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INVESTIGATION OF THE GEOKINETICS HORIZONTAL IN SITU
OIL SHALE RETORTING PROCESS

Quarterly Report for the Period October—December 1983

By
Kenneth B. Henderson

March 1984
Date Published

Work Performed Under Contract No. FC20-78LC10787

Geokinetics, Inc.
Salt Lake City, Utah

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

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HORIZONTAL IN SITU OIL SHALE
RETORTING PROCESS

QUARTERLY REPORT

October, November, December 1983

by

Kenneth B. Henderson

GEOKINETICS, INC.

391 Chipeta Way, D-2
Salt Lake City, Utah 84108

Date Published - March 1984

PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY

Under Cooperative Agreement #DE-FC20-78LC10787

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INTRODUCTION

The Geokinetics In Situ Oil Shale Project is a cooperative venture between Geokinetics Inc. (GKI) and the U.S. Department of Energy (DOE). The project is governed by DOE Cooperative Agreement #DE-FC20-78LC10787. The objective is to develop an in situ process for recovering shale oil using a fire front moving in a horizontal direction. The project is being conducted at a field site, Kamp Kerogen, located 70 miles south of Vernal, Utah, on Section 2, Range 22 East, Township 14 South, Uintah County, Utah.

The process is a true in situ method for extracting oil from oil shale. The oil shale is fractured by explosives placed in blastholes drilled from the surface. After a specific area has been fractured to create an in situ retort, air injection wells are drilled at one end and off gas recovery (air-out) wells are drilled at the other. The oil shale is ignited at the air injection wells and air is continually injected to establish and maintain a burning front. The front is moved in a horizontal direction through the fractured rock. This heats the shale, driving out the shale oil which drains to the bottom of the retort where it is recovered through oil production wells. As retorting progresses from the air-in to the air-out wells, the residual coke serves as the primary fuel source to sustain the moving burn front. The combustion gases are recovered from the off gas wells.

FOURTH QUARTER AND 1983 SUMMARY

Retort #26 was shut-in on February 22, 1983, having produced 22,889 barrels of oil by that date. The oil production pumps were operated for 17 days after shut-in, producing an additional 217 barrels of oil for a total of 23,106 barrels of oil during 246 days of production. The dismantling of Retort #26 was begun during the last two weeks of March and completed during April.

Reclamation work was begun on Retorts #24, #25, and #26. Retort #24 is being used for the U.S. Forest Service surface revegetation study.

The installation of retort equipment, piping and instrumentation of Retort #27 was conducted from January into May. Retort #27 was ready to ignite during July, but the decision was made not to do so pending completion of the Retorts #27 and #28 off gas processing plant. Retort #27 was ignited on August 11, 1983 with a new ignition procedure. By December 31, 1983, the retort had completed 139 days of operation and produced 11,420 barrels of oil.

Re-entry drilling on Retort #28 continued from January through March. The construction of production and observation wells began in April and completed in June. Air injection and off gas piping and manifolding began in June and, along with the installation of electrical and instrumentation wiring, was completed in September. Retort #28 was ignited on October 18, 1983. On December 31, 1983, it had completed 74 days of operation and produced 5,285 barrels of oil.

Wet weather during May and June hampered work on the evaporation pond for Retorts #27 and #28. The pond was finished and inspected during August and was first put into service with the ignition of Retort #27.

Site preparation for the off gas processing plant for Retorts #27 and #28 began in January. However, most of the construction took place after the first part of April. To date, the oil storage tanks, demister tanks, air coolers, ammonia absorber and stripper, afterburner stack (the afterburner stack has been converted to a low NO_x burner), H_2S absorber and stripper, ammonia stripper-reboiler, and a small heat exchanger have been installed. The two process vessels associated with the sulfur plant modification were installed during July and August along with the process piping. The gas piping, including the by-pass system through the plant is complete; the installation of process piping in the ammonia plant is also complete. All injection, vacuum, and spare blowers are all operational. The entire plant was completed and put through an initial shakedown run December 31, 1983. Concentration levels of H_2S and NH_3 in the retort off gas have not warranted plant operation during the fourth quarter.

DESCRIPTION OF FOURTH QUARTER TECHNICAL PROGRESS

I. EDITOR'S NOTE

There is a minor change in the format of this report regarding the "Description of Technical Progress" for Retorts #27 and #28. As in the past, information specifically related to each retort will be presented under the respective retort heading. However, Retorts #27 and #28 are being supplied in parallel by the same set of air injection and off gas blowers. Because occurrences associated with the air-in and off gas system affect both retorts similarly, a combined Retorts #27 and #28 "Description of Technical Progress" section has also been included.

II. RETORT #27

Retort #27 was ignited on August 11, 1983. On December 31, 1983 it had completed 139 days of operation and had produced 11,420 barrels of oil and 16,445 barrels of water (see Figures 1 and 2, and Table 1). Figure 3 is a plan view of Retort #27 with retort process wells. The air-in wells also serve as ignition wells. Figure 4 is a plan view of Retort #27 with instrumentation wells.

As discussed in the third quarterly report, Retort #27 experienced difficulties during the early stages of the burn which may have caused lower initial oil production rates. However, sometime between elapsed days 59 and 60 there was a significant increase in oil production (see Figure 1). Because the trend of the oil production rates after that was clearly upward, it was assumed that conditions (temperatures and air flow rates) in the retort had improved. Another indication of improving conditions in the retort was a steady increase in oil production rates while air injection rates remained relatively constant. Based on past retorting experience, such an occurrence indicated a fire front may have moved from lower into higher grade shale.

Geokinetics has accumulated a large amount of operating data and experience from several successful experimental retort burns. This experience has made it possible to define, with a high degree of certainty, not only how oil production rates vary directly with air flow rates, but how oil yield from a given grade of shale will vary relative to air flow rates and retort cross sectional areas.

The air-in/oil production relationship can be described as follows: At increased air flow rates, more oxygen is supplied for combustion. Increased and more efficient combustion generates larger and hotter volumes of combustion gases. The net result is that the hotter, larger volume of off gas can retort a proportionately larger volume of oil from the down stream shale bed. There is a heat supply maximum point, above which increased heating causes the oil to either crack or actually burn. Accordingly, for maximum retorting efficiency, it has been estimated that Retort #27 would require about 8,000 scfm of air, which is approximately 1 scfm per square foot of retort cross section.

Based on relationships used to describe oil recovery rates, Retort #27 is expected to produce approximately 128 barrels per day of oil. As shown in Table 1, the retort averaged 124 barrels per day from day 60 through day 139.

