstration MIS retorts. The burn was scheduled to last nine weeks. The demonstration retort—about 9 m square and 51 m high—was ignited at the top, some 204 m below the earth's surface. A downhole burner was lowered from the surface through a 300-mm vertical casing to the retort. A mix of natural gas and air was used for ignition. Some 160–320 m³ (1000–2000 bbl) of oil will likely be recovered from the first retort.

This was the first burn in the company's $140-million program to demonstrate commercial feasibility of the MIS technology. Two additional burns—each about 122 m tall—are planned by the end of 1981. About 6.4 dam³ (40 000 bbl) of oil will be produced from all three demonstration retorts. The oil will be used for research and testing purposes. □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# F E D E R A L  O I L  S H A L E  T R A C T  C-A

## RIO BLANCO OIL SHALE COMPANY

### Development Scheme

Tract C-a is under lease to the Rio Blanco Oil Shale Company (a general partnership of Gulf Oil and Standard of Indiana). Approved DDP's call for development in essentially a two-phased approach using modified in-situ (MIS) methods adapted for moderately deep overburden (less than 1,000 feet (305 m)). The initial or Modular Development Phase (MDP) will result in construction and operation of three MIS retorts increasing from 166 feet (51 m) in height with 30 by 30 foot (4 x 9 m) cross section to near commercial size of 400 feet (122 m) high with 60 by 150 foot (18 by 46 m) in plan dimensions, and a temporary retort off-gas and product oil treatment plant . Additional retorts may be rubblized and burned during the MDP if additional data is needed. Commercial phase retorts will be approximately 700 feet (214 m) tall and up to 200 feet (61 m) in cross section.

Individual MIS retorts will be developed using bore holes drilled from the surface for emplacement of rubblizing explosives from bottom to top of the planned MIS retort chamber. Explosives will be detonated in stages from the bottom upward. After initial blasts, shale rubble equal to approximately 40 percent of the volume of the retort chamber will be drawn out the chamber bottom through the mine production level, hoisted to the surface by a skip operating in the Service/Production shaft and stockpiled for probable future above ground retorting. Once rubble equal to the required void volume is withdrawn from the bottom of the retort chamber, remaining oil shale will be explosively broken to fill all but a narrow attic at the top of the chamber. The boreholes will then be used for lowering igniters into the top of the retort chamber and to supply air and steam to sustain and control the retorting process.

The northern portion of the tract will probably be developed first followed by the southern half with barrier pillars left along the complex NW-SE trending fault system that essentially divides the tract in two. Life of operations will be from 20 to 40 years depending on whether both northern and southern portions of the tract are retorted. MIS operations with surface retorting could recover 1.7 to 2.5 billion barrels ($2.7 \times 10^8 m^3$ to $4.0 \times 10^8 m^3$) or 20 to 30 percent of the inplace shale oil resource over the breadth of retorted zone. The development scheme is conceptually depicted in figures, except the intermediate mine levels in Figure 11 will not be developed.

Due to moderately deep overburden, Tract C-a could be developed by open pit mining methods. This would nearly double the estimated resource recovery to 58 percent of the inplace shale oil over the depth of the pit. Such an approach was originally proposed by the Tract C-a lessees, but was abandoned due to economic reasons and the need for off-tract sites for initial overburden deposition and surface retorts. The Department of Interior, however, does not currently have authority to grant the lessees off-tract land-use.

During 1979, production and ventilation shafts were sunk, and the lower most (production) mine level was advanced toward the site of the first MDP retort (Retort 0). Construction of a temporary retort off-gas treatment plant and associated water handling and oil storage facilities were also nearly completed in 1979. Work was started on expansion of mine and well dewatering systems to essentially "dry up" the MDP retort area.

Production from Retort 0 is anticipated by late 1980. Maximum production rate during the MDP is estimated to be 750 bbl/day (1.4 $dm^3/s$) or 50,000 barrels (8 x $10^3$ $m^3$) total. If each succeeding scale-up of MDP retort size and anticipated production rate is successful, and if market conditions appear favorable, the lessees may elect to expand operations to commercial scale of 76,000 bbl/day (140 $dm^3/s$) by the late 1980's using a combination of MIS and surface retorting.

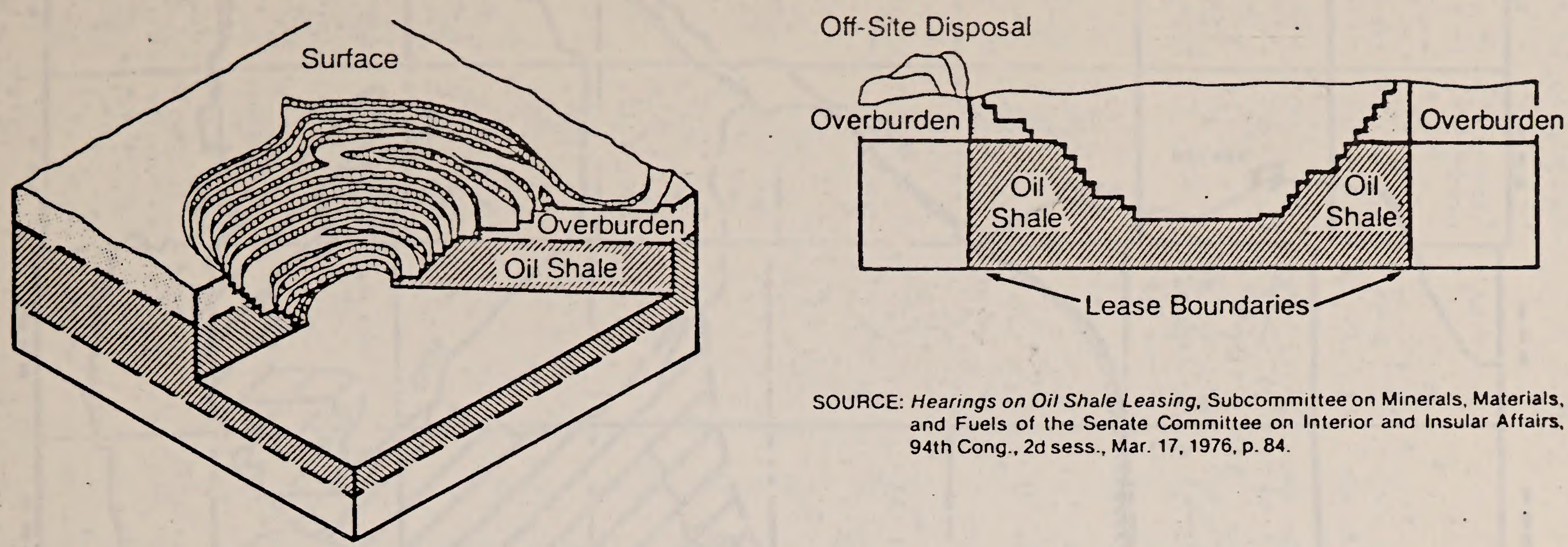
C-a
(5,090 acres)

| | | |
|---|---|---|
| >15 gal/ton | 8 billion barrels | |
| >25 gal/ton | 6 billion barrels | |
| >30 gal/ton | 4 billion barrels | |
| Overburden to Mahogany | 100-800 feet | |
| Mahogany Zone | 130 feet | 25 gpt |

Tract C-a is located in what has been identified as the prime open-pit mining area of the Piceance Basin. This area is 7% of that part of the basin underlain by >15 gpt oil shale. There are an estimated 100 billion barrels recoverable by open-pit methods within the area, having a vertical stripping ratio of <1:1.

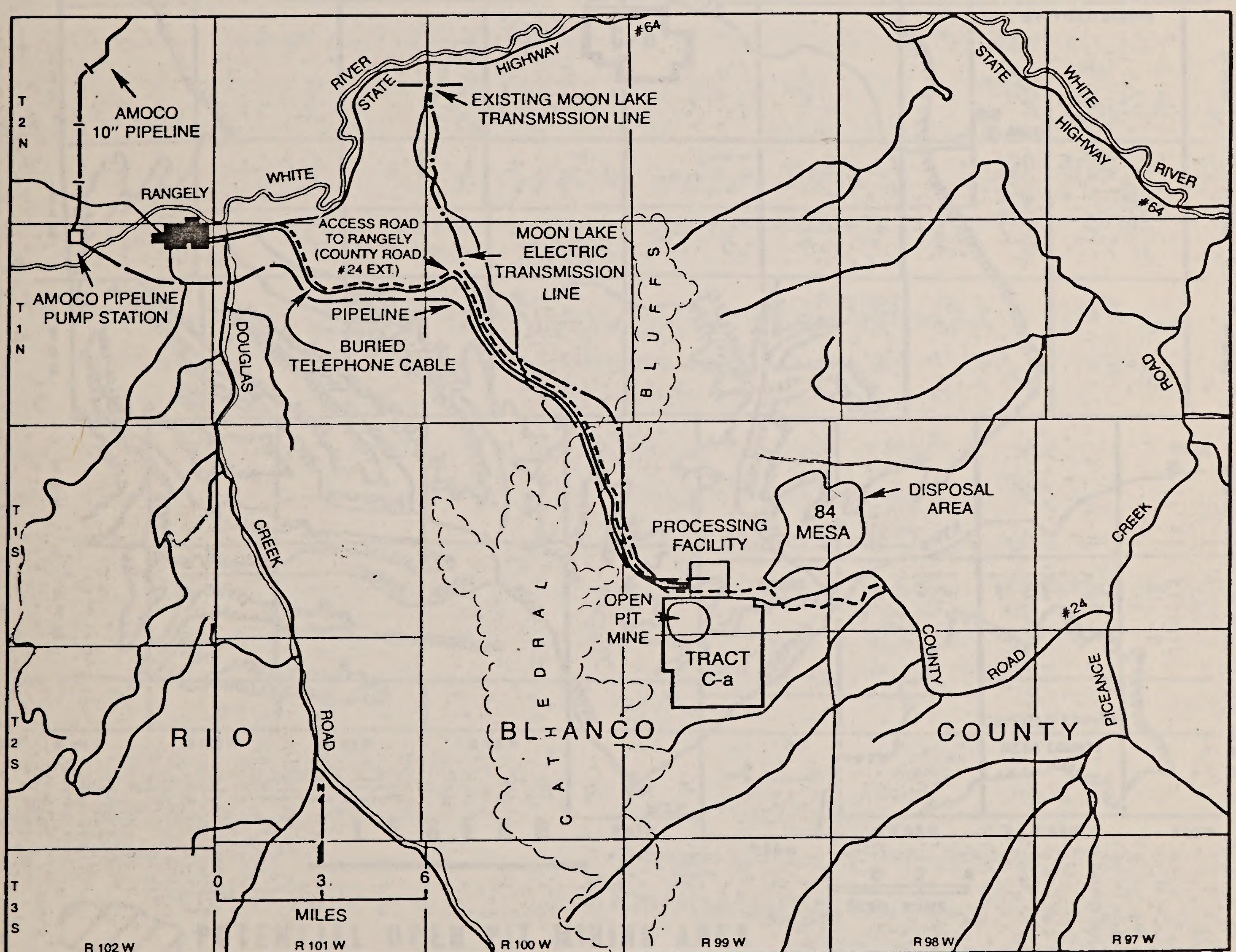
Open-pit mining on tract C-a could recover about 5.2 billion barrels of oil with a recovery factor of 58%. Room-and-pillar mining could recover about 1.1 billion barrels at a recovery of 12%. Modified in-situ with surface retorting of the development rock might recover 1.7-2.5 billion barrels at a recovery of 20-30%.

Figure 6.—Open-Pit Mining Concept Featuring Offtract Waste Disposal

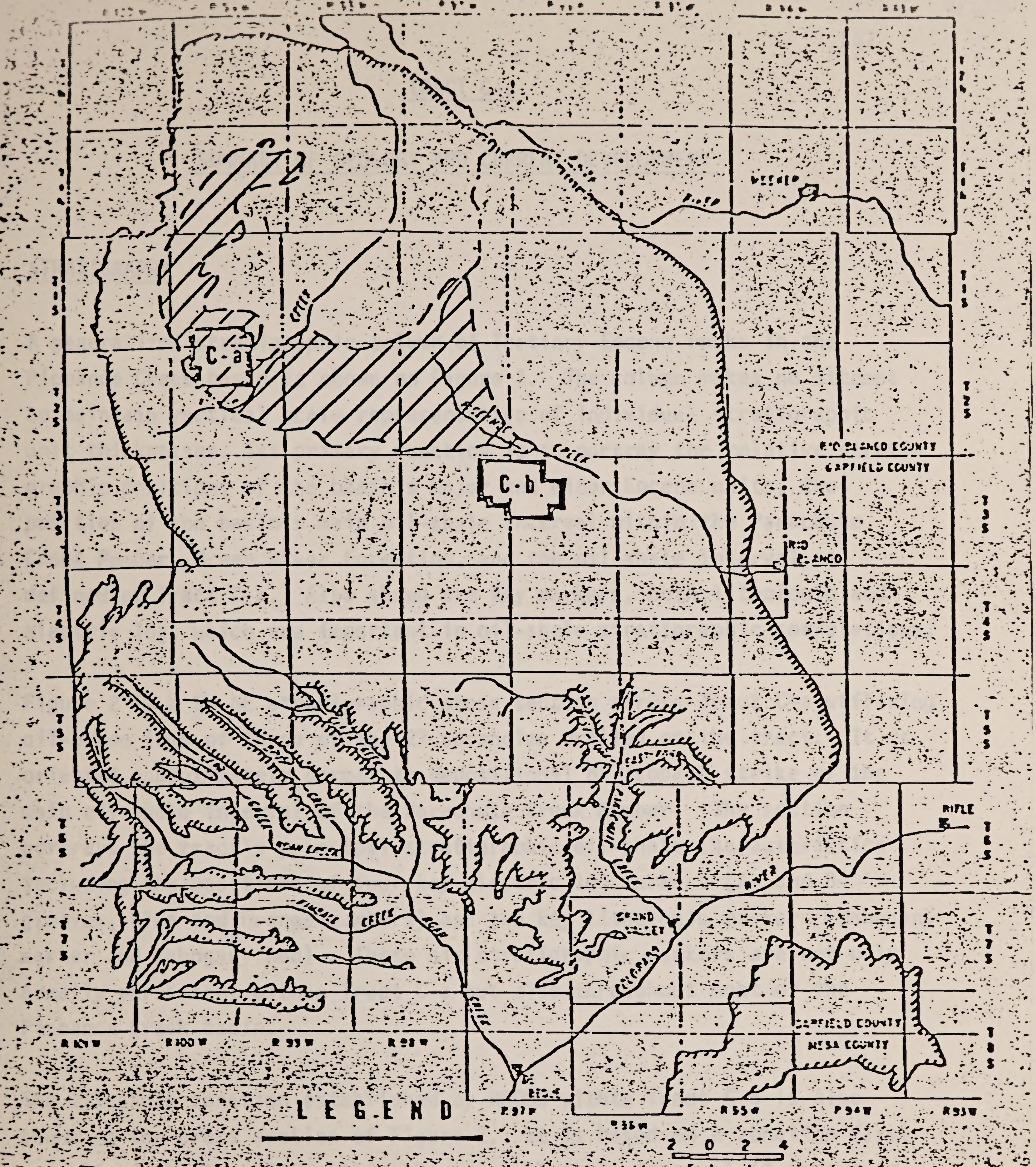



SOURCE: *Hearings on Oil Shale Leasing*, Subcommittee on Minerals, Materials, and Fuels of the Senate Committee on Interior and Insular Affairs, 94th Cong., 2d sess., Mar. 17, 1976, p. 84.

Figure 7.—Original Development Plan for Colorado Tract C-a




SOURCE: Rio Blanco Oil Shale Project, *Detailed Development Plan Tract C-a*, Gulf Oil Corp. and Standard Oil Co. (Indiana), March 1976, p. I-3.




LEGEND

POTENTIAL OPEN PIT MINING AREA

APPROXIMATE OUTLINE OF GREEN RIVER FORMATION

OUTLINE OF GREEN RIVER FORMATION FROM U.S.B.M. RI-7357

POTENTIAL OPEN PIT MINING RESERVE
NORTHERN PICEANCE CREEK BASIN

RBOSC 6/5/80
EAZ

# TRACT C-a

## SUMMARY OF GEOLOGY AND CURRENT DEVELOPMENT

### STRATIGRAPHY

A generalized stratigraphic column of Tertiary Eocene rocks in the Piceance Creek basin is shown on Figure 1. The column makes no attempt to maintain vertical scale representative of individual stratigraphic unit thicknesses. Its primary function is to portray the relative stratigraphic positions of the basin's major and minor Eocene units, the position of the basin's main oil-shale interval within the Parachute Creek Member, Green River Formation, and the oil-shale interval as defined at Tract C-a. Also shown are key markers, both lithologic and electric log, which are important in oil-shale stratigraphic correlations.

Figure 2 is a SW-NE stratigraphic cross section across Tract C-a utilizing oil-grade logs of three of the 27 coreholes drilled on the tract. It is oriented approximately normal to depositional or isopach strike of the main oil-shale interval of the Parachute Creek Member. The section portrays the tract's principal stratigraphic oil-shale characteristics including the positions of four key electric log markers (A- and B-grooves, Blue and Orange markers) and two key lithologic markers (Mahogany marker and Mahogany bed). These six stratigraphic markers are not only areally persistent within Tract C-a but also throughout most of the Piceance Creek basin.

The oil-shale zonation established by RBOSC within Tract C-a is also shown on the cross section of Figure 2. It is based on a zonation first established by the USGS within the main oil-shale interval (A-groove to Blue marker) on a regional scale. The Rio Blanco zonation expands that of the USGS stratigraphically above and below the main oil-shale interval resulting in 19 discrete oil-shale zones; 9 relatively rich and 10 relatively lean. These zones are designated L-00 through L-8 in stratigraphically ascending order with the alternating rich and lean zones

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identified "R" and "L", respectively. However, the Mahogany and A-groove (AG) zonal nomenclature is retained because of their well-established usage.

STRUCTURE

The regional setting of Tract C-a within the Piceance Creek basin is shown on Figure 3. The tract (approx. 5,100 ac.) is situated on the basin's west flank where regional dip is basinward generally to the east and northeast.

Figure 4 portrays Tract C-a structure based on photogeologic mapping, surface geologic mapping and subsurface corehole and well control. The horizon mapped is the middle of the A-groove, the key electric log marker immediately above the Mahogany zone shown on the cross section of Figure 2 (corehole CE 702 log). In general, beds within the tract strike to the north and northwest and dip gently basinward to the east and northeast at rates of 200-350' per mile (2-4°) except where locally disturbed by folds and faults.

The structural framework of Tract C-a is dominated by the low-relief southeast plunging Sulfur Creek anticlinal nose and three en echelon graben (fault systems) on its northeast flank. The trends of these graben are all parallel or subparallel to the Sulfur Creek anticlinal axis. The northernmost graben is the most structurally complex of the three with up to 237' of displacement mapped at the surface where it crosses Corral Gulch. Several minor folds and subsidiary faults complete the structural framework. All faults thus far mapped are high angle to vertical.

RESOURCES

A total of 27 coreholes have been drilled on Tract C-a to define its resources. Combined, these coreholes have yielded some 33,000' or 6.25 miles of core.

Shale Oil: The entire oil-shale interval underlying Tract C-a (L-8 zone through L-00 zone of Figure 2) increases in both thickness and grade across the tract basinward to the northeast. It averages 1,235' in thickness and 20.5 G/T oil in grade, and contains 9.1 billion barrels of shale oil in place. Overburden atop this interval averages 340' in thickness.

To put that shale grade into some perspective, a block of 20.5 G/T shale the size of an average office desk weighs 3.2 tons and contains about 1.6 barrels of shale oil. In more familiar oil-field terminology, 20.5 G/T is equivalent to about 1,500 barrels of oil per acre-foot.

Of the total in-place resource of 9.1 billion barrels, about 80% or 7.3 billion barrels are contained within the main oil-shale interval (Mahogany through R-2 zones of Figure 2). This interval averages 895' in thickness and 23.2 G/T in grade with an average overburden thickness of 480'.

Recoverable shale oil at Tract C-a is highly dependent upon the method of development applied. Three methods have been considered by RBOSC; namely, open-pit mining, underground mining (multi-level, room and pillar) and modified in situ. With a total in-place resource of 9.1 billion barrels, estimated recoveries for each of the three methods are as follows:

| Method | Recoverable (Bil. Bbls.) | Recovery Factor (%) |
|---|---|---|
| Open-Pit Mining | 5.2 | 57 |
| Underground Mining | 1.1 | 12 |
| Modified In Situ (MIS) | 1.7-2.5 | 19-27 |

Tract development by open-pit mining would exploit the total oil-shale interval present and result in a pit bottoming out at the base of the L-00 zone of Figure 2. Development by underground mining would be selectively confined to several of the richer oil-shale zones shown on Figure 2.

Tract development by MIS includes surface retorting of oil shale mined out in the preparation of underground retorts. The lower recovery values listed above reflect initial development of about the upper two-thirds of the total oil-shale interval (top R-8 through base R-4 zones of Figure 2). The higher values include potential additional recoveries in a second phase of development in which the lower one-third of the total shale interval might be exploited.

Of the three methods of development considered, open-pit mining clearly would result in the greatest shale-oil recovery at Tract C-a. This was the approach submitted in RBOSC's original 1976 Detailed Development Plan (DDP). However, the plan called for off-tract lands for both the processing plant and spent-shale disposal. These lands were determined to be unavailable. MIS development of the tract offers the next best resource recovery and this is the approach now being pursued as outlined in our 1977 Revised DDP.

Dawsonite: The mineral dawsonite [$NaAl(OH)_2CO_3$], a potential source of alumina, is present within the tract's R-2 through R-5 zones (Figure 2). It occurs as microscopic crystals finely disseminated throughout the oil shale and as thin laminations along bedding planes. About 360 million tons of dawsonite are estimated present under Tract C-a containing about 125 million tons of alumina. Recoverable dawsonite is yet to be determined.

Nahcolite: The mineral nahcolite ($NaHCO_3$), a potential source of soda ash, is present within the tract in very minor amounts scattered throughout several of the oil-shale zones. It occurs as thin beds, stringers, nodules and crystal coatings on vug walls and on shale partings. Most of the nahcolite originally deposited within Tract C-a has been subsequently removed by groundwater leaching (dissolution). Its current very limited presence precludes its designation as a significant tract resource.

## DEVELOPMENT

RBOSC is currently in the Modular Development Phase (MDP) of MIS development of Tract C-a. The objectives of this phase are to gain operating

experience, improve process efficiency and define capital and operating costs for a commercial-sized operation termed the Commercial Phase.

The MDP program consists of the sequential preparation and burn of three relatively small MIS retorts, the third and largest of which is 60' x 150' x about 400' high as presently designed. The burn of the last retort in this phase is scheduled for completion in early 1982. Total shale oil to be produced from these three retorts is estimated at about 50,000 barrels.

In the Commercial Phase, somewhat larger MIS retorts are envisioned. Coupled with surface retorting of mined-out shale, production of 76,000 barrels of shale oil per day is tentatively scheduled.

In basic terms, shale-oil production by the MIS method utilizes established mining methods to develop underground chambers whose function is essentially identical to conventional surface retorts. A fraction of each chamber's total contained shale volume is first drawn (excavated) to obtain a pre-designed void volume or porosity. The chamber's remaining shale volume is then fragmented by drilling and blasting. The resulting porous rubblized shale mass within the chamber is then retorted in place.

Based on a recently completed extensive review of MIS technology, RBOSC has made substantial changes in its originally designed MDP program. Figure 5 is an isometric drawing which shows the <u>previous</u> program and its mine plan to develop and burn five relatively small MIS retorts. These retorts ranged in size from 30' x 30' x 140' high to 100' x 100' x about 400' high. An extensive mine network consisting of seven levels (A through G) was required to develop the five retorts.

The <u>current</u> MDP program is shown on the isometric drawing of Figure 6. This new program reduces the number of MIS retorts from five to three and the number of mine levels to prepare and burn them from seven to two.

In the current MDP program, the preparation and burn of the three retorts is actually accomplished from both the mine and the surface. The drawn or excavated fraction of each retort is removed via the mine's G Level. The remaining fraction is then rubblized using blastholes drilled from the surface. Retort burn is initiated by a downhole burner lowered to the top of the retort from the surface. Fluids produced from each retort are conveyed via G Level for pumping to the surface.

Sub-E Level surrounds the three MIS retorts and serves as a drainage gallery for upper aquifer groundwater. This level is positioned just below the base of the upper aquifer and longholes drilled from it upward into the aquifer are designed to dewater the entire three-retort area. The level's objective is to virtually "dry out" the retort line and prevent any upper aquifer water from flowing into the retorts to preclude their burn.

As previously described, the currently planned Commercial Phase of Tract C-a development consists of shale-oil production from both MIS retorting (underground) and surface retorting. Even if MIS retorting is successful, an efficient surface retorting method is needed to process the substantial quantities of oil shale mined out during the preparation of large-scale MIS retorts. Should MIS retorting be unsuccessful for any reason, then an efficient surface retorting process is still critical as an integral part of alternative methods of tract development (open-pit or underground mining). Optimum surface retorting is therefore critical to any commercial development of the tract.

To determine the optimum surface retorting method for use at Tract C-a, RBOSC extensively reviewed several technologies and selected the Lurgi-Ruhrgas (L-R) process as the most promising. Planning is now underway for the construction of a 4,400 T/D L-R modular demonstration retort on tract.

Lastly, the MIS method of shale-oil production on a commercial scale at Tract C-a has great potential but is recognized as risky at this point in time. Many questions related to its technical and economic feasibility require answers based on hard data. RBOSC has committed over $90 million to the current MDP program to provide those answers.

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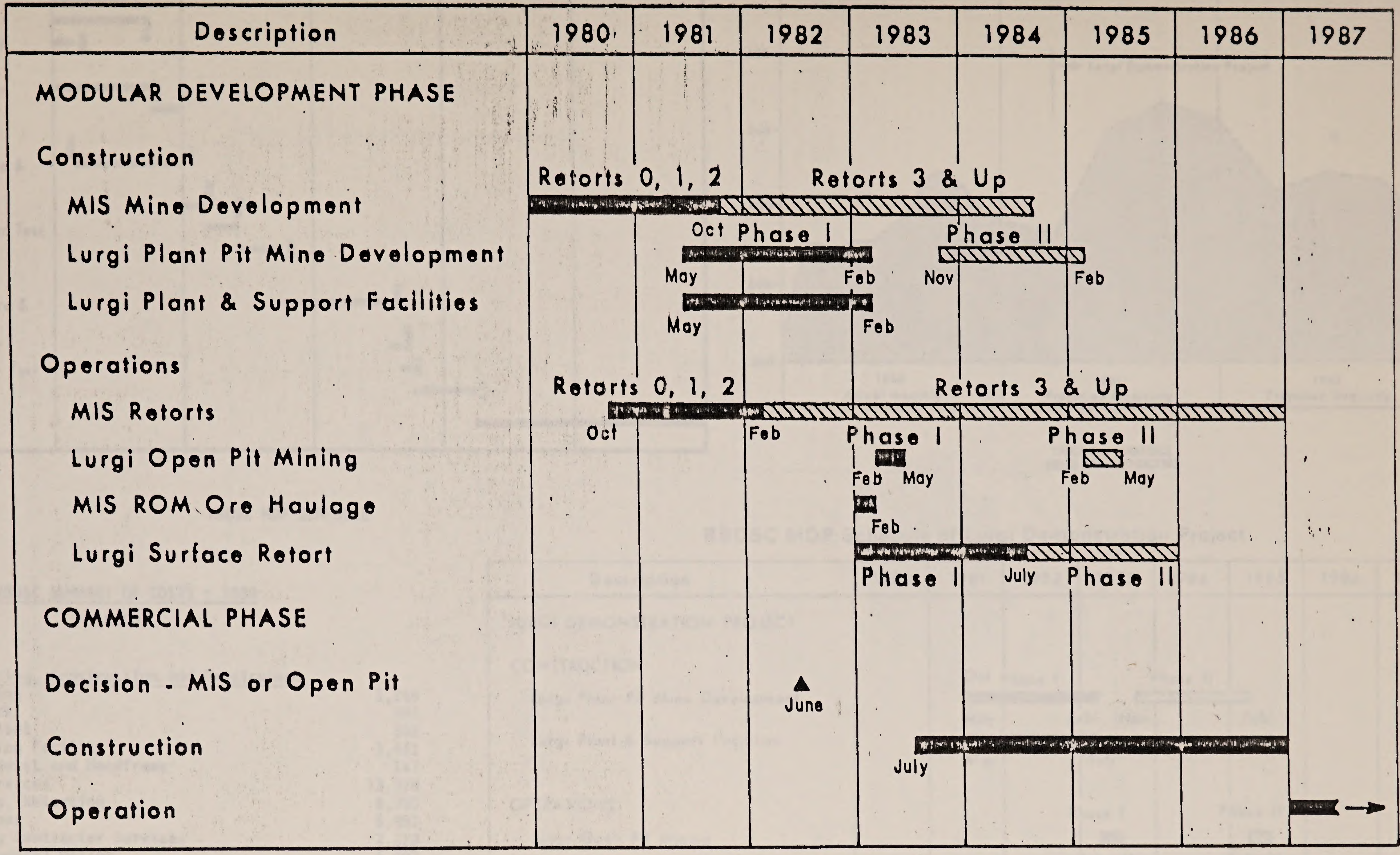
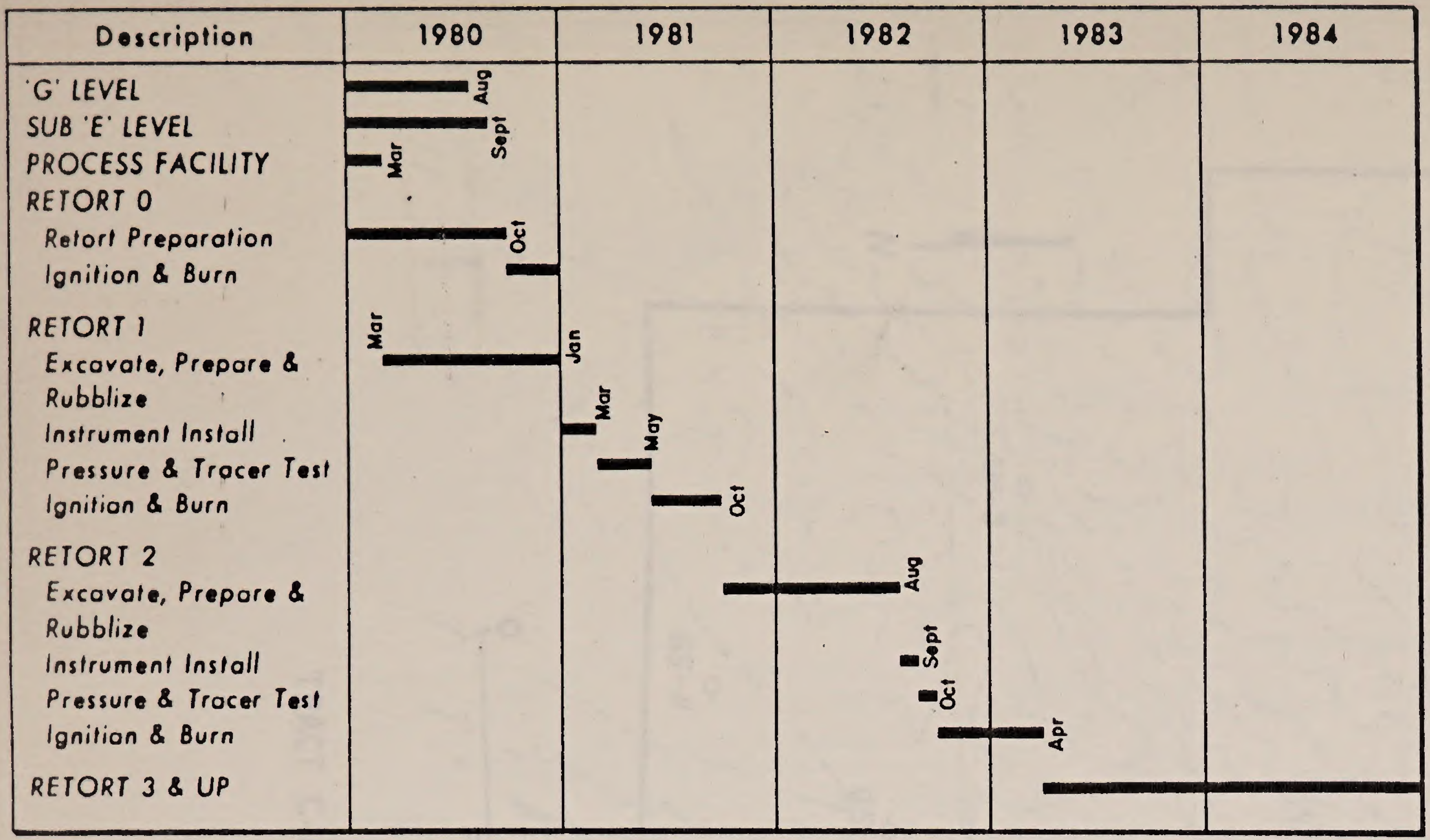


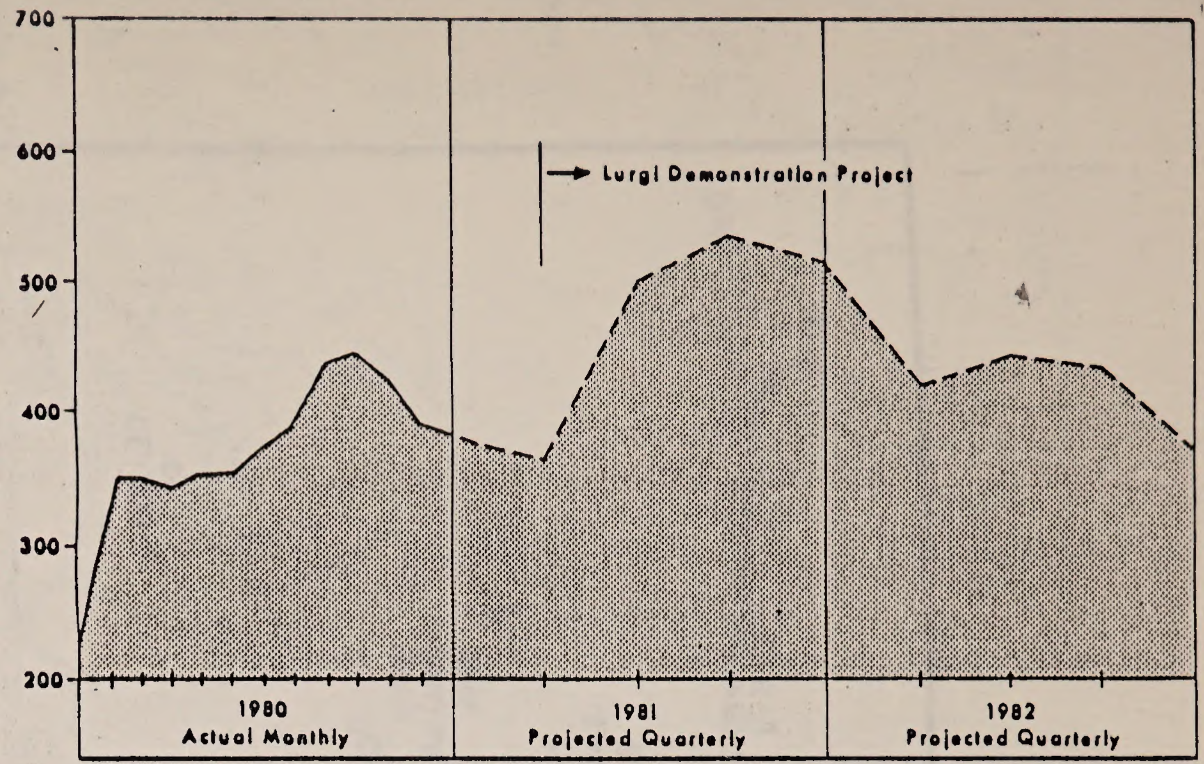

Figure 1-1-6

RBOSC Construction and Operation Schedule

## MDP Schedule Retorts 0, 1, 2, 3 & Up




RBOSC MDP SCHEDULE

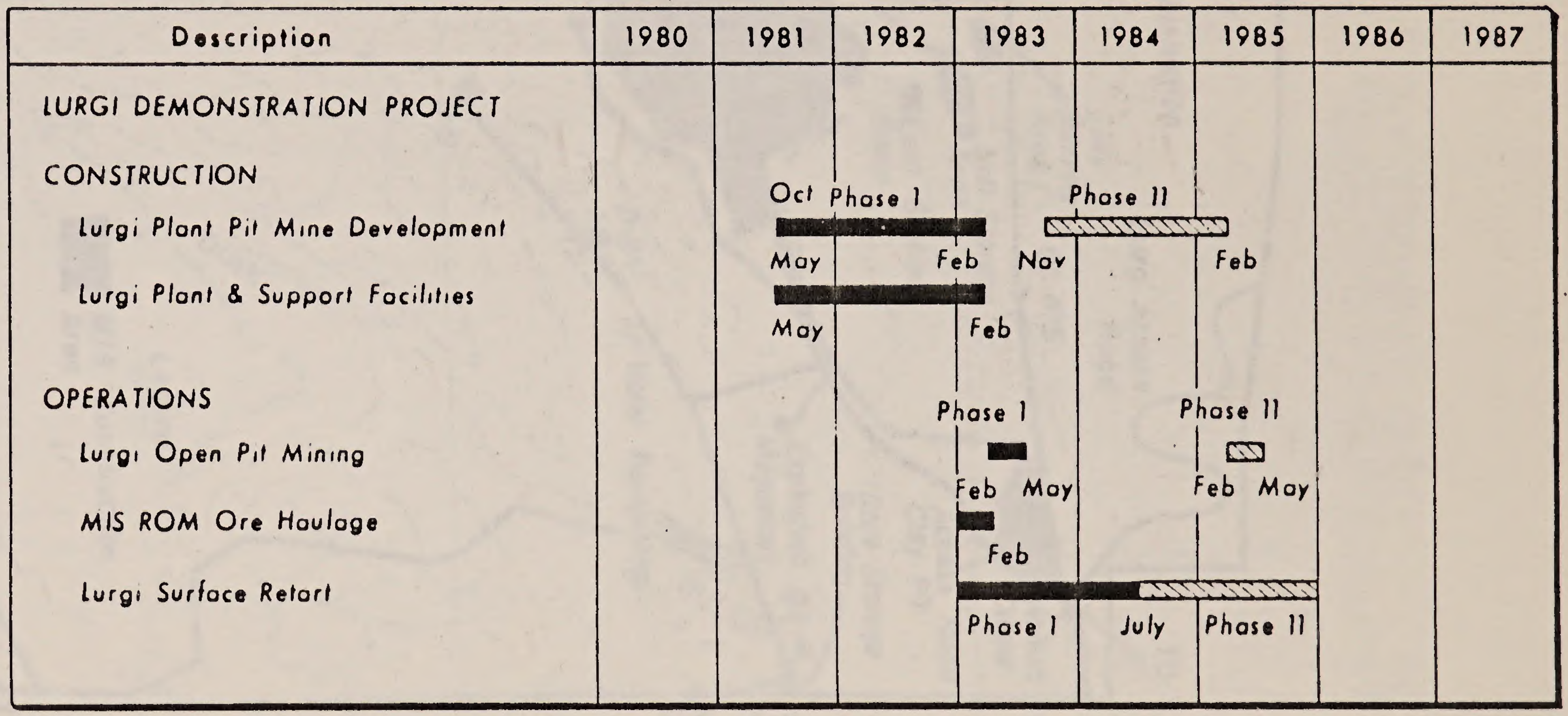



TRACT C-a WORKFORCE
RBOSC AND CONTRACTORS

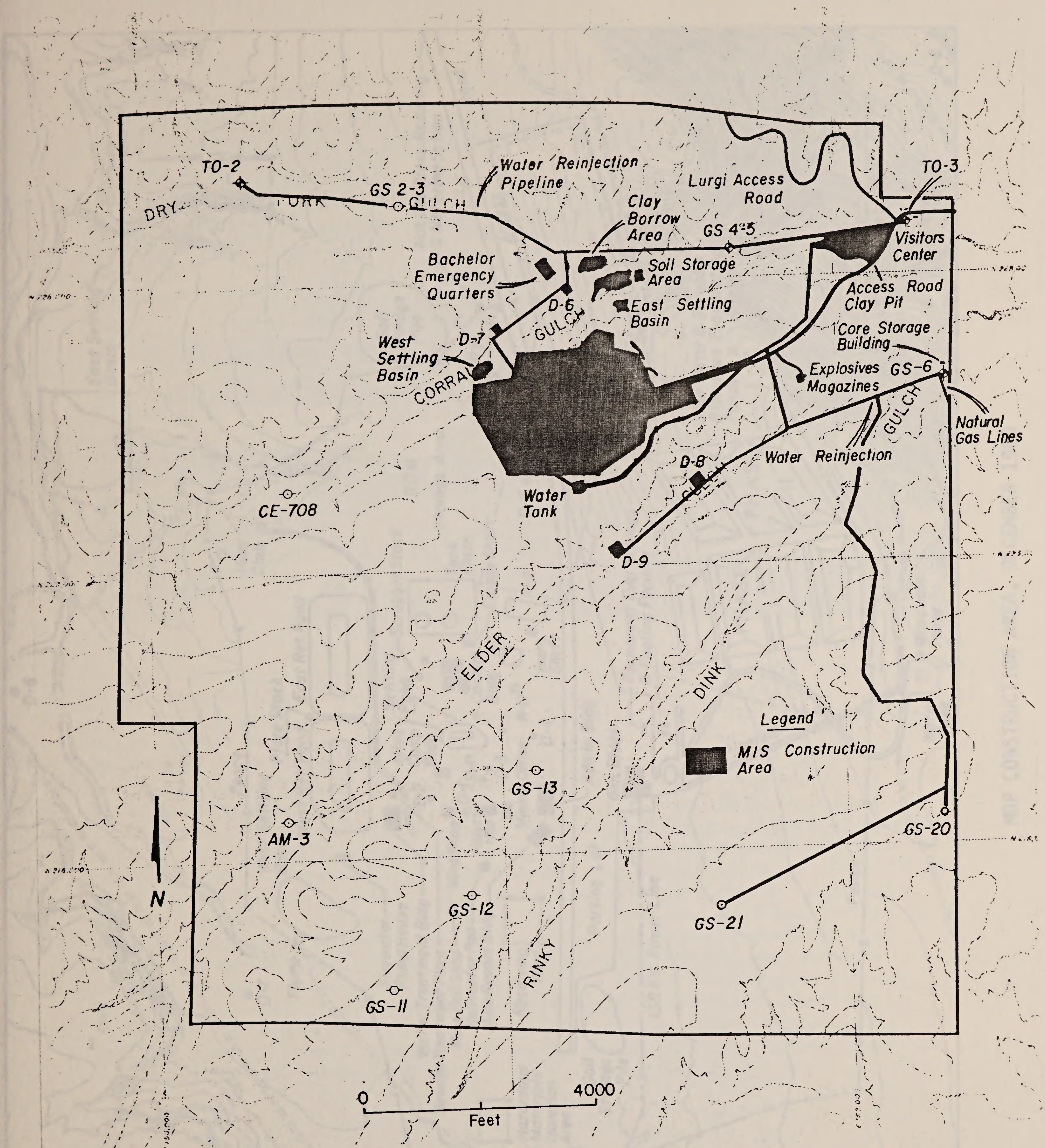
### RBOSC SUMMARY OF COSTS - 1980
($000)

| | |
|---|---|
| Engineering, Construction and Development | |
| Dewatering | 1,248 |
| Site Work | 534 |
| Power Plant | 302 |
| Processing Facility | 1,441 |
| Shaft, Hoist and Headframe | 147 |
| Mine Services | 13,978 |
| Drifting, Retorting | 6,755 |
| Operations | 6,951 |
| Managing Contractor Services | 2,222 |
| Technological Design | 5,187 |
| Environmental | 283 |
| Other | 1,488 |
| Lurgi Project - Phase I | 4,102 |
| Total Development | $44,647 |
| Administrative | $ 3,633 |
| Total C-a Project | $48,280 |

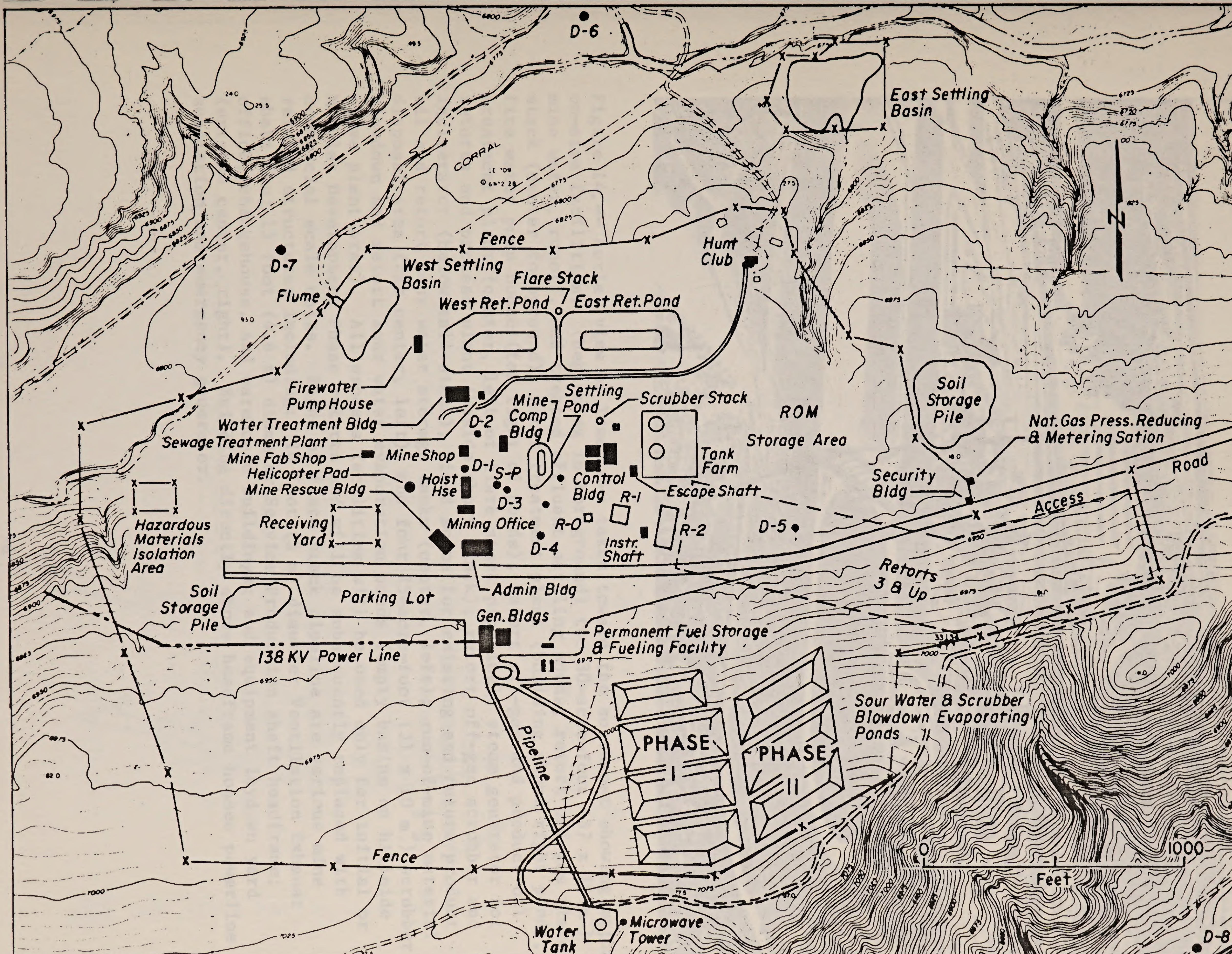
## RBOSC MDP Schedule of Lurgi Demonstration Project




RBOSC CONSTRUCTION AND OPERATION SCHEDULE




TRACT C-a PLOT PLAN, DECEMBER 1980




MDP CONSTRUCTION AREA, DECEMBER 1980

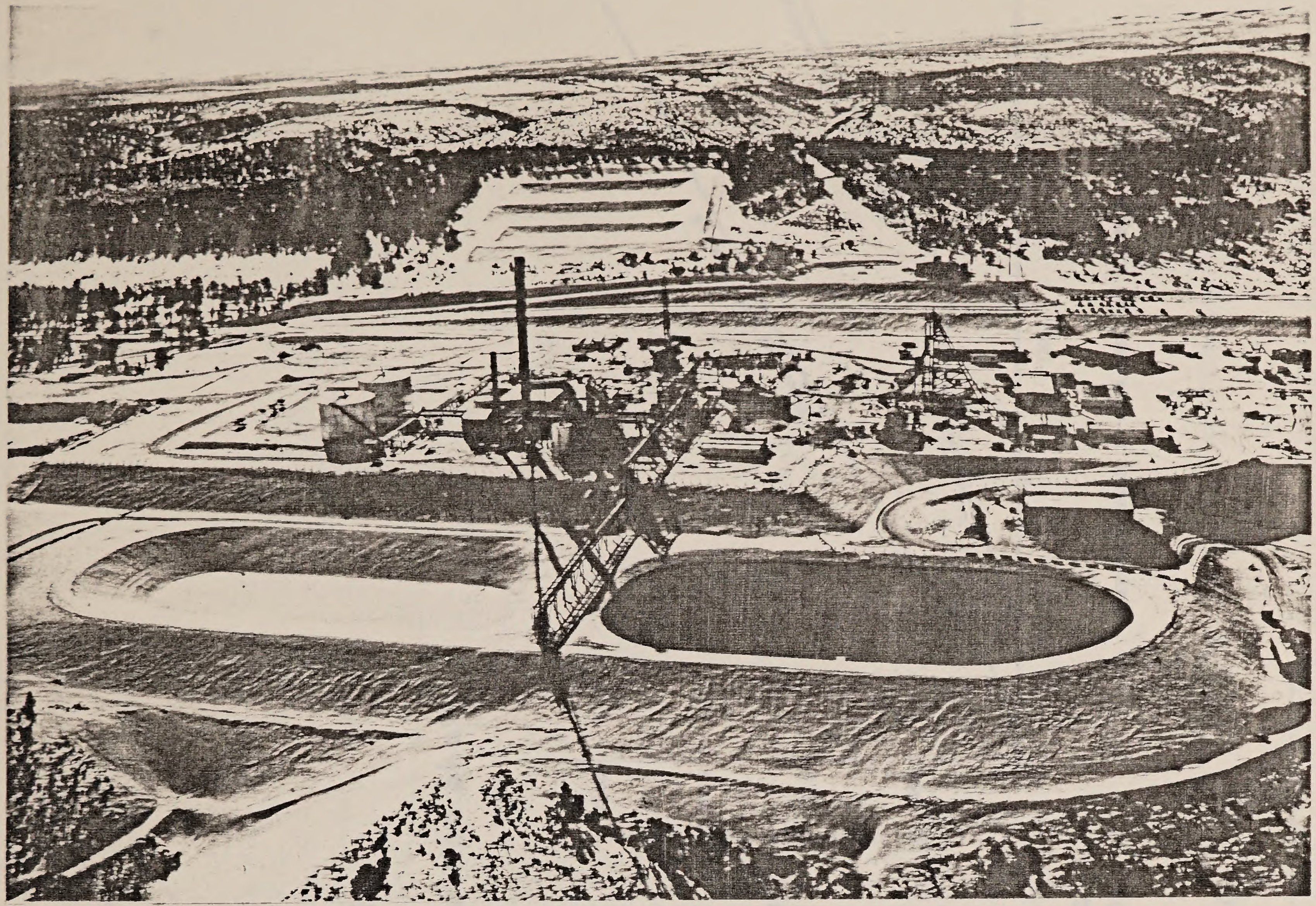
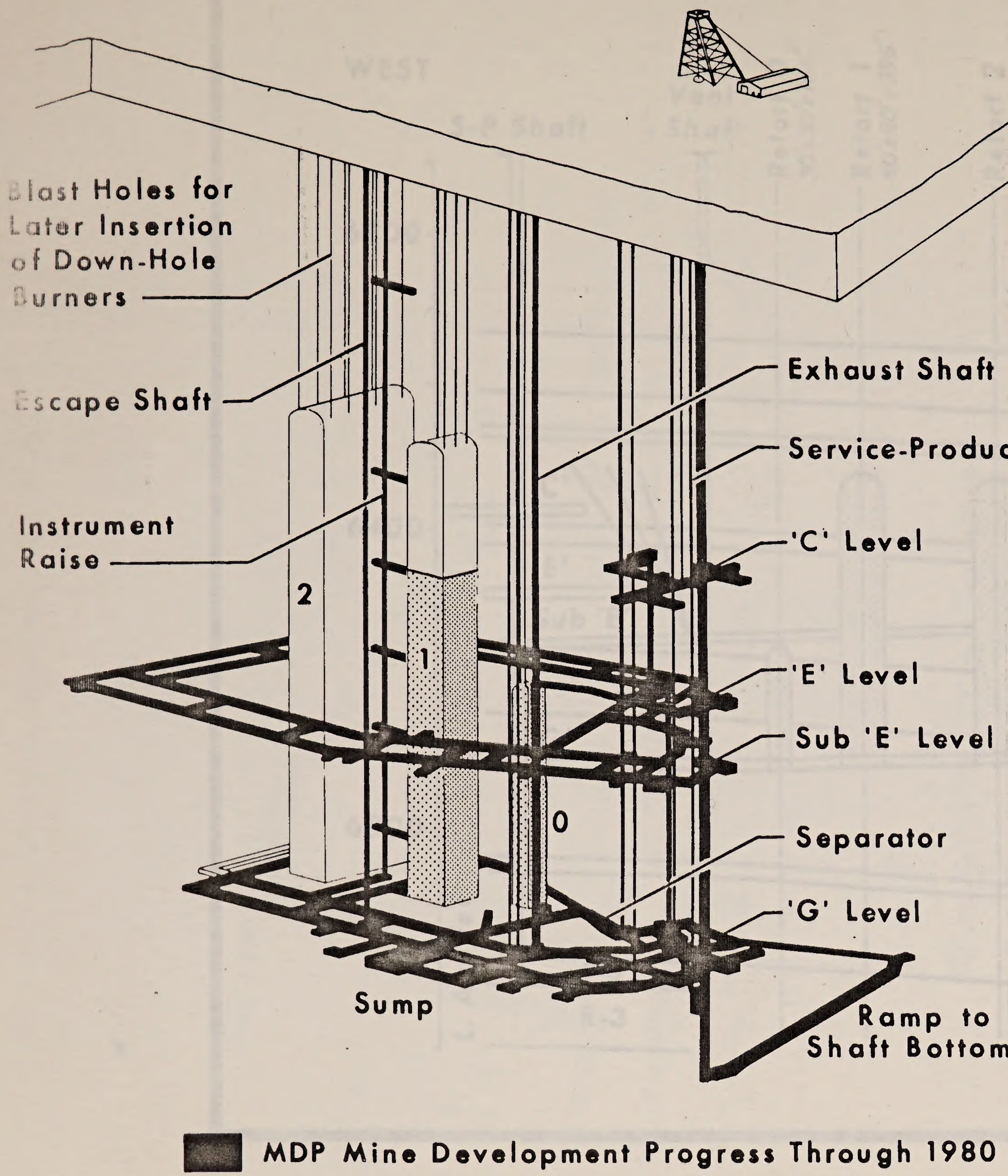
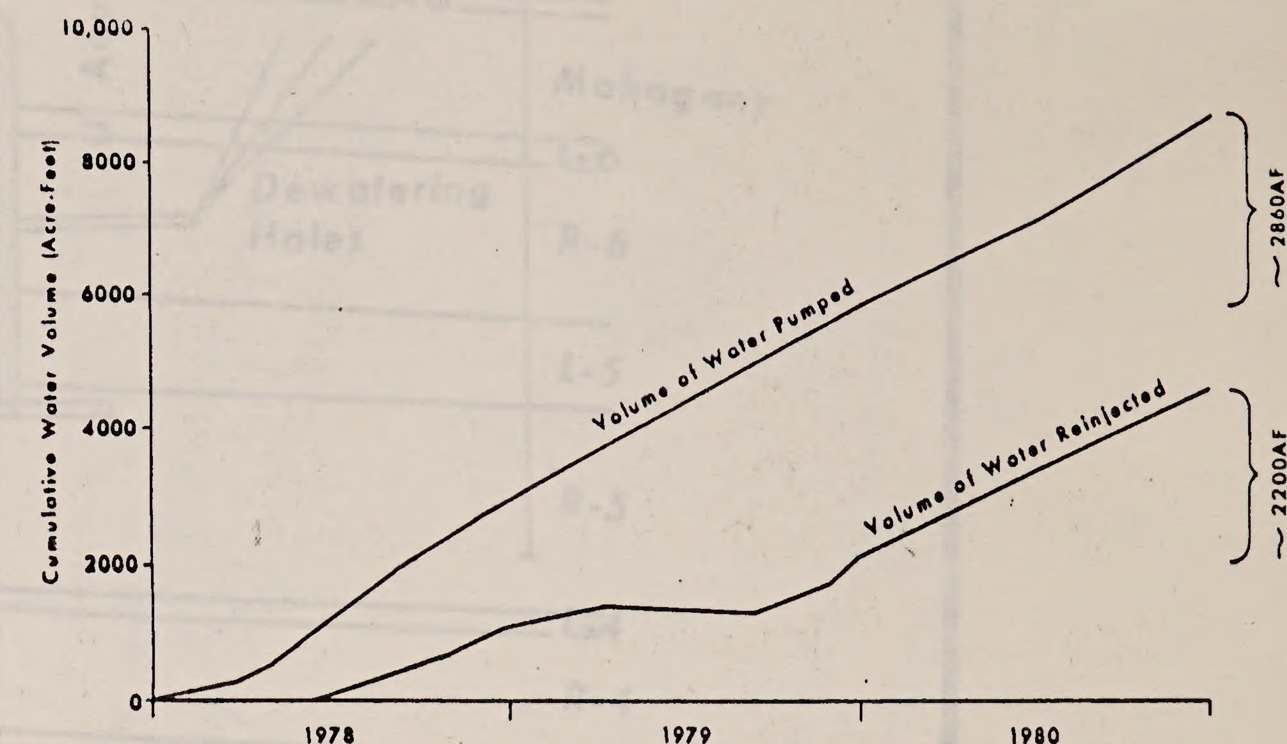


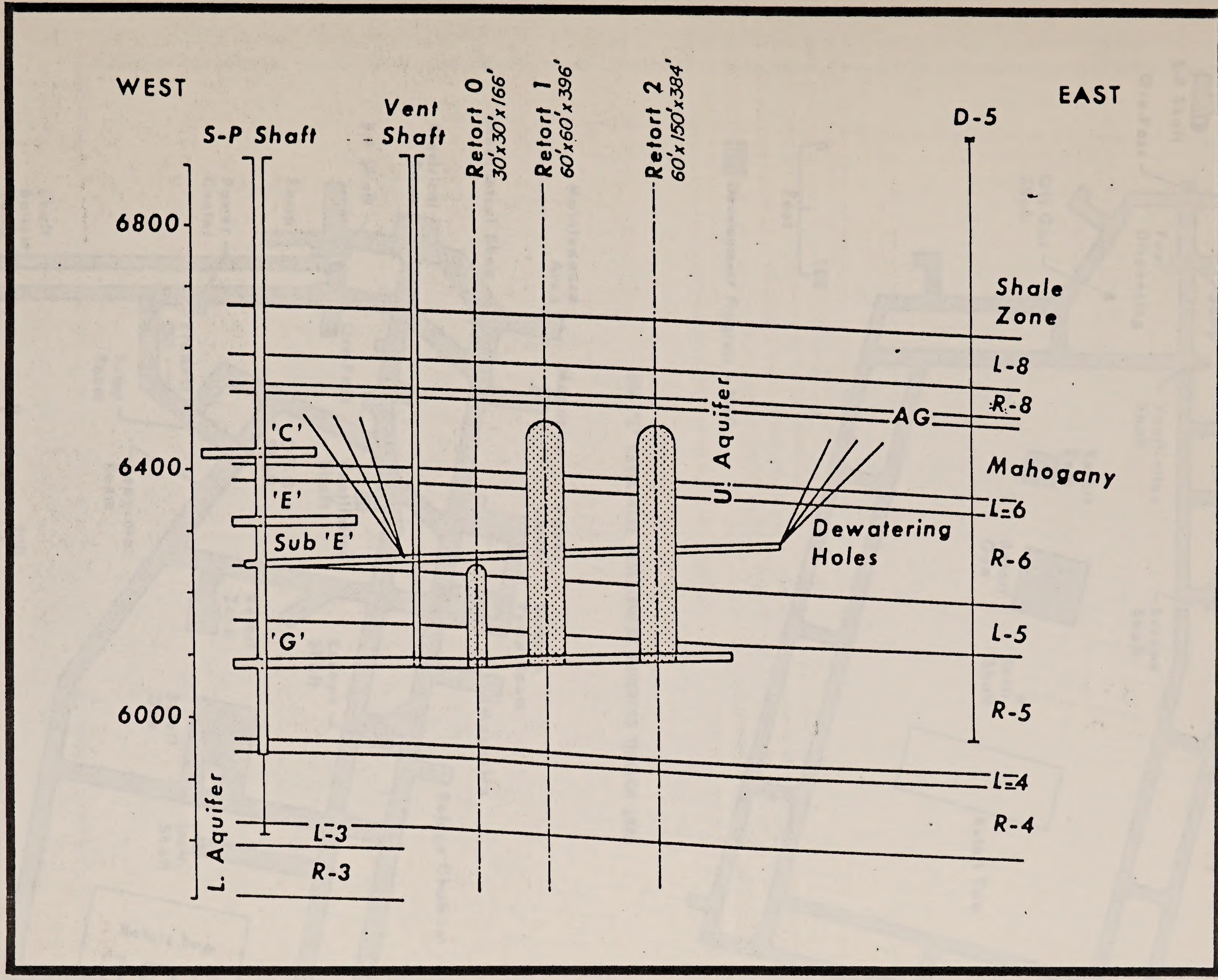
Figure 14.-- Aerial view of Tract C-a taken toward the southwest showing major on-site facilities: (beginning in foreground) two 30-acre-foot (37 x $10^3$ $m^3$) mine water, runoff, and treated effluent settling ponds; retort off-gas flare stack (center foreground); water treatment plant (building above right pond); fire water pump house (far right of ponds); retort off-gas and product oil treatment plant (center, left of flare stack pipeline); steam generator for retorts and process plant (beside short stack); retort off-gas scrubber and incinerator (below tall stack); diked space for existing and future product oil and retort sour water storage tanks (center, left); run-of-mine material disposal area (far center, left); and four 25-acre-foot (31 x $10^3$ $m^3$) scrubber blowdown and retort sour water evaporation ponds (empty basins on hillside above plant area). All process facilities will be used only for initial or Modular Development Phase retorts and will be subsequently replaced with commercial scale units. Right of flare stack pipeline are various mine related structures including: 10 foot (3 m) diameter Ventilation Exhaust shaft fan; 15 foot (4.6 m) diameter Service/Production shaft headframe; office, changehouse, and warehouse buildings; and equipment laydown yard (extreme center, right). Building directly above headframe houses powerline substation and emergency generator.




MDP MINE DEVELOPMENT PROGRESS THROUGH DECEMBER 1980

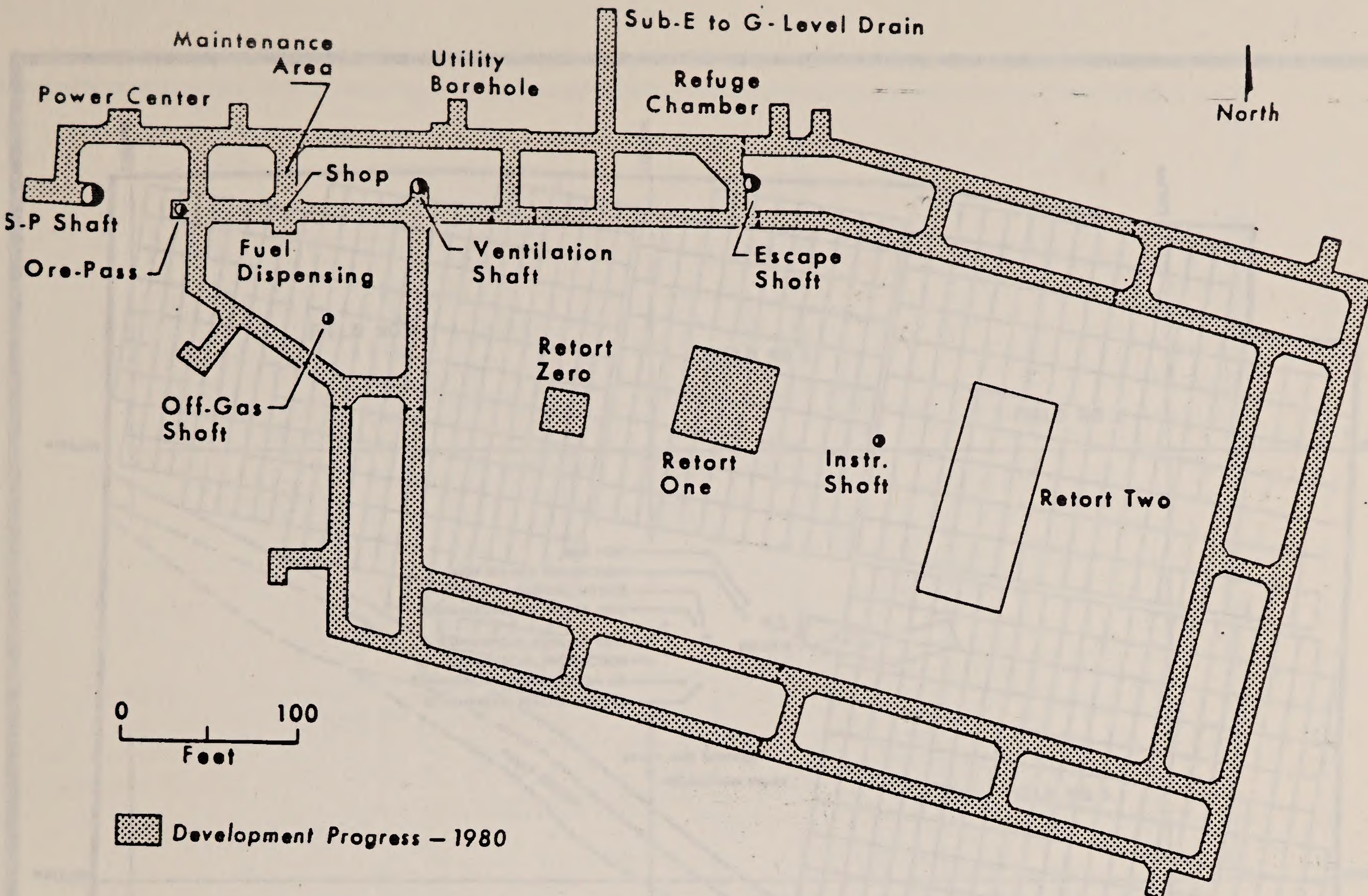



CUMULATIVE VOLUME OF WATER PUMPED AND REINJECTED 1978-1980

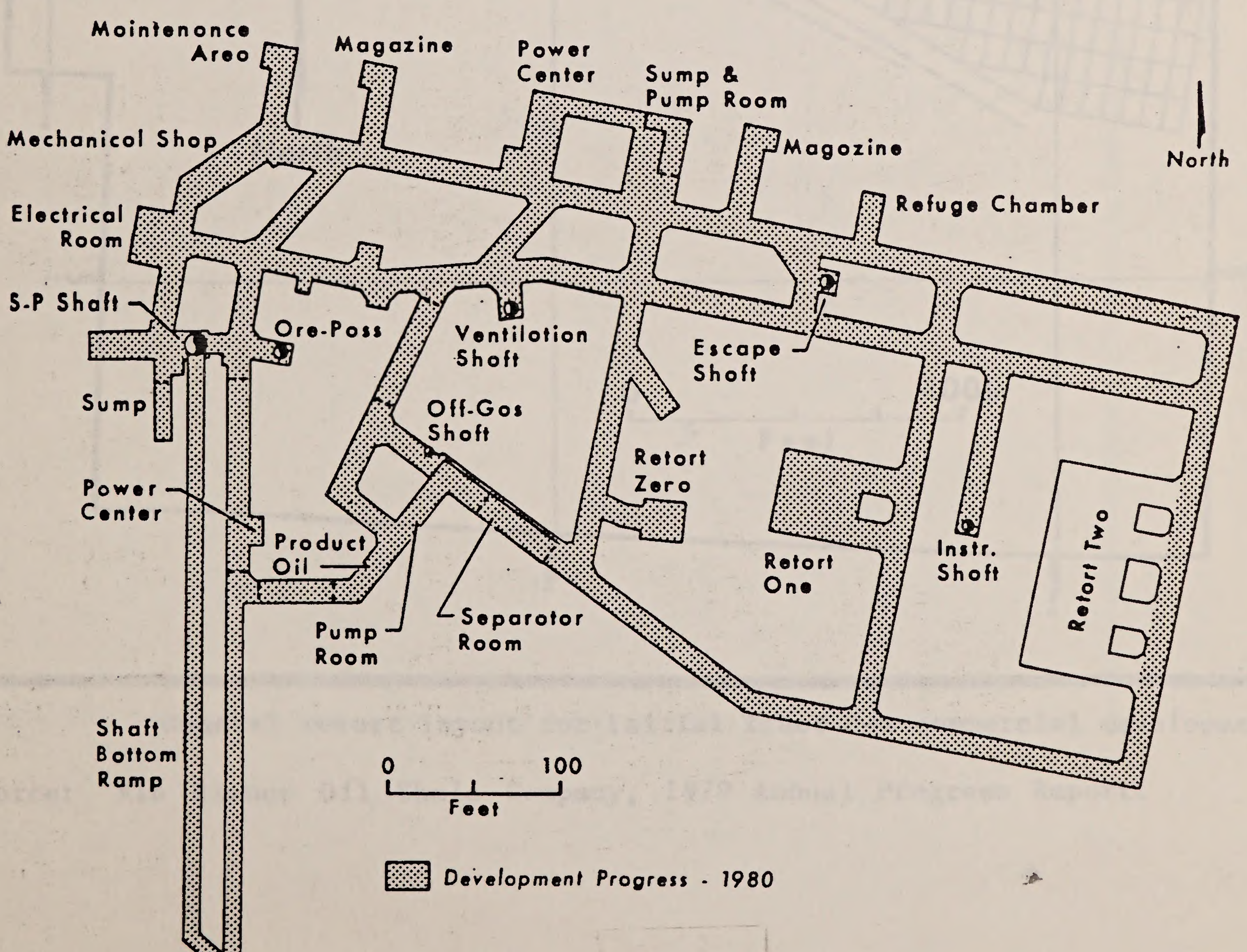



Cross section of Tract C-a showing Modular Development Phase retort size and stratigraphic relation.

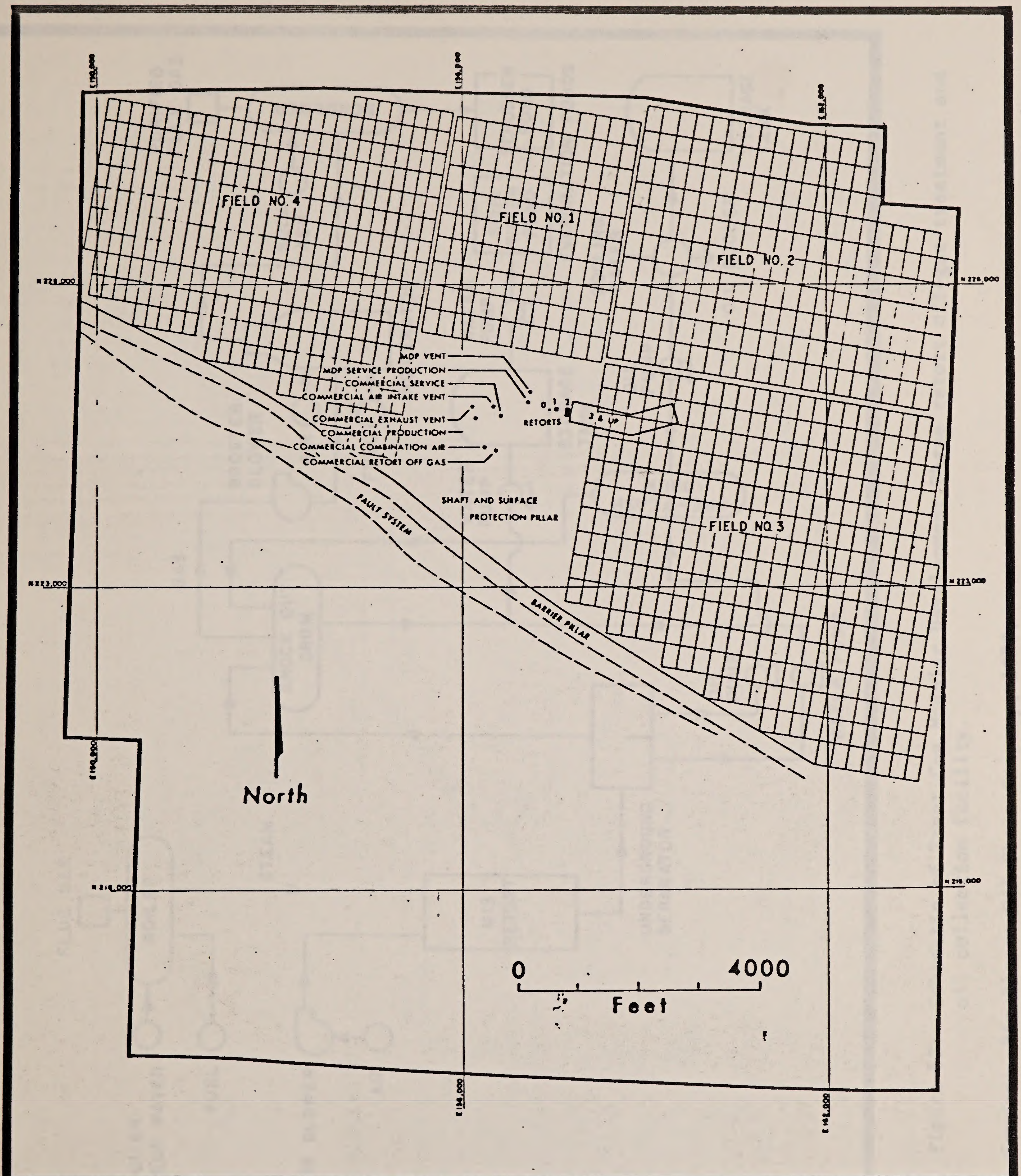
Source: Rio Blanco Oil Shale Company, 1979 Annual Progress Report.




SUB "E" LEVEL MINE DEVELOPMENT PROGRESS THROUGH 1980




"G" LEVEL MINE DEVELOPMENT PROGRESS THROUGH DECEMBER 1980




General retort layout for initial Tract C-a commercial development.

Source: Rio Blanco Oil Shale Company, 1979 Annual Progress Report.

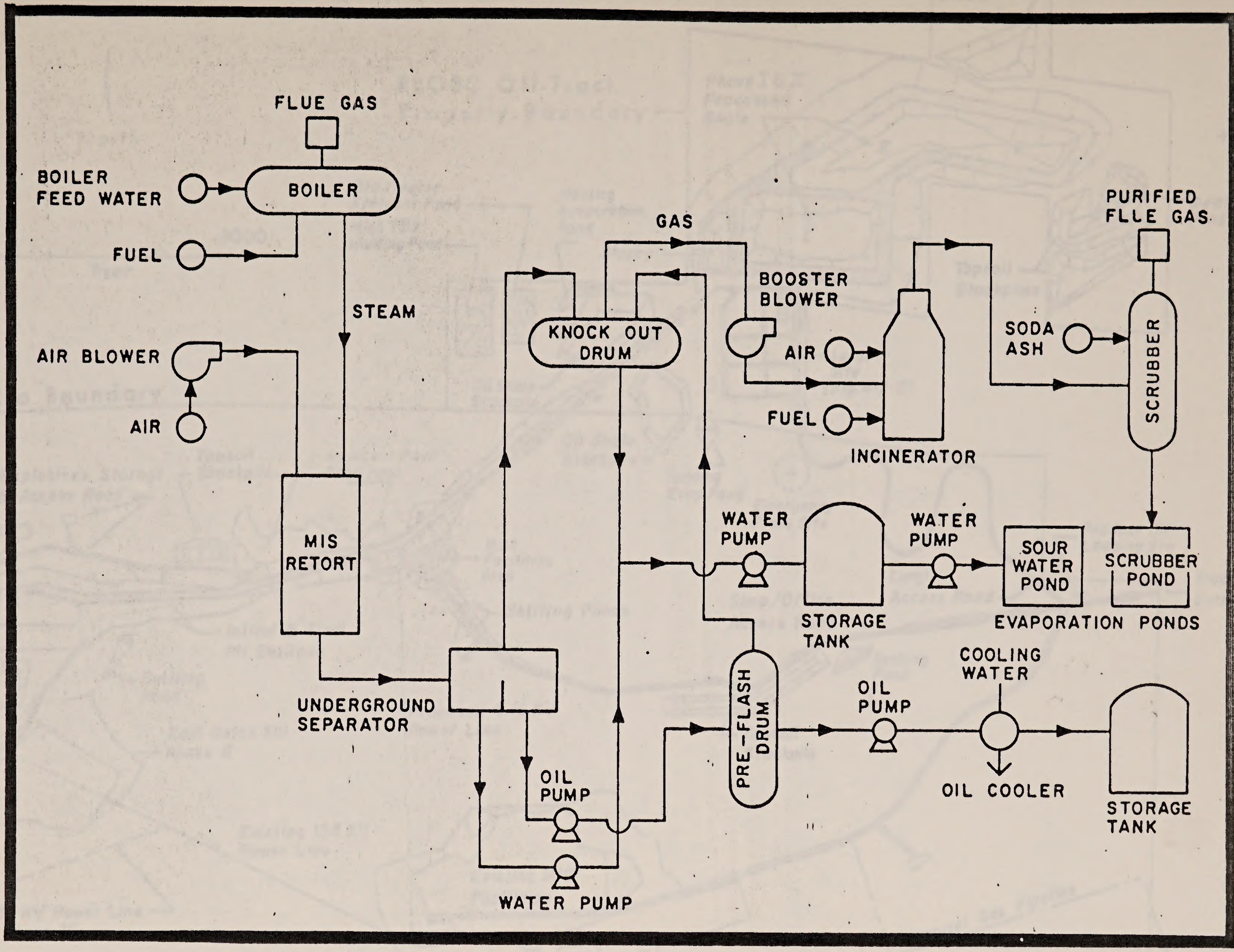



Figure 52: Schematic of Tract C-a Modular Development Phase retort off-gas treatment and oil collection facility.

Source: Rio Blanco Oil Shale Company, 1979.