On day 85, air injection rates were reduced so that repair work on the retort surface could be completed. Normally, the overburden on a retort forms a reasonably tight barrier to gas leakage. This is especially true if the air-in and off gas blowers are operated to provide a net negative pressure downstream of the combustion front. However, in the case of Retort #27, the air injection end of the retort slumped in shortly after blasting (see August 1983 Monthly Report). Consequently, the overburden was disturbed enough to allow retort gases to escape through the surface inspite of attempts to draw negative pressure on the retort. Repairs to the retort consisted of cutting the overburden over the slumped-in zone to a depth of several feet and then carefully compacting it as it was replaced. The repairs were successful.

Winterization of the retort equipment began early in November and continued through the end of the period.

III. RETORT #28

Retort #28 was ignited on October 18, 1983. On December 31, 1983, it had completed 74 days of operation and produced 5,285 barrels of oil and 9,671 barrels of water (see Figures 1 and 2, and Table 2). Figure 5 is a plan view of Retort #28 with process wells. The air-in wells also serve as ignition wells. Figure 6 is a plan view of Retort #28 with instrumentation wells.

The ignition procedure was the diesel ignition technique. This procedure, used first to ignite Retort #27, is actually a variation of the charcoal point technique (see August and October 1983 Monthly Reports, pages 5 and 6, respectively). All ignition wells were first ignited with small (10-20 pound) quantities of hot charcoal. Diesel fuel was then injected into each well at the rate of approximately 0.2 gpm for six continuous hours. Combustion air was injected into and gases drawn off the retort by blowers already in operation on Retort #27. As ignition proceeded, this technique showed several advantages over the previously used charcoal point technique. Two of the major advantages were: 1) a quicker lighting time (10 wells per day as opposed to 5 wells per day), and 2) wider ignition bands. The ignition thermocouples indicated that the shale ignited in band widths of up to 20 feet, instead of the one and two foot bands which resulted when the charcoal point technique was used. As a result, temperatures along the first row of thermocouples rose quickly.

Within a few hours, adjustments were made in the air injection rates to bring the ignition bands into a straight, steadily advancing fire front. According to design calculations, a retort the size of Retort #28 requires approximately 8,000 scfm of injected air for efficient retorting. Retort #28 should produce approximately 134 barrels per day of shale oil.

On elapsed day 60, 12 barrels of hot process water were pumped down observation well #5 in an effort to free pump #5 and to clear out any cold oil that may have been plugging the middle production manifold. The production recorded on day 61 indicated that the procedure was successful (see Table 2). Part of the 168 barrels produced on day 61 probably came from oil retorted earlier in the burn which could not be recovered because it had cooled and become too viscous before it reached the pumps. Between elapsed day 60 and the end of the period, Retort #28 averaged 134 barrels per day (see Table 2).

It is noted that both Retorts #27 and #28 experienced significant increases in production rates on or about elapsed day 60.

IV. RETORTS #27 AND #28

As has been previously stated, one of the most important objectives of Geokinetics' long range research and development program has been to determine the most efficient size for an in situ retort as defined in terms of cost, operability, and oil yield. As the size of the retorts has increased from the original 300 square foot (10' x 30', 900 cubic feet) retort to the present 100,000+ square foot retorts (Retort #27: 300' x 330', 2,970,000 cubic feet; Retort #28: 300' x 340', 3,060,000 cubic feet) so have the requirements for support operations increased.

There are several support operations and each is necessary to the overall success of the project. Having a sufficient supply of electrical power has been an item of major concern since the first retort was burned at Kamp Kerogen. The first generator supplied only a few watts of power to drive a small blower, a production pump and occasionally to provide some service to the personnel living at the site. Since that time, power demands have grown to the extent that generators supplying hundreds of kilowatts are now required.

Power for the current work is being supplied by a natural gas fired, one megawatt generator. Standby power is supplied by a natural gas driven (650 kilowatt) and a diesel driven (750 kilowatt) generator, installed in parallel with the one megawatt unit.

During construction and for the early operation of Retort #27, the 650 kilowatt generator supplied power for the site. On about day 60 of the Retort #27 burn, the one megawatt unit was brought on line to replace the 650 kilowatt unit. The changeover went reasonably well and the system was stable. However, on Retort #27's day 65, Retort #28 was ignited. Within hours, the air-in and off gas blowers were turned up to begin servicing both retorts, and production pumps on both retorts were also turned on as retorting progressed.

As the drawdown on the system increased, it became obvious the one megawatt generator could not handle the load by itself and the 650 kilowatt unit was brought on line. Within a few hours and for no obvious reason at the time, one of the generators shutdown, and as a result, several blowers and production pumps immediately shutdown. Everything was restarted and appeared satisfactory, but within a few hours the same event happened. After several similar events, it was decided the generators could not be made to work in parallel because power supply restrictions were unacceptable.

Many attempts were made during the next several days to correct the problem. Even though several operating and maintenance specialists from various equipment vendors visited the site and provided assistance, the operational stability of the system did not markedly improve.

On December 15, 1983, Geokinetics invited Merrill Shumway, a consulting electrical engineer from Ford, Bacon & Davis engineering firm, to inspect the entire system and to recommend corrective measures. As he stated in his first report, his "purpose in visiting the site was to assist in identifying the problems associated with trying to operate two different sized generators in parallel".

In general terms, he explained that "the two generators were 'fighting' each other. Once they were on line, one would have a different power factor than the other, and after a while, one generator would shut down with phase reversal or over current problems as the load would change." (Ford, Bacon & Davis Incorporated, Salt Lake City offices, interoffice memo, December 21, 1983).

While at the site, the engineer took amperage readings at the motors and transformers. The voltage on one transformer was low by 20 volts, so the taps were changed. The amp readings on the 700 hp blower motor were determined to fluctuate for reasons he could not account for at the time. He did speculate that the fluctuations could have been caused by "the type of load on the motor" or by a "very unstable feed." Until further tests could be run, he suggested installing capacitors on each of the blower motors. This would offer the generators a much better chance to run in parallel. The capacitors, rather than the generators, would then supply the reactive power to the motors which would improve the stability. The capacitors would also reduce the current draw to the motors, thus improving the overall efficiency. As of the end of the fourth quarter, steps were being taken to have the capacitors installed.

Another "bottle-neck" to the efficient and stable operation of the generators was determined to be a reduced natural gas supply pressure. As of the end of the period, measures were being worked out with Mountain Fuel Supply to bring the operating pressure up 75 psi.