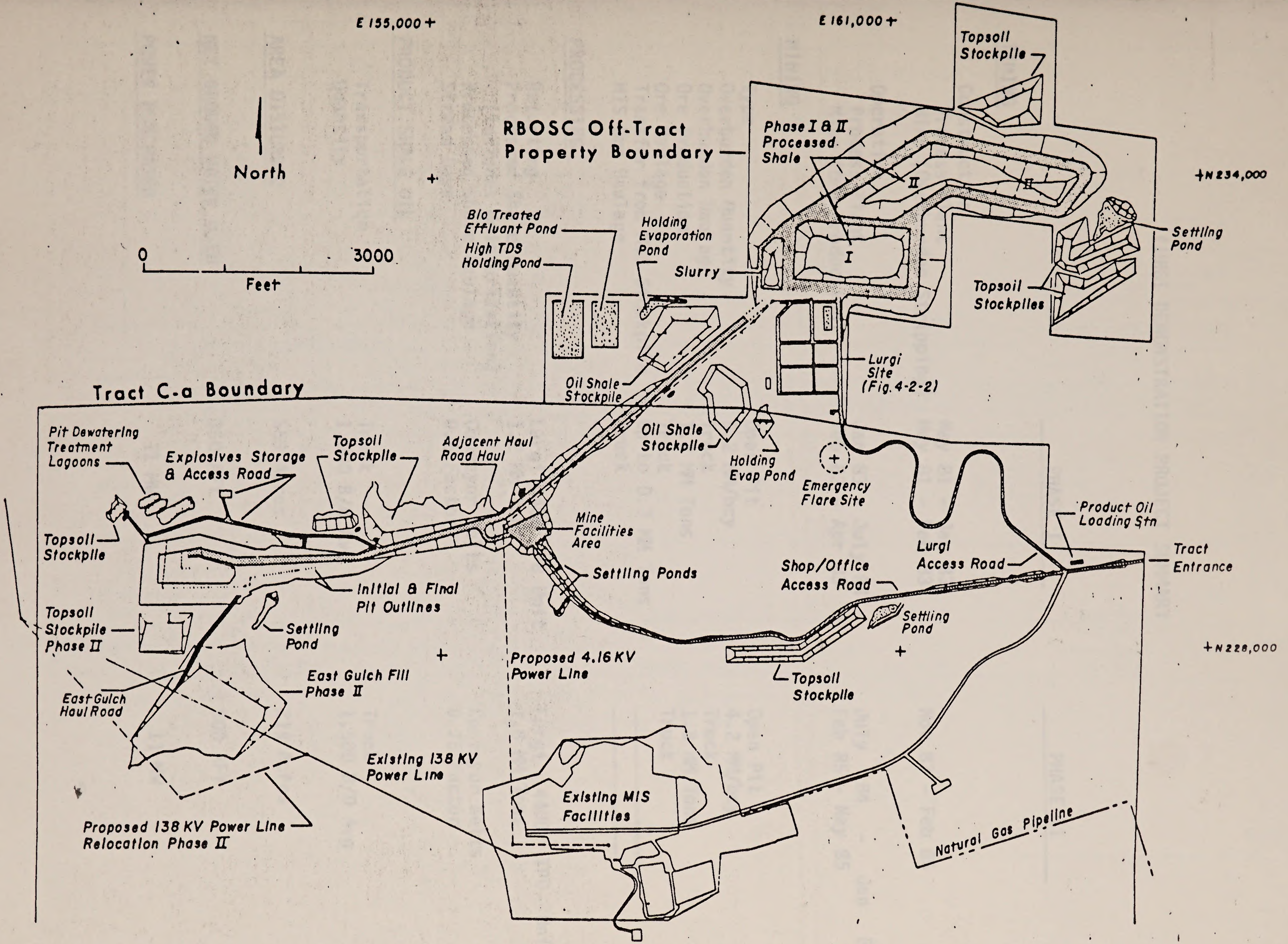



Figure 1.1-5
Lurgi Demonstration Project Plot Plan

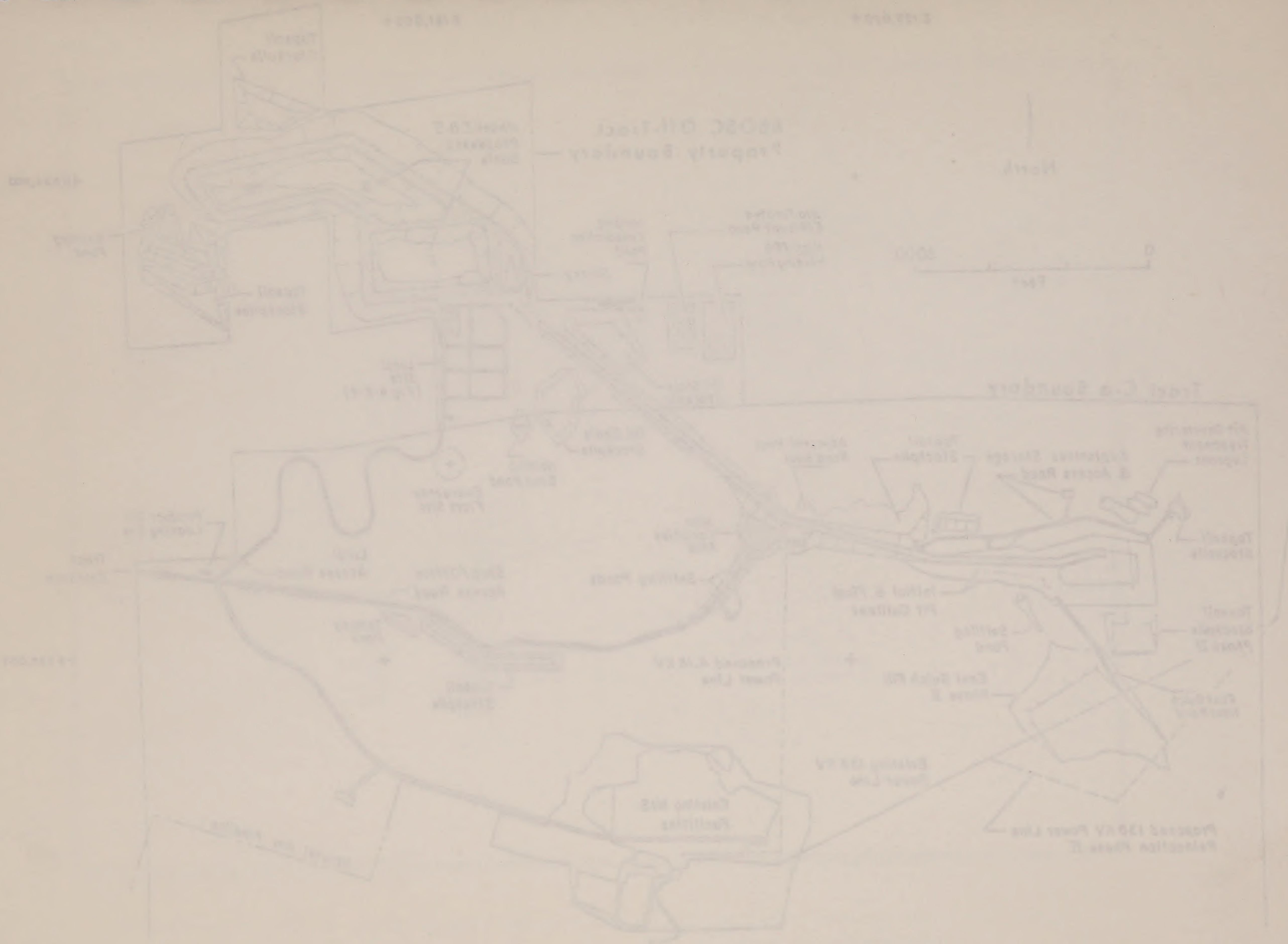



Figure 1.1-5
Lurgi Demonstration Project Plot Plan

LURGI DEMONSTRATION PROJECT SUMMARY

| | PHASE I | PHASE II |
|---|---|---|
| **TIMING** | | |
| Construction | | |
| Process Plant | May 81 - Jan 83 | |
| Mine (Overburden Stripping) | May 81 - Feb 83 | Nov 83 - Feb 85 |
| Operation | | |
| Process Plant | Jan 83 - July 84 | July 84 - Jan 86 |
| Mine (Ore Production) | Feb 83 - Apr 83 | Feb 85 - May 85 |
| **MINING** | | |
| Type | Open Pit | Open Pit |
| Overburden Quantity | 5.2 MM/bcy | 4.2 MM/bcy |
| Overburden Haulage | Truck | Truck |
| Ore Production | 1.2 MM Tons | 1.8 MM Tons |
| Ore Haulage | Truck | Truck |
| Transfer from MIS Stockpile | Up to 0.3 MM Tons | ________ |
| MIS Ore Haulage | Truck | ________ |
| **PROCESSING** | | |
| Retorting | Lurgi 4400 TPD Unit | Lurgi 4400 TPD Unit |
| Processed Shale Quantity (Includes Moisturization) | 1.2 MM Tons | 1.8 MM Tons |
| Processed Shale Haulage | Conveyor Belts | Conveyor Belts |
| Stream Days | 0.5 Factor | 0.75 Factor |
| **PRODUCT SHALE OIL** | | |
| Transportation | Truck | Truck |
| Quantity | 1,000 B/D Avg | 1,500 B/D Avg |
| **AREA DISTURBED** | 559 Acres | 214 Acres |
| **NET GROUND WATER USED** | 350 AFY | 500 AFY |
| **POWER PURCHASED** | 11 MW | 11 MW |

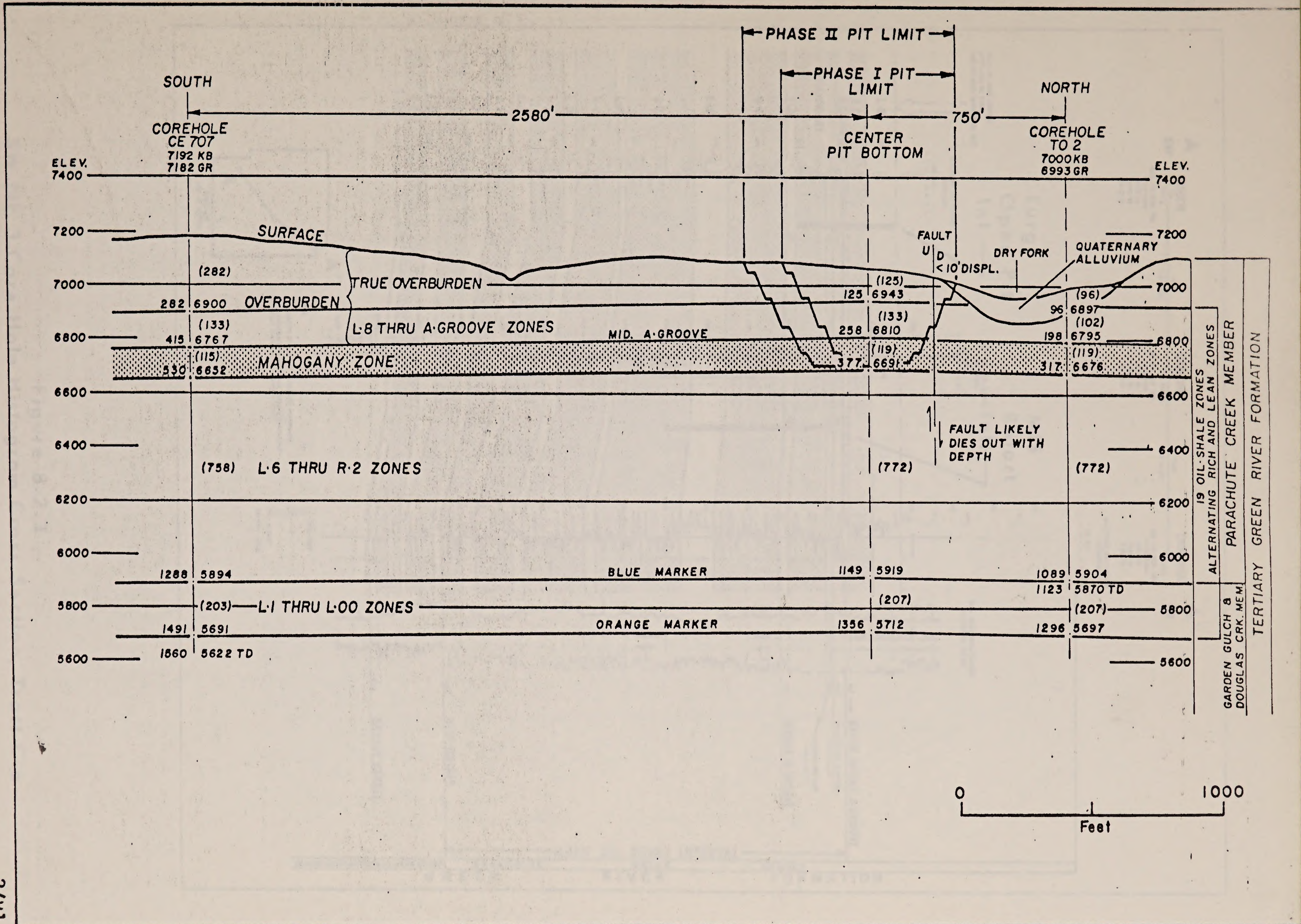



Figure 2-6-2



2/81

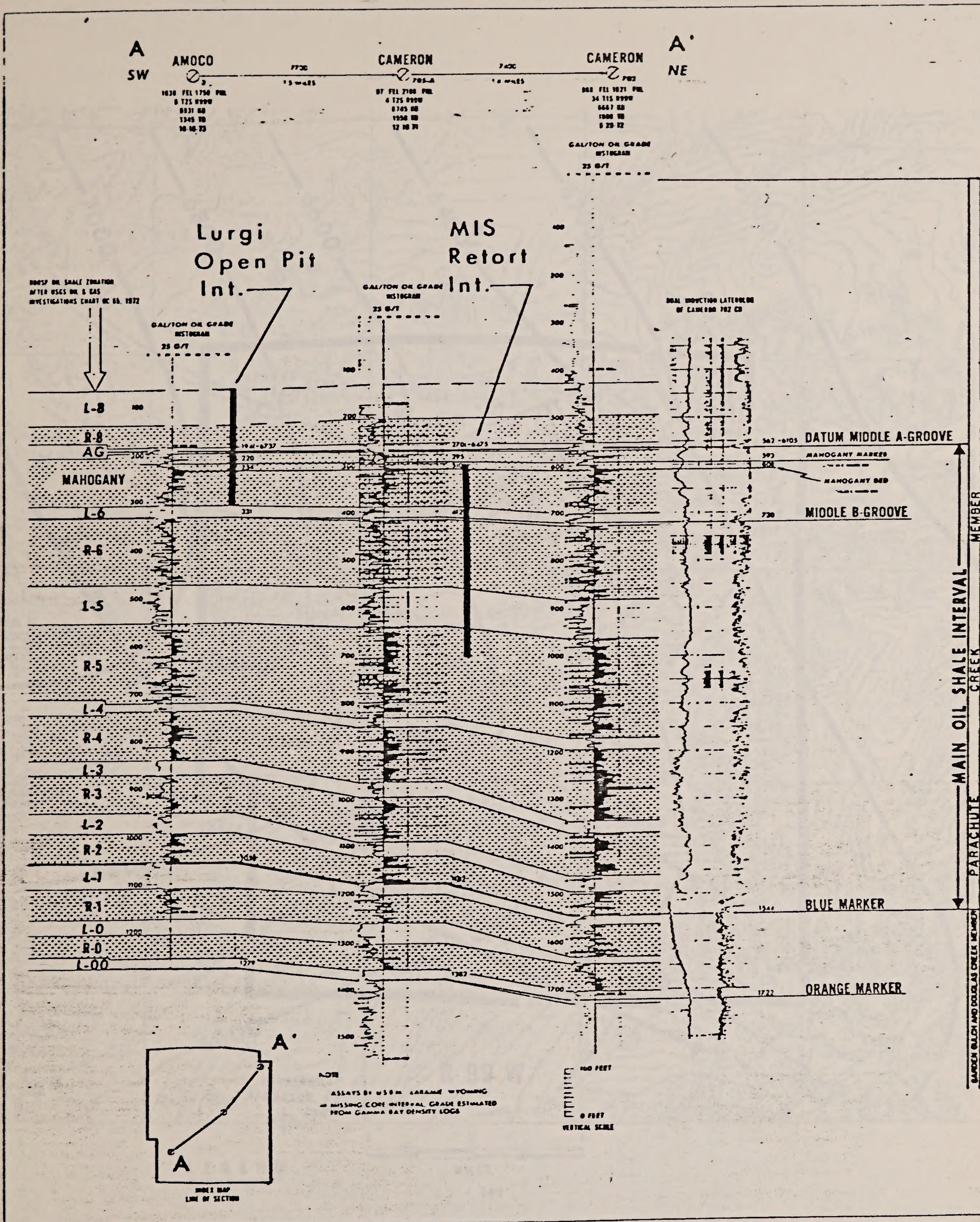
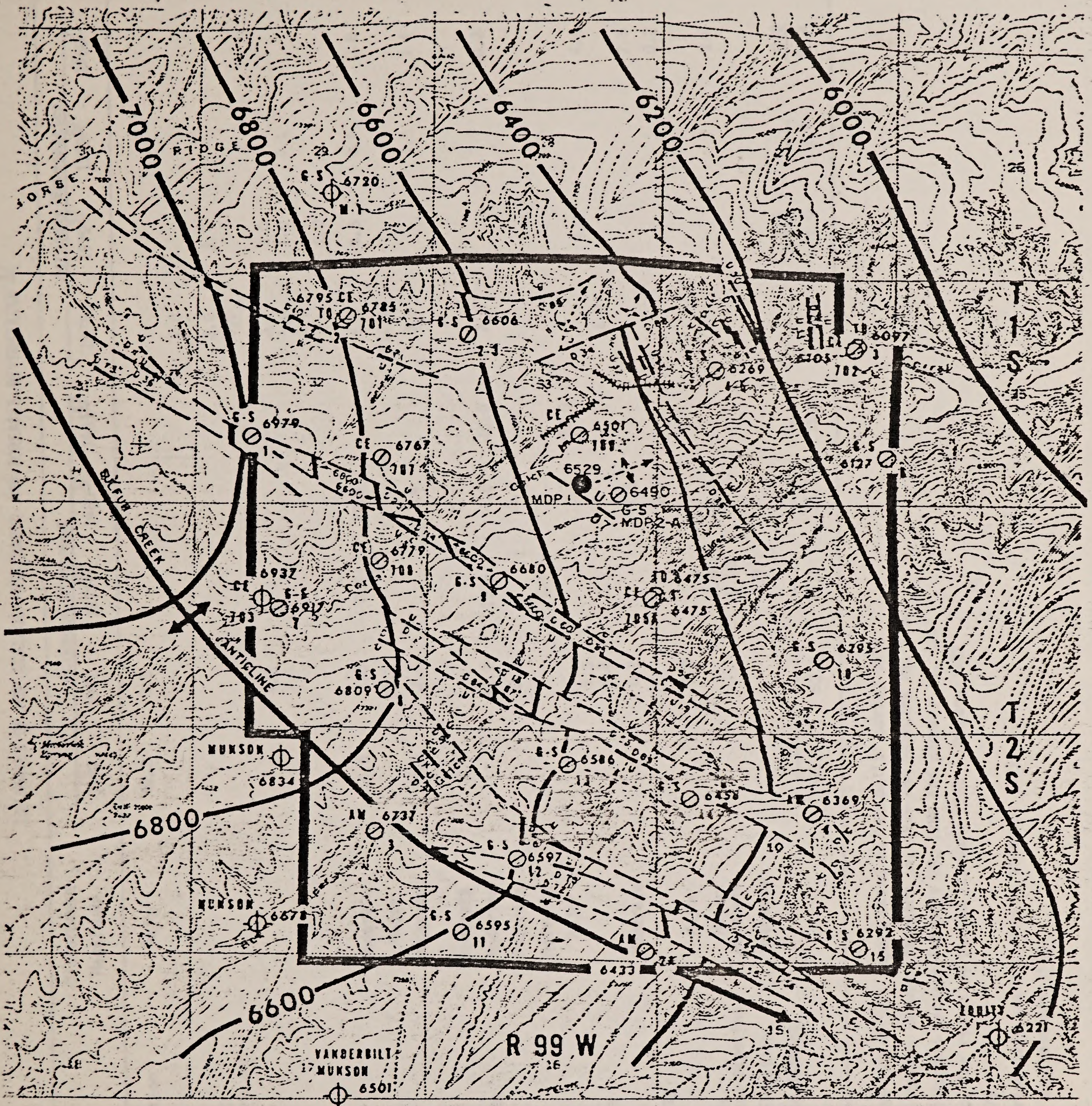



Figure 8-2-3
SW-NE 3-Core Hole Histogram Cross Section, Tract C-a




**LEGEND**

0 ½ 1

MILES

C.I. = 200'

- ⊘ CORE HOLE
- ⏀ CONVENTIONAL WELL
- 6475 DATUM MIDDLE A-GROOVE
- OBSERVED SURFACE FAULT. DISPLACEMENT
- PROJECTED FAULT
- ALLUVIUM SLUMP
- ● MDP MINE SERVICE-PRODUCTION SHAFT

Figure 4

TRACT C-a MIDDLE A-GROOVE STRUCTURE MAP

ESTIMATES OF MDP ACREAGES DISTURBED AND ACREAGES REVEGETATED [1]

| Disturbed Area | Disturbance Magnitude | Acreages Disturbed 1977 | Acreages Disturbed 1978 | Acreages Disturbed 1979[2] | Acreages Disturbed 1980[3] | Acreages Disturbed 1981[4] | Acreages Revegetated 1978 | Acreages Revegetated 1979[5] | Acreages Revegetated 1979[6] | Acreages Revegetated 1980[7] |
|---|---|---|---|---|---|---|---|---|---|---|
| Mine Service Area Retention Ponds & Plant Site | Major | 48.2 | 3.2 | | | | | | | |
| Retention Ponds | | | | | | | 8.0 | | | |
| Plant Sideslopes | | | | | | | 12.0 | | | |
| Area Near Hunting Club | | | | | | | 2.0 | 1.0 | | |
| Area Between Water Tank and Plant Site | | | | | | | 5.0 | | | |
| Diversion System | | | 4.2 | | | | 3.0 | 3.0 | | |
| Settling Basins | | | 3.4 | | | | 1.0 | 1.0 | 0.1 | |
| Equipment Yard | | | | | | | 3.0 | | | |
| Area Near Substation | | | | | | | | 1.0 | | |
| Access/Service Roads | Moderate | 10.0 | 3.0 | 0.4 | 17.0 | | 6.5 | 6.5 | 0.5 | 0.8 |
| ROM Disposal Area | Major | | 12.3 | | | | 10.0 | | | |
| Soil Storage (1,2,3,4) Storage A,B,C,D | Moderate | 4.0 | 3.0 | | 1.4 | | 3.0 | | 1.3 | 1.4 |
| Powder Magazine | Moderate | 0.9 | | | 0.2 | | | | | |
| Water Reinjection System | Moderate | | 12.2 | 13.8 | 4.0 | 15.0 | 7.0 | | | 10.3 |
| Transmission Line | Moderate | | 0.5 | | 0.7 | | | | | |
| Natural Gas Pipeline | Moderate | | | 0.8 | | | | | | |
| Reservoirs & Soil Pits | Major | | | | | 20.0 | | | | |
| Access Road Sand Pit | | | 9.5 | | | | | 5.0 | | 4.5 |
| Hunting Road Clay Pit | | | 4.0 | 0.9 | | | 2.0 | | | |
| Monitoring Facilities | Moderate | | 0.2 | | 3.5 | | | | | 2.6 |
| Trailer Parking Facility | | | | | 0.5 | | | | | 0.2 |
| Evaporation Field | Major | | 7.0 | | | | | | | |
| Scrubber Blowdown Ponds | Major | | | 8.9 | 8.0 | | | | | 1.8 |
| Scrubber Blowdown Pond Pipeline | Moderate | | | 0.05 | | | | | | |
| Airplane Ridge Road Relocation | Moderate | | | 1.9 | | | | | | |
| Old Airplane Ridge Road Segment | | | | | | | | 8.5 | | 0.8 |
| TOTALS | | 63.2 | 62.5 | 26.8 | 35.3 | 35.0 | 62.5 | 26.0 | 1.9 | 22.4 |

[1] Acreages revised from 1979 Annual Report based on "as built" survey data

[2] Includes acreages disturbed between February 16, 1979 and February 29, 1980

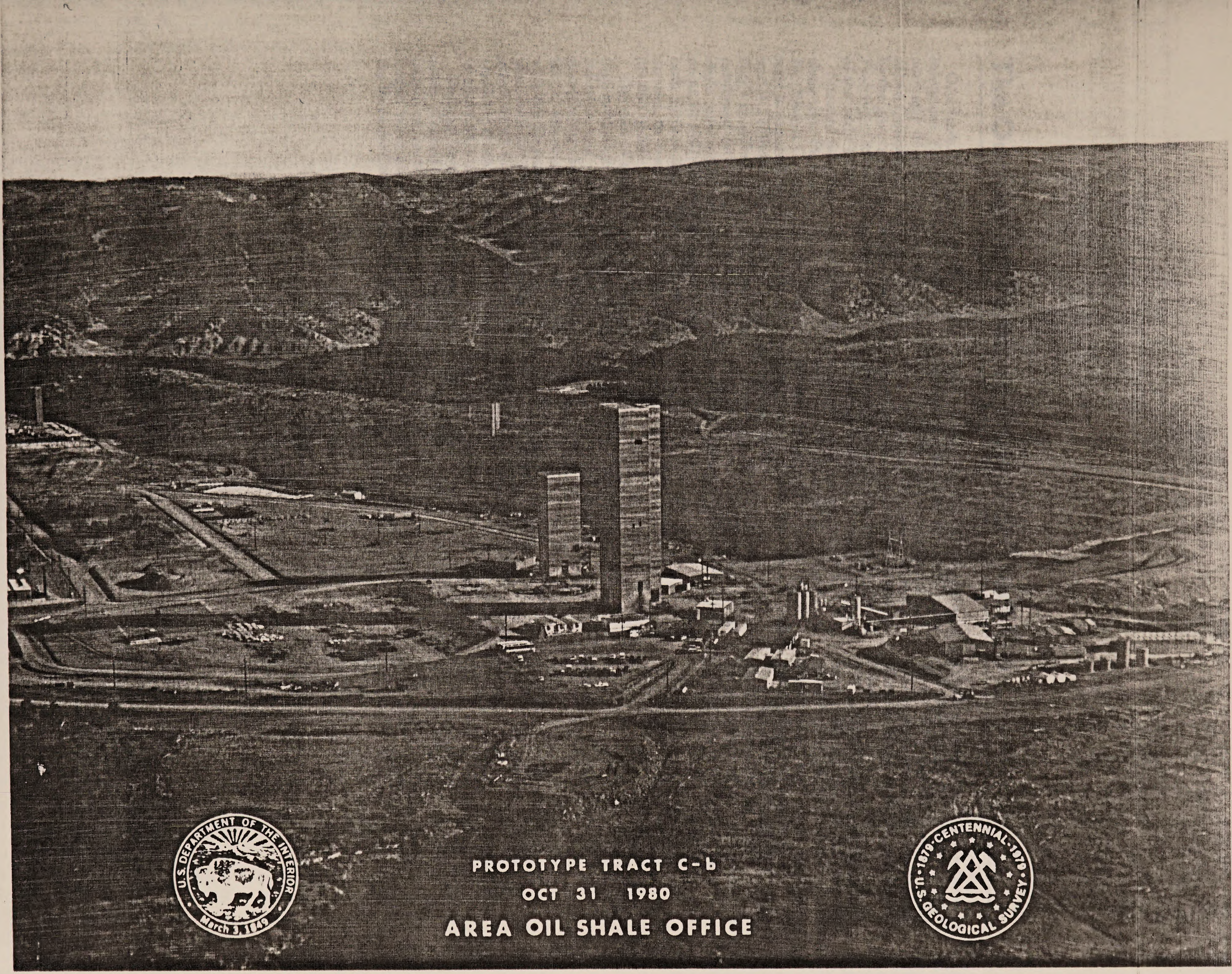
[3] Includes acreages disturbed between February 29, 1980 and January 31, 1981

[4] Estimated disturbance for reporting period February 1981 - January 1982

[5] Areas seeded May 1979

[6] Area redisturbed during 1979 and reseeded in November 1979

[7] Area seeded October and November 1980


PROTOTYPE TRACT C-b
OCT 31 1980
AREA OIL SHALE OFFICE
U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849
1879 CENTENNIAL 1979
U.S. GEOLOGICAL SURVEY

# The Occidental-Tenneco Project at Tract C-b

Occidental Oil Shale Inc. (Oxy), and its partner, Tenneco Shale Oil Co., are currently developing Tract C-b, one of two Colorado oil shale tracts leased by the government under the Federal Prototype Oil Shale Leasing Program of the early 1970s.

Situated near the center of the oil shale-rich Piceance Creek Basin in Rio Blanco County, CO, the 21 $km^2$ tract is expected to yield nearly 0.17 $km^3$ (1.1 billion bbl) of shale oil using Oxy's modified in situ (MIS) process combined with surface retorting of the shale removed during mine development. In 1991, full oil production from both surface and MIS retorts is expected to reach about 15 $dam^3/d$ (94 000 bbl/d).

The cost of the project may run as high as $5.9 billion, when adjusted for inflation and other expenses. The partnership announced late last year that a financing proposal was filed with the Department of Energy. The plan calls for a federal guarantee of about $2.25 billion, in 1980 dollars, escalated at 8%/a for 10 years resulting in about $4.3 billion.

Designs for the in situ retorts currently planned for the tract are largely based on tests performed at Oxy's Logan Wash experimental facility in the Piceance Creek Basin about 16 km from DeBeque, CO. Underground engineering designs, presently being developed by the Denver-based division of Dravo Engineers and Constructors, call for numerous in situ retorts each having a common height of 88 m, and varying in cross sectional area among development phases. Retorts will be grouped in "clusters" of six and developed to meet full MIS production of 8.7 $dam^3/d$ (55 000 bbl/d) in 1988.

According to current plans, six to eight Lurgi retorts will be operational between 1985 and 1991. The surface retorts are expected to produce nearly 6.4 $dam^3/d$ (40 000 bbl/d) in 1990. Spent shale created from these units will be stored on the tract and revegetated to blend with the surrounding terrain.

Tract operations are currently in the shaft sinking stage, which began early in 1979. The production, service, and ventilation/escape shafts are nearing their completed depths of about 600 m. Engineering designs for various shaft accessories, as well as designs for a variety of surface support facilities, are well underway. □

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Cathedral Bluffs is a Colorado general partnership between Occidental Oil Shale, Inc. ("OOSI"), a subsidiary of Occidental Petroleum Corporation ("Occidental"), and Tenneco Shale Oil Company ("TSOC"), a subsidiary of Tenneco Inc. ("Tenneco").

The project (the "Project") is an underground oil shale mine with both underground and aboveground shale oil production retorting facilities required for the production of 94,000 barrels per day (daily average for the year) of shale oil, with reserves for 30 years operation. The Project is owned and operated by Cathedral Bluffs and is located on a 5,094 acre tract of land in Rio Blanco County, Colorado, leased by Cathedral Bluffs from the United States of America.

First production is projected for 1985 and full production is expected to be reached in 1990. Total capital cost is estimated to be about $3 billion in 1980 dollars excluding capitalized interest. The total Project cost, including capitalized interest and other capitalized costs is estimated to be approximately $5.9 billion, adjusted for inflation at an estimated annual rate of 8% through 1990 ("Total Project Cost"). Based on this estimate, Cathedral Bluffs proposes that the United States guarantee approximately $4.3 billion in loans for the Project.

The feedstock for the Project's modified-in-situ ("MIS") process will be oil shale rubblized in underground retorts. The feedstock for the surface retorting process will consist of oil shale mined in the preparation of the MIS retorts.

The Project reserves are a 290' upper interval (development horizon) of the oil shale deposit on the C-b Tract comprised of both high and low-grade sections. These reserves are sufficient to supply the feedstock to produce 94,000 barrels per day of shale oil for 30 years.

At full production the products recovered from retorting the oil shale with the MIS process and with the surface retorting process will be 94,000 barrels per day (bpd) of raw shale oil, and 229 short tons per day (tpd) of fertilizer-quality anhydrous ammonia.

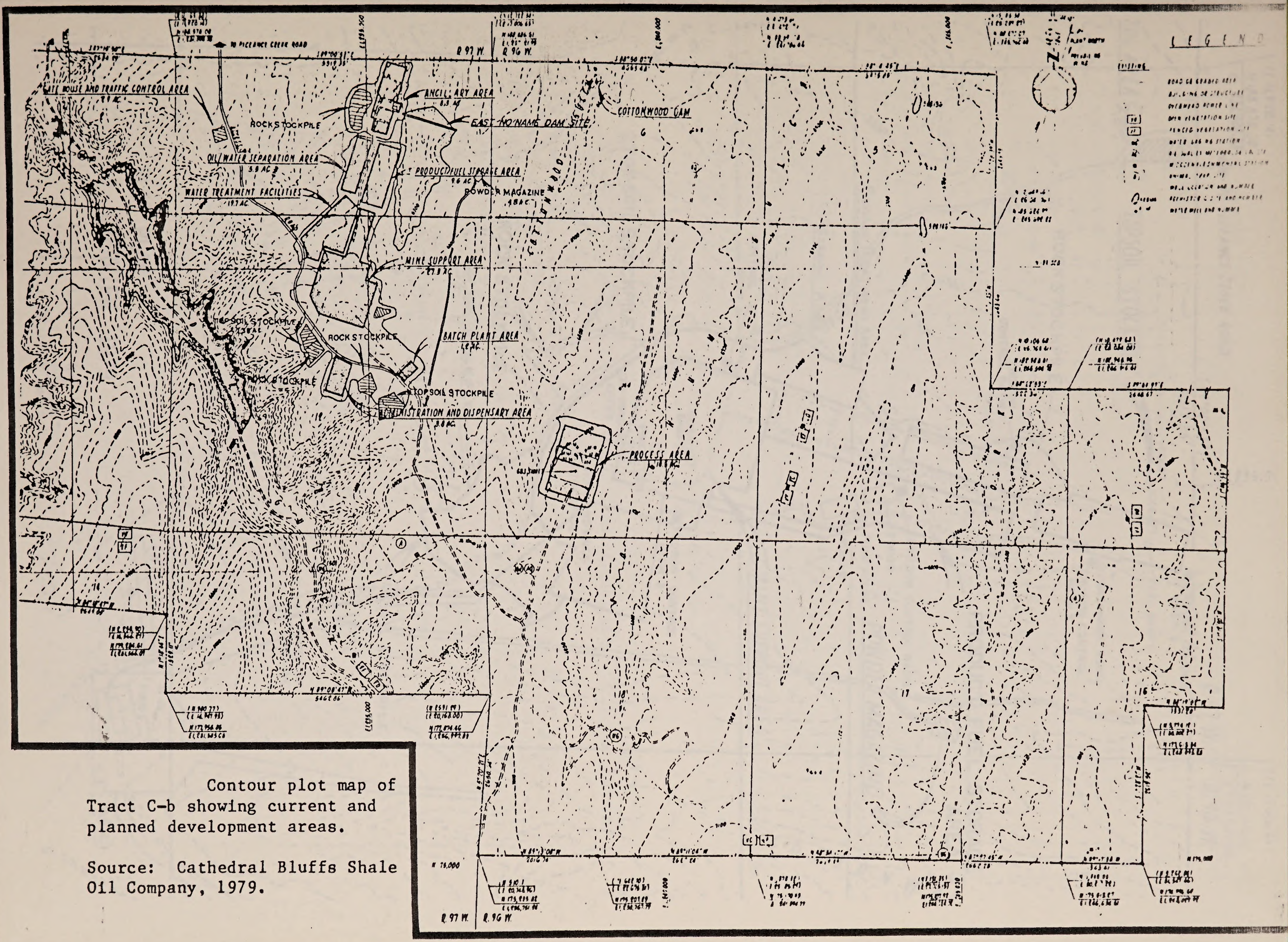
In addition, 2,390 MM standard cubic feet per day (scfd) of offgases produced by the MIS and surface retorting processes will be used to generate steam. This steam will: (1) satisfy the processing requirements; (2) generate enough electrical power to meet the Project's electricity demand; and, (3) provide excess cogenerated power for export.



Nearly 50 million years ago, lakes covered the area now known as the Green River formation. For about 10 million years, these lakes accumulated thousands of tons of sediments from surrounding volcanoes and cliffs along with dying plant and animal matter. Through the years of layering and compaction, the organic and inorganic materials hardened into a finely textured sedimentary rock called oil shale. Now buried some 1,200 ft below the surface, these oil shale rocks lock dark brown layers of kerogen; an organic substance that can be decomposed to yield shale oil.

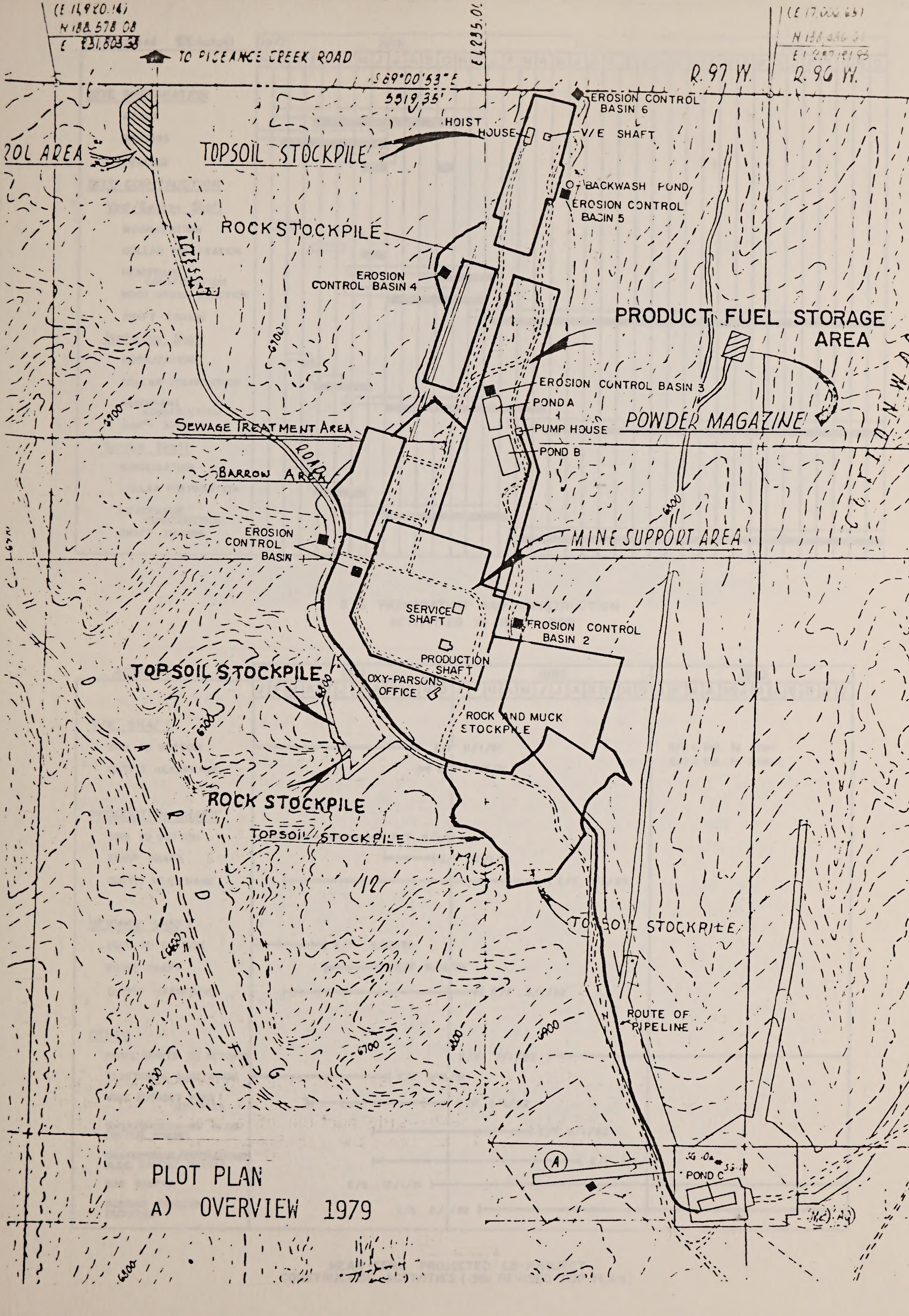
Estimates show that the Green River Formation holds nearly 2 1/2 times the current free world oil reserves. An in place resource of about 2.82 billion bbls of oil exist over the full 5,094 acres of the C-b tract. Since 505 acres of the tract are restricted due to shaft and boundry pillars, safety regulations, boundry irregularities, and design considerations, and overall recovery yield of 1.06 billion bbls is expected from the mining project. This is approximately 41.7 percent of the available site resource. From the total amount of shale oil recovered, approximately 63.6 percent will be derived from in situ retorting while the remaining 36.4 percent will be obtained from surface retorting of the raw shale produced from void excavation and other mine development.

Surface retorting of shale removed from two mine levels above and below the selected stratigraphic horizon along with other points outside the resource base will yield an additional 28 million bbls of oil. Other areas above and below the proposed MIS development horizon contain varying degrees of oil shale deposits. A more than 1,000 foot thick zone of alternating rich and lean deposits lay beneath the development area. Nearly 400 feet of much leaner deposits are found above the development area. The proposed mine development plan would have no adverse effects on future mining of lower levels and only a limited effect on the upper levels. For additional details, see Section 4.0, Mine Development Plan.

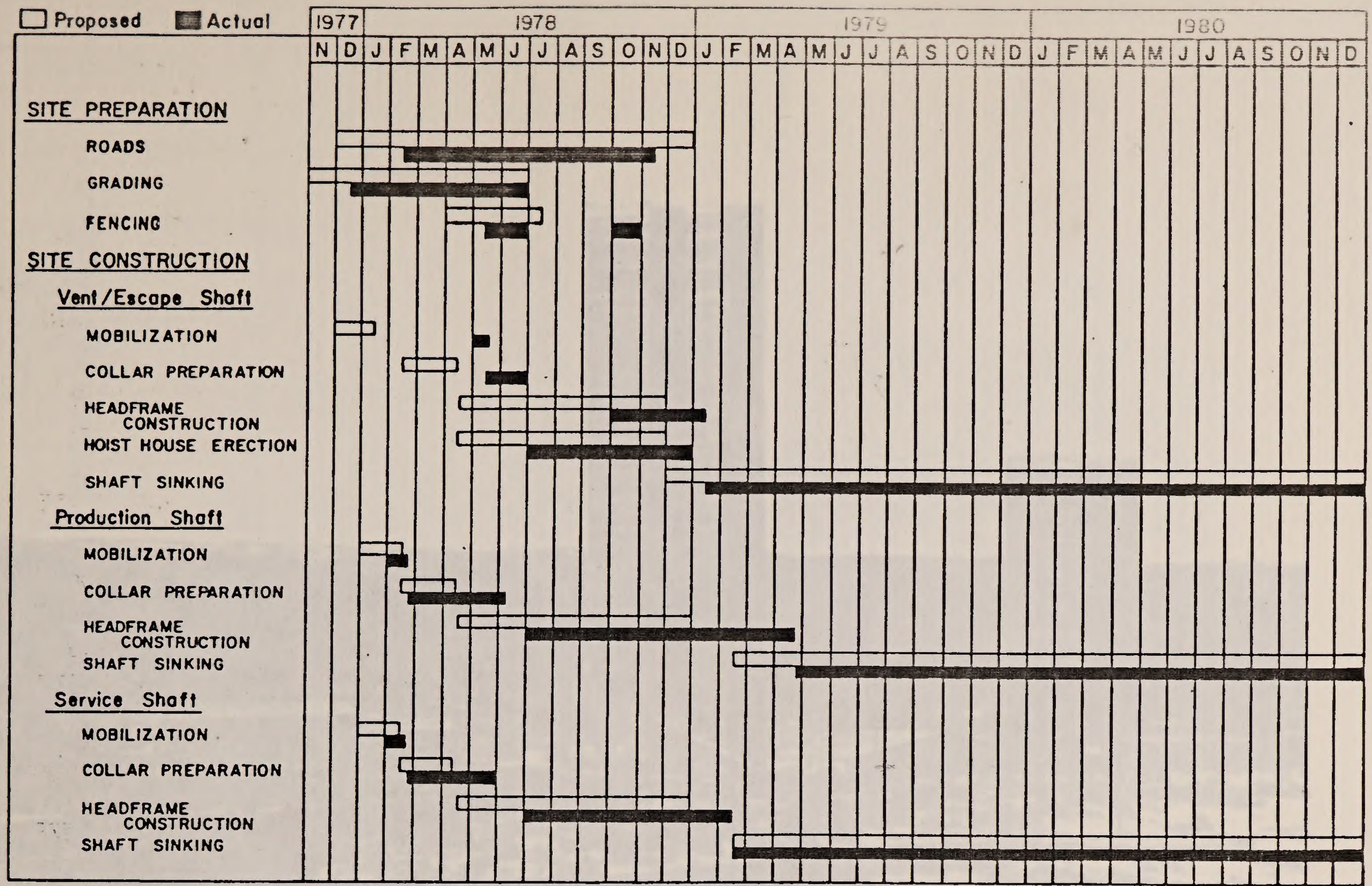



Contour plot map of Tract C-b showing current and planned development areas.

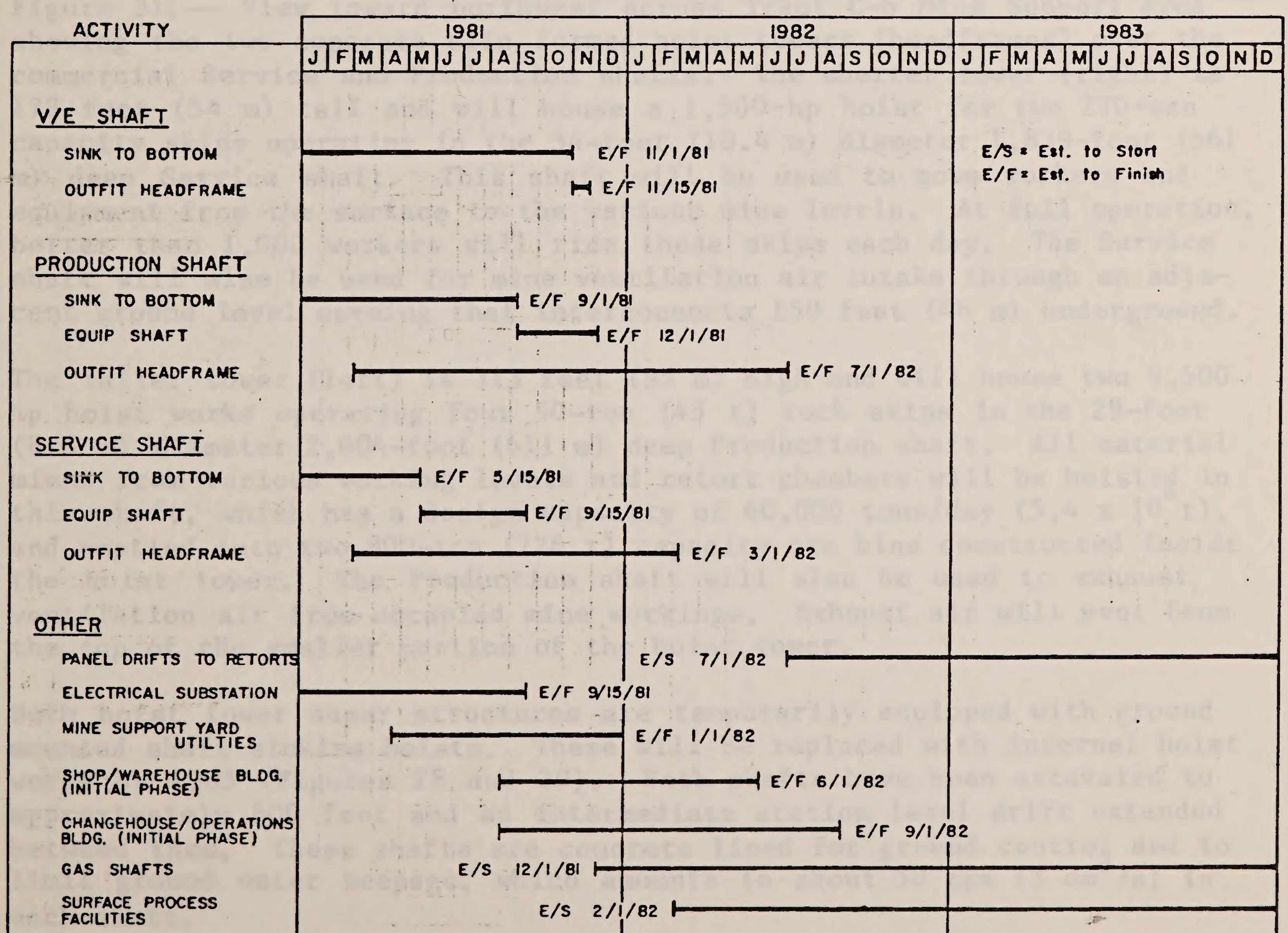
Source: Cathedral Bluffs Shale Oil Company, 1979.




PLOT PLAN
A) OVERVIEW 1979




C-b PREPARATION AND CONSTRUCTION ACTIVITIES IN 1977 – 1980




NEAR-TERM PROJECTED CB PROJECT CONSTRUCTION ACTIVITIES (1981 REVISED DDP PLAN)

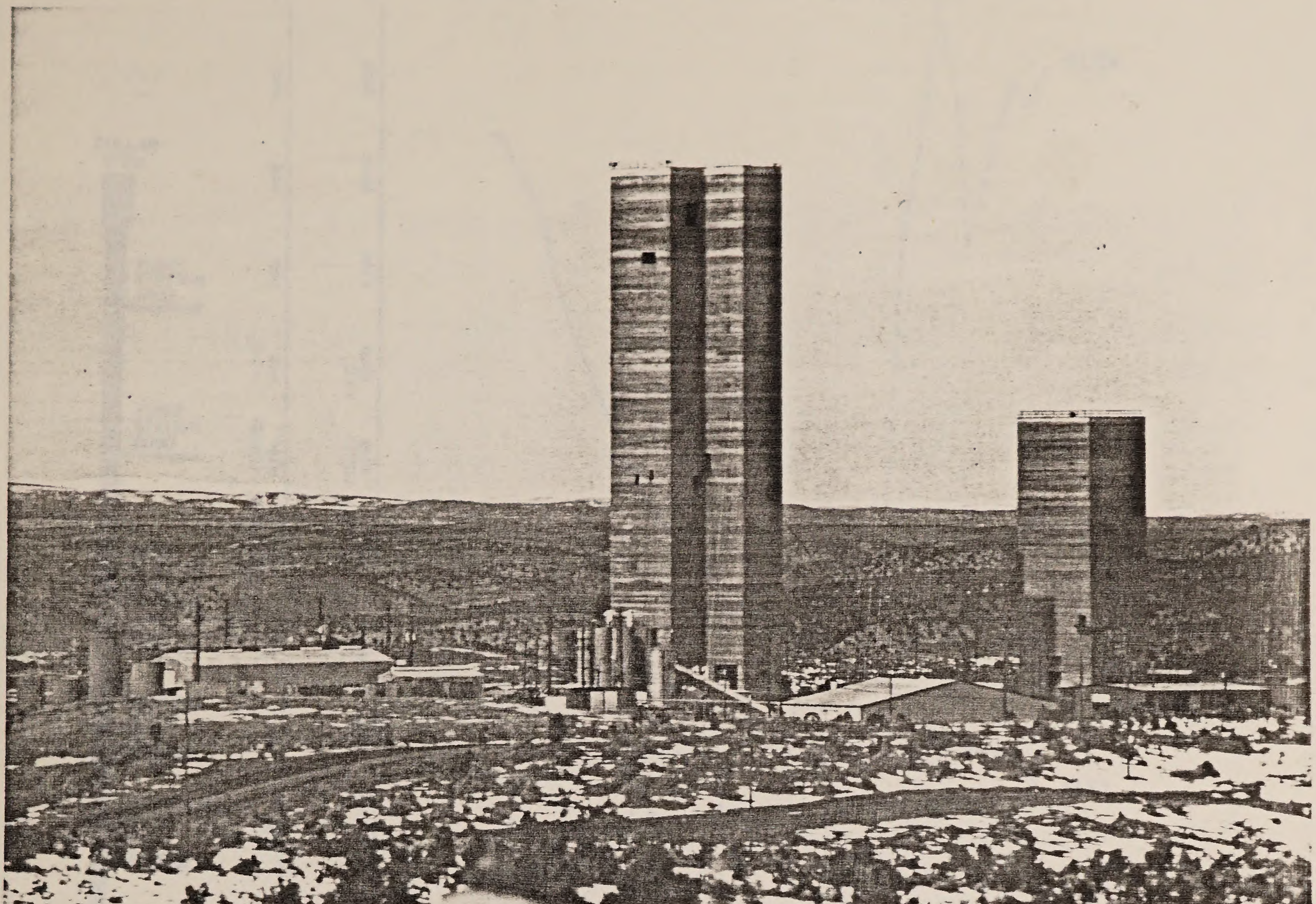
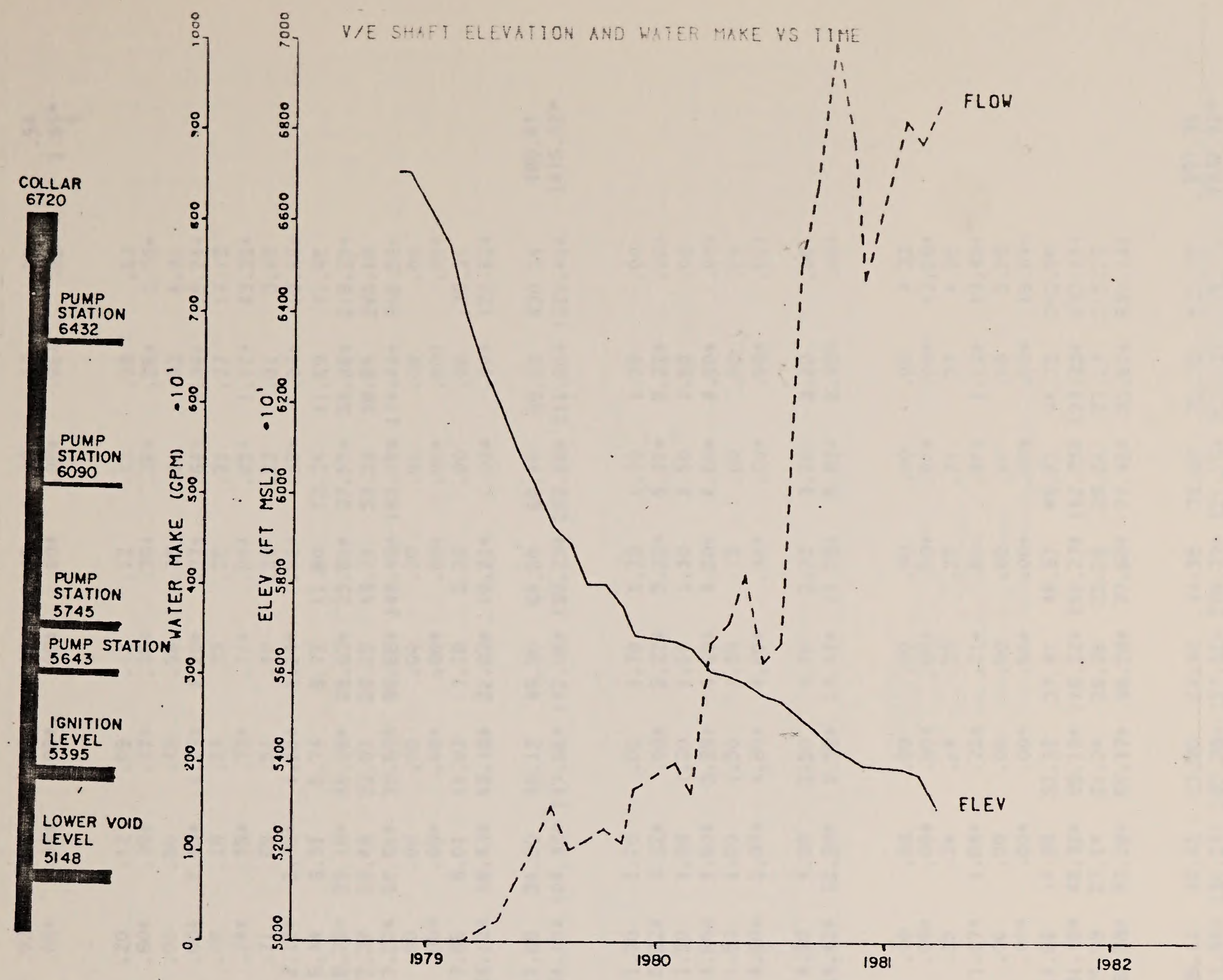
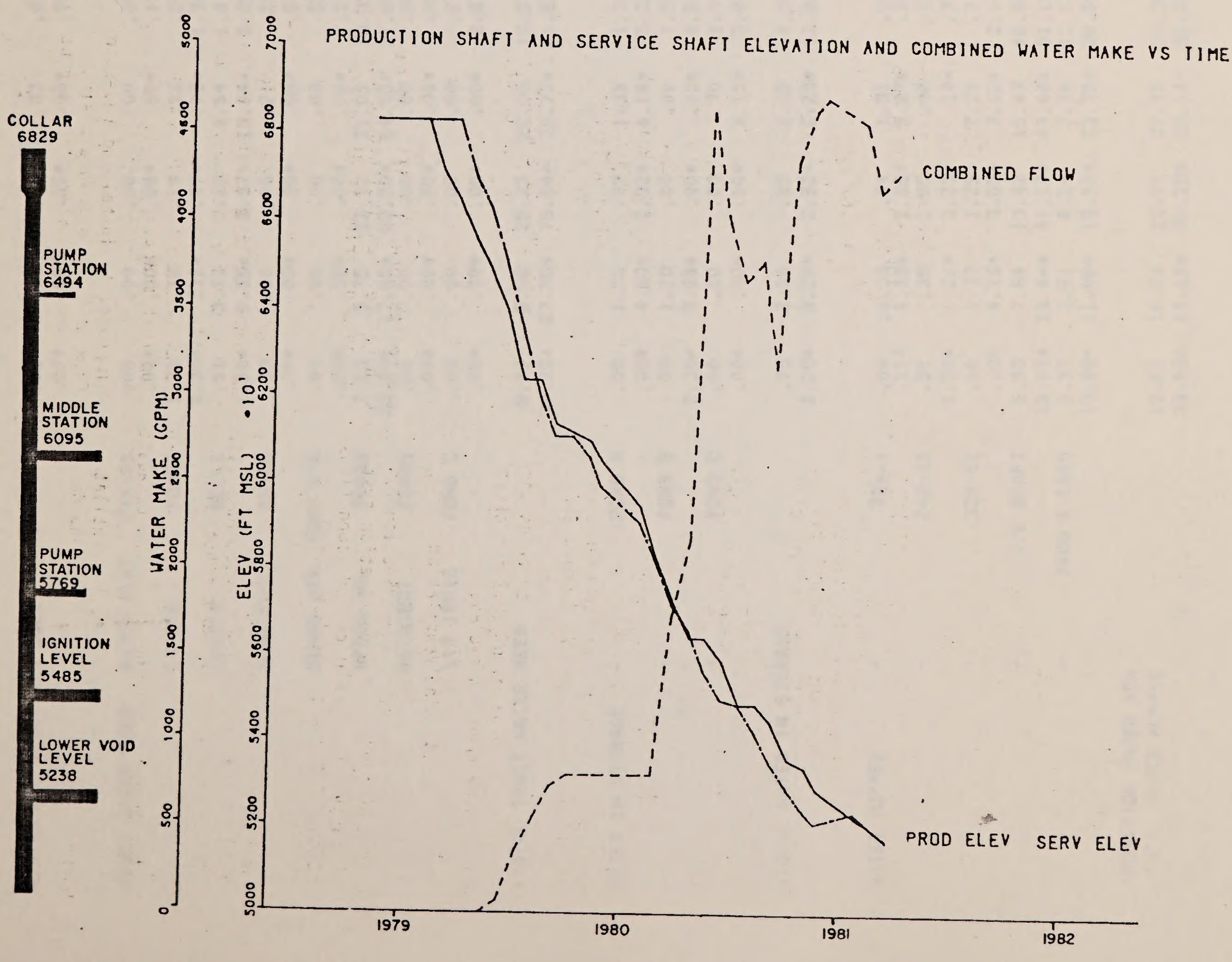


Figure 31. -- View toward northwest across Tract C-b Mine Support Area showing the two concrete slip formed hoist towers (headframes) over the commercial Service and Production shafts. The shorter tower (right) is 178 feet (54 m) tall and will house a 1,500-hp hoist for two 270-man capacity skips operating in the 34-foot (10.4 m) diameter 1,839-foot (561 m) deep Service shaft. This shaft will be used to move workers and equipment from the surface to the various mine levels. At full operation, better than 1,000 workers will ride these skips each day. The Service shaft will also be used for mine ventilation air intake through an adjacent ground level opening that interconnects 150 feet (46 m) underground.

The taller tower (left) is 313 feet (95 m) high and will house two 9,500 hp hoist works operating four 50-ton (45 t) rock skips in the 29-foot (8.8 m) diameter 2,004-foot (611 m) deep Production shaft. All material mined from various working levels and retort chambers will be hoisted in this shaft, which has a design capacity of 60,000 tons/day ($5.4 \times 10^4$ t), and emptied into two 800-ton (726 t) capacity ore bins constructed inside the hoist tower. The Production shaft will also be used to exhaust ventilation air from occupied mine workings. Exhaust air will vent from the top of the smaller portion of the hoist tower.

Both hoist tower super structures are temporarily equipped with ground mounted shaft sinking hoists. These will be replaced with internal hoist works by 1983 (Figures 28 and 29). Both shafts have been excavated to approximately 800 feet and an intermediate station level drift extended between them. These shafts are concrete lined for ground control and to limit ground water seepage, which amounts to about 50 gpm (3 $dm^3$/s) in each shaft.

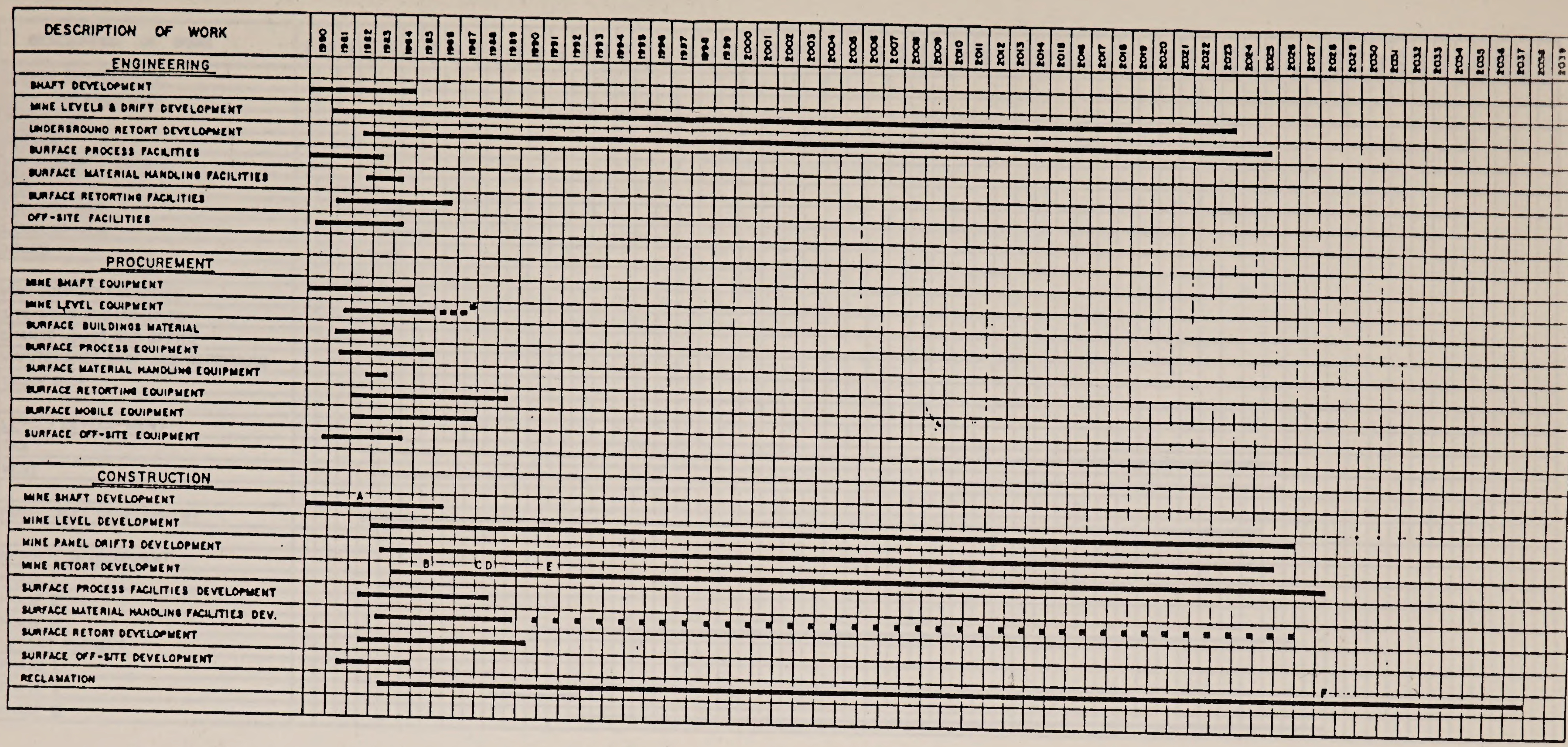

V/E SHAFT ELEVATION AND WATER MAKE VS TIME
COLLAR 6720
PUMP STATION 6432
PUMP STATION 6090
PUMP STATION 5745
PUMP STATION 5643
IGNITION LEVEL 5395
LOWER VOID LEVEL 5148
WATER MAKE (GPM) •10¹
0
100
200
300
400
500
600
700
800
900
1000
ELEV (FT MSL) •10¹
5000
5200
5400
5600
5800
6000
6200
6400
6600
6800
7000
FLOW
ELEV
1979
1980
1981
1982


PRODUCTION SHAFT AND SERVICE SHAFT ELEVATION AND COMBINED WATER MAKE VS TIME
COLLAR 6829
PUMP STATION 6494
MIDDLE STATION 6095
PUMP STATION 5769
IGNITION LEVEL 5485
LOWER VOID LEVEL 5238
WATER MAKE (GPM)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
ELEV (FT MSL) •10¹
5000
5200
5400
5600
5800
6000
6200
6400
6600
6800
7000
COMBINED FLOW
PROD ELEV
SERV ELEV
1979
1980
1981
1982

## 1981 C-B WATER USAGE (10**6 GALLONS, * =ACRE FEET)

| USE | SOURCE | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTAL YTD | TOTAL YRS TD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OFF-TRACT WTR USED POTABLE | TOWN | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .03 | .03 | .29 | |
| | | .07* | .06* | .06* | .08* | .08* | .08* | .08* | .08* | .08* | .08* | .08* | .08* | .89* | |
| *TOTAL OFF-TRACT WTR USED | | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .03 | .03 | .29 | .54 |
| | | .07* | .06* | .06* | .08* | .08* | .08* | .08* | .08* | .08* | .08* | .08* | .08* | .89* | 1.65* |
| TRACT WATER USED BATCH PLNT | 24X-25 | .00 | .00 | .00 | .00 | .06 | .20 | .12 | .09 | .12 | .12 | .12 | .08 | .90 | |
| | | .00* | .00* | .00* | .00* | .19* | .60* | .38* | .27* | .36* | .36* | .36* | .26* | 2.76* | |
| CONSTR | PONDS | 1.75 | .10 | .15 | .23 | .57 | .00 | .80 | .48 | .39 | .25 | .21 | .03 | 4.97 | |
| | | 5.38* | .31* | .47* | .72* | 1.74* | .00* | 2.45* | 1.47* | 1.20* | .77* | .64* | .06* | 15.24* | |
| CONSTR | WELLS | .51 | 3.12 | 3.25 | 4.54 | 1.01 | .08 | .18 | .24 | .23 | .29 | .31 | .37 | 14.12 | |
| | | 1.55* | 9.59* | 9.97* | 13.94* | 3.09* | .24* | .55* | .72* | .71* | .90* | .95* | 1.12* | 43.33* | |
| DUST CNTL | PONDS | .00 | .00 | .00 | .21 | .22 | .71 | .88 | .51 | .40 | .30 | .23 | .01 | 3.49 | |
| | | .00* | .00* | .00* | .66* | .68* | 2.19* | 2.72* | 1.55* | 1.24* | .92* | .69* | .04* | 10.68* | |
| GLAND WTR | PUMP STA | .00 | .00 | .00 | .00 | .52 | 6.44 | 9.51 | 9.74 | 9.72 | 11.60 | 12.24 | 11.69 | 71.45 | |
| | | .00* | .00* | .00* | .00* | 1.58* | 19.76* | 29.18* | 29.88* | 29.83* | 35.61* | 37.55* | 35.86* | 219.25* | |
| NPDES REL | PONDS | 7.63 | 5.76 | 22.32 | 21.01 | 10.32 | 2.37 | 16.49 | 23.01 | 28.25 | 48.71 | 53.38 | 56.85 | 296.10 | |
| | | 23.40* | 17.66* | 68.50* | 64.46* | 31.68* | 7.27* | 50.61* | 70.60* | 86.68* | 149.46* | 163.79* | 174.44* | 906.56* | |
| REINJECT | PONDS | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | |
| | | .00* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | |
| SPR IRRIG | POND C | .00 | .00 | .00 | .00 | .87 | 7.86 | 6.01 | 14.07 | 7.18 | 3.33 | .00 | .00 | 39.31 | |
| | | .00* | .00* | .00* | .00* | 2.67* | 24.12* | 18.43* | 43.16* | 22.03* | 10.21* | .00* | .00* | 120.63* | |
| *TOTAL TRACT WATER USED | | 9.89 | 8.98 | 25.73 | 26.00 | 13.57 | 17.66 | 34.00 | 48.12 | 46.30 | 64.60 | 66.48 | 69.03 | 430.34 | 480.81 |
| | | 30.33* | 27.56* | 78.94* | 79.77* | 41.63* | 54.19* | 104.32* | 147.66* | 142.06* | 198.23* | 203.98* | 211.80* | 1320.46* | 1475.32* |
| WATER IN STORAGE - | POND A | .00 | 1.50 | .95 | 1.35 | 1.70 | 1.70 | 1.70 | .00 | 1.70 | 1.70 | 1.70 | 1.70 | .00 | |
| | | .00* | 4.60* | 2.92* | 4.14* | 5.22* | 5.22* | 5.22* | .00* | 5.22* | 5.22* | 5.22* | 5.22* | .00* | |
| - | POND B | .75 | 1.20 | .00 | .00 | 1.50 | 1.50 | 1.50 | 1.30 | 1.50 | 1.50 | 1.50 | 1.50 | .00 | |
| | | 2.30* | 3.68* | .00* | .00* | 4.60* | 4.60* | 4.60* | 3.99* | 4.60* | 4.60* | 4.60* | 4.60* | .00* | |
| - | POND C | .00 | .00 | .00 | .70 | 1.00 | 1.50 | 1.00 | 1.50 | 1.50 | .15 | .00 | .00 | .00 | |
| | | .00* | .00* | .00* | 2.15* | 3.07* | 4.60* | 3.07* | 4.60* | 4.60* | .46* | .00* | .00* | .00* | |
| *TOTAL WATER IN STORAGE | | .75 | 2.70 | .95 | 2.05 | 4.20 | 4.70 | 4.20 | 2.80 | 4.70 | 3.35 | 3.20 | 3.20 | .00 | |
| | | 2.30* | 8.28* | 2.92* | 6.29* | 12.89* | 14.42* | 12.89* | 8.59* | 14.42* | 10.28* | 9.82* | 9.82* | .00* | |
| WATER PUMPED - | 33X-1 | .04 | 1.36 | .94 | 1.91 | .06 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | 4.32 | |
| | | .11* | 4.19* | 2.89* | 5.87* | .20* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | 13.26* | |
| - | 24X-23 | .51 | .39 | 1.05 | .08 | .23 | .35 | .34 | .24 | .23 | .29 | .31 | .37 | 4.39 | |
| | | 1.55* | 1.21* | 3.23* | .24* | .72* | 1.07* | 1.04* | .72* | .71* | .90* | .95* | 1.12* | 13.46* | |
| - | 32X-12 | .00 | 1.37 | 1.25 | 2.55 | .71 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | 5.88 | |
| | | .00* | 4.19* | 3.85* | 7.82* | 2.18* | .00* | .00* | .00* | .00* | .00* | .00* | .00* | 18.04* | |
| - | V/E SHAFT | 8.50 | 7.64 | 13.42 | 15.47 | 16.68 | 16.68 | 14.96 | 32.32 | 37.91 | 48.97 | 46.52 | 44.72 | 303.80 | |
| | | 26.07* | 23.44* | 41.17* | 47.46* | 51.19* | 51.18* | 45.92* | 99.19* | 116.32* | 150.27* | 142.75* | 137.23* | 932.19* | |
| - | PROD & SERV | 3.57 | 3.61 | 6.24 | 7.74 | 12.57 | 19.09 | 27.14 | 21.34 | 26.26 | 25.29 | 25.24 | 27.27 | [illegible] | |
| | | 10.96* | 11.08* | 19.15* | 23.75* | 38.56* | 58.58* | 83.28* | 65.47* | 80.58* | 77.60* | 77.46* | 83.67* | 630.14* | |
| POSITION PAPER NOW<br>*TOTAL WATER PUMPED | | 12.61 | 14.38 | 22.91 | 27.75 | 30.26 | 36.12 | 42.43 | 53.90 | 64.40 | 74.55 | 72.07 | 72.29 | 523.75 | 597.35 |
| | | 38.69* | 44.11* | 70.28* | 85.14* | 92.84* | 110.84* | 130.24* | 165.38* | 197.62* | 228.77* | 221.15* | [illegible] | [illegible] | 1832.92* |

## MASTER ENGINEERING, PROCUREMENT AND CONSTRUCTION SCHEDULE




* IS A CONTINUOUS ACTIVITY THROUGH MINE DEVELOPMENT

MILESTONES:

A. PRODUCTION SHAFT EQUIPPED AND FULLY OPERATIONAL
B. IGNITE FIRST RETORT
C. BEGIN PHASE II DEVELOPMENT
D. FULL OIL PRODUCTION
E. BEGIN PHASE III DEVELOPMENT
F. BEGIN PLANT SHUTDOWN AND FINAL RECLAMATION



Figure 3.1 MASTER ENGINEERING, PROCUREMENT AND CONSTRUCTION SCHEDULE

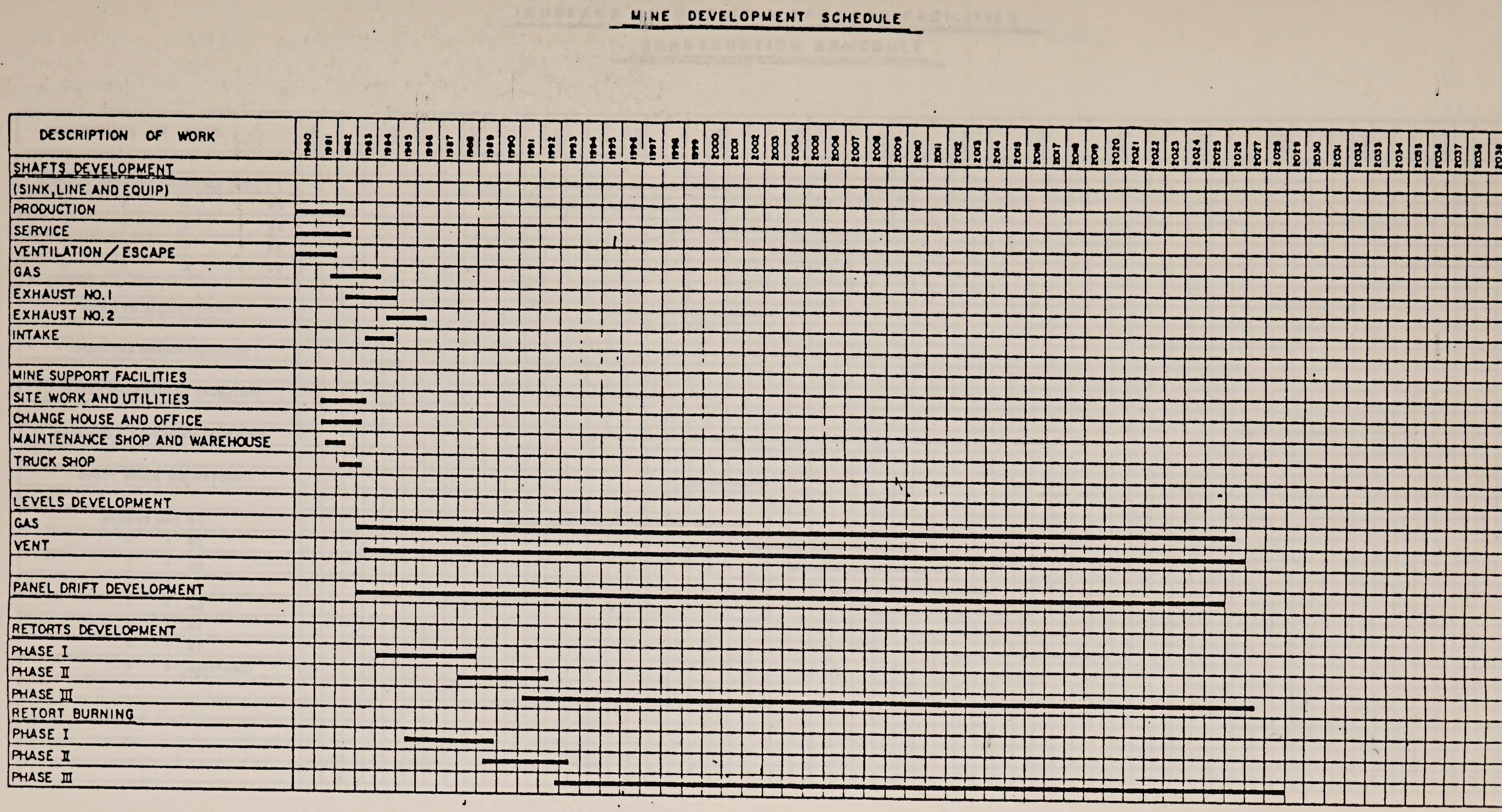
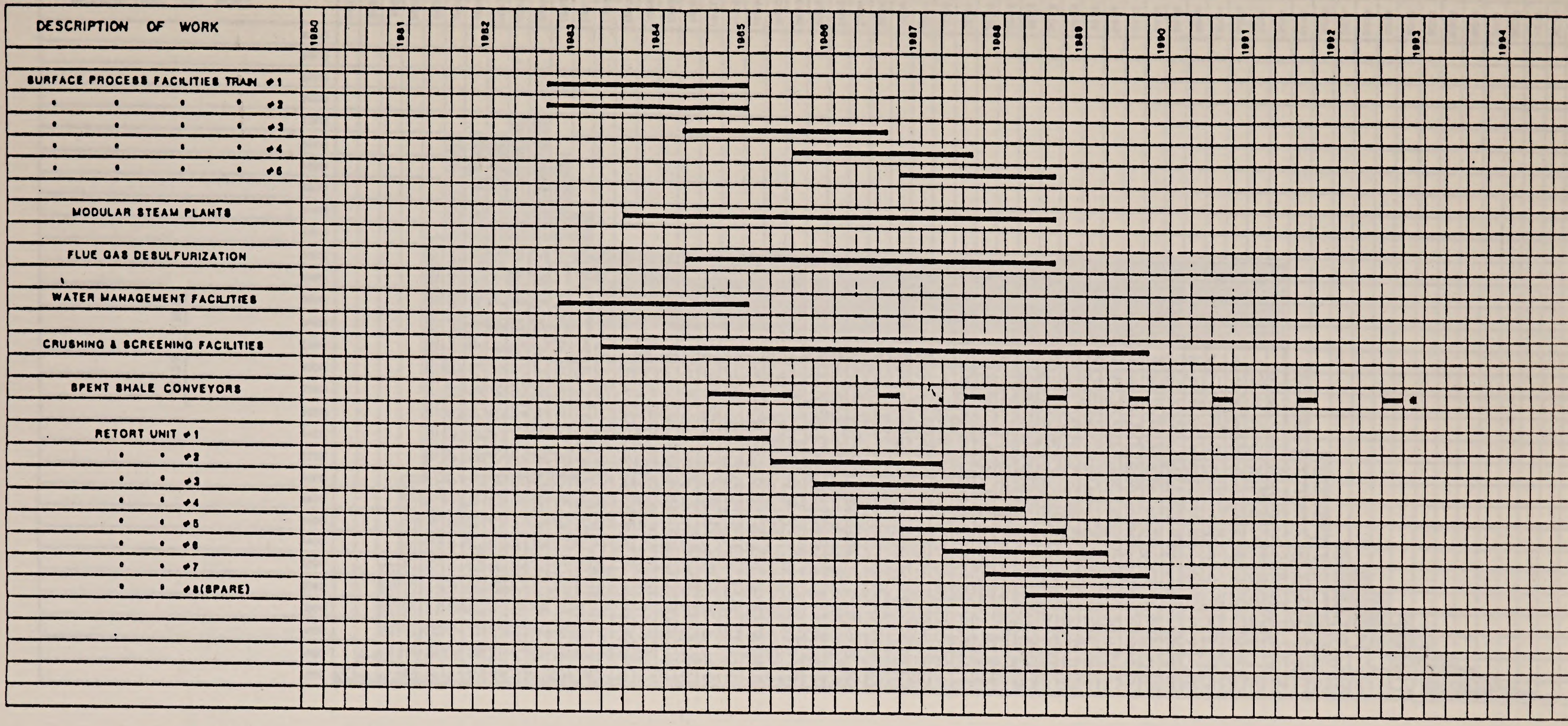