V. OFF GAS PROCESSING FACILITY

The general construction of the off gas processing facility was completed before the beginning of the period. The two stage low NO_x burner was extensively tested early in the fourth quarter to

optimize its efficiency. The tests involved varying the primary and secondary air injection rates and water spray volume in the stack while simultaneously monitoring the temperatures and the nitrogen dioxide concentrations within the stack. Design water spray rates and combustor temperatures were achieved during the tests. It was also determined that if water flow rates in the combustor could be adjusted over a broader range, then wider variations in off gas flow rates could be accommodated.

By the end of the quarter, ammonia and hydrogen sulfide concentration levels in the retort off gas were nearly high enough to require their removal. Tables 3 and 4 list the 10 day average composition of Retorts #27 and #28 off gas streams; the values are in volume percent. Table 5 lists the NH_3 and H_2S concentrations in the off gas. The heating values are in Btu/scf. However, because the electrical system at the site was not stable, the off gas plant could not be started up before the end of the reporting period. Start up is expected sometime in January.

Winterization of the facility began in mid November and continued through the end of this quarter.

VI. ENVIRONMENTAL RESEARCH

A. ENVIRONMENTAL PERMITS

Air Quality (Prevention of Significant Deterioration - PSD) - During December, Geokinetics received verbal approval from the Utah Bureau of Air Quality (UBAQ) to delay the emissions compliance test for the retort afterburner to allow time for Retorts #27 and #28 to reach design operating conditions. The emissions compliance test, originally scheduled to be conducted before the end of calendar year 1983, must be performed using approved EPA reference methods for sampling stationary sources of air pollutants. The purpose of the test is to demonstrate that emissions from the off gas afterburner are within the limits established by the UBAQ in

their PSD approval order. Written approval from the UBAQ for the extension is to be received by Geokinetics during January 1984.

B. HYDROLOGIC RESEARCH

1. Surface Impacts - A draft report covering the soil infiltration work carried out for Geokinetics by the Utah State University Foundation during the summer of 1983 was completed during October. The overall study objective was to characterize the surface hydrologic properties of several different land conditions of Geokinetics' in situ retorting operation. The goals of the study were:

- a. To determine point infiltration rates and parameters on two different land types using two different methods. The two land types, as described in the following sections, are: 1) native sagebrush lands, preparatory to clearing and oil retorting operations, and 2) prepared retort areas. The two methods are: 1) double ponding ring infiltrometers, and 2) modular drop forming infiltrometers.
- b. To synthesize hydrologic loss rate parameters for the sites from the infiltration data. The loss rate parameters synthesized are runoff curve numbers (CN), used in the curve number method of direct runoff response from rainstorms. Infiltration rates measured also function as loss rates.

Methods - A total of 120 plot infiltrometer runs were made under different combinations of land types ("Sage" or "Retort"), Antecedent moisture ("Dry" or "Wet") and methods of measurement ("Ponding" or "Rainfall"). These are as follows:

1. Land type: The "sage" condition was native untreated sagebrush land which had been designated for preparation as a retort. As shown in Figure 7, the sites are about 1/4 mile south of the present Kamp. "Retorts" were prepared retorts to burn but not yet in operation (Retorts #27 and #28). The land surface was bare and compacted, and had been driven on.
2. Antecedent moisture: "Dry" conditions were those in a natural summer moisture status. This was usually characterized by a dry and/or dusty surface, with some unknown residual soil moisture. Though several rainstorms occurred during the study period, measurements were deferred for several days following. "Wet" conditions were those found the day following a dry run. That is, a "dry" run was followed the next day with a "wet" run.
3. Method of measurement: "Ponding" runs were measurements made with a double ponding ring infiltrometer. The rings 1/8 inch thick by 18 inches and 12 inches in diameter, were inserted concentrically to a depth of about 3 inches. The bottoms had a sharpened edge and the tops a welded reinforcing strip to provide durability and to aid in their placement. They were operated with a 1 inch (2.54 cm) head of water, maintained with a point gage and inputs measured with a graduated cylinders or, if necessary, a surgical syringe. The timed water budget of the center ring is considered to be infiltration.

"Rainfall" runs were made by simulating rainfall with a drop-forming device, approximately 2 feet square, with a fall height of about 6 feet. The rain falls on corresponding small catchment defined with steel plate boundaries and a collecting trough. Volumetric measurements of rainfall and runoff over measured time intervals allows the determination of apparent

infiltration as the difference between the two rates. The rainfall intensity varied slightly (5.9 to 6.3 cm/hr.) from run to run, but was assumed uniform throughout the run.

Sampling Design - The 120 plots were sampled as shown in Table 6. The "sage" locations were on three different sites; the "retorts" on two different prepared retorts. Within each type, sampling was further stratified into "locations". A location consisted of a closely associated set of measurements, consisting of 2 ponding ring setups and a rainfall setup, usually all within about 4-6 feet of each other. Ideally the rings were to be about four feet apart with the rainfall plot between them. Each location was then run wet and dry over a span of no more than two days. The locations were selected as "representative" of the acre samples and were separated by at least 100 feet.

With few exceptions, runs were for at least 60 minutes duration, with measurements at 2 minute intervals for the first 20 minutes and every 5 minutes thereafter. Water temperature was taken, as were occasional readings of electrical conductivity. Rainfall runs noted the time runoff began and ended. Plot cover characteristics were noted. Although plot slope was not measured, a consistent modest slope ($\pm 10\%$) was a location selection factor.

Data Analysis - Analysis of the data for the 120 plot runs were for the coefficients of Hortons' infiltration capacity equation:

$$f(t) = F_c = (F_o - F_c) e^{-kt}$$

where:

- (1) F_c and F_o are the long term constant infiltration rates and the infiltration rate at $t=0$ respectively; and,

- (2) k is a coefficient indicating the rate of approach to F_c .

Fitting of data to the Horton's equation was accomplished via a least square iteration process. In addition, to account for the temperature dependent viscosity effects, the F_c values were adjusted to a basis of 55°F using a viscosity equation provided by Heggen¹.

Almost all fits show a high value for the drawdown coefficient " k ". Values of $10\text{--}20\text{ hr}^{-1}$ were common, indicating a rapid satisfaction of the transient capillary phase of infiltration. Constant or near-constant infiltration rates were commonly attained after 10-20 minutes. The remainder of the time in the 60 minute runs usually demonstrated this near-constant rate with some occasional noise superimposed.

The temperature-viscosity corrected results of the above described curve fits as shown in Figure 8, demonstrate the relative magnitudes of infiltration and the rankings for the land types (sage and retorts), moisture conditions (dry and wet), and test methods (ponding and rainfall), and the relative positions of the test locations. The data is also summarized in statistical moment form as given in Table 7.