Figure 3.2 MINE DEVELOPMENT SCHEDULE

## SURFACE RETORTING & PROCESS FACILITIES

## CONSTRUCTION SCHEDULE




* CONTINUOUS ACTIVITY THROUGH MINE DEVELOPMENT

Figure 3.3 SURFACE RETORTING & PROCESS FACILITIES CONSTRUCTION SCHEDULE

## MANPOWER REQUIREMENT SCHEDULE

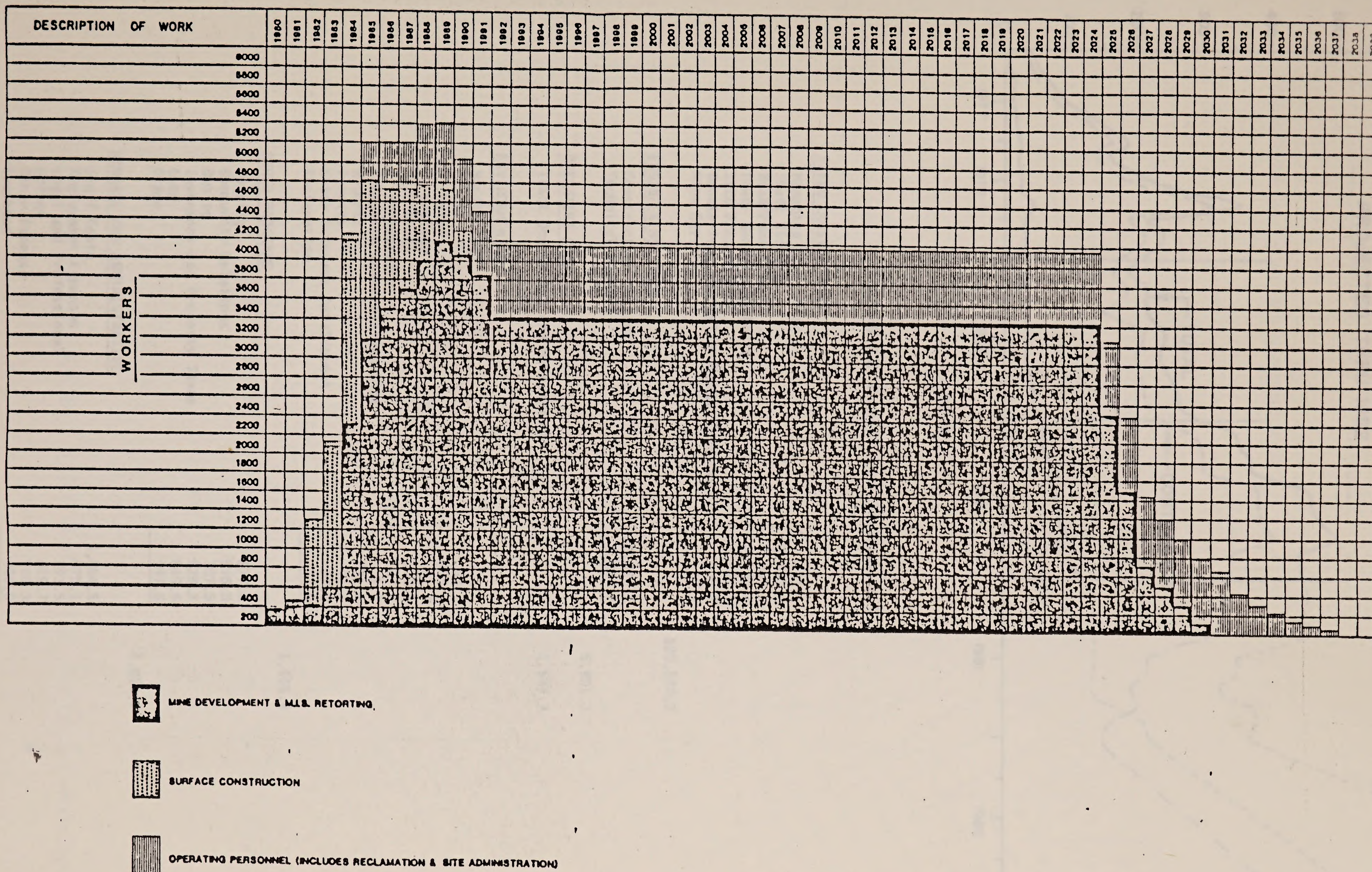
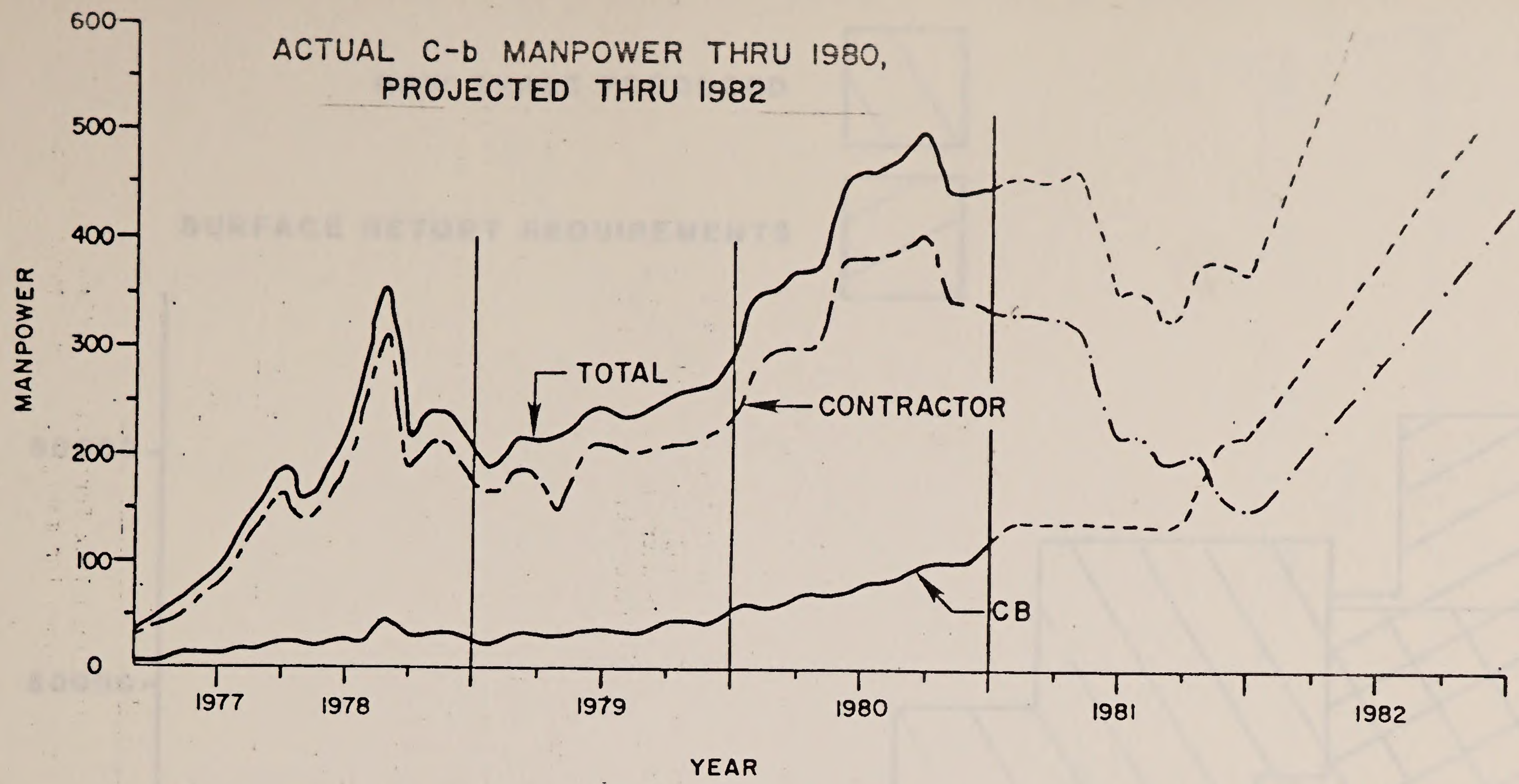


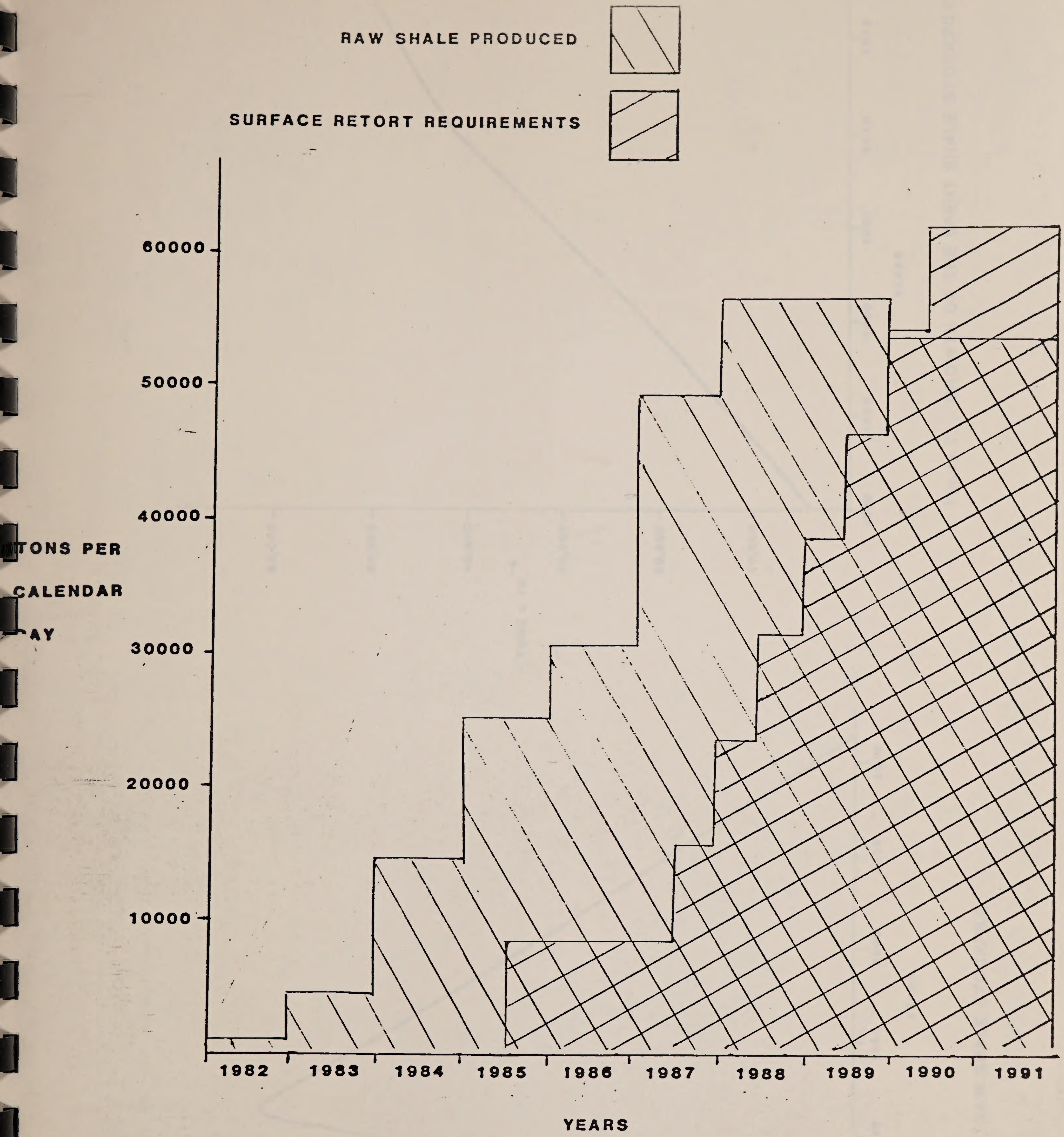



Figure 3.7 MANPOWER REQUIREMENT SCHEDULE




1980 C.B. Expenditures (In Thousands)

| | | |
|---|---|---|
| FIELD CONSTRUCTION | | |
| Managing Contractor | $ 411.1 | |
| Shaft Sinking | 22,637.8 | |
| Headframe Costs | 1,355.5 | |
| Power Generating Costs | 2,793.4 | |
| Site Preparation | 1,897.3 | |
| Dewatering, Irrigation & Water Treatment | 430.1 | |
| Mine Services | 19.1 | |
| | | $29,544.3 |
| ENGINEERING COSTS | | |
| Construction Support | 2,856.6 | |
| Technical Support | 3,044.7 | |
| | | 5,901.3 |
| OPERATING COSTS | | |
| Tract Operations and Maintenance | | 1,587.7 |
| ENVIRONMENTAL | | |
| Monitoring: | | |
| Air | 93.1 | |
| Water | 855.4 | |
| Geology | 11.7 | |
| Biology | 103.1 | |
| Photography | 22.2 | |
| Ecosystem Interrelationships | 1.1 | |
| Reports | 231.4 | |
| Permits | 42.1 | |
| Water Resource Development | 69.3 | |
| Reclamation | 37.0 | |
| | | 1,466.4 |
| OTHER PROGRAMS | | |
| Housing | 277.8 | |
| Community Relations | 556.0 | |
| Busing | 707.5 | |
| Insurance and Property Taxes | 625.2 | |
| Land | 849.6 | |
| Other | 997.6 | |
| | | 4,013.7 |
| GENERAL AND ADMINISTRATIVE | | |
| Staff Costs | 5,854.5 | |
| Employment Expenses | 975.1 | |
| Legal and Professional | 193.5 | |
| Office | 519.7 | |
| Other Expense | 156.3 | |
| Overhead | 300.0 | |
| | | 7,999.1 |
| TOTAL PROJECT | | $50,512.5 |




RAW SHALE PRODUCED AND SURFACE RETORT REQUIREMENTS

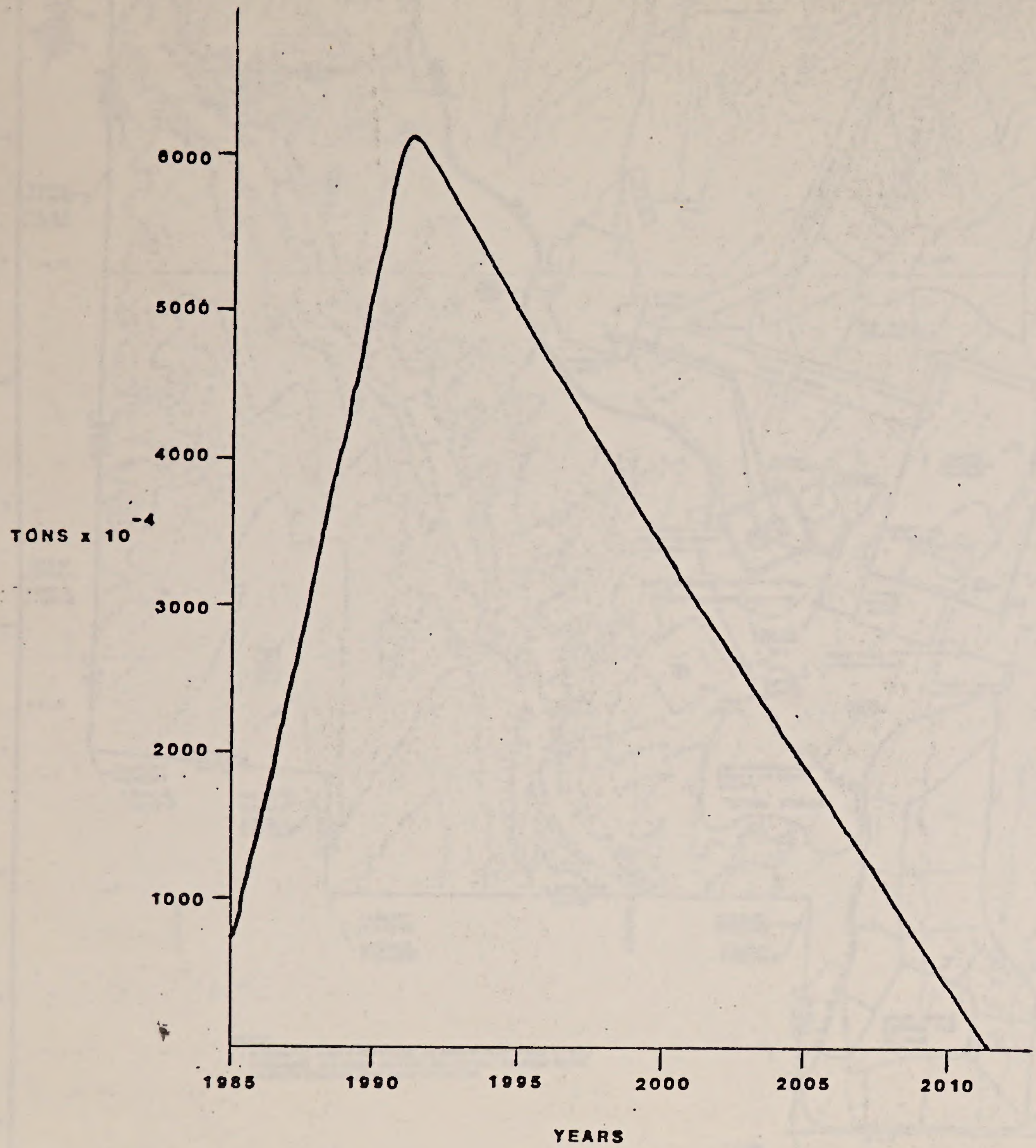



Figure 7.2 RAW SHALE STOCKPILE

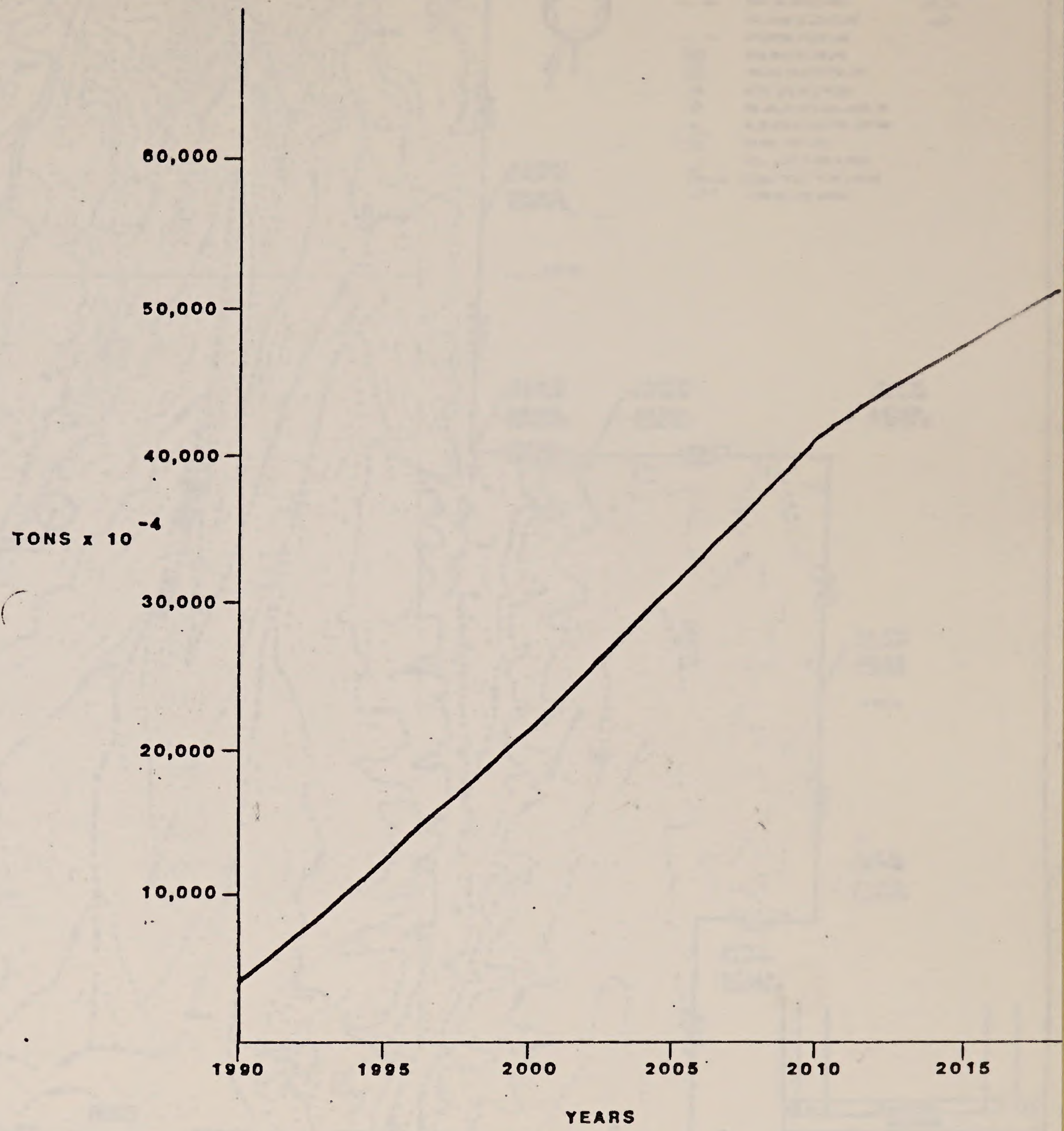
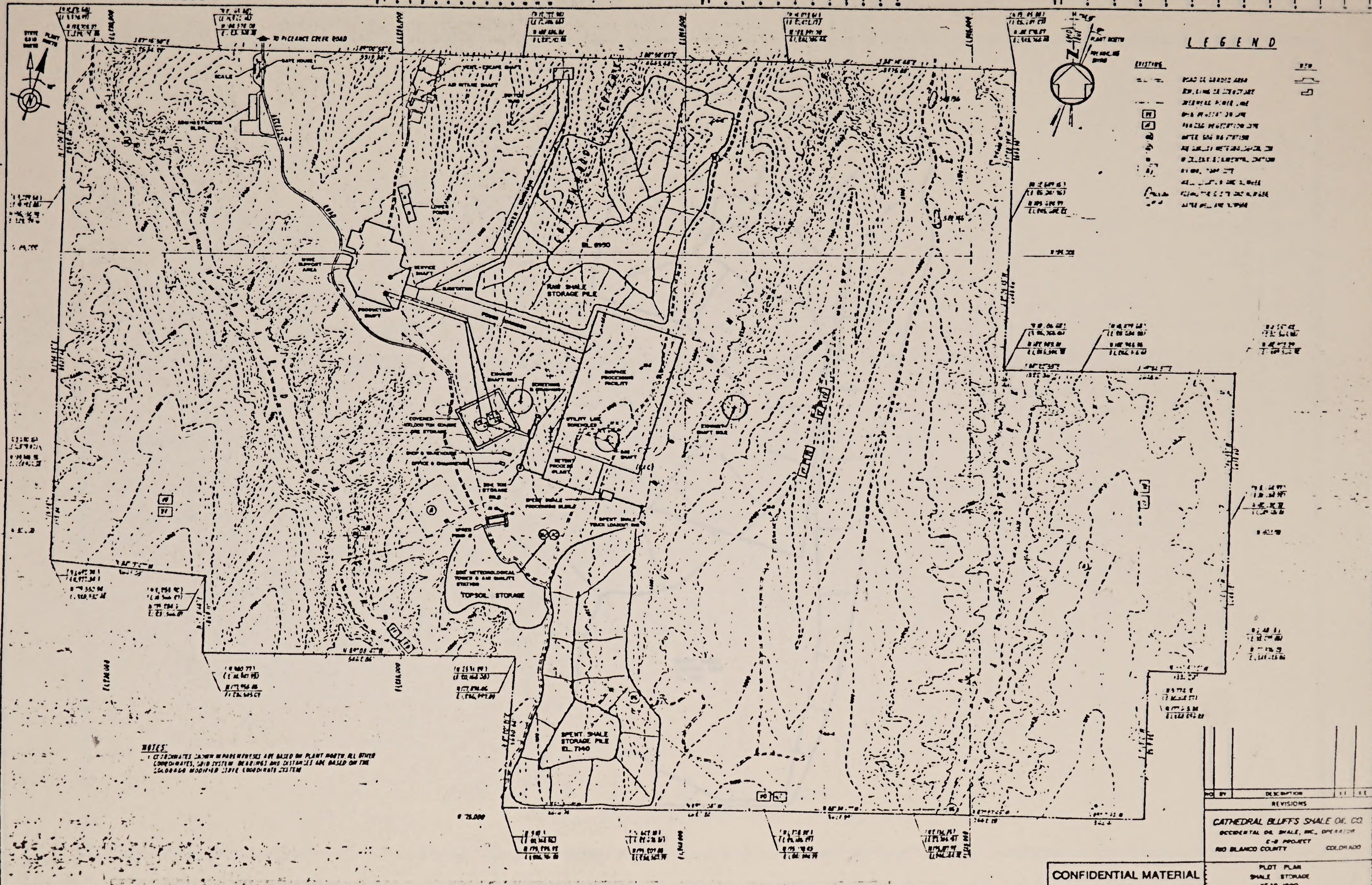
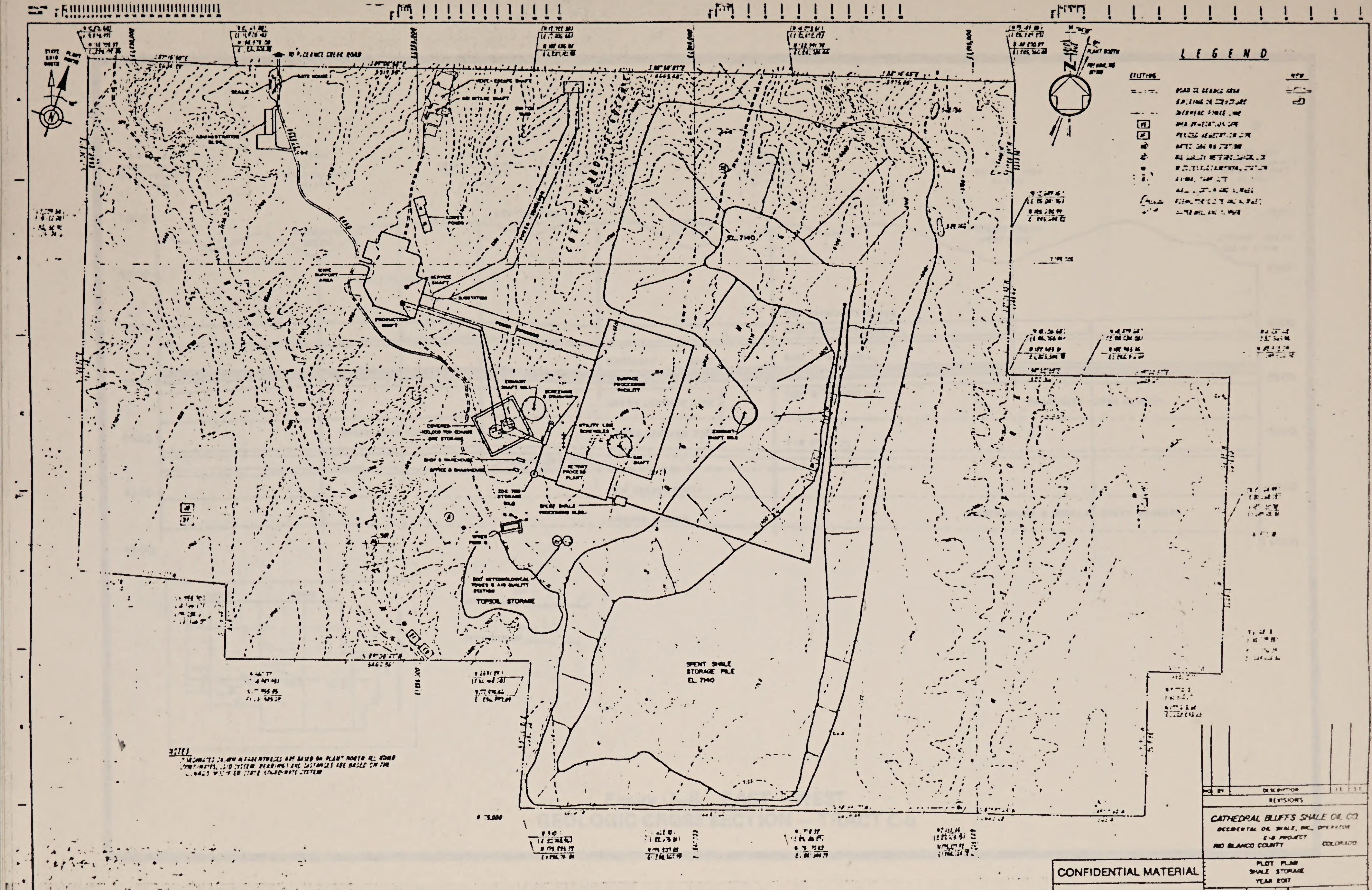



Figure 7. GROWTH OF THE SPENT SHALE STOCKPILE




YR 1990: Raw shale pile at max.




**YR 2017: Processed shale pile at max. area**

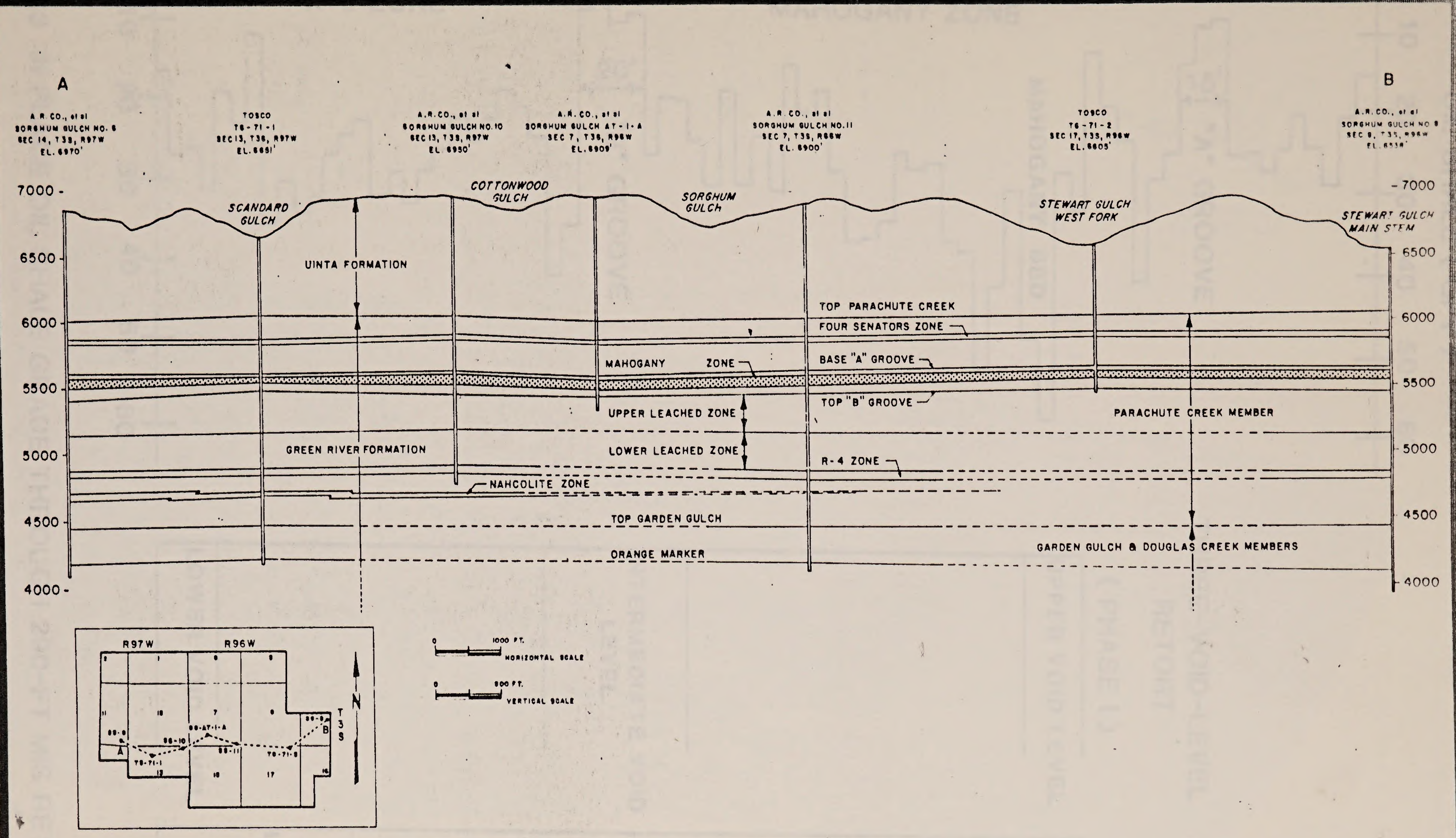



Figure II–8 EAST – WEST
GEOLOGIC CROSS SECTION – TRACT C-b

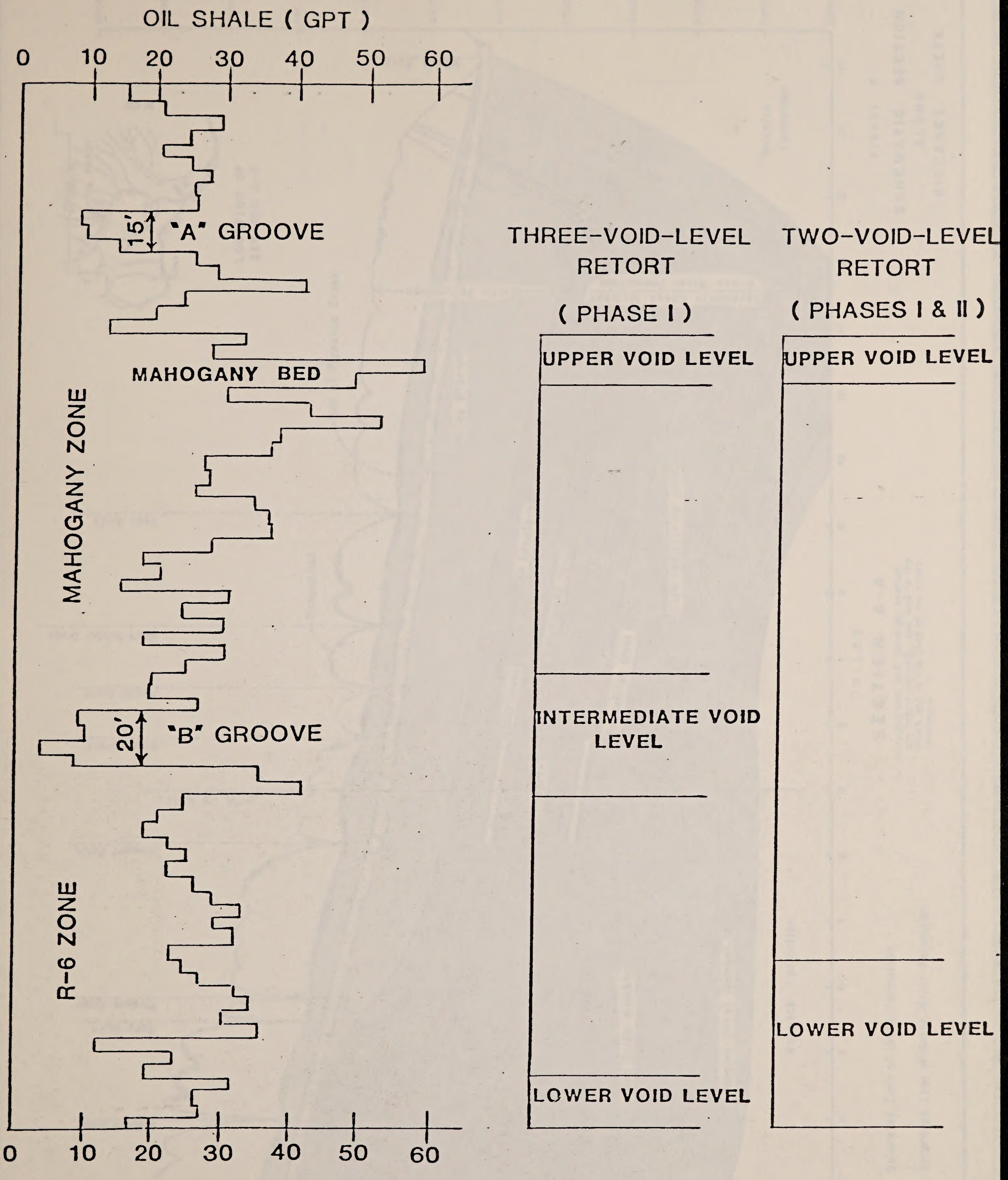
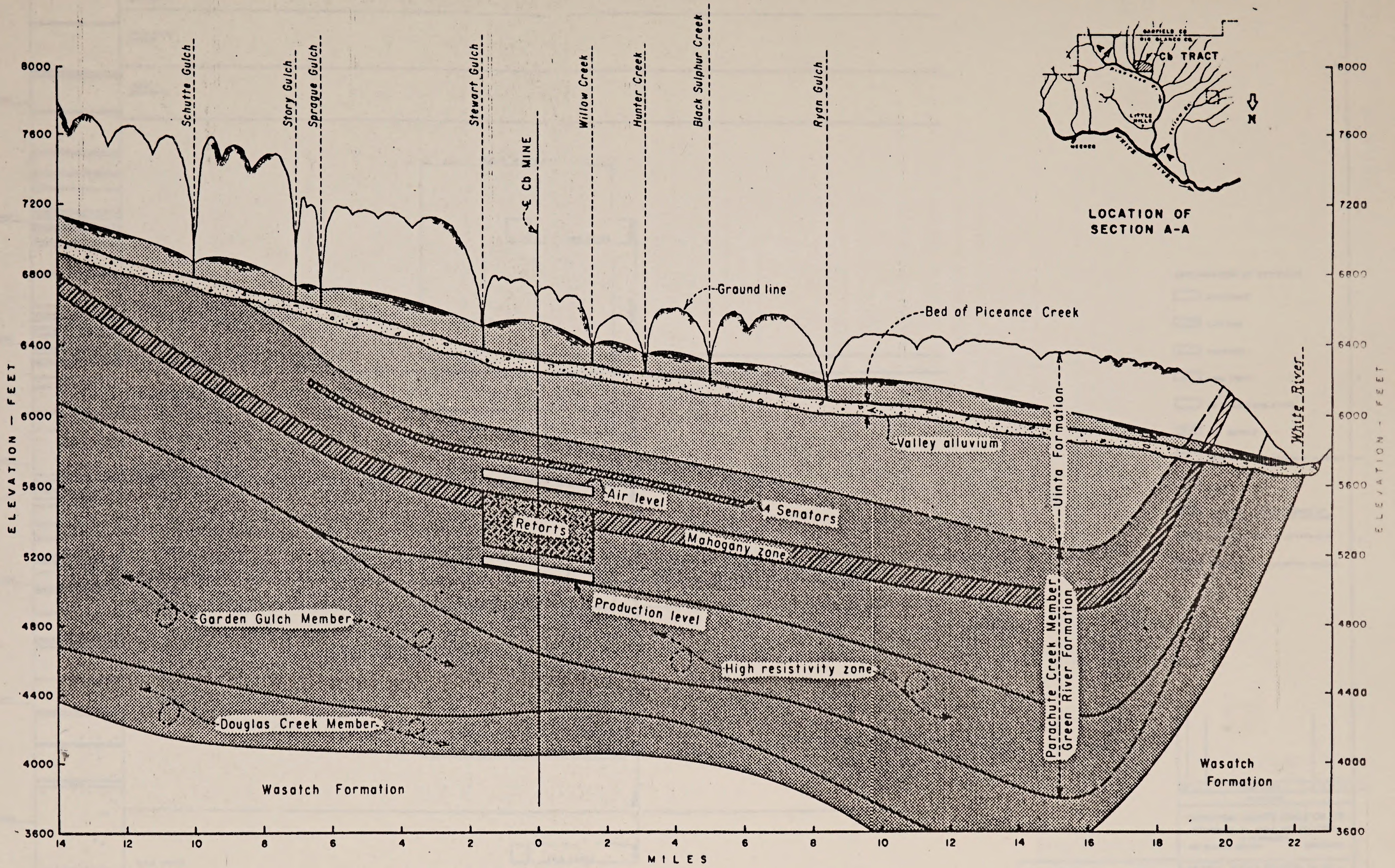



Figure 1.3 IN PLACE OIL SHALE GRADE THROUGH 290-FT MIS RETORT




Saturated Zone of Uinta Formation

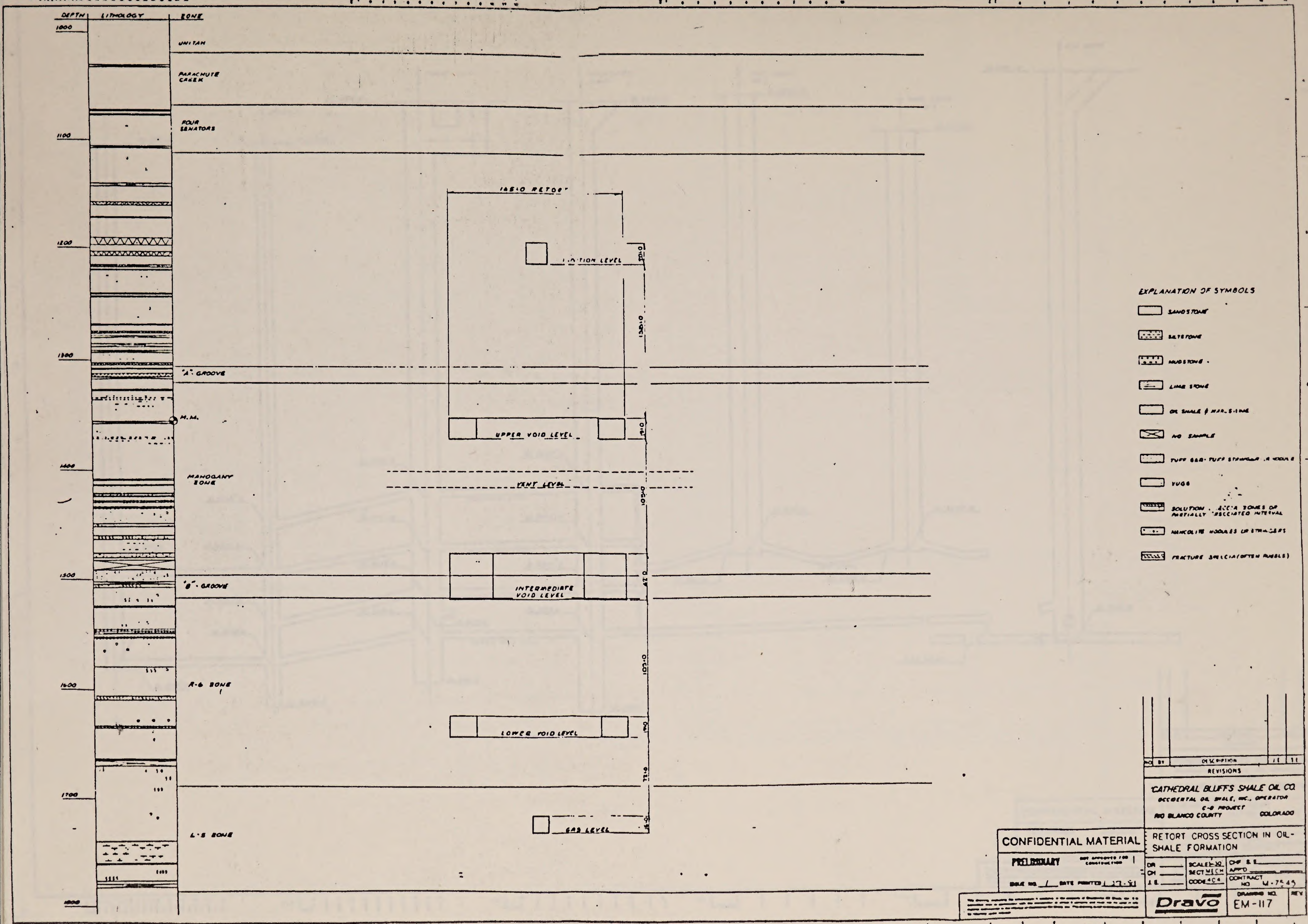
Saturated Zone of Green River Formation

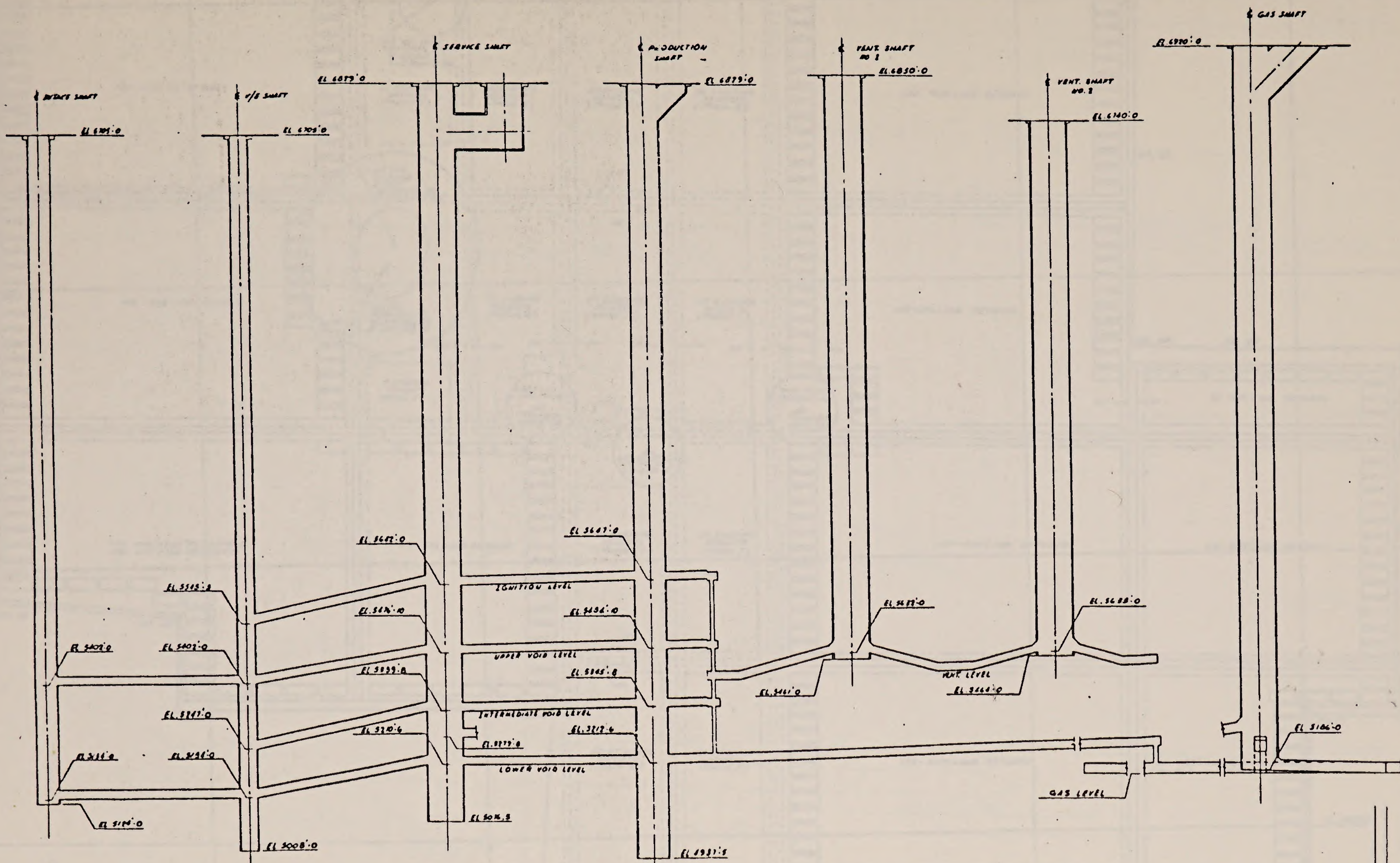
SECTION A-A

(Ground line and geologic section are taken, roughly, one mile to the south and to the west of the creek channel.)

FIGURE 2

SCHEMATIC SECTION ALONG PICEANCE CREEK


DEPTH
LITHOLOGY
ZONE
1000
1100
1200
1300
1400
1500
1600
1700
1800
UNITAH
PARACHUTE CREEK
FOUR SENATORS
"A" GROOVE
M.M.
MAHOGANY ZONE
"B" GROOVE
R-6 ZONE
L-5 ZONE
UPPER VOID LEVEL
VENT LEVEL
INTERMEDIATE VOID LEVEL
LOWER VOID LEVEL
GAS LEVEL
EXPLANATION OF SYMBOLS
SANDSTONE
SILTSTONE
MUDSTONE
LIME STONE
NO SAMPLE
VUGS
REVISIONS
DESCRIPTION
CATHEDRAL BLUFFS SHALE OIL CO.
C-B PROJECT
RIO BLANCO COUNTY
COLORADO
CONFIDENTIAL MATERIAL
RETORT CROSS SECTION IN OIL-SHALE FORMATION
PRELIMINARY
Dravo
DRAWING NO.
EM-117




| NO | BY | DESCRIPTION | | |
|---|---|---|---|---|
| | | | | |

REVISIONS

CATHEDRAL BLUFFS SHALE OIL CO.
OCCIDENTAL OIL SHALE, INC., OPERATOR
C-B PROJECT
RIO BLANCO COUNTY COLORADO

CONFIDENTIAL MATERIAL

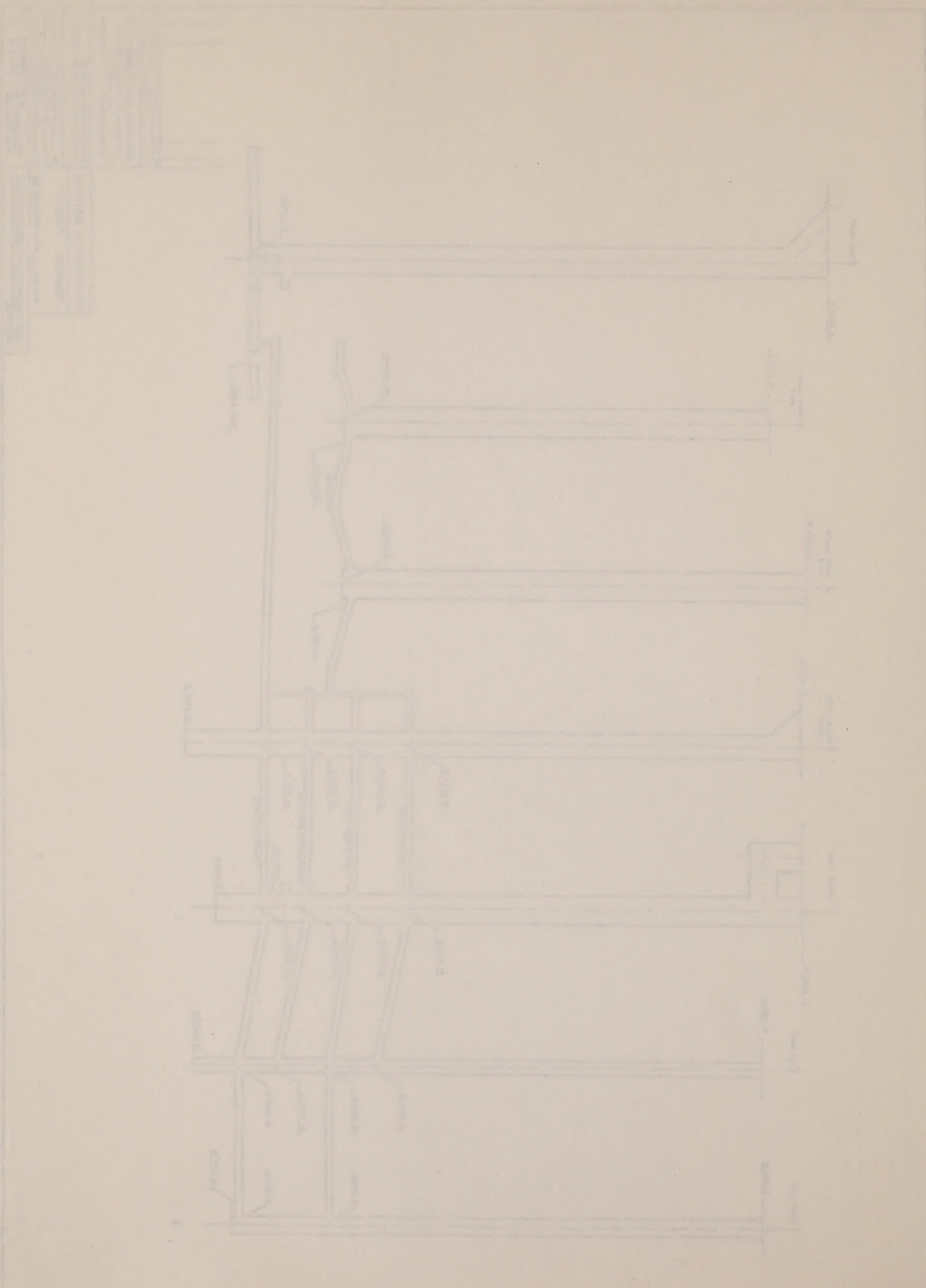
GENERAL ARRANGEMENT
VERTICAL CROSS SECTION OF SHAFTS

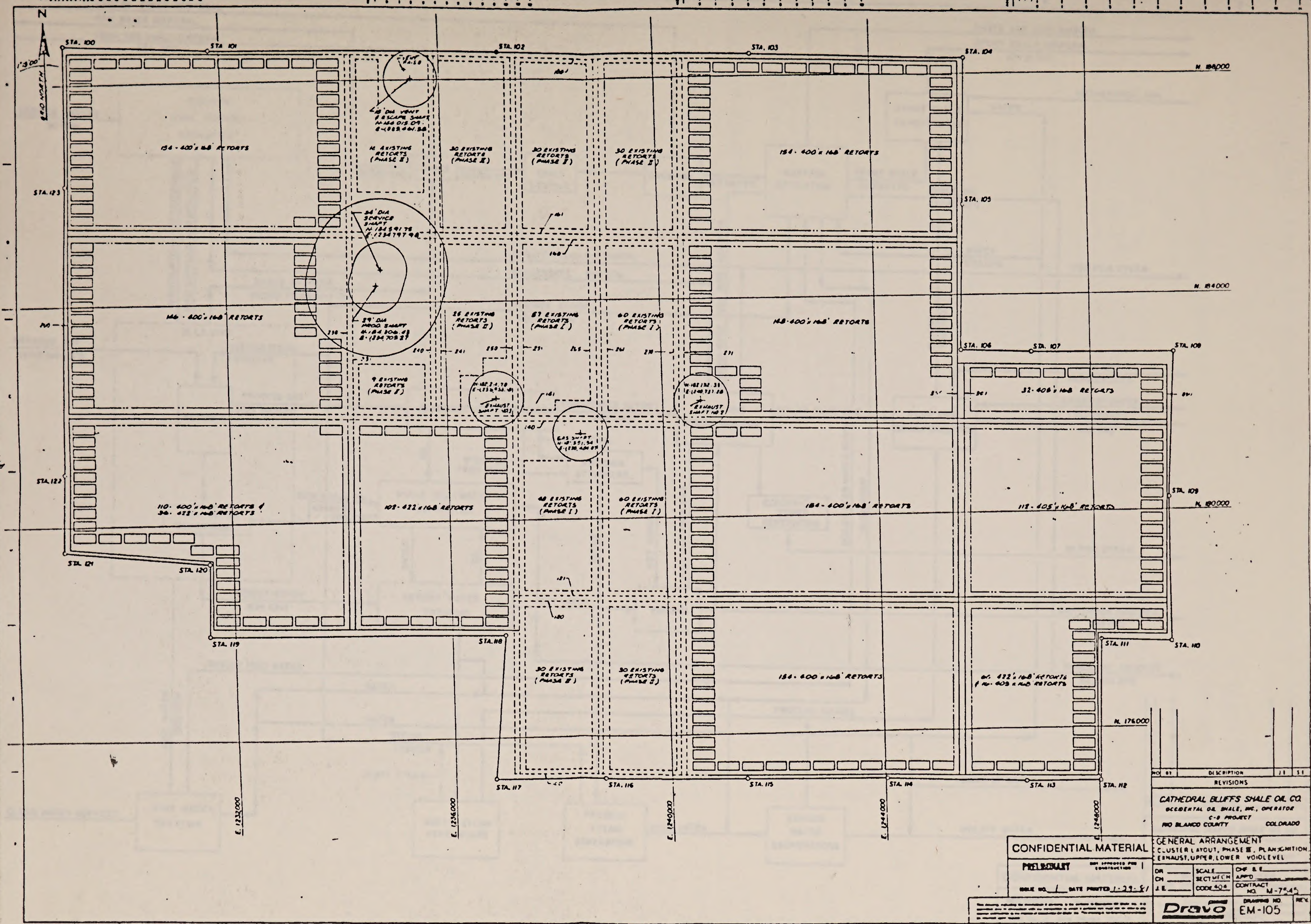
PRELIMINARY — NOT APPROVED FOR CONSTRUCTION

ISSUE NO. 1 DATE PRINTED 1-29-81

DR ____ SCALE: NONE CHF. S.E. ____
CH ____ SECT. MECH APP'D ____
J.E. ____ CODE 404 CONTRACT NO. M-7545

Dravo DRAWING NO. EM-116 REV.




N
STA. 100
STA. 101
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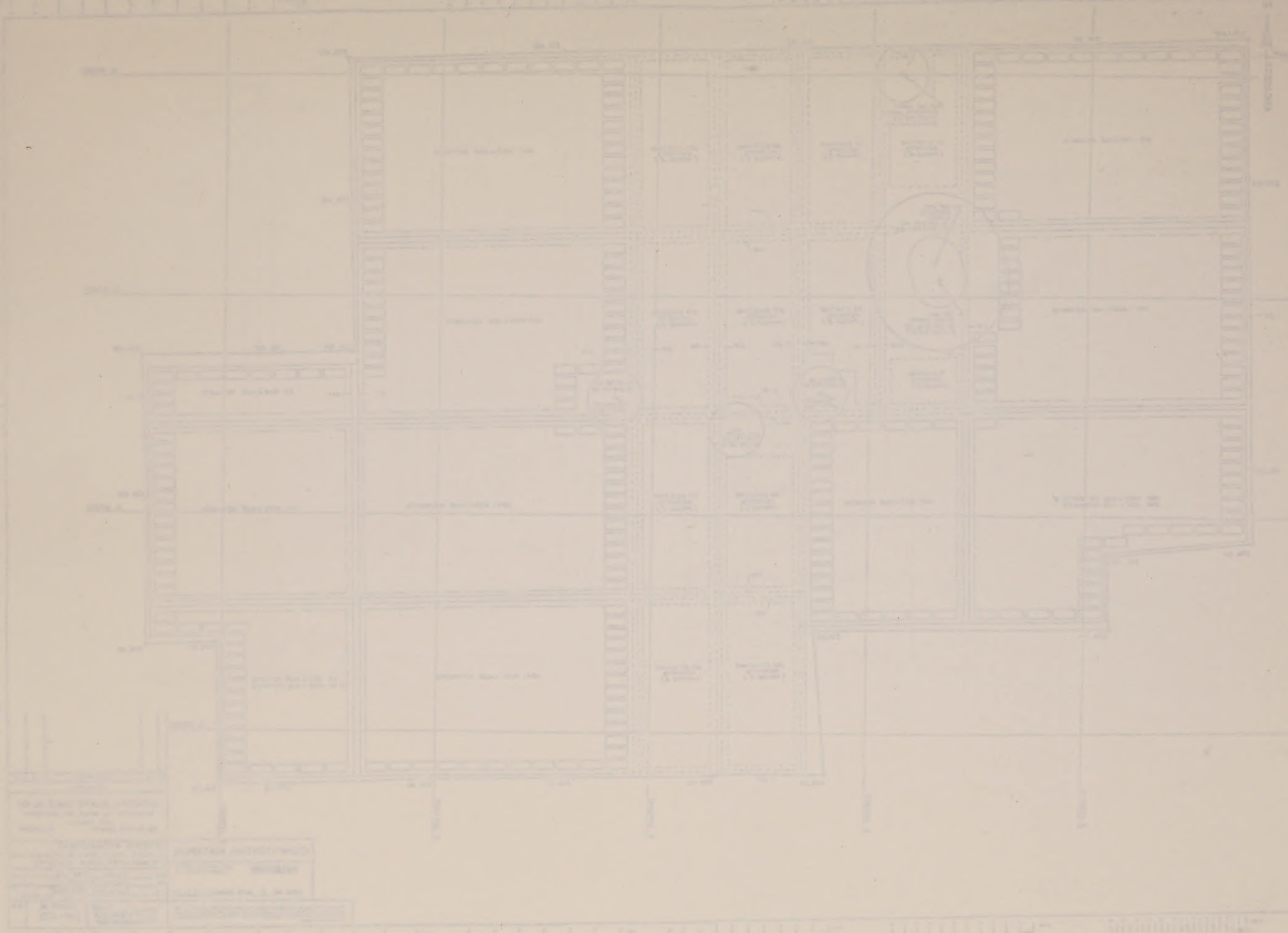
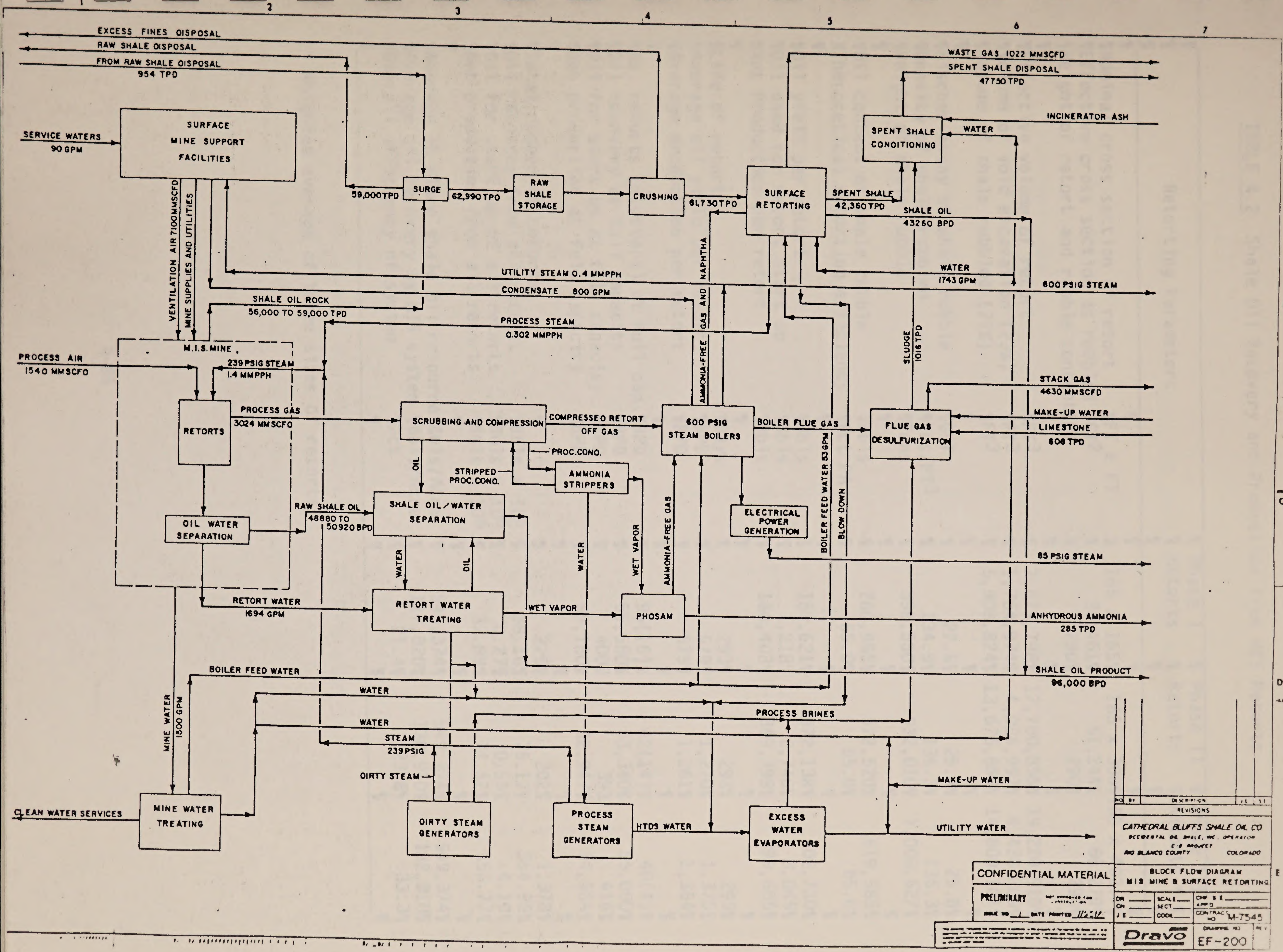
STA. 121
STA. 122
STA. 123
N. 188000
N. 184000
N. 180000
N. 176000
E. 1232000
E. 1236000
E. 1240000
E. 1244000
E. 1248000
154 - 400' x 168' RETORTS
16 EXISTING RETORTS (PHASE II)
30 EXISTING RETORTS (PHASE II)
30 EXISTING RETORTS (PHASE II)
30 EXISTING RETORTS (PHASE II)
154 - 400' x 168' RETORTS
146 - 400' x 168' RETORTS
26 EXISTING RETORTS (PHASE II)
57 EXISTING RETORTS (PHASE I)
60 EXISTING RETORTS (PHASE I)
148 - 400' x 168' RETORTS
9 EXISTING RETORTS (PHASE II)
32 - 408' x 168' RETORTS
110 - 400' x 168' RETORTS &
36 - 432' x 168' RETORTS
102 - 432' x 168' RETORTS
48 EXISTING RETORTS (PHASE I)
60 EXISTING RETORTS (PHASE I)
184 - 400' x 168' RETORTS
118 - 405' x 168' RETORTS
30 EXISTING RETORTS (PHASE II)
30 EXISTING RETORTS (PHASE II)
154 - 400' x 168' RETORTS
34' DIA SERVICE SHAFT
29' DIA PROD. SHAFT
EXHAUST SHAFT
GAS SHAFT
EXHAUST SHAFT NO 2
CATHEDRAL BLUFFS SHALE OIL CO.
OCCIDENTAL OIL SHALE, INC., OPERATOR
C-B PROJECT
RIO BLANCO COUNTY COLORADO
CONFIDENTIAL MATERIAL
GENERAL ARRANGEMENT
CLUSTER LAYOUT, PHASE III, PLAN IGNITION
EXHAUST, UPPER, LOWER VOID LEVEL
PRELIMINARY
ISSUE NO. 1 DATE PRINTED 1-29-81
SCALE
SECT MECH
CODE 404
CONTRACT NO. M-7545
REVISIONS
DESCRIPTION
Dravo
DRAWING NO.
EM-105
REV.





EXCESS FINES DISPOSAL
RAW SHALE DISPOSAL
FROM RAW SHALE DISPOSAL
954 TPD
SERVICE WATERS
90 GPM
SURFACE MINE SUPPORT FACILITIES
VENTILATION AIR 7100 MMSCFD
MINE SUPPLIES AND UTILITIES
59,000 TPD
SURGE
62,990 TPD
RAW SHALE STORAGE
CRUSHING
61,730 TPD
SURFACE RETORTING
WASTE GAS 1022 MMSCFD
SPENT SHALE DISPOSAL
47750 TPD
SPENT SHALE CONDITIONING
INCINERATOR ASH
WATER
SPENT SHALE
42,360 TPD
SHALE OIL
43260 BPD
WATER
1743 GPM
UTILITY STEAM 0.4 MMPPH
CONDENSATE 800 GPM
600 PSIG STEAM
SHALE OIL ROCK
56,000 TO 59,000 TPD
PROCESS STEAM
0.302 MMPPH
AMMONIA-FREE GAS AND NAPHTHA
SLUDGE
1016 TPD
M.I.S. MINE
PROCESS AIR
1540 MMSCFD
239 PSIG STEAM
1.4 MMPPH
RETORTS
PROCESS GAS
3024 MMSCFD
SCRUBBING AND COMPRESSION
COMPRESSED RETORT OFF GAS
600 PSIG STEAM BOILERS
BOILER FLUE GAS
FLUE GAS DESULFURIZATION
STACK GAS
4630 MMSCFD
MAKE-UP WATER
LIMESTONE
606 TPD
PROC. COND.
STRIPPED PROC. COND.
AMMONIA STRIPPERS
OIL
BOILER FEED WATER 636 GPM
BLOW DOWN
SHALE OIL/WATER SEPARATION
RAW SHALE OIL
48880 TO 50920 BPD
OIL WATER SEPARATION
ELECTRICAL POWER GENERATION
WATER
WET VAPOR
AMMONIA-FREE GAS
65 PSIG STEAM
RETORT WATER
1694 GPM
RETORT WATER TREATING
WET VAPOR
PHOSAM
ANHYDROUS AMMONIA
285 TPD
BOILER FEED WATER
SHALE OIL PRODUCT
96,000 BPD
WATER
PROCESS BRINES
WATER
MINE WATER
1500 GPM
STEAM
239 PSIG
DIRTY STEAM
MAKE-UP WATER
CLEAN WATER SERVICES
MINE WATER TREATING
DIRTY STEAM GENERATORS
PROCESS STEAM GENERATORS
HTDS WATER
EXCESS WATER EVAPORATORS
UTILITY WATER
REVISIONS
CATHEDRAL BLUFFS SHALE OIL CO
OCCIDENTAL OIL SHALE, INC., OPERATOR
C-B PROJECT
RIO BLANCO COUNTY COLORADO
CONFIDENTIAL MATERIAL
BLOCK FLOW DIAGRAM
MIS MINE & SURFACE RETORTING
PRELIMINARY
CONTRACT NO M-7545
Dravo
EF-200

TABLE 4.2 Shale Oil Recovery and Production from MIS Retorts

| Retorting Parameters | | Phase I Retorts | Phase II Retorts | Phase III Retorts * |
|---|---|---|---|---|
| Nominal cross section of retort | FT x FT | 165 x 165 | 165 x 380 | 168 x 403.7 |
| Effective cross section as rubbled | $FT^2$ | 26,461 | 61,244 | 66,279 |
| Height of retort and rubble content | FT | 290 | 290 | 290 |
| | | | | |
| Effective volume of retort | $FT^3$ | 7,673,798 | 17,760,856 | 19,220,910 |
| Volume of void excavation (23%) | $FT^3$ | 1,764,974 | 4,084,997 | 4,420,809 |
| Volume of shale rubbled (77%) | $FT^3$ | 5,908,824 | 13,675,859 | 14,800,101 |
| | | | | |
| Fischer assay of shale rubble | GPT | 27.5 | 25.8 | 25.8 |
| Density of shale rubbled | $Lbs/FT^3$ | 134.9 | 136.3 | 136.3 |
| Weight of shale rubble | Tons | 398,550 | 932,010 | 1,008,627 |
| | | | | |
| Oil content of shale rubble | Bbls | 260,955 | 572,520 | 619,585 |
| Theroretical retorting efficiency | Pct FA | 65.0 | 65.0 | 65.0 |
| | | | | |
| Oil yield per retort | Bbls | 169,621 | 372,138 | 402,730 |
| Oil used for retort start up | Bbls | 1,218 | 2,740 | 3,045 |
| Net Production per retort | Bbls | 168,403 | 369,398 | 399,685 |
| | | | | |
| Life of retort | Days | 293 | 293 | 293 |
| Average oil yield per retort | BPD | 579 | 1,270 | 1,375 |
| Average production per retort | BPD | 575 | 1,261 | 1,364 |
| | | | | |
| No. retorts (clusters) at full cap. | BPD | 96(16) | 42(14) | 40(4) |
| Oil recovery at full capacity | BPD | 55,580 | 53,340 | 55,000 |
| Oil for start up at full capacity | BPD | 400 | 393 | 416 |
| Net production at full capacity | BPD | 55,180 | 52,947 | 54,584 |
| | | | | |
| Total number of retorts | | 225 | 202 | 1,378 |
| Oil recovery from all retorts | Bbls x $10^6$ | 38.16 | 75.17 | 554.96 |
| Oil for start up of all retorts | Bbls x $10^6$ | 0.27 | 0.55 | 4.19 |
| Net production from all retorts | Bbls x $10^6$ | 37.89 | 74.62 | 550.77 |
| | | | | |
| Average in place shale oil resource | Bbls/Acre | 549,374 | 549,374 | 549,374 |
| Average oil recovery by MIS system | Bbls/Acre | 117,820 | 130,910 | 182,910 |
| Overall efficiency of system | Pct | 21.4 | 23.8 | 33.3 |

* Weighted average of three sizes of retorts

Estimates of Disturbed and Revegetated Acreage[1]

| Disturbed Area[2] | Acreage Disturbed Before 1980 | Acreage Disturbed During 1980 | Acreage Revegetated Before 1980 | Acreage Revegetated During 1980 |
|---|---|---|---|---|
| 1) Guard House & Truck Scale Area | 3.4 | | | |
| 2) Sewage Treatment Plant & Road | | 1.4 | | |
| 13) Topsoil Stockpile at site | | 0.3 | | 0.3 |
| 3) Heliport & Public Relations Facility | 0.6 | | | |
| 4) Main Access Road | 23.5 | | | |
| 5) Ancillary Area | 17.2 | | | |
| 6) Proposed Dame Site (East No Name) | 1.2 | | 1.2 | |
| 7) Switchyard Area & Access Road | | 6.1 | | |
| 8) Explosive Storage Area | 1.8 | | | |
| 9) Mine Support Area | 72.2 | | | |
| 10) Raw Shale Storage Area | 6.0 | 5.0 | | |
| 11) Rock Stockpile Areas | 7.7 | | | |
| 12) Topsoil Stockpiles (near Support Area) | 5.5 | 3.0 | 5.5 | 3.0 |
| 13) Water Discharge & Application Area | | | | |
| (Pond "C" Area) | 3.7 | | | |
| Irrigation System Pipelines[3] | 4.0 | | 4.0 | |
| 14) Abandoned Access Road | 10.0 | | 10.0 | |
| TOTALS[4] | 156.8 | 15.8 | 20.7 | 3.3 |

[1]Acreages revised from 1979 Annual Report based on aerial photos taken in 1980.

[2]Enumerated disturbed acreage in column corresponds to that shown on "C.B. Tract Disturbed Areas Map", Figure 6-1.

[3]Acreage is an estimate-did not come from aerial photos.

[4]Total acreage disturbed to date = 172.6

Total acreage revegetated to date = 24.0

# DEVELOPMENTS

# at

# *OTHER*

# *SITES*

# The Multi Minerals Corp. Program at Horse Draw

In 1977, the US Bureau of Mines drilled a 2.4-m-diam, 723-m-deep experimental mine shaft at its research site in the Piceance Creek Basin. In April 1979, Multi Mineral Corp., a subsidiary of The Charter Co., signed an agreement with USBM to operate this research tract—known as Horse Draw—56 km southwest of Meeker, CO.

MMC hopes to offset much of the expense of mining oil shale by recovering nahcolite and dawsonite, two potentially valuable minerals found within the shale. The company also hopes to prove that its (Integrated In Situ) recovery method is environmentally acceptable; it reportedly does not produce spent shale residue on the surface, nor does it use or contaminate surface water.

MMC is currently in the experimental mining phase of a three-part demonstration program which may proceed to full-scale modular testing and then to commercialization. Large-scale process testing is scheduled to begin in mid 1981, when construction of the company's adiabatic retort in Grand Junction is complete. MMC's goal is to be in commercial operation by early 1987, with production capacity of 8 dam³/d (50 000 bbls/d) of oil shale, 9 kt/d each of nahcolite and soda ash, and 900 t/d of alumina. A Department of Energy report estimates MMC's project costs will be in excess of $700 million.

The company's experimental mining involves room-and-pillar mining at the 560-m level in a bedded nahcolite and shale zone about 2.4 m thick, averaging about 60% nahcolite. Four rooms of different sizes are mined around a common pillar. The object is to get technical and mine health/safety data for designing a commercial mine to produce 910 kt/a of nahcolite beginning in early 1984. The 560-m level mining is complete but data are still being analyzed. Experimental mining is also planned at the 650- and 680-m levels to acquire mine health and safety data and design data for a commercial size Integrated In Situ mine.

MMC uses a modified in situ mining method it calls the Integrated In Situ Process. The mining and much of the recovery process takes place underground in sealed chambers. The process can be considered a three-step operation: mining, to recover nahcolite; retorting, to extract shale oil; and leaching, to recover the alumina and soda ash. Few surface facilities are required. An estimated maximum of 20% of the crushed rock may be temporarily stored on the surface before being processed and returned underground. Unlike combustion retorting, MMC's retorting is done with a gas-to-solids heat exchange involving relatively low temperatures, the company says, that reduces trace element contamination and uses less energy to retort the shale. Also, the company uses no surface water or underground fresh water in its recovery process. Rather, the MMC recovery method is designed to use salty water from an underground aquifer.

To date, almost all oil shale research and development and all oil shale mining have been conducted in the upper, Mahogany zone of the Piceance Creek Basin. But MMC is mining the lower, Saline Zone of the USBM tract. This zone, thicker than the Mahogany, contains the world's only known commercial amounts of nahcolite and dawsonite.

MMC is the only oil shale company involved in recovery of the relatively rare nahcolite mineral. During the company's current experimental program, about 4.5 kt of 80% pure nahcolite will be recovered for testing at a Colorado utility and other locations.

A recently signed agreement between MMC and Industrial Resources Inc. allows MMC to acquire about 34 km² of nahcolite-bearing sodium leases in the Piceance Creek Basin next to the Horse Draw facility. This puts MMC in a leaseholding position for the first time.□

 MINING ENGINEERING (ISSN 0026-5187) is published monthly by the Society of Mining Engineers of AIME at Caller No. D, Littleton, CO 80127, Telephone:

# USBM-MULTI MINERAL

(2,323 acres)

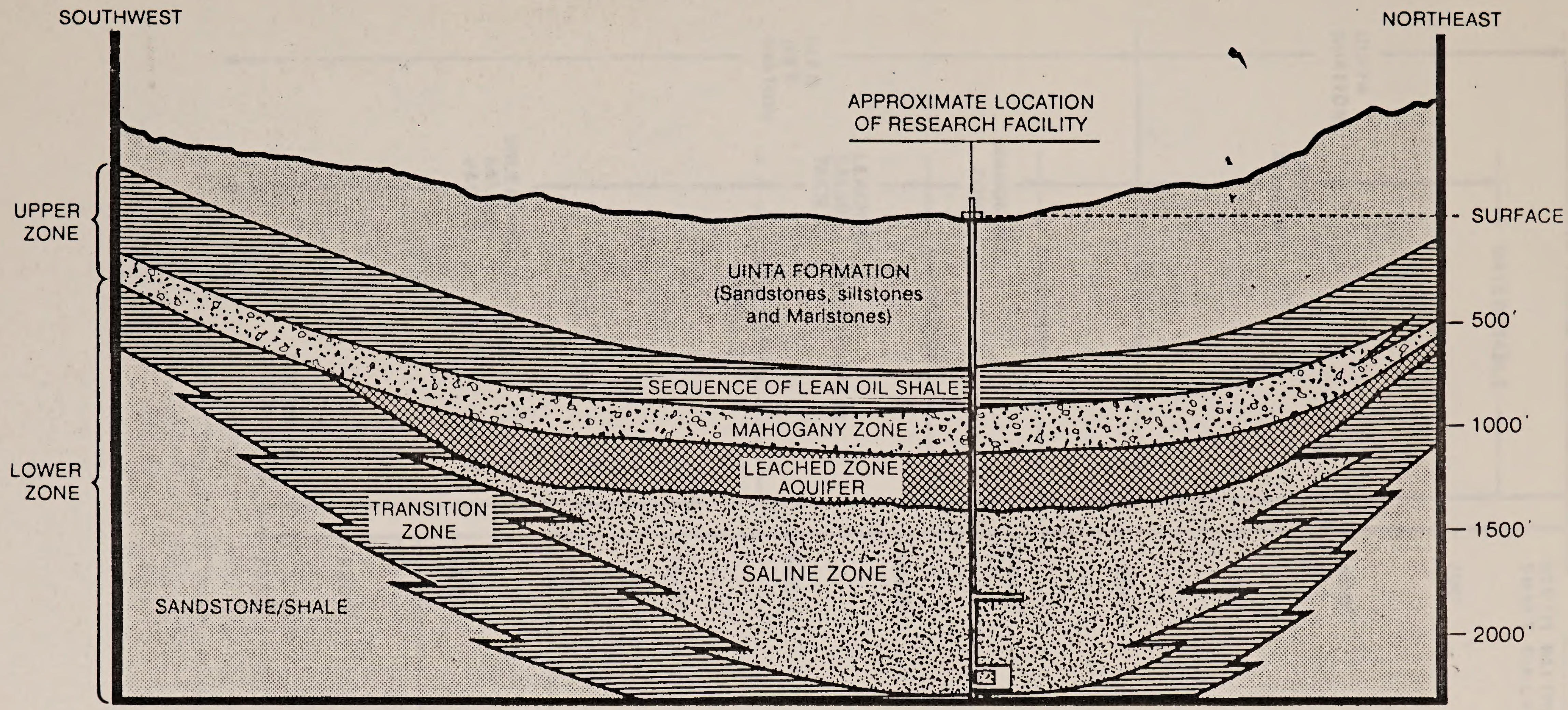
Overburden to Mahogany 800-1400 feet

| | | |
|---|---|---|
| Mahogany Zone | 175 feet | 30 gpt |
| R-6 | 200 feet | 28.5 gpt |
| L-5 | 90 feet | 17.6 gpt |
| R-5 | 350 feet | 24.0 gpt |
| L-4 | 60 feet | 20.3 gpt |
| R-4 | 230 feet | 30.7 gpt |
| L-3 | 40 feet | 18.7 gpt |
| R-3 | 130 feet | 26.4 gpt |
| L-2 | 20 feet | 15.6 gpt |
| R-2 | 90 feet | 35.4 gpt |

Nahcolite: 426 feet averages > 20%

Dawsonite: 406 feet averages ≥ 5%

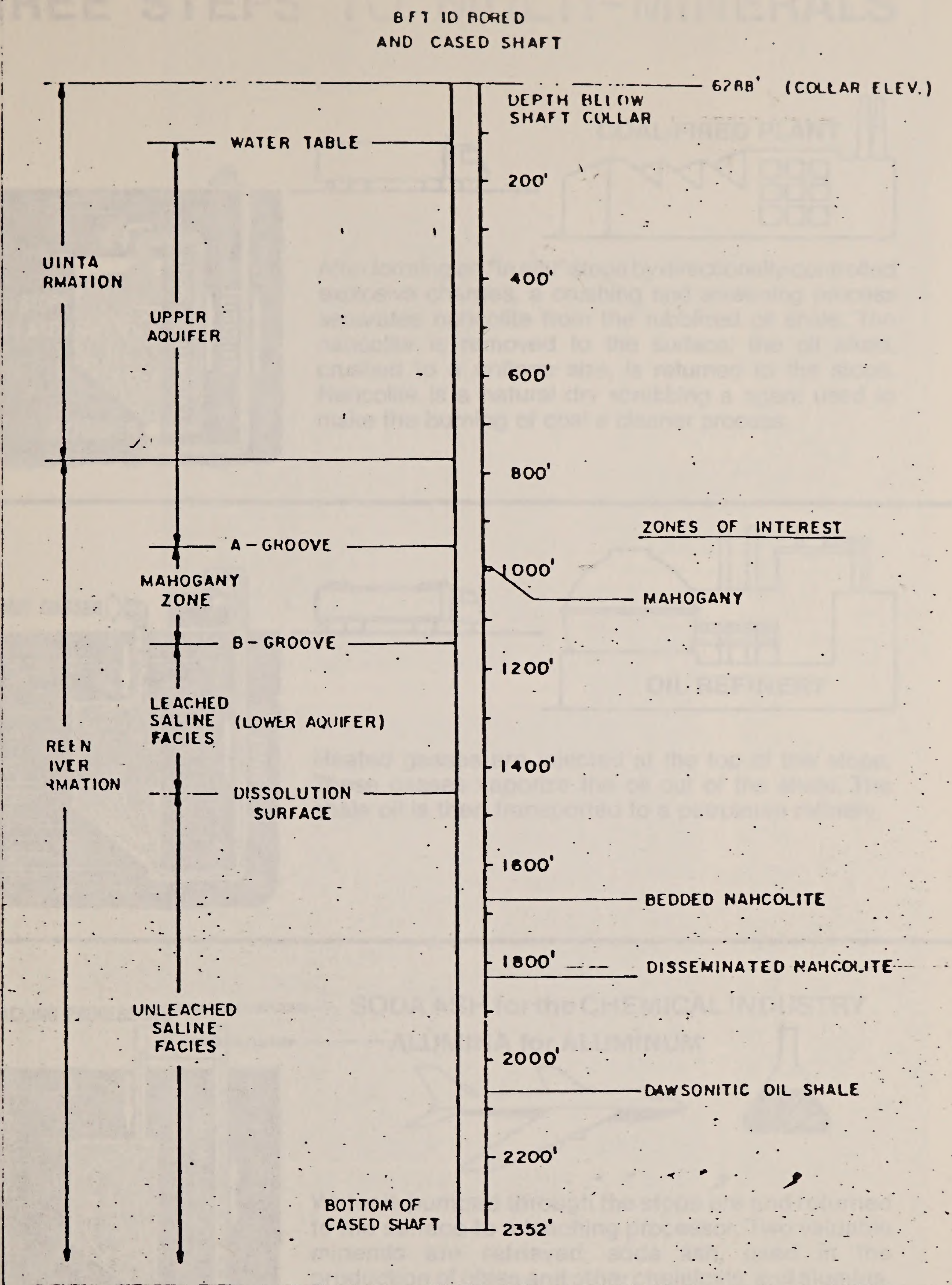
## SCHEMATIC CROSS SECTION SHOWING OIL SHALE BEDS




PICEANCE CREEK BASIN, COLORADO

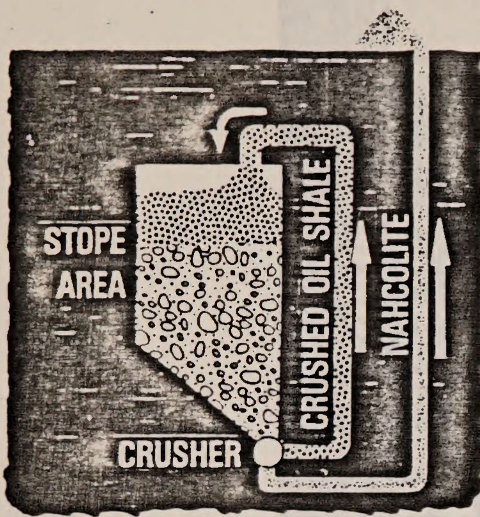
MULTI MINERAL CORPORATION
SUBSIDIARY OF THE CHARTER CO.