An analysis of variance was performed on the data. The following conclusions were made from the analysis:

1. Differences were obvious between the land types ("sage" and "retorts") and the moisture conditions ("wet" vs. "dry").
2. The contrast between ponding measurements and rainfall simulation measurements is in accord with general expectations on sage sites, but less understandable due to the low values on the retorts.

3. The dry conditions provide indistinguishable results, but the wet runs show higher infiltration rates with rainfall measurements. This may be attributed to a number of factors: a) observed incomplete coverage of the plot with the rainfall simulator, b) splash losses, c) measurement noise combined with the subtraction of two near-equal quantities, or d) a genuine unknown physical process associated with rainfall.

Curve Number Synthesis - The creation of curve numbers (CN) from infiltration data was accomplished by generating rainfall excess from designed storms of given intensity distribution and depth, through superposition of interval intensities on strips of interacting infiltration points. Runoff rates were converted to runoff depths and summed over a storm's duration. These runoff depths were then used to define a curve number for the rainfall depth.

Briefly, the curve numbers were developed using wet antecedent moisture conditions for predicting storm runoff from extreme events. The curve number calculation was done via the equation:

$$s = 5 \left(P = 2Q - \sqrt{4Q^2 + 5PQ} \right)$$

where: Q = rainfall excess in inches

P = accumulated precipitation in inches

s = storage index depth in inches

Results - A summary of these calculations is shown in Table 8. A graphical display for the sage sites is shown in Figure 9.

The results indicate curve numbers vary with storm duration, return period (storm rainfall), and land type. The latter is expected. The influence of distribution and depth may be best understood as

arising because of fundamental differences between the two methods of calculating storm runoff. The CNs calculated here are for specific storm distributions (not naturally observed site data), very specific land types, and a loss rate approach.

The fundamental definition of CN comes from the notion of small watershed rainfall-runoff, observed over a number of years and defined on annual floods. Such events arise from a variety of storm distributions, durations, and depths not presumed here. With this in mind, "consensus" curve numbers are given in Table 9. These are merely the arithmetic averages of 10 and 100 year storms.

The average should be used with the critical storm duration judged appropriate. Shorter storms of thunderstorm origin seem to dominate in the area, thus suggesting a design using a four (4) hour duration for extreme events (see Figure 10).

For the general mass of sagebrush site data, the relationship between rainfall and ponding is closely approximated by a general rule-of-thumb which states that rainfall results will be "about half of ponding results". In fact, using only the sage data and forcing the fit through the origin gives a ratio (slope) of 0.44.

2. Surface/Subsurface Impact Studies - The collection of on-site baseline hydrologic data was primarily completed during December. The data collection is part of a study to determine baseline conditions and address the potential of the in situ process to affect surface and subsurface hydrologic systems.

The purpose of the data collection was to:

- a. Establish the probable hydrologic consequences of proposed mining and reclamation activities.
- b. Design possible mitigation and reclamation plans;
and

- c. Comply with state and federal environmental regulations.

The field data was primarily collected by Law Engineering Company ("LAW") of Denver, Colorado. An interim data report will be submitted to Geokinetics in January to document the field investigation and preliminary data analysis conducted by LAW.

Additional data collection activities, including water quality and water level sampling, will be conducted in January. This will complete the initial baseline data collection.

Preliminary analysis of the pressure-permeability testing conducted during June 1983 was completed during December with initial results indicating an increase in rock permeability adjacent to blasted retort areas.

The goal of the testing was to provide hydraulic conductivity values of rock strata adjacent to and below blasted in situ retorts. This would assist Geokinetics in estimating potential impacts upon groundwater flow regimes (both vertically and horizontally) and potential pollutant transport from retorting activities.

Permeability tests were previously conducted by Kaman Tempo, Denver, Colorado, in two (2) test holes (AH-1 and CH-12) in 1981 (see Figure 11). Angle hole #1 (AH-1) was drilled beneath Retort #24 while corehole #12 (CH-12) was an existing test hole well removed at the time from retorting activities.

The results of Kamans' testing indicated there was not a significant difference between rock permeabilities adjacent to an in situ retort with permeabilities of undisturbed rock (Hoylman, 1981).

Permeability tests conducted in coreholes 1 through 5 located adjacent to Retort #28 indicated a slight increase in rock permeability related to fracturing near retorts to that of CH-12

(Tables 10 and 11). However, permeabilities were still in the range of 10^{-4} to 10^{-8} cm/s.

Examination of cores obtained from rubble and burned retort zones indicates these materials are extensively altered and highly variable with respect to texture, color and amount of remaining rock. This variability is probably a result of differences in the effects of blasting and in the temperatures and efficiencies of the burn. These materials appear to have a much greater porosity and permeability than undisturbed rocks.

Corehole PTH-1 was cored on Retort #28 for an interval of about 85 feet beginning about 15 feet below the blasting zone of Retort #28. Data from this core indicated possible slight increase in fractures down to about 40 feet below the base of the retort. This fracturing may represent the maximum depth to which permeability may be increased by the retorting process. This depth is still approximately 30 feet above the top of the zone of interbedded tar sands and massive limestones considered to be a major barrier to vertical groundwater movement.

The high residual rock temperatures following retorting restricts obtaining permeability data directly from retorts. However, additional examination of cores from these zones and the completion of wells in adjacent areas will serve to quantify effects of retorting on permeability. This work was completed in the subsurface field investigation and characterization studies completed in December. Results should be presented in January.

C. ECOLOGICAL RESEARCH

1. Land Rehabilitation - The fall seeding of the U.S. Forest Service revegetation plot study on Retort #24 was implemented on October 25 and 26, 1983. The study was designed to yield information on alternative cultural methods (methods commonly used) and suitable herbaceous and shrub species for establishing a level

of vegetative cover adequate to meet government reclamation requirements.

The five specific objectives of the study are: 1) to determine the relative success of direct seeding in conjunction with three mulching treatments (straw, wood fiber, or no mulch), 2) to evaluate the vegetative stand obtained when only herbaceous species are used or when both herbaceous and shrubby species are used, 3) to obtain preliminary information on the value of supplemental water applied by irrigation during the growing season on successful vegetation establishment, 4) to assess the effect of season of direct seeding (spring vs. autumn) on vegetation establishment, and 5) to determine the success of establishment of several native shrub species when direct seeded in association with perennial grasses.

According to the study plan (1st Quarterly report 1983) the application of gypsum and inorganic fertilizer was made prior to seedbed preparation (ripping and harrowing). The material was spread on the test area with a two-wheeled fertilizer spreader.