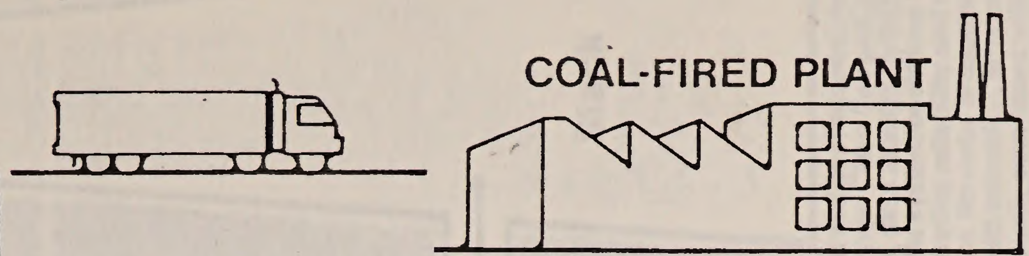
330 NORTH BELT EAST • SUITE 200 • HOUSTON, TEXAS 77060 • (713) 931-0330


8 FT ID BORED
AND CASED SHAFT
6288' (COLLAR ELEV.)
DEPTH BELOW
SHAFT COLLAR
WATER TABLE
200'
400'
600'
800'
1000'
1200'
1400'
1600'
1800'
2000'
2200'
2352'
UINTA
RMATION
UPPER
AQUIFER
A - GROOVE
MAHOGANY
ZONE
B - GROOVE
LEACHED
SALINE
FACIES
(LOWER AQUIFER)
REEN
IVER
RMATION
DISSOLUTION
SURFACE
UNLEACHED
SALINE
FACIES
BOTTOM OF
CASED SHAFT
ZONES OF INTEREST
MAHOGANY
BEDDED NAHCOLITE
DISSEMINATED NAHCOLITE
DAWSONITIC OIL SHALE

# THREE STEPS TO MULTI-MINERALS

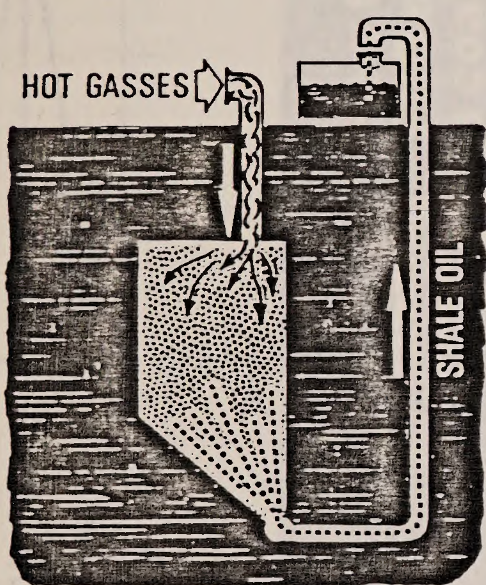
1.

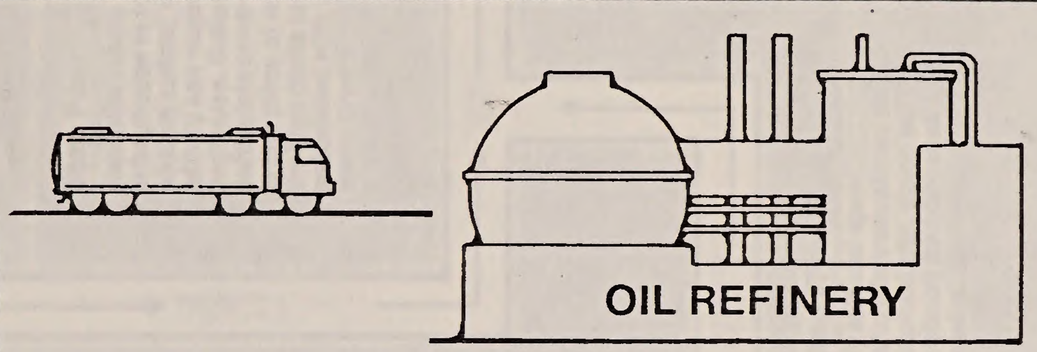



After forming an "in situ" stope by directionally-controlled explosive charges, a crushing and screening process separates nahcolite from the rubblized oil shale. The nahcolite is removed to the surface; the oil shale, crushed to a uniform size, is returned to the stope. Nahcolite is a natural dry scrubbing a agent used to make the burning of coal a cleaner process.

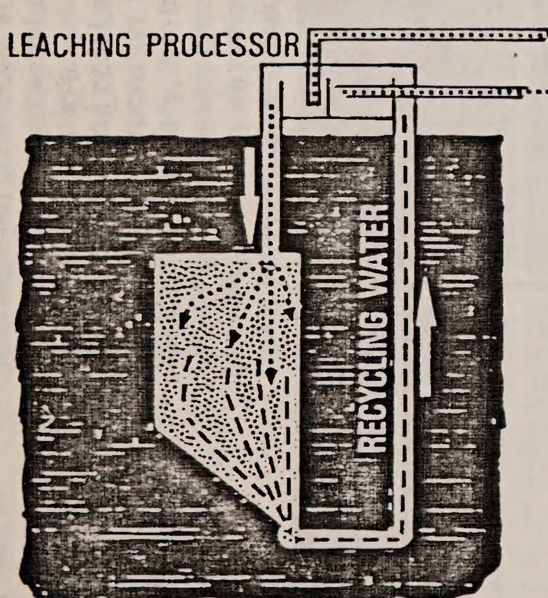
2.



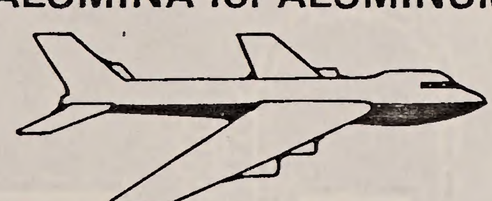

Heated gasses are injected at the top of the stope. These gasses vaporize the oil out of the shale. The shale oil is then transported to a petroleum refinery.

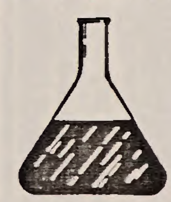
3.




SODA ASH for the CHEMICAL INDUSTRY

ALUMINA for ALUMINUM





Water is pumped through the stope ore and returned to the surface to a leaching processor. Two valuable minerals are retrieved: soda ash, used in the production of glass and other chemicals; and alumina, the source of aluminum.

SCHEMATIC DRAWINGS (NO SCALE)

MULTI MINERAL CORPORATION
SUBSIDIARY OF THE CHARTER CO.

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## *Nahcolite has proven potential.*

Nahcolite is a naturally occurring sodium bicarbonate which has been demonstrated in a number of pilot and full-scale tests to be an efficient dry scrubbing agent for the removal of sulfur dioxide ($SO_2$) from stack gases in coal-fired power plants. Projected chemical properties of nahcolite production samples indicate total sodium bicarbonate content of ±80 weight percent.

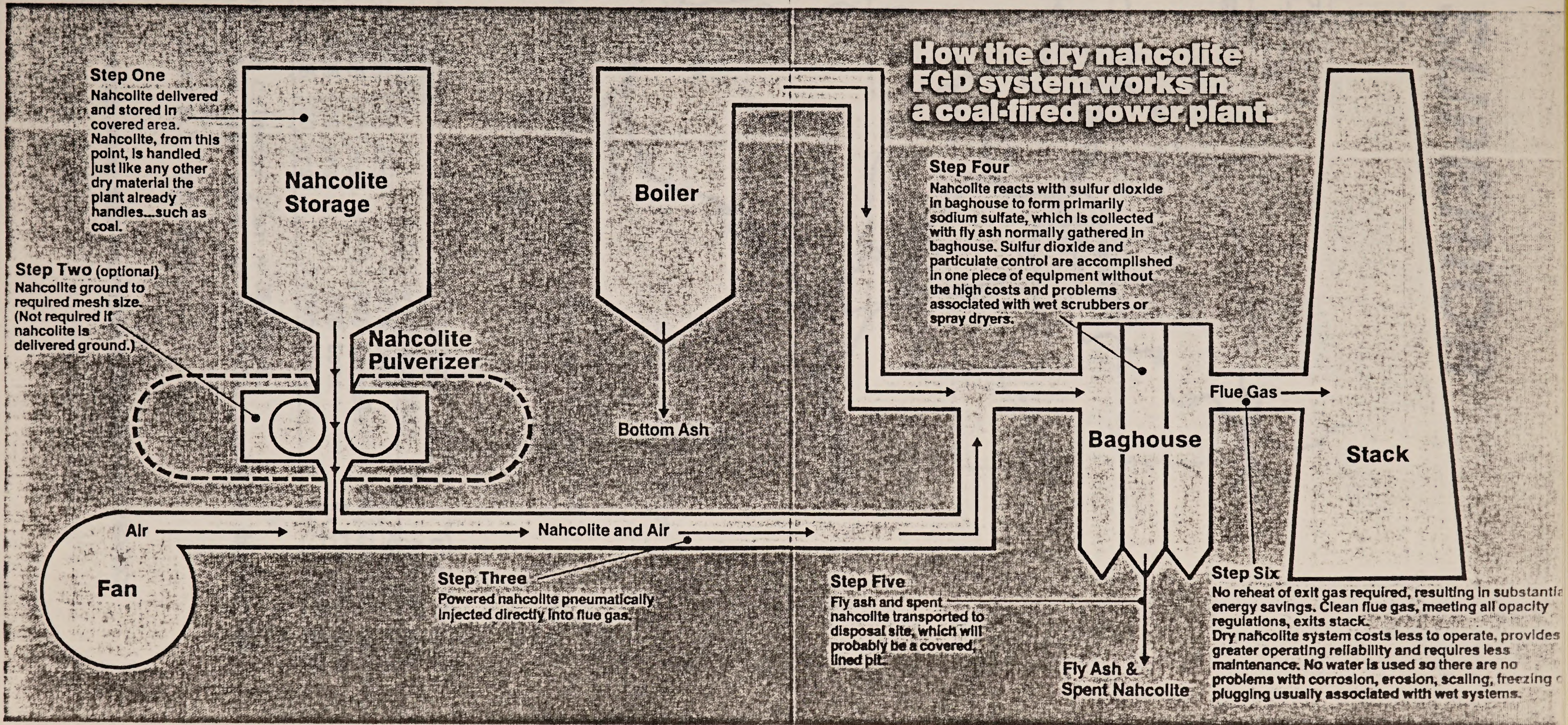
Dry desulfurization using nahcolite offers many advantages, including lower capital costs, higher operating reliability, and lower energy and water consumption.

Vast deposits of nahcolite are found in the Piceance Creek basin in northwest Colorado. Total reserves of nahcolite in the basin are estimated to be approximately 30 billion tons, which are sufficient to scrub one billion tons per year of .5% sulfur coal for over 800 years.

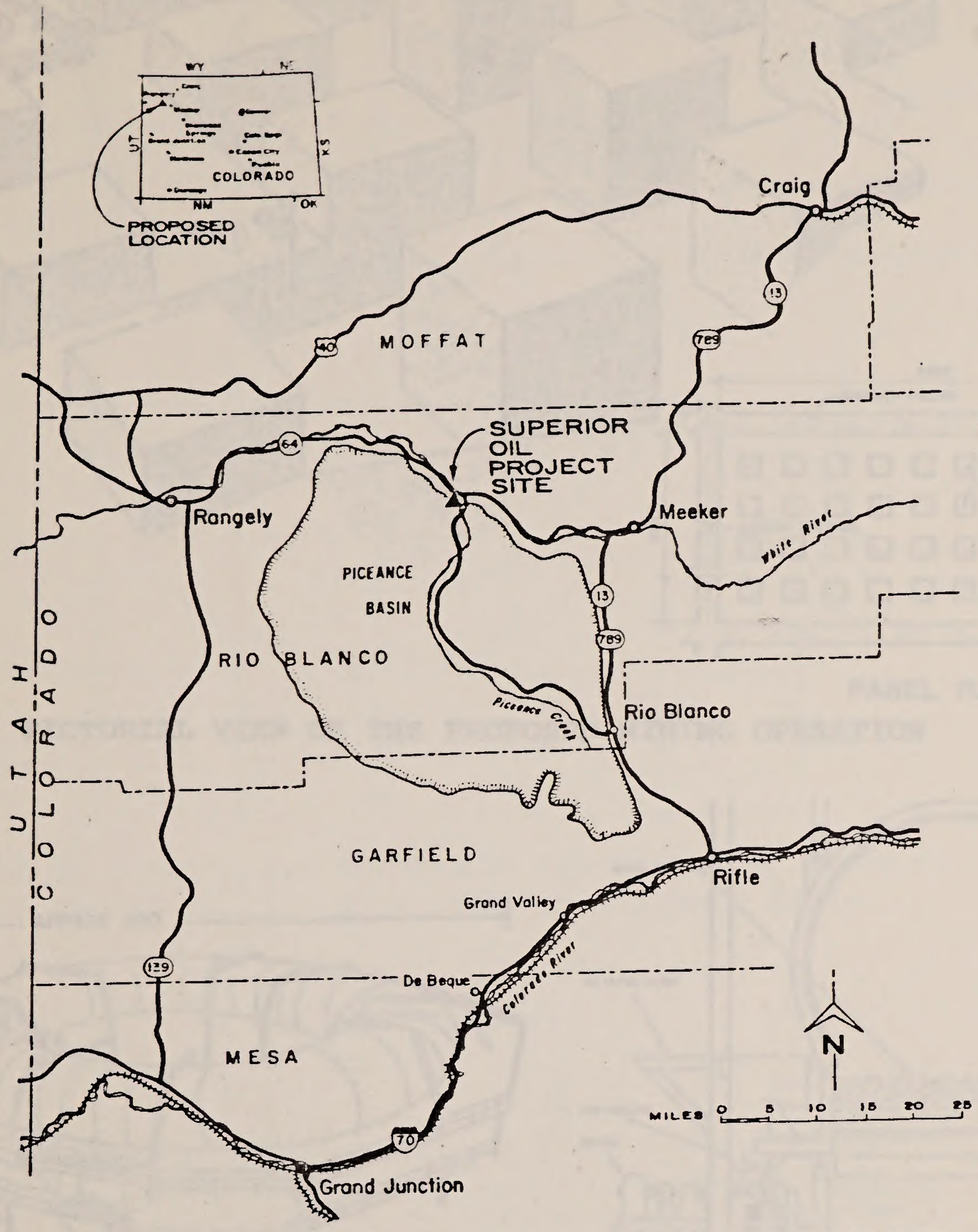
Multi Mineral Corporation, a subsidiary of The Charter Company, is in the process of acquiring the necessary permits to open a one million ton per year nahcolite production facility in the Piceance Creek basin.

***When Multi Mineral will make nahcolite available.***

| Production Stages | Timetable |
|---|---|
| Permitting<br>Construction<br>Commercial Production | First Quarter of 1984 |



# SUPERIOR



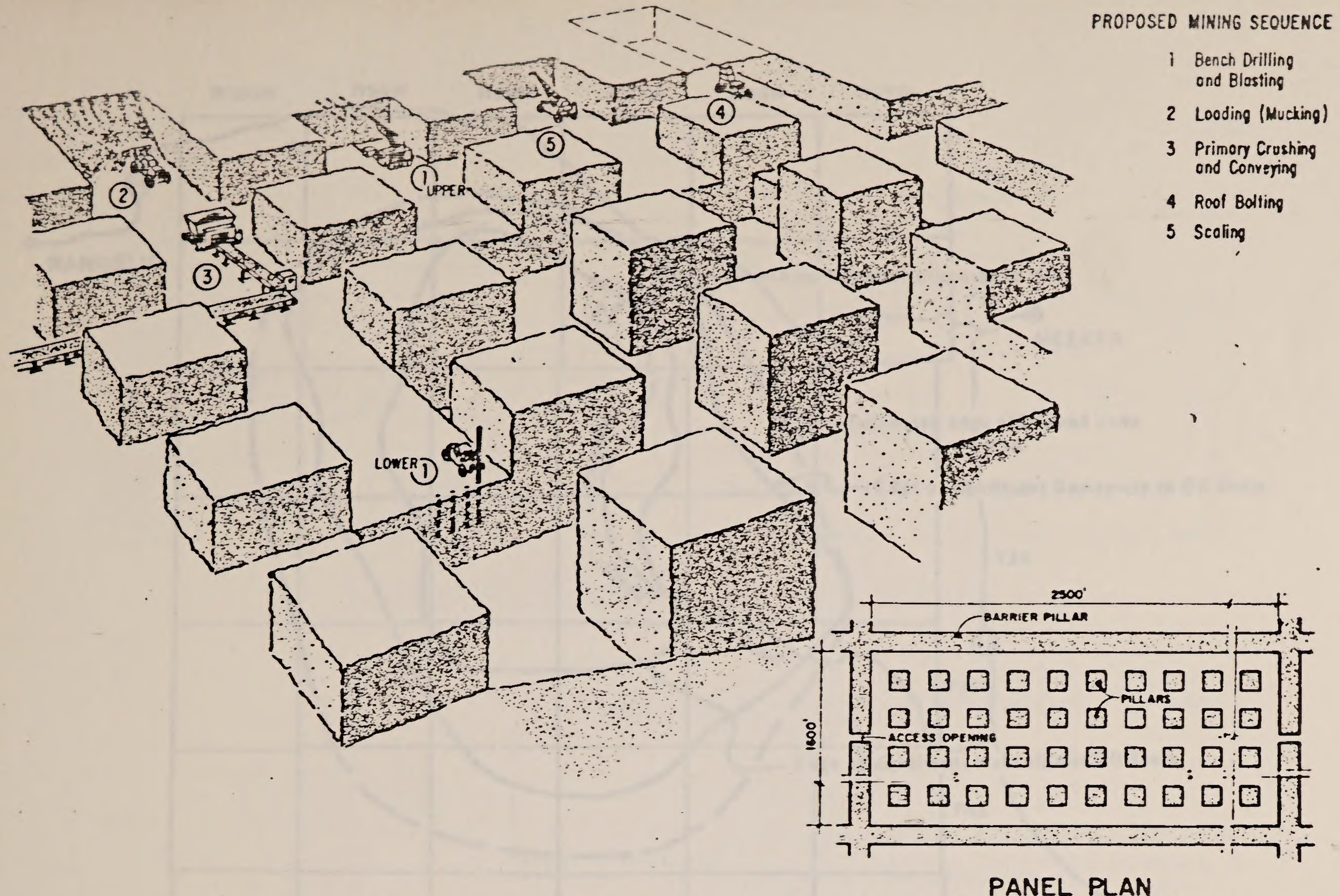

LOCATION MAP OF THE PROPOSED SUPERIOR OIL PROJECT

MAP 1-1

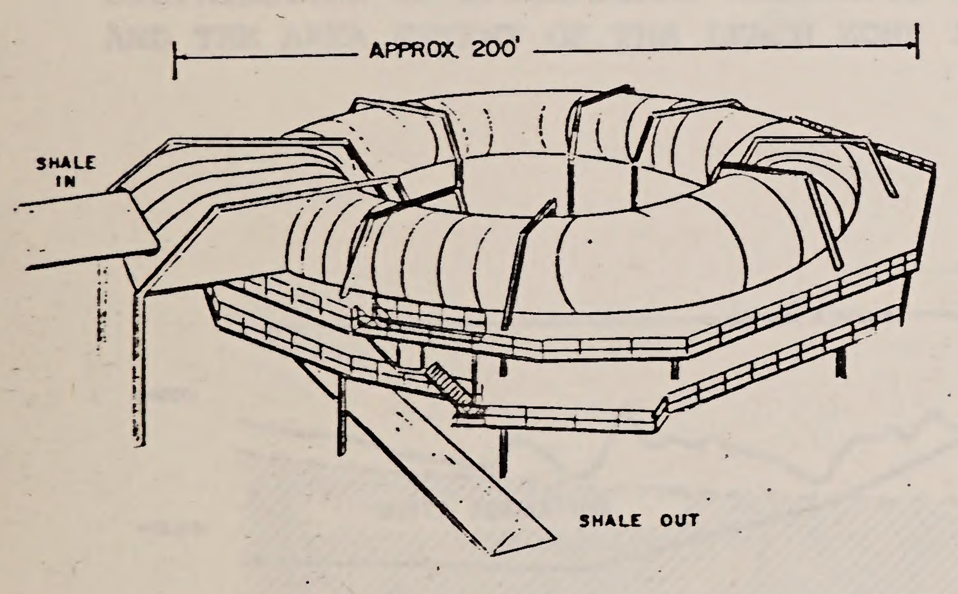
| Product | Assumed Timetable | Average Daily Production | Total Project Production |
|---|---|---|---|
| Nahcolite | 1983 to 2006 (23 yrs) | 4,878 tons | 40,290,000 tons |
| Shale Oil | 1987 to 2006 (20 yrs) | 11,586 barrels | 84,578,000 barrels |
| Alumina | 1987 tp 2006 (20 yrs) | 580 tons | 4,234,000 tons |
| Soda Ash | 1987 to 2006 (20 yrs) | 1,005 tons | 7,337,000 tons |

Note:
Production is based on one calendar year = 365 days.
The average daily production rate shown for nahcolite would be during the full-scale production period.
A barrel is equivalent to 42 U.S. gallons.

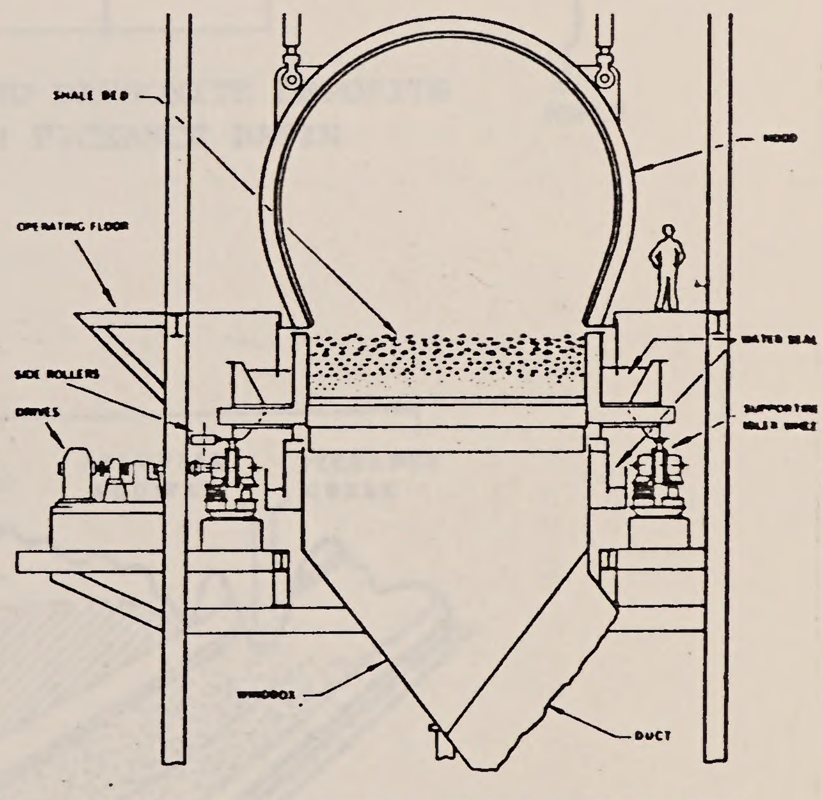
SUMMARY OF PRODUCTION FROM THE PROPOSED SUPERIOR OIL PROJECT




PICTORIAL VIEW OF THE PROPOSED MINING OPERATION




CONCEPTUAL VIEW OF THE PROPOSED CIRCULAR GRATE RETORT




CROSS SECTIONAL VIEW OF THE PROPOSED RETORT

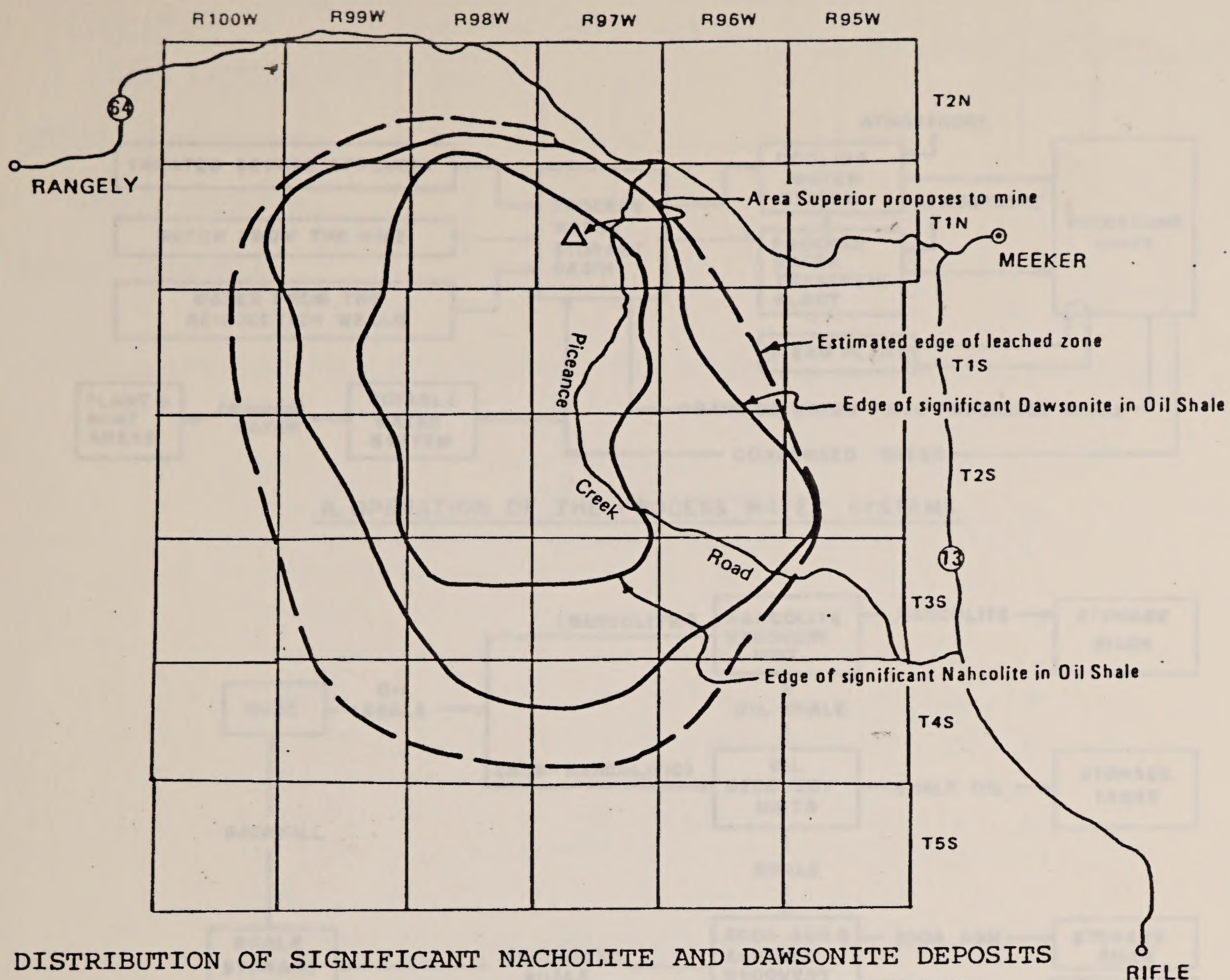
CONCEPTUAL AND CROSS SECTION VIEWS OF THE PROPOSED RETORT

| | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987-2006 | 2007 | 2008 | Total |
| Tons | 191 | 299 | 1,433 | 495 | 80 | 520 | 104,724 | 7,532 | 125,154 |

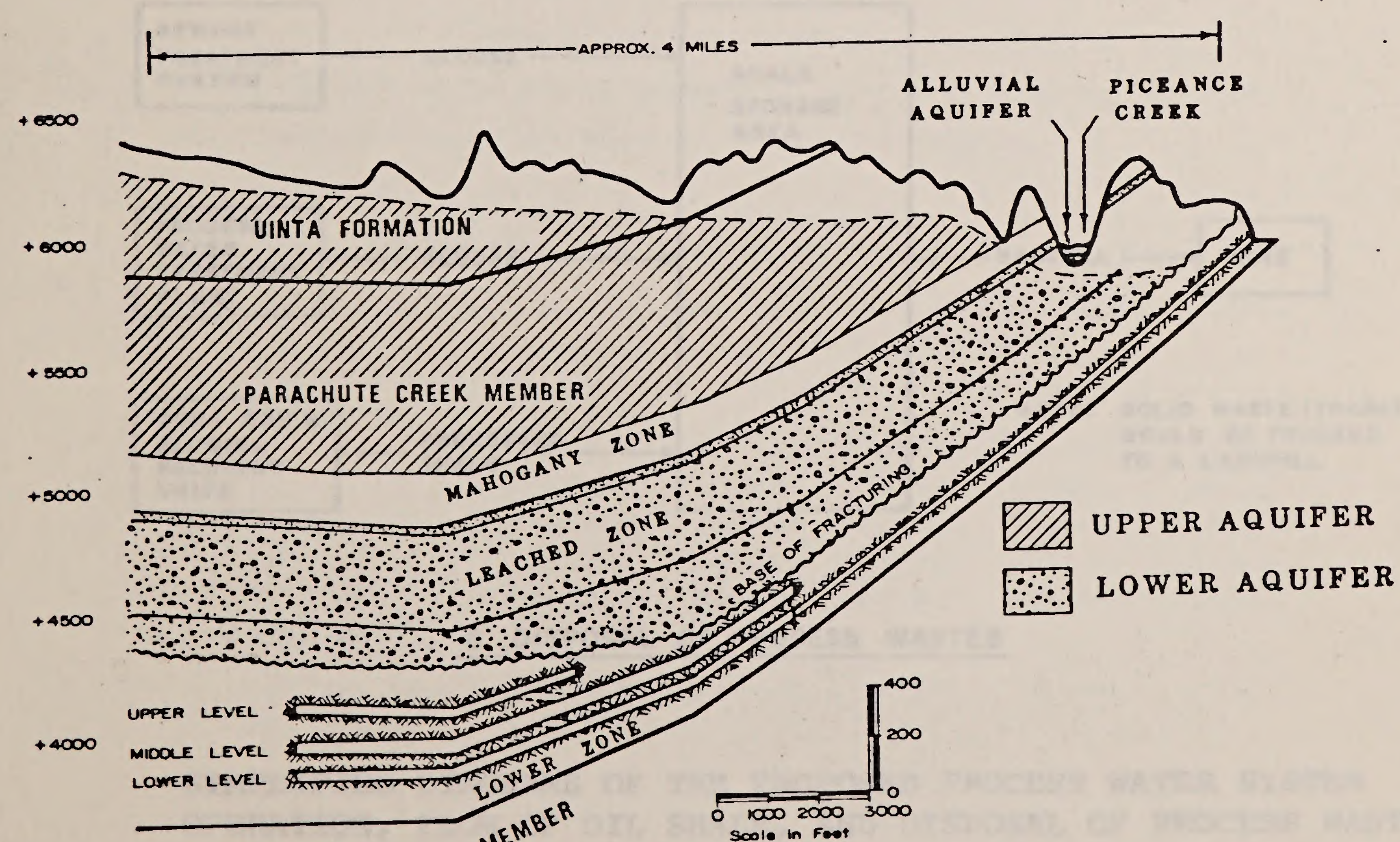
**Note:**

Quantities remain constant throughout operation of the project (1987-2006).

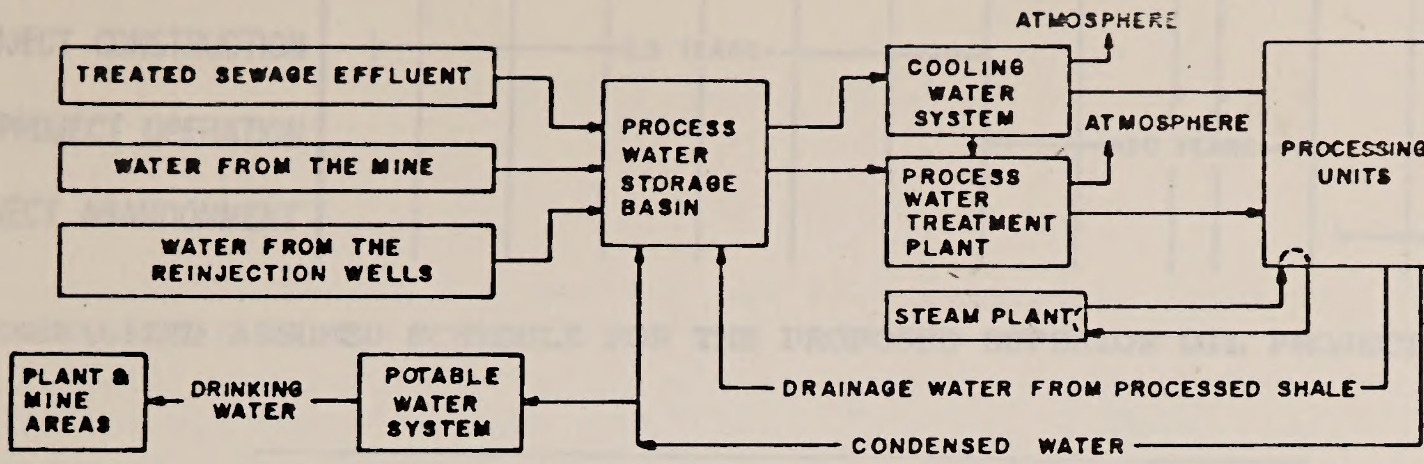
PROPOSED TONS OF SOLID WASTE TO BE DISPOSED (tons/year)



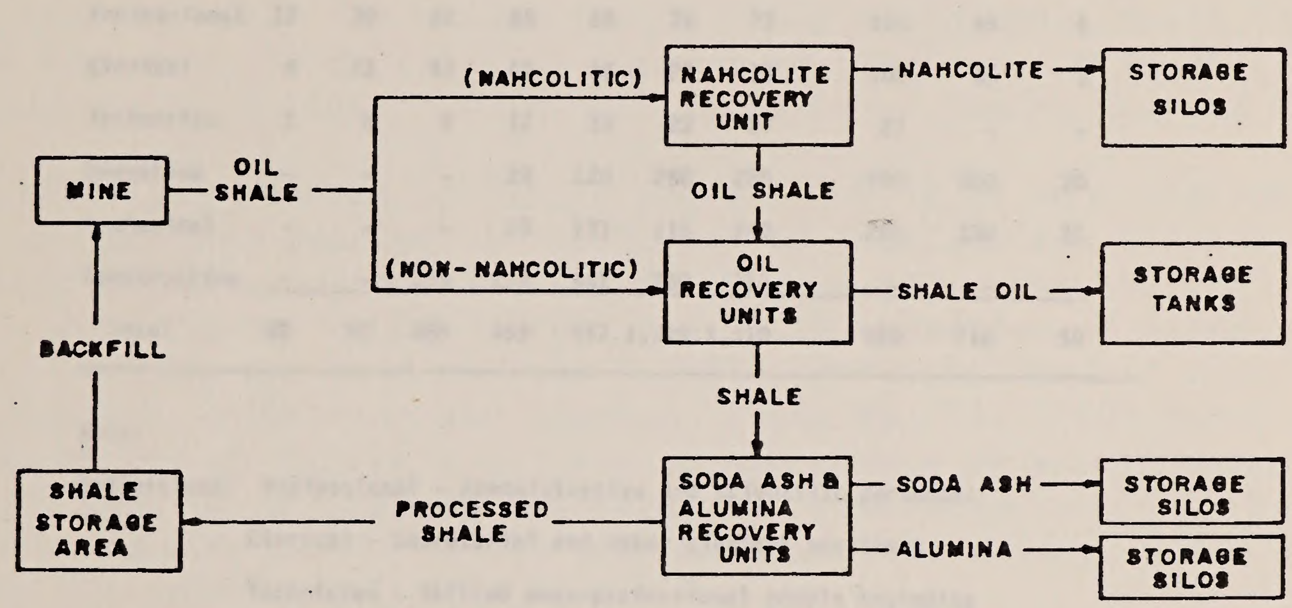

DISTRIBUTION OF SIGNIFICANT NACHOLITE AND DAWSONITE DEPOSITS AND THE AREA EXTENT OF THE LEACH ZONE IN PICEANCE BASIN



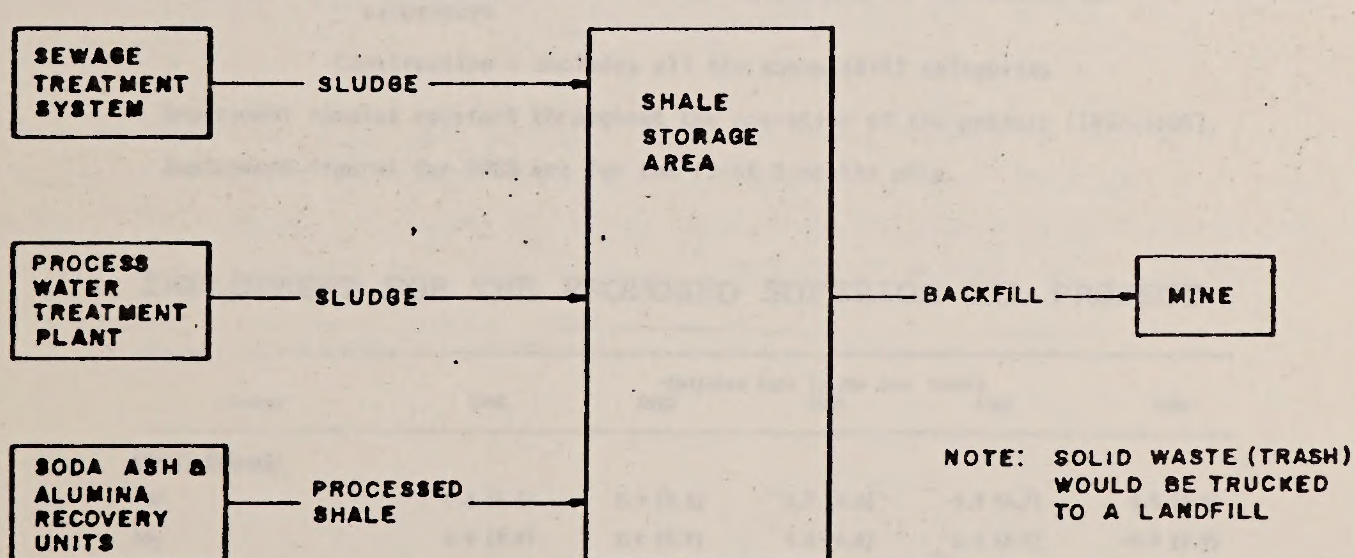

CROSS SECTION VIEW OF THE GEOLOGY
AND THE THREE PROPOSED MINING LEVELS




A. OPERATION OF THE PROCESS WATER SYSTEMS

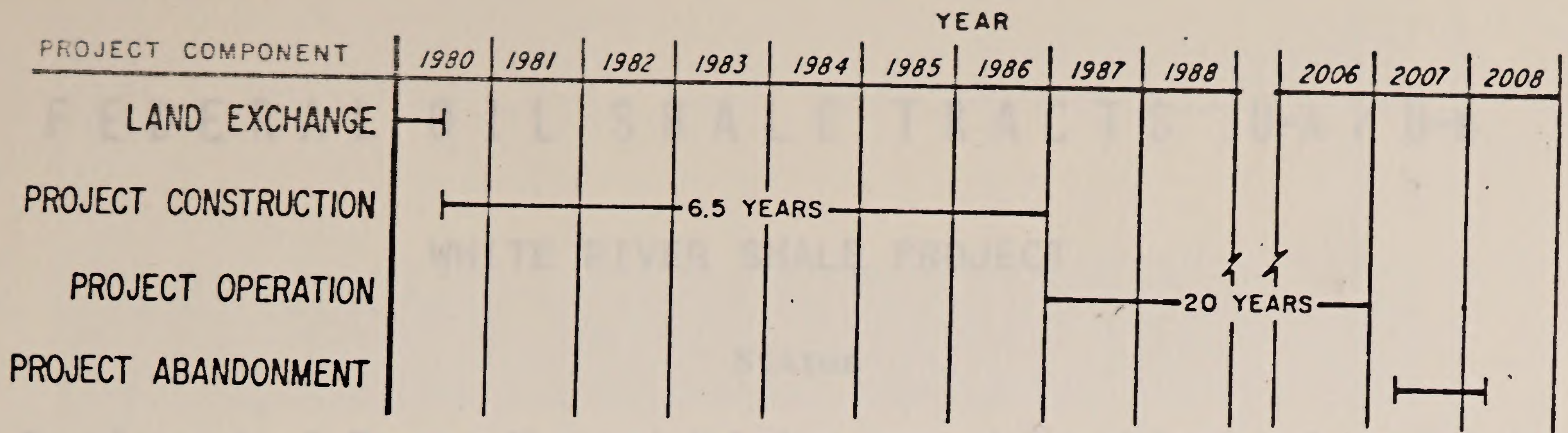



B. FLOW OF OIL SHALE




C. DISPOSAL OF PROCESS WASTES

SIMPLIFIED DIAGRAMS OF THE PROPOSED PROCESS WATER SYSTEM OPERATION, FLOW OF OIL SHALE, AND DISPOSAL OF PROCESS WASTES




GENERALIZED ASSUMED SCHEDULE FOR THE PROPOSED SUPERIOR OIL PROJECT

| Skill Category | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987-2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average Number of Employees/Year | | | | | | | | | |
| Professional | 12 | 30 | 62 | 65 | 68 | 70 | 72 | 105 | 45 | 5 |
| Clerical | 6 | 12 | 43 | 62 | 68 | 72 | 75 | 102 | 35 | 3 |
| Technician | 2 | 8 | 8 | 12 | 18 | 22 | 27 | 27 | - | - |
| Operative | - | - | - | 20 | 120 | 260 | 285 | 400 | 300 | 20 |
| Mechanical | - | - | - | 25 | 131 | 115 | 140 | 286 | 330 | 21 |
| Construction | - | - | 153 | 274 | 442 | 790 | 711 | - | - | - |
| Total | 20 | 50 | 268 | 458 | 847 | 1,329 | 1,310 | 920 | 710 | 50 |

Note:

Definitions: Professional - Administrative and scientific personnel

Clerical - Secretarial and other clerical positions

Technician - Skilled semi-professional people including draftsmen, and chemical laboratory technicians

Operative - Miners, plant operators, drivers, and guards

Mechanical - Building and maintenance tradesmen such as electricians, pipefitters, heavy equipment operators, and carpenters

Construction - Includes all the above skill categories

Employment remains constant throughout the operation of the project (1987-2006).

Employment figures for 2008 are for the first 3 months only.

EMPLOYMENT FOR THE PROPOSED SUPERIOR OIL PROJECT

| Source | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|
| | Emission Rate lbs/hr (max lb/hr) | | | | |
| Diesel Exhaust: | | | | | |
| TSP | 1.8 (2.2) | 2.0 (3.5) | 4.2 (4.2) | 2.4 (3.7) | 0.5 (0.8) |
| $SO_2$ | 2.0 (2.9) | 2.2 (3.7) | 4.4 (4.4) | 2.3 (3.0) | 0.8 (0.9) |
| CO | 35.6 (51.1) | 69.2 (82.0) | 45.5 (46.7) | 51.2 (58.2) | 30.4 (30.4) |
| NMHC | 1.6 (3.7) | 3.4 (4.0) | 3.7 (3.7) | 2.1 (2.6) | 0.5 (0.5) |
| $NO_x$ | 28.9 (40.6) | 29.8 (47.7) | 62.6 (62.6) | 32.9 (42.3) | 8.9 (13.2) |
| Fugitive Dust: | | | | | |
| Construction Activities - TSP | 42.6 (52.8) | 29.1 (51.5) | 3.6 (4.6) | 7.2 (8.1) | 1.4 (4.8) |
| Shale Storage Area Stockpile - TSP: | | | | | |
| Material Handling | | | 2.4 | 2.4 | 2.4 |
| Wind Erosion | | | 1.2 | 1.2 | 1.2 |
| Initial Operational: | | | | | |
| Nahcolite and Secondary Crusher - TSP | | | 2.8 | 2.8 | 4.1 |
| TOTAL TSP | 44.4 (55.0) | 31.1 (55.0) | 14.2 (15.2) | 16.0 (18.2) | 9.6 (13.3) |

AIR EMISSIONS DURING PROJECT CONSTRUCTION

# FEDERAL OIL SHALE TRACTS U-A / U-B

## WHITE RIVER SHALE PROJECT

### Status

Development of Tracts U-a and U-b has been delayed by legal action including cases stemming from Utah's statehood land selection rights (in-lieu lands) and unvacated prior mining claims. In the former case, the U.S. District Court's (Salt Lake City), Findings of Fact, Conclusion of Law, and Decree of June 8, 1976, favored Utah's position that "indemnity selections" of in-lieu lands in Uintah County could be made acre-for-acre, rather than the Department of Interior's position of value-for-value under the Taylor Grazing Act. The United States Court of Appeals, Tenth Circuit (Denver) on August 8, 1978, ruled in support of Utah's claim to 157,255.90 acres of land which include Federal Oil Shale Lease Tracts U-a and U-b.

On May 18, 1977, the lessees of Tracts U-a and U-b filed suit against the Department of Interior seeking an injunction to indefinitely suspend lease diligent development requirements including bonus bid payments, until conflicts with overlapping mining claims and state selection of lands were resolved. A hearing was held on June 3, 1977, and continued to June 8, 1977, when a preliminary injunction was granted (Civil No. C77-0165) which stated that "The Secretary of Interior and any of his agents or subordinates are enjoined from seeking to enforce the terms and conditions of (the) Leases of Tracts U-a and U-b or any of the obligations...thereunder in any manner...during the pendency of this action."

Fate of Tracts U-a and U-b now rests with the U.S. Supreme Court which is expected to rule shortly on the December 5, 1979, filing of the Justice Department's appeal to district court findings in favor of Utah's land selection claim.

A DDP was submitted by the joint venture (White River Shale Project for development of the two Utah tracts by underground mining and surface retorting. The plans, however, have not been reviewed or acted on by the AOSO due to the ensuing suspension of operations and court order injunction.

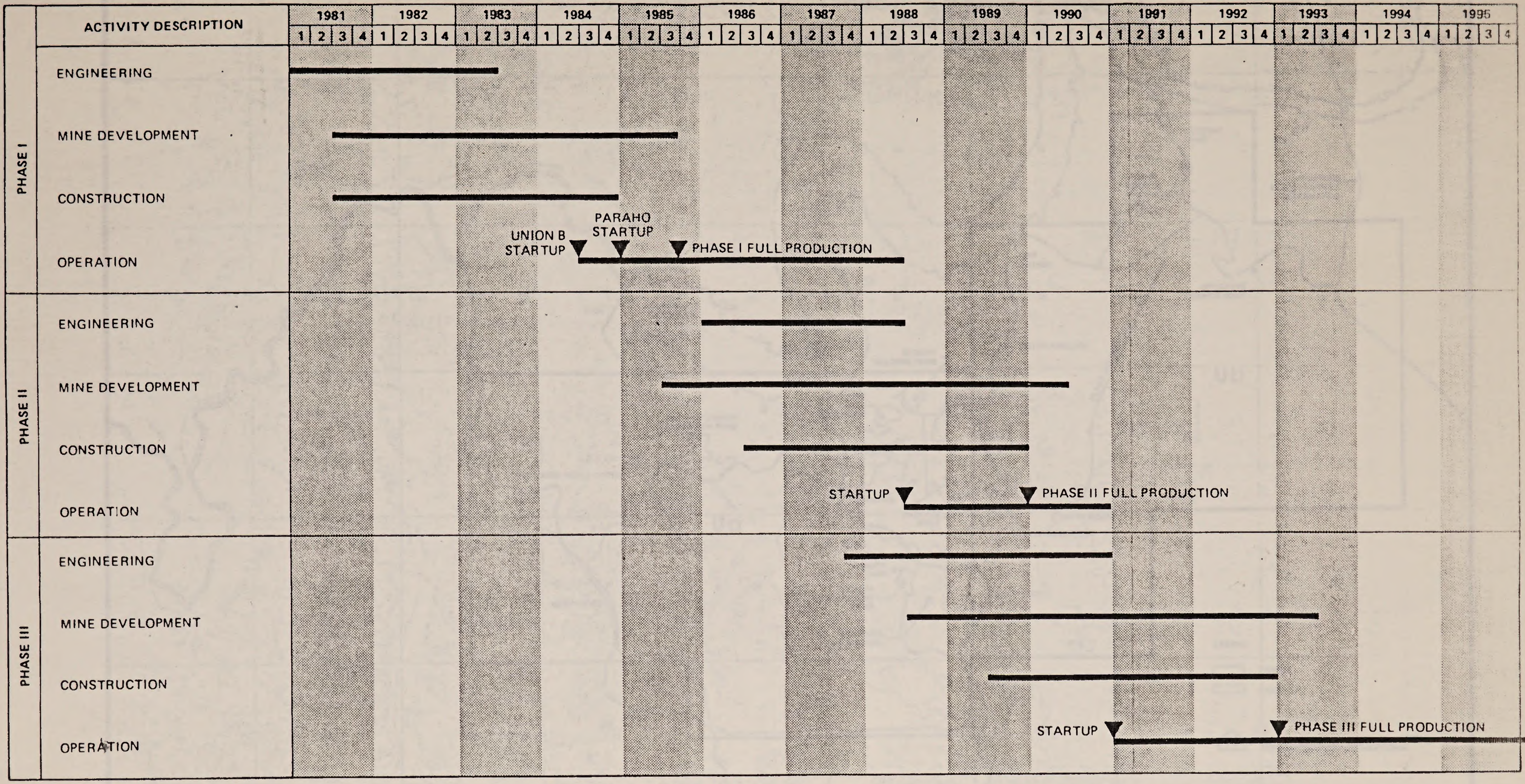



Figure 1.4-2 WHITE RIVER SHALE PROJECT SCHEDULE

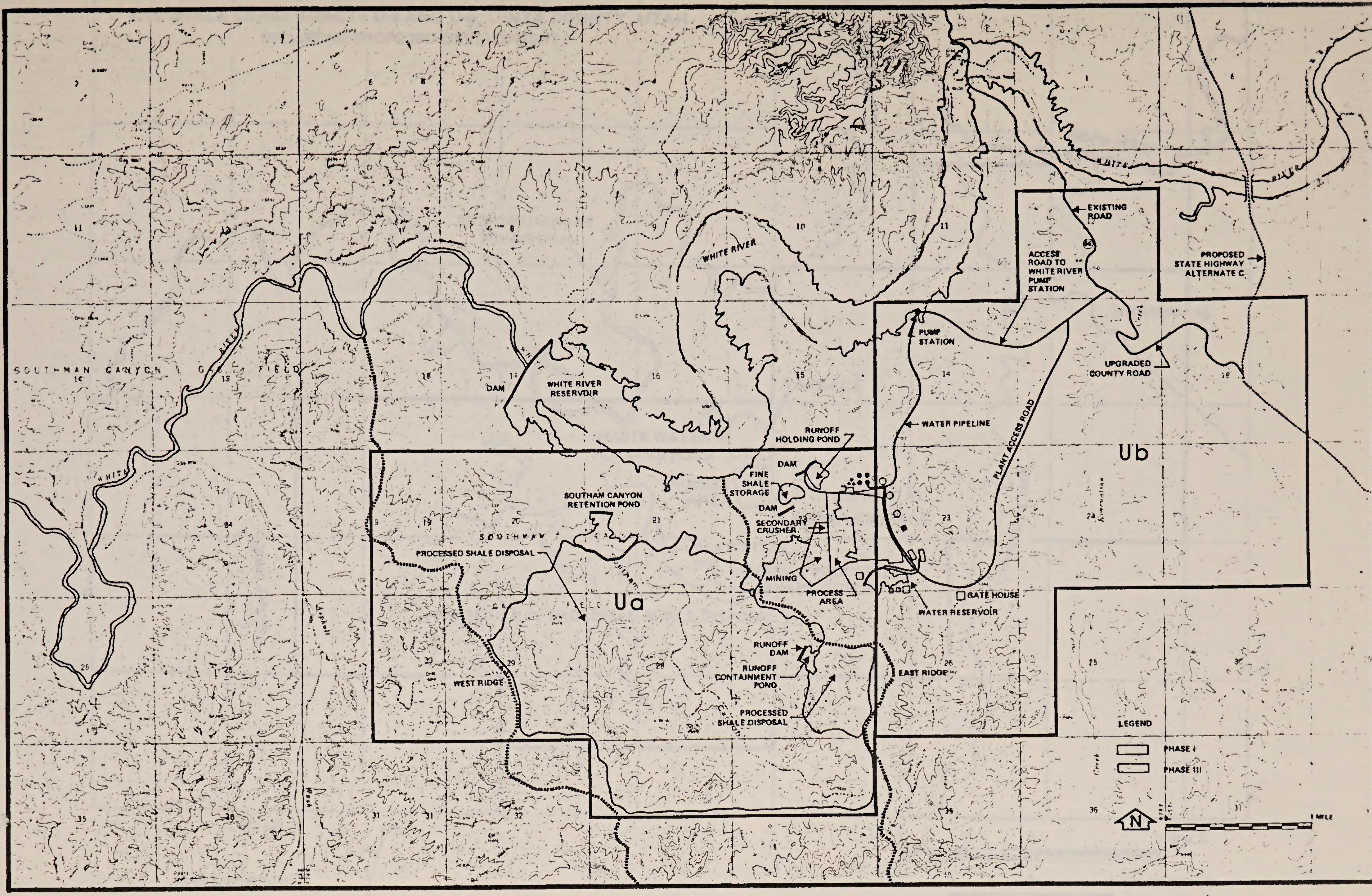
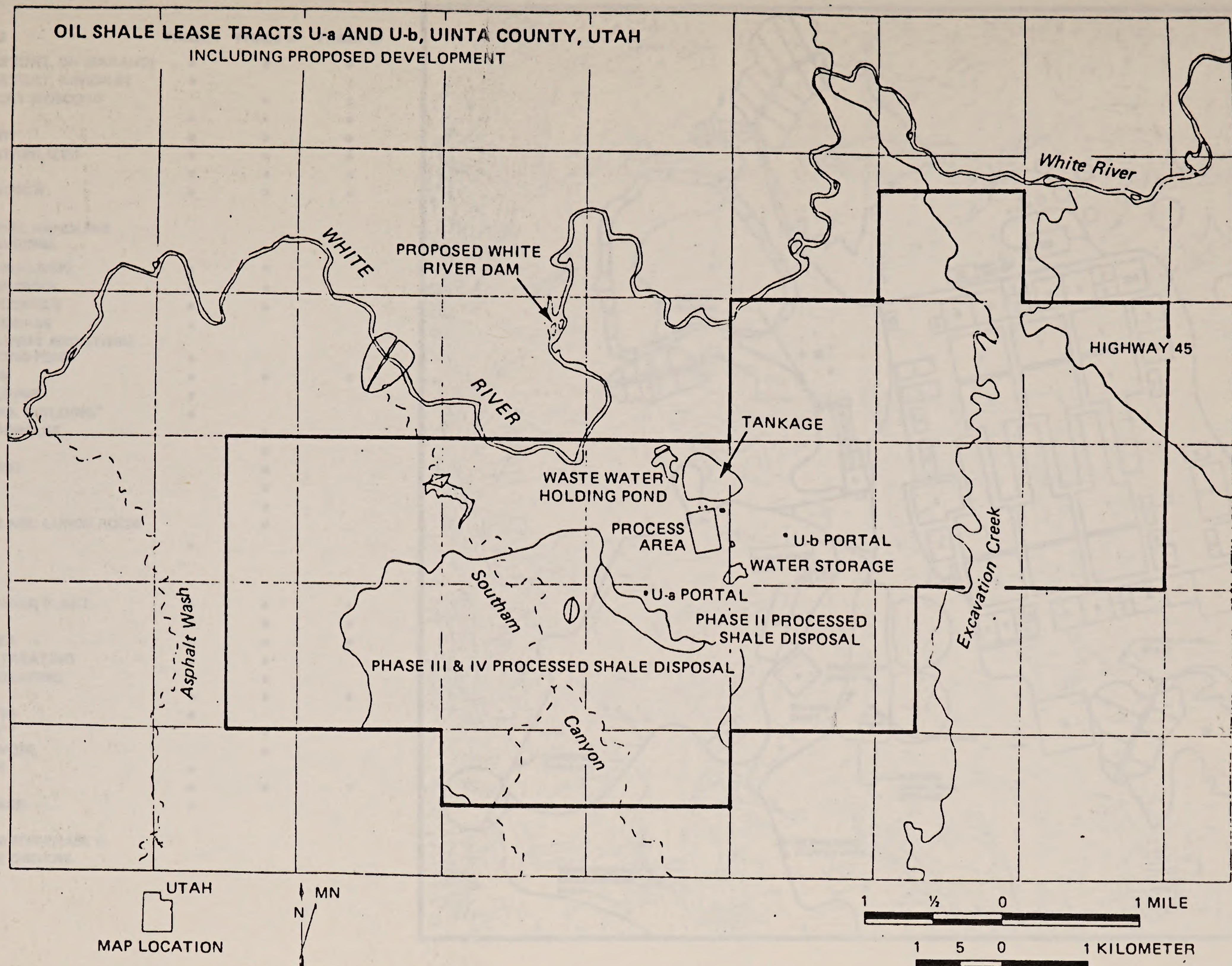



Figure 3.4-1 OVERALL SITE PLAN

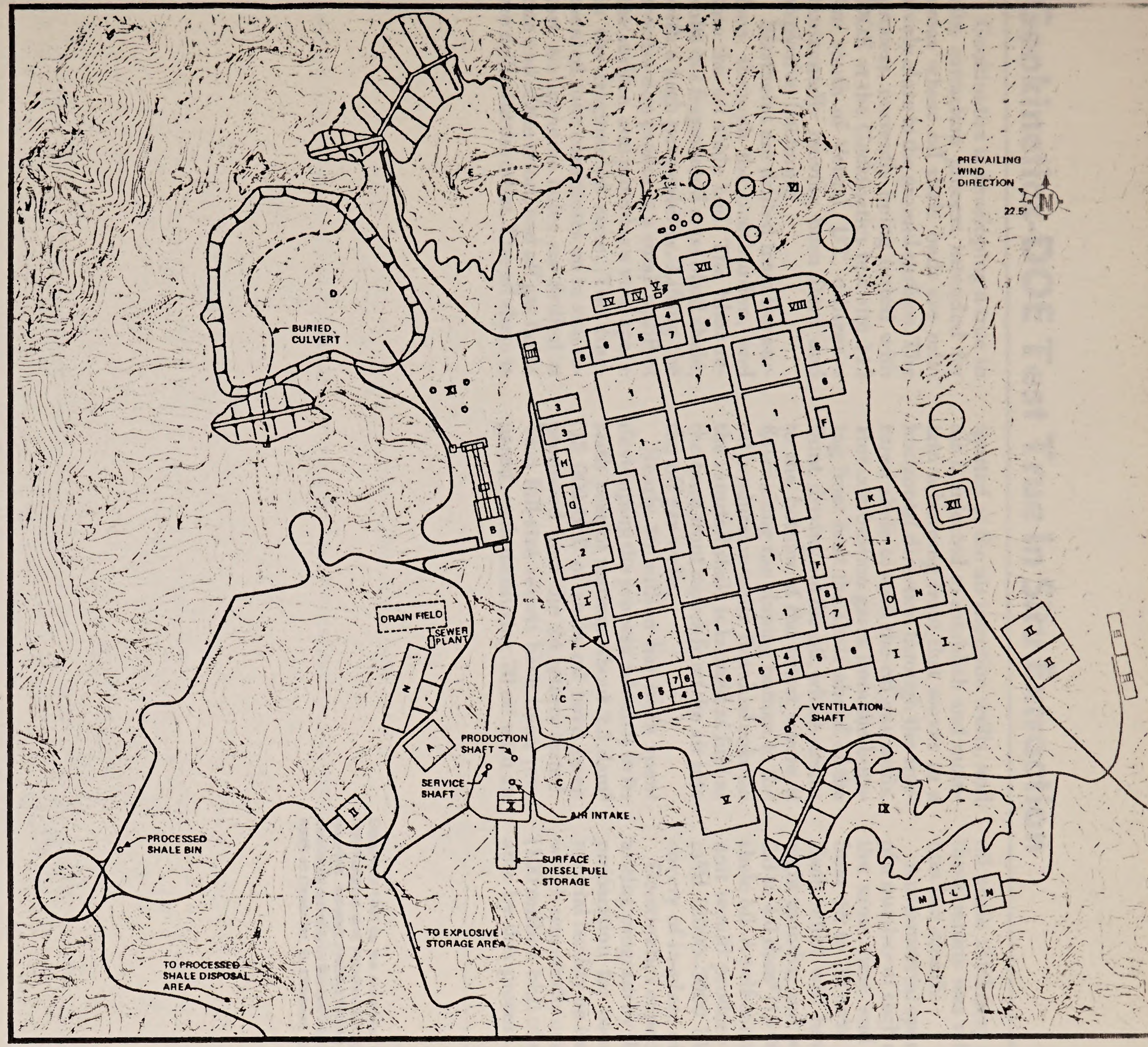



General development plot plan of Tracts U-a and U-b.

**LEGEND:**

| PROCESS FACILITIES | PHASE I | PHASE II | PHASE III |
|---|---|---|---|
| 1 COARSE SHALE RETORT, DH (PARAHO) | • | • | • |
| 2 COARSE SHALE RETORT, (UNION B) | • | | |
| 3 FINE SHALE RETORT (TOSCO II) | | • | • |
| 4 GAS SCRUBBER | • | • | • |
| 5 SULFUR RECOVERY | • | • | • |
| 6 ABSORBER AND STABILIZER | • | • | • |
| 7 DESALTER | • | • | • |
| 8 SOUR WATER STRIPPER | • | • | • |
| **MINING AND MATERIAL HANDLING FACILITIES AND BUILDINGS** | | | |
| A – MINE SERVICE BUILDING | • | • | |
| B – SECONDARY CRUSHER | • | • | |
| C – RAW SHALE STOCKPILE | • | • | |
| D – FINE SHALE STORAGE | • | | |
| E – TREATED EFFLUENT AND STORM RUN-OFF HOLDING POND | • | | |
| F – CONTROL ROOM | • | • | • |
| G – GENERAL BUILDING | • | | |
| H – ADMIN. AND LAB. BUILDING* | • | | |
| J – SHOP AND WAREHOUSE | | • | |
| K – FIRE HOUSE | | • | |
| L – ADMIN. BUILDING | | • | |
| M – CAFETERIA | | • | |
| N – PARKING LOT | | • | |
| O – CHANGE ROOM AND LUNCH ROOM | | • | |
| P – GATEHOUSE | • | | |
| **UTILITIES** | | | |
| I BOILER AND POWER PLANT | • | • | • |
| II SUBSTATION | • | • | • |
| III COOLING TOWER | • | • | • |
| IV WASTEWATER TREATING | • | • | |
| V RAW WATER TREATING | • | • | |
| VI TANKAGE | • | • | • |
| VII TRUCK LOADING | • | | |
| VIII PUMP STATION** | | • | |
| IX WATER RESERVOIR | | • | |
| X COLD STORAGE | • | | |
| XI FLARE | • | • | • |
| XII SULFUR STORAGE | • | | |

*WILL BECOME LAB FOR PHASE II.
**PROVIDED BY THE OWNERS.



# Geokinetics-DOE Test True In Situ Extraction

Geokinetics is developing a true in situ extraction process intended for areas where oil shale beds are relatively close to the ground surface. The process, currently being tested with DOE at the Geokinetics test site 113 km south of Vernal, UT, utilizes a horizontally moving burn front and explosive fracturing.

Blastholes are drilled from the surface, through the overburden, and into the oil shale bed. The blast results in a fragmented mass of oil shale, with a high permeability. Lifting the overburden produces a small uplift of the surface, and provides a void space in the fragmented zone. The fragmented zone constitutes an in situ retort. Air injection holes are drilled at one end of the retort, and off gas holes are drilled at the other. The oil shale is ignited at the air injection wells, and air is injected to establish and maintain a burning front that moves in a horizontal direction through the fractured shale toward the off gas wells. Hot combustion gases from the burning front heat the shale ahead of the front, driving out the oil, which drains to the bottom of the retort where it flows along the sloping bottom to the oil production wells. Residual coke on the retorted shale is burned as fuel as the burn front moves from the air into the off gas wells.

Nearly $8 million has been spent developing the process, which is in its sixth year of testing. About 2.3 $dam^3$ (15 000 bbl) of shale oil have been produced from the 24 retorts tested. Two full-size retorts have been prepared, each measuring 70 $m^2$ with an oil shale thickness of 10 m. One of these retorts was scheduled for ignition last month.

A commercial operation will consist of a number of such retorts burning at the same time and each producing from 16 to 32 $m^3/d$ (100–200 bbl/d). Each retort will have a life of six to eight months, and will produce from 2.3 to 4.0 $dam^3$ (15 000–25 000 bbl) of shale oil. A self-contained production unit would produce from 320 to 475 $m^3/d$ (2000–3000 bbl/d). A 50% recovery of in-place oil is expected.

Geokinetics expects to complete its testing program by the end of 1982, in preparation for constructing a commercial facility on its Utah properties, which reportedly contain over 16 $hm^3$ (100 million bbl) of shale oil recoverable by this process.□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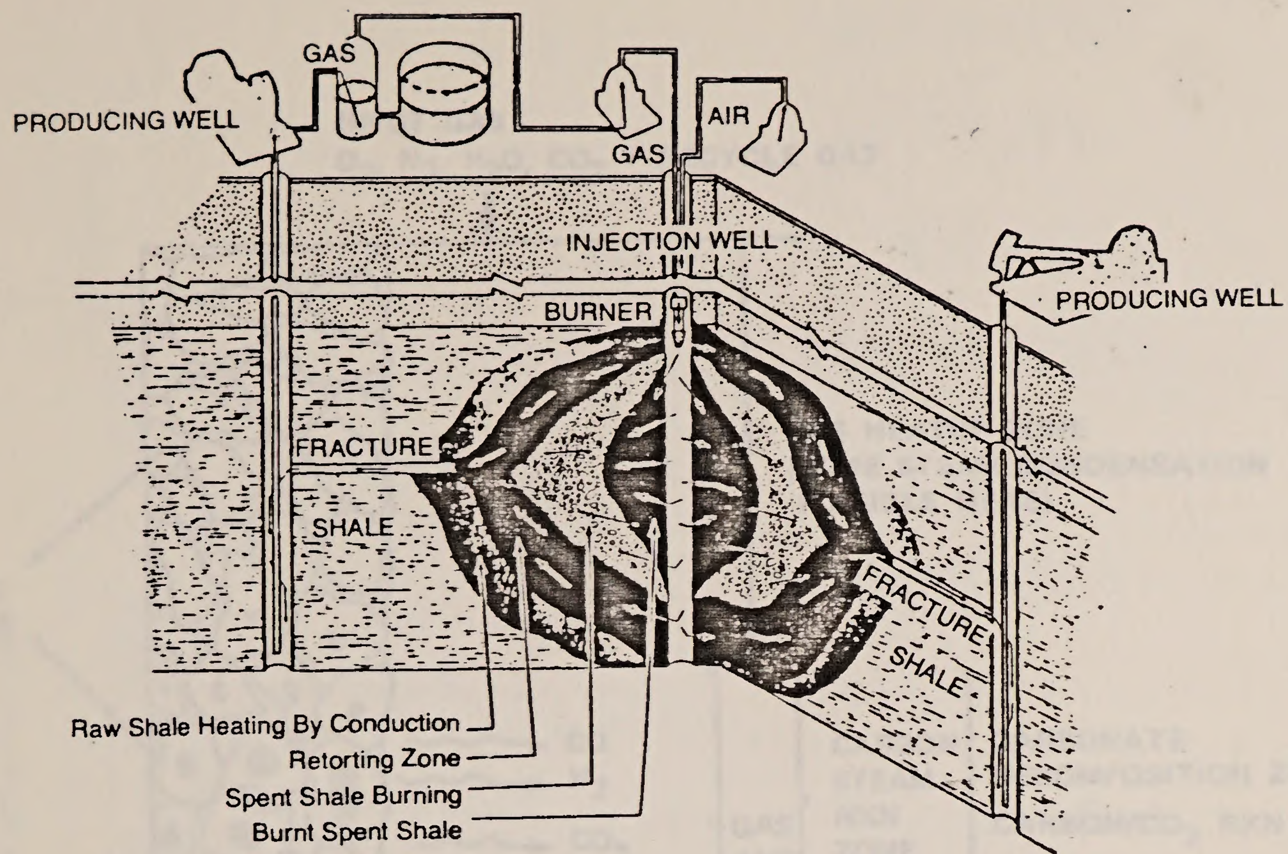
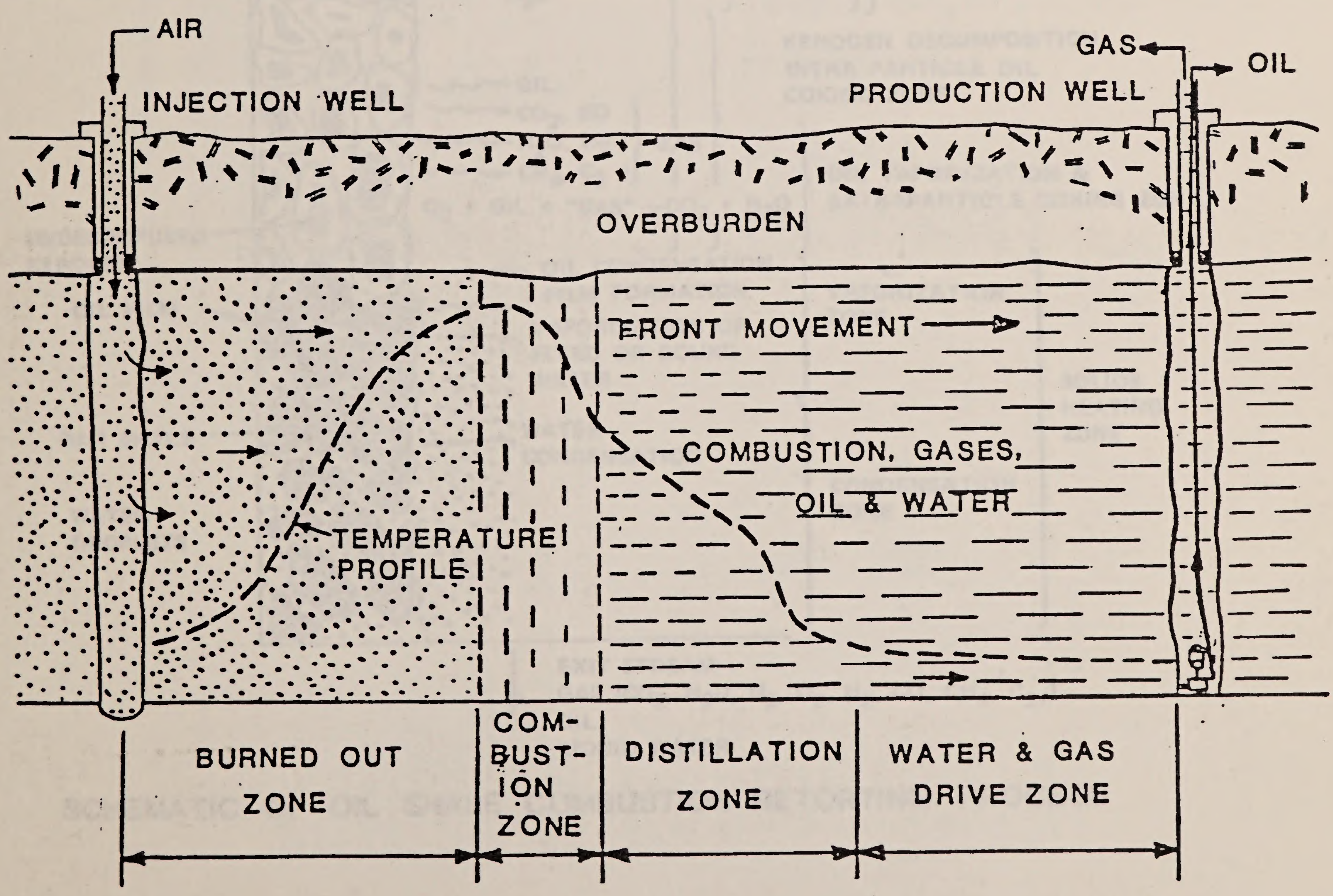
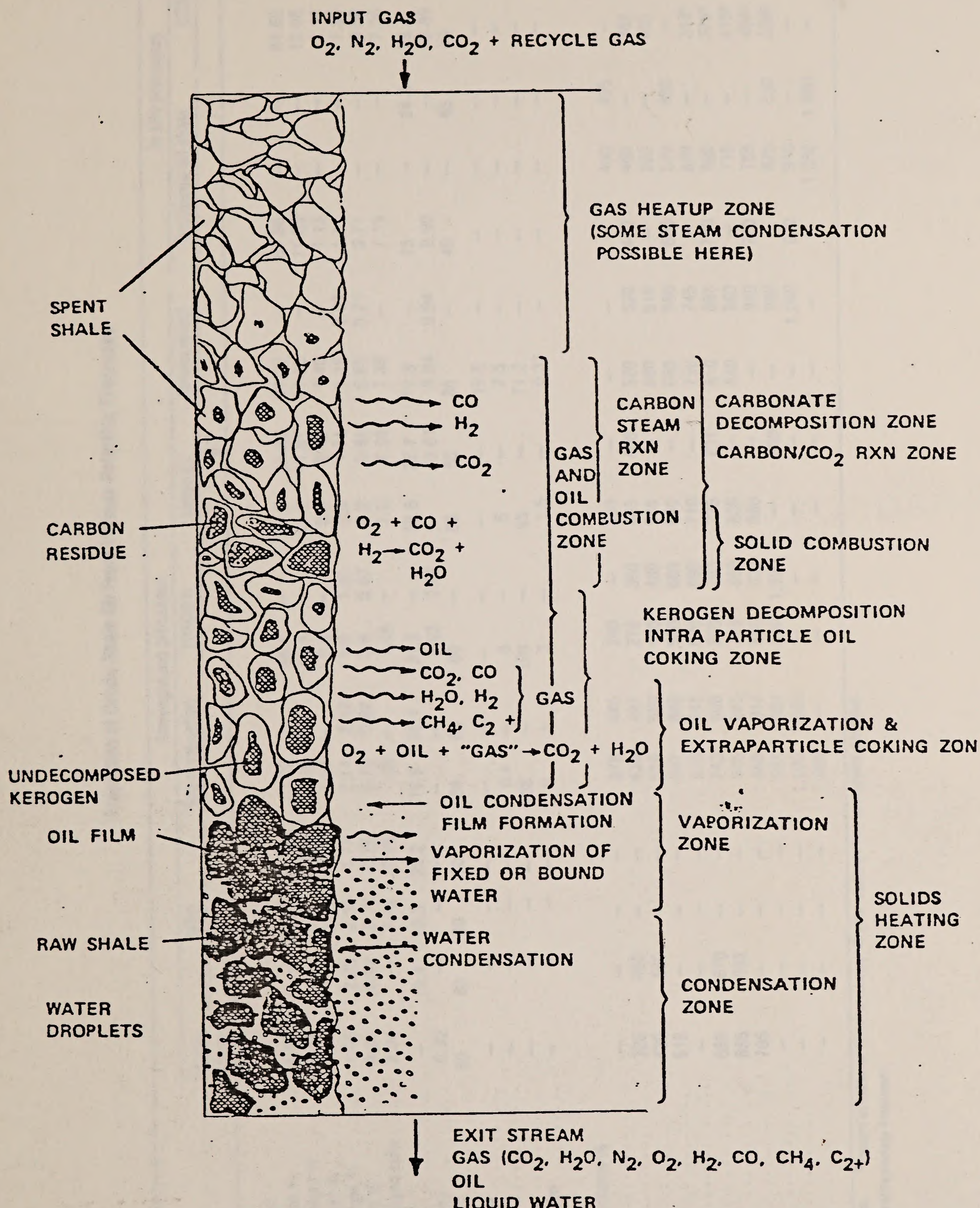
True In Situ Oil Shale Retorting




SOURCE: B. F. Grant, "Retorting Oil Shale Underground—Problems and Possibilities," *Quarterly of the Colorado School of Mines*, vol. 59, No. 3, July 1964, p. 40.




Vertical Cross Section of True In Situ Retorting




SCHEMATIC OF OIL SHALE COMBUSTION RETORTING PROCESS

## Properties of Crude Shale Oil From Various Retorting Processes

| Retort | Fischer assay | Aboveground processes | | | | | | | | | | | In situ processes | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NTU | | | Gas combustion | | TOSCO II | | Union Oil | | Paraho direct | | Occidental oil shale | | | USBM | |
| | | | | | | | | | "A" | "B" | | | | | | | |
| Retort, weight percent | | | | | | | | | | | | | | | | | |
| Carbon, weight % | 84.59 | — | 84.61 | 84.58 | 83.92 | — | 85.1 | — | 84.0 | 84.80 | 84.90 | — | 84.86 | — | — | 84.60 | — |
| Hydrogen, weight % | 11.53 | — | 11.40 | 11.76 | 11.36 | — | 11.6 | — | 12.0 | 11.61 | 11.50 | — | 11.80 | — | — | 12.08 | — |
| Oxygen, weight % | — | — | 1.10 | — | 1.67 | — | 0.8 | — | 0.9 | 0.90 | 1.40 | — | 1.13 | — | — | 1.18 | — |
| Nitrogen, weight % | 1.96 | 2.20 | 2.10 | 1.77 | 2.14 | 2.12 | 1.9 | 1.85 | 2.0 | 1.74 | 2.19 | 2.00 | 1.50 | — | — | 1.55 | 1.41 |
| Sulfur, weight % | 0.61 | 0.92 | 0.79 | 0.76 | 0.70 | 0.68 | 0.9 | 0.67 | 0.9 | 0.81 | 0.61 | 0.71 | 0.71 | — | — | 0.59 | 0.72 |
| Carbon/hydrogen ratio | 7.34 | — | 7.42 | 7.19 | 7.39 | — | 7.34 | — | 7.0 | 7.30 | 7.38 | — | 7.19 | — | — | 7.00 | — |
| Gravity, °API | — | 19.4 | 20.3 | 25.2 | 19.8 | 21.1 | 21.2 | — | 18.6 | 22.7 | 19.3 | — | 25 | — | 24.3 | 28.4 | 28.4 |
| Specific gravity | 0.92 | — | — | — | — | — | 0.93 | 0.93 | — | 0.81 | 0.94 | 0.94 | 0.90 | — | — | 0.89 | — |
| Pour point, °F | 80 | 80 | 90 | 70 | 84 | 85 | 80 | — | 80 | 60 | 85 | — | 40 | — | 65 | 40 | 40 |
| Arsenic, p/m[a] | — | — | — | — | — | — | — | — | — | — | 19.6 | — | — | — | — | — | — |
| Nickel, p/m | — | — | — | — | 6.4 | — | 6 | — | 6 | — | 2.5 | — | — | — | — | — | — |
| Iron, p/m | — | — | — | — | 108 | — | 100 | — | 55 | — | 71.2 | — | — | — | — | — | — |
| Vanadium, p/m | — | — | — | — | 6. | — | 3 | — | 1.5 | — | 0.37 | — | — | — | — | — | — |
| Distillation, volume % | | | | | | | | | | | | | | | | | |
| 5 @ °F | — | — | — | — | 378 | 445 | 200 | — | 390 | — | — | — | — | 400 | 405 | — | 61 |
| 10 @ °F | 326 | 493 | — | — | 438 | 497 | 275 | 360 | 465 | 400 | 520 | 530 | 440 | 460 | — | 382 | 620 |
| 20 @ °F | 430 | 560 | — | — | 529 | 589 | 410 | 480 | 565 | — | 600 | 610 | — | 520 | — | 405 | 648 |
| 30 @ °F | 518 | — | — | — | 607 | 668 | 500 | 600 | 640 | — | 680 | 680 | 600 | 570 | 600 | — | 666 |
| 40 @ °F | — | — | — | — | 678 | 742 | 620 | 690 | 710 | — | 750 | 745 | — | 620 | — | 343[b] | 681 |
| 50 @ °F | 655 | 670 | — | — | 743 | 808 | 700 | 780 | 775 | 731 | 810 | 805 | 700 | 680 | — | 375[b] | 699 |
| 60 @ °F | 685 | 692 | — | — | 805 | 865 | 775 | 860 | 830 | — | 840 | 860 | — | 715 | — | 415[b] | 732 |
| 70 @ °F | 705 | — | — | — | 865 | 918 | 850 | 935 | 980 | — | — | 910 | 770 | 765 | — | 464[b] | 768 |
| 80 @ °F | — | — | — | — | 935 | 984 | 920 | 1,020 | — | 960 | — | 980 | — | 825 | 830 | 528[b] | 809 |
| 90 @ °F | — | — | — | — | 1,030 | 1,065 | — | — | — | — | — | 1,040 | 920 | 910 | — | — | 867 |
| 95 @ °F | — | — | — | — | 1,099 | — | — | — | — | — | — | — | — | 1,050 | 1,000 | — | 914 |

[a]Parts per million. [b]Vacuum distillation at 40 mm of mercury. All other results are from atmospheric distillation.

SOURCE: Office of Technology Assessment.