As in the spring, the shrub seed was broadcast by hand to ensure an even distribution. The grass and forb seed was mixed together and sown with a Brillion seeder-packer after the shrub seed had been sown. Thus, the Brillion also served to press the shrub seed into the soil.

The seeding rate was intended to be the same as that used in the spring seeding. This was accomplished reasonably well on the grass-forb seeded areas with 1,025 grams remaining and the seed hopper after all 10 strips had been seeded. However, when only 30 percent of the seeding operation on the grass-forb-shrub strips had been completed, it was realized that seed was being dispensed from the Brillion seeder in greater than the desired quantity. The setting on the hopper of the Brillion was then changed from the "wide open" position to a setting of "3" for the seeding of the remaining 70 percent of the area. Thus, as closely as can be determined, the seeding rate for the autumn seeding was as follows:

For treatments A and B:

lbs/acre, PLS

Blue grama	1.00
Alkali sacaton	.50
Indian ricegrass	2.90
Tall wheatgrass	5.90
Beardless wheatgrass	3.90
Western wheatgrass	3.90
Bluebunch wheatgrass-Quackgrass hybrid	3.00
Russian wildrye	3.90
Utah sweetvetch	1.30
Munro glovemallow	.06
Gooseberry-leaf globemallow	.26
Palmer penstemon	<u>.21</u>
TOTAL	26.80

For treatments C, D, and E:

	<u>lbs/acre, PLS</u>	
Blue grama	0.90	(1.9) ¹
Alkali Sacaton	0.50	(1.0)
Indian ricegrass	1.90	(3.9)
Tall wheatgrass	2.90	(5.8)
Beardless wheatgrass	1.90	(3.9)
Western wheatgrass	1.90	(3.9)
Bluebunch wheatgrass-Quackgrass hybrid	2.90	(5.8)
Russian wildrye	1.90	(3.9)
Utah sweetvetch	0.70	(1.1)
Munro globemallow	.06	(0.1)
Gooseberry-leaf globemallow	.25	(0.5)
Palmer penstemon	.20	(0.4)
Fourwing saltbush	5.70	
Shadscale	4.90	
Big sagebrush	.40	
Winterfat	3.20	
Rubber rabbitbrush	.13	
TOTAL	30.34	(46.5)

¹ Amount in parentheses is the estimated seeding rate for treatments C, D, and E in Block 5, and treatment E and the south 1/2 of treatment C in Block No. 4 of the autumn-seeded area.

For the record, the seeding of the grass-forb-shrub treatments in Block No. 5, through the south 1/2 of treatment C in Block No. 4 was being spread in two great a quantity. Thus, it should be recognized, in future evaluations of the established vegetation, that these portions of the autumn-seeded area were seeded quite heavily.

Thermocouple psychrometers were installed at two locations on the portion of the autumn-seeded area that will be irrigated and at two locations on the portion that will not be irrigated. Psychrometer numbers and their locations are shown as follows:

PSYCHROMETERS LOCATED AT GEOKINETICS

Study Site on October 24, 1983

Treatment B (irrigated), Block No. 2

<u>Psychrometer number</u>	<u>Depth (in.)</u>
26	4
28	8
21	12

Treatment C (irrigated), Block No. 4)

<u>Psychrometer number</u>	<u>Depth (in.)</u>
2	4
5	8
18	12
13	24

Treatment B (irrigated), Block No. 2)

<u>Psychrometer number</u>	<u>Depth (in.)</u>
6	4
9	8
25	12
3	24

Treatment C (irrigated), Block No. 4)

<u>Psychrometer number</u>	<u>Depth (in.)</u>
15	4
23	8
162	12

In addition to the USFS study, revegetation of 10 acres of disturbed land was completed between October 26 and November 4, 1983, in accordance with the State of Utah Mined Land Reclamation Act (Title 40-B, Utah Code Annotated 1953). The purpose of the revegetation was to comply with the Act and meet the following objectives:

1. Return the land concurrently with process operations or within a reasonable amount of time thereafter to a stable ecological condition compatible with past, present and probable future local land use;
2. Minimize or prevent present and future on-site or off site environmental degradation caused by Geokinetics operations to the ecologic and hydrologic regimes; and
3. Minimize or prevent future hazards to public safety and welfare.

The total revegetated land consists of two (2) acres: 1) Retorts #3 through #26 (excluding 7, 11, 13, 16, 19, 20, 22 and 24) with adjacent areas; and 2) Retorts #21 and #23 with additional non-retorted area (see Figure 9).

The pre-disturbed native vegetation of the areas was dominated by sagebrush-grass and sagebrush-saltbush types with interspersed areas of the pinyon-juniper type. Soils are silt loam derived primarily from a marlstone parent material.

Soil samples were taken from the top 12 inches of the soil profile in disturbed areas during September and exhibited the following characteristics:

Soil reaction (pH): 8.3 - 9.1 ($\bar{x}$ = 8.8)
Electrical conductivity (mmhas/em): 0.6 - 5.7 ($\bar{x}$ = 1.8)
Organic matter (%): 1.7 - 4.2 ($\bar{x}$ = 2.5)
Available nitrogen (ppm): 0.4 - 7.1 ($\bar{x}$ = 4.0)
Available phosphorous (ppm): 0.01 - 0.58 ($\bar{x}$ = 0.12)

Sodium (meq/l) 8.3 - 42.2 ($\bar{x}$ = 24.6)

Estimated SAR¹: 2.8 - 8.6 ($\bar{x}$ = 5.3)

1-SAR (Sodium Adsorption Ratio) is an expression of the relative activity of sodium ions in exchange reactions with soil.

Two separate native-introduced seed mixtures, Mix A and B, were used on the disturbed areas. Mixture A, used on Area 1, was primarily collected locally (within the Uintah Basin), and Mixture B, used on Area 2, was primarily collected outside of the local area. The purpose of the two different mixtures is to, in general terms, distinguish whether a local seed collection will have greater establishment and long-term success over a mixture collected outside of the local area. Individual plant species of the two mixtures are listed as follows:

<u>Common Name</u>	<u>Scientific Name</u>	<u>Seeding Rate</u> *PLS (lbs/ac)
Mixture A - Locally Collected		
1. Western wheatgrass	<u>Agropyron smithii</u>	3.4
2. Intermediate wheatgrass	<u>A. intermedium</u>	3.2
3. Blue gramma	<u>Bouteloua gracilis</u>	1.4
4. Indian Ricegrass	<u>Oryxopsis hymenoides</u>	1.2
5. Bottlebrush squirreltail	<u>Sitanion hystrix</u>	1.1
6. Russian wildrye	<u>Elymus junceus</u>	1.3
7. Green mormon tea	<u>Ephedra viridis</u>	0.9
8. Antelope bitterbrush	<u>Purshia tridentata</u>	1.3
9. Winterfat	<u>Ceratoides lanata</u>	1.9
10. Four-wing saltbush	<u>Atriplex canescens</u>	2.9
11. Northern sweetvetch	<u>Hedysarum boreale</u>	1.1
12. Rocky Mountain penstemon	<u>Penstemon strictus</u>	0.2
13. Scarlet globemallow	<u>Sphaeralcea coccinea</u>	0.3
		20.2

Mixture B - Non-local collection

<u>Common Name</u>	<u>Scientific Name</u>	<u>Seeding Rate</u> *PLS (lbs/ac)
1. Western wheatgrass	<u>Agropyron smithii</u>	2.9
2. Tall wheatgrass	<u>A. elongatum</u>	2.1
3. Bearded bluebunch wheatgrass	<u>A. spicatum inerme</u>	3.6
4. Russian wildrye	<u>Elymus junceus</u>	1.6
5. Blue gramma	<u>Bouteloua gracilis</u>	1.2
6. Alkali sacaton	<u>Sporabulus airoides</u>	1.0
7. Indian ricegrass	<u>Oryxopsis hymenoides</u>	3.1
8. Nevada mormon tea	<u>Ephedra nevadensis</u>	0.8
9. Antelope bitterbrush	<u>Purshia tridentata</u>	0.8
10. Fourwing saltbush	<u>Atriplex canescens</u>	1.2
11. Shadscale	<u>A. confertifolia</u>	0.5
12. Winterfat	<u>Ceratoides lanata</u>	<u>0.8</u>
		19.6

*Pure live seed (PLS) expressed seed quality. PLS is actually the percent of pure, viable seed in a particular lot of seed. PLS is calculated by multiplying the percent total germination by the purity and dividing by 100:

$$\text{Percent PLS} = \frac{\text{Purity \%} \times \text{Germination \%}}{100}$$

Prior to seeding, inorganic fertilizer was broadcast on both areas at a rate of approximately 65 lbs/acre of nitrogen in the form of ammonium sulfate and 45 lbs/acre of phosphorus in the form of triple superphosphate. The fertilizer was incorporated into the top foot of soil by shallow ripping and chisel plowing. Both seed mixtures were sown with a Brillion seeder-cultipacker, drawn by a dual-wheeled conventional farm tractor.

The revegetated areas will be visually inspected in the spring of 1984 to determine the degree of seed germination, as well as quantitatively sampled areas in the early fall of 1984 for first-year success.

D. ATMOSPHERIC RESEARCH

1. Retort Fugitive Emissions Study - The first sampling period (one of three) was conducted during November on the surface of Retort #28. The purpose of this study is to determine the rate of any fugitive gaseous hydrocarbon and carbon monoxide emissions from the surface of an in situ retort.

A total of 50 samples were collected using a sampling method developed by Monsanto Research Corporation and following the test protocol (study plan) developed by TRC Environmental Consultants for Geokinetics (see September 1983 report). This first suite of samples is designed to represent the early period of the burn of Retort #28. The remaining two sampling periods are tentatively scheduled for May and August of 1984 and are to represent middle and late periods of the retort burn, respectively. It is expected that an additional 200 samples will be generated from the remaining two sampling periods. Of the total samples, an expected 20% will be utilized for "control" and quality assurance purposes.

Analytical results of the November samples are not yet available from the Geokinetics' field site laboratory. It is expected that preliminary results will be presented in the first quarter of 1984.

2. Air Quality - Emissions data from the retort off gas afterburner are presented in Table 12. As this table indicates, the emissions during the reporting period were below the allowable limits permitted by the Utah Bureau of Air Quality.

REFERENCES

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- (3) Hoylmar, Edward W., and Quinn, George W. 1981, "Infiltration and Permeability Testing at Geokinetics Oil Shale Site", a Draft Report Prepared for Industrial Environmental Research Laboratory, Office of Research and Development, USEPA by Kaman Tempo,. 25p.
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SAT., 31 DEC., 1983

OIL PRODUCTION TO E.D. 139

RETORT #27 - 11419.5

RETORT #28 - 5285.8

Figure 1. Oil Production to Elapsed Day 139
for Retorts #27 and #28

Elapsed Day 139
RETORT #27 - 16,445

Elapsed Day 79
RETORT - #28 - 9,671

Figure 2. Water production - Retorts #27 and #28

Figure 3. Retort #27 - Process Well Locations

Thermocouple Well •
 Retort Pressure Well △
 Ignition Retort Pressure Well ⊙

Scale: 1" = 50'

Figure 4. Retort #27 - Plan View Instrumentation Wells.

Figure 5. Retort #28 - Process Well Locations

Thermocouple Well .
 Retort Pressure Well ▲
 Ignition Retort Pressure Well ○

Scale: 1"= 50'

Figure 6. Retort #28 - Plan View, Instrumentation Wells

Figure 7. GENERAL LOCATION OF INFILTROMETER TEST SITES AT GEOKINETICS' KAMP KEROGEN SITE

Figure 8. Frequency arrays of infiltration capacities f_c (corrected for temperature-viscosity effects). Straight lines shown are moment fits to log-normal distributions.

Figure 9. Relationship between ponding and rainfall determined f_c (corrected for temperature-viscosity effects).

Note: Farmer-Fletcher Intermountain Storm Distribution (Reference #2)
 Type "B" National Engineering Handbook Storm Distribution (Reference #3)

Figure 10. Runoff curve numbers for various durations, distributions, and depths.

SCALE: 1" = 200'

Figure 11. Packer-Permeability Test Hole Locations

TABLE 1

RETORT #27

OIL AND WATER PRODUCTION (EBLS)
AIR INJECTION AND OFF-GAS (SCFM)

ELAPSED DAY	DAILY OIL	CUMM. OIL	DAILY WATER	CUMM. WATER	AIR INJECTION	OFF-GAS RECOVERY
1	0.0	0.0	0.0	0.0	0	0
2	0.0	0.0	0.0	0.0	0	0
3	0.0	0.0	0.0	0.0	3613	0
4	0.0	0.0	0.0	0.0	3789	4082
5	0.0	0.0	296.8	296.8	4040	3481
6	0.0	0.0	319.7	616.5	4120	5291
7	0.0	0.0	229.2	845.7	4198	5221
8	0.0	0.0	181.0	1026.7	4275	4860
9	0.0	0.0	194.6	1221.3	4572	4923
10	0.0	0.0	175.2	1396.5	4572	4605
11	0.0	0.0	355.6	1752.1	4275	5150
12	0.0	0.0	164.1	1916.2	4572	4923
13	0.0	0.0	253.6	2169.8	4572	4766
14	8.3	8.3	244.8	2414.6	4572	4766
15	.1	8.4	373.1	2787.7	4572	5150
16	3.5	11.9	248.1	3035.8	4572	5150
17	0.0	11.9	237.3	3273.1	4572	5150
18	0.0	11.9	229.1	3502.2	4425	5150
19	4.7	16.6	127.7	3629.9	4572	5221
20	0.0	16.6	234.0	3863.9	4572	5434
21	0.0	16.6	242.7	4106.6	4572	5504
22	0.0	16.6	266.1	4372.7	4572	5504
23	.1	16.7	219.4	4592.1	4572	5504
24	.8	17.5	176.1	4768.2	4572	5640
25	5.4	22.9	249.6	5017.8	4572	5673
26	7.5	30.4	247.7	5265.5	4425	5673
27	8.3	38.7	263.7	5529.2	5110	6153
28	9.8	48.5	207.1	5736.3	4848	6153
29	11.2	59.7	231.8	5968.1	4711	6244
30	19.4	79.1	234.0	6202.1	4711	6335
31	20.6	99.7	233.8	6435.9	4711	6305
32	17.1	116.8	224.7	6660.6	4711	6270
33	29.8	146.6	223.9	6884.5	4711	6394
34	26.7	173.3	215.6	7100.1	4711	6250
35	26.5	199.8	203.2	7303.3	4780	6364
36	21.1	220.9	192.1	7495.4	4848	6335
37	30.1	251.0	208.6	7704.0	5110	7586
38	31.1	282.1	230.8	7934.8	6464	9708
39	49.7	331.8	271.3	8206.1	5236	9300
40	27.4	359.2	271.1	8477.2	5713	9250
41	54.6	413.8	256.2	8733.4	5713	8255
42	81.1	494.9	222.9	8956.3	5826	8917
43	57.4	552.3	217.5	9173.8	5826	9022
44	56.9	609.2	250.9	9424.7	5596	9610
45	57.3	666.5	218.4	9643.1	5538	9532

RETORT #27

OIL AND WATER PRODUCTION(BBLS)
AIR INJECTION AND OFF-GAS(SCFM)

ELAPSED DAY	DAILY OIL	CUMM. OIL	DAILY WATER	CUMM. WATER	AIR INJECTION	OFF-GAS RECOVERY
46	42.9	709.4	224.5	9867.6	5480	9610
47	46.3	755.7	225.6	10093.2	5990	10368
48	49.0	804.7	232.8	10326.0	5713	9852
49	44.3	849.0	210.4	10536.4	5826	9883
50	38.9	887.9	223.9	10760.3	4275	9610
51	48.1	936.0	202.4	10962.7	4275	9610
52	62.7	998.7	206.4	11169.1	4275	10146
53	59.9	1058.6	210.8	11379.9	4275	10296
54	64.5	1123.1	197.0	11576.9	4275	9922
55	69.1	1192.2	156.4	11733.3	4275	9532
56	70.4	1262.6	122.4	11855.7	4275	9727
57	73.1	1335.7	126.9	11982.6	4275	9727
58	75.3	1411.0	126.7	12109.3	4425	9922
59	58.2	1469.2	102.8	12212.1	3958	10072
60	173.8	1643.0	112.5	12324.6	5110	9532
61	182.9	1825.9	110.9	12435.5	4572	10296
62	102.1	1928.0	91.7	12527.2	4572	9532
63	94.5	2022.5	83.7	12610.9	4572	10109
64	111.1	2133.6	82.6	12693.5	4275	9922
65	190.4	2324.0	101.6	12795.1	4498	10109
66	119.1	2443.1	86.2	12881.3	4120	7975
67	99.9	2543.0	42.9	12924.2	5826	7879
68	97.0	2640.0	47.9	12972.1	5937	7122
69	94.8	2734.8	56.6	13028.7	6362	7975
70	125.0	2859.8	91.2	13119.9	6362	7927
71	133.7	2993.5	56.6	13176.5	6362	7783
72	130.8	3124.3	72.2	13248.7	6464	7783
73	119.5	3243.8	89.5	13338.2	6046	7879
74	127.4	3371.2	66.3	13404.5	6046	7831
75	136.8	3508.0	54.3	13458.8	5359	7831
76	132.8	3640.8	37.6	13496.4	5480	7879
77	119.5	3760.3	42.9	13539.3	5559	7879
78	132.9	3893.2	49.2	13588.5	5359	7831
79	124.0	4017.2	35.2	13623.7	5359	7831
80	124.8	4142.0	43.1	13666.8	5110	7831
81	130.9	4272.9	33.4	13700.2	5110	7879
82	133.1	4406.0	17.9	13718.1	5110	7831
83	135.3	4541.3	32.1	13750.2	5045	7831
84	115.8	4657.1	26.5	13776.7	5045	7879
85	124.6	4781.7	78.8	13855.5	3958	7831
86	99.7	4881.4	89.5	13945.0	4040	7831
87	114.8	4996.2	77.4	14022.4	3958	7879
88	13.8	5010.0	7.3	14029.7	4040	7927
89	178.1	5188.1	156.8	14186.5	4120	7831
90	148.9	5337.0	102.0	14288.5	4120	7783

RETORT #27

OIL AND WATER PRODUCTION(BBLS)
AIR INJECTION AND OFF-GAS(SCFM)

ELAPSED DAY	DAILY OIL	CUMM. OIL	DAILY WATER	CUMM. WATER	AIR INJECTION	OFF-GAS RECOVERY
91	138.4	5475.4	96.6	14385.1	4120	7783
92	142.8	5618.2	61.5	14446.6	5359	7685
93	126.4	5744.6	31.9	14478.5	5298	7831
94	157.5	5902.1	43.0	14521.5	5236	7831
95	135.6	6037.7	46.8	14568.3	5173	7807
96	115.6	6153.3	29.8	14598.1	5223	7903
97	132.4	6285.7	69.1	14667.2	5236	8023
98	132.5	6418.2	56.6	14723.8	5110	8023
99	126.8	6545.0	36.2	14760.0	5236	7831
100	128.4	6673.4	27.0	14787.0	5236	7927
101	128.8	6802.2	56.6	14843.6	5236	7831
102	132.9	6935.1	32.6	14876.2	4040	5837
103	136.4	7071.5	30.9	14907.1	4711	7016
104	117.9	7189.4	23.0	14930.1	5110	7783
105	128.8	7318.2	20.6	14950.7	5110	7783
106	130.0	7448.2	31.5	14982.2	4980	7636
107	107.0	7555.2	66.5	15048.7	4351	7122
108	154.0	7709.2	56.9	15105.6	4130	8658
109	100.1	7809.3	32.1	15137.7	5173	7723
110	82.0	7891.3	38.3	15176.0	4980	7281
111	95.9	7987.2	63.7	15239.7	4980	7332
112	84.1	8071.3	46.3	15286.0	5045	8093
113	92.4	8163.7	85.1	15371.1	4980	8116
114	102.6	8266.3	26.4	15397.5	4914	8116
115	105.6	8371.9	28.2	15425.7	5110	7879
116	111.3	8483.2	39.6	15465.3	4848	7927
117	208.3	8691.5	37.9	15503.2	6100	8023
118	130.9	8822.4	31.3	15534.5	5596	7281
119	252.1	9074.5	14.8	15549.3	4850	6300
120	132.2	9206.7	29.3	15578.6	4980	7069
121	115.7	9322.4	69.6	15648.2	4980	8473
122	160.4	9482.8	69.4	15717.6	3702	8473
123	135.0	9617.8	57.9	15775.5	5110	7927
124	109.2	9727.0	48.7	15824.2	5236	8116
125	91.9	9818.9	25.1	15849.3	5173	8162
126	121.3	9940.2	51.6	15900.9	4980	8023
127	139.6	10079.8	52.5	15953.4	5110	7975
128	88.3	10168.1	32.5	15985.9	5110	7536
129	102.2	10270.3	41.0	16026.9	5110	7586
130	74.2	10344.5	27.7	16054.6	5173	6128
131	107.0	10451.5	47.9	16102.5	5173	5293
132	119.4	10570.9	37.7	16140.2	4120	4766
133	129.0	10699.9	40.0	16180.2	4780	5221
134	99.9	10799.8	31.4	16211.6	4780	7783
135	81.9	10881.7	32.1	16243.7	4498	6453

RETORT #27

OIL AND WATER PRODUCTION(BBLS)
AIR INJECTION AND OFF-GAS(SCFM)

ELAPSED DAY	DAILY OIL	CUMM. OIL	DAILY WATER	CUMM. WATER	AIR INJECTION	OFF-GAS RECOVERY
136	132.0	11013.7	58.5	16302.2	4711	7975
137	152.0	11165.7	59.5	16361.7	4275	13200
138	138.7	11304.4	47.5	16409.2	4198	5221
139	115.1	11419.5	39.7	16448.9	4628	6678

TABLE 2

RETORT #28

OIL AND WATER PRODUCTION(BBLS)
AIR INJECTION AND OFF-GAS(SCFM)

ELAPSED DAY	DAILY OIL	CUMM. OIL	DAILY WATER	CUMM. WATER	AIR INJECTION	OFF-GAS RECOVERY
1	0.0	0.0	0.0	0.0	0	0
2	0.0	0.0	0.0	0.0	0	0
3	.6	.6	126.2	126.2	4113	5148
4	0.0	.6	225.4	351.6	4113	5538
5	.1	.7	127.0	478.6	4113	5610
6	0.0	.7	126.7	605.3	4113	5703
7	0.0	.7	227.6	832.9	4113	5706
8	.9	1.6	205.8	1038.7	4113	5804
9	1.6	3.2	260.4	1299.1	4113	5711
10	1.6	4.8	262.3	1561.4	4113	5572
11	1.7	6.5	222.7	1784.1	4113	5771
12	.9	7.4	184.2	1968.3	4113	5837
13	3.1	10.5	257.2	2225.5	4113	5771
14	3.0	13.5	212.8	2438.3	4113	5771
15	4.1	17.6	222.8	2661.1	4314	5837
16	3.5	21.1	231.0	2892.1	4314	5837
17	3.7	24.8	243.2	3135.3	4314	5837
18	2.3	27.1	189.4	3324.7	4215	5739
19	3.2	30.3	203.0	3527.7	4314	5739
20	5.0	35.3	196.9	3724.6	4113	5771
21	8.8	44.1	173.7	3898.3	4314	5639
22	10.9	55.0	195.3	4093.6	4113	5837
23	6.7	61.7	188.6	4282.2	4009	5771
24	9.4	71.1	212.6	4494.8	4009	5706
25	10.1	81.2	197.5	4692.3	4009	5771
26	12.5	93.7	176.5	4868.8	4009	5706
27	13.4	107.1	156.3	5025.1	4599	5771
28	16.1	123.2	146.6	5171.7	4690	5771
29	20.4	143.6	128.7	5300.4	4690	5711
30	24.7	168.3	159.0	5459.4	4599	5837
31	19.3	187.6	51.0	5510.4	4599	5771
32	33.3	220.9	226.1	5736.5	4690	5837
33	13.5	234.4	127.9	5864.4	4599	5771
34	18.4	252.8	122.1	5986.5	4599	5771
35	42.9	295.7	131.1	6117.6	4599	5771
36	45.6	341.3	142.8	6260.4	4599	5771
37	36.3	377.6	80.8	6341.2	2908	4300
38	43.3	420.9	100.4	6441.6	3789	5504
39	66.0	486.9	100.1	6541.7	4690	6153
40	18.7	505.6	114.6	6656.3	4690	6153
41	38.2	543.8	140.0	6796.3	4506	6091
42	65.8	609.6	144.2	6940.5	4113	5572
43	45.0	654.6	112.7	7053.2	3679	5074
44	33.4	688.0	80.7	7133.9	4779	5074
45	38.2	726.2	76.9	7210.8	4690	4923

RETORT #28

OIL AND WATER PRODUCTION(BBLS)
AIR INJECTION AND OFF-GAS(SCFM)

ELAPSED DAY	DAILY OIL	CUMM. OIL	DAILY WATER	CUMM. WATER	AIR INJECTION	OFF-GAS RECOVERY
46	35.9	762.1	69.1	7279.9	4690	5074
47	45.1	807.2	155.9	7435.8	4690	5399
48	30.3	837.5	63.4	7499.2	4779	4472
49	30.3	867.8	81.5	7580.7	4867	5572
50	31.1	898.9	75.9	7656.6	4779	5364
51	32.9	931.8	82.4	7739.0	4411	5504
52	29.1	960.9	80.5	7819.5	5889	7215
53	36.4	997.3	88.8	7908.3	5441	7175
54	31.9	1029.2	76.9	7985.2	4690	6153
55	44.7	1073.9	90.5	8075.7	4599	6851
56	40.0	1113.9	100.2	8175.9	4690	6684
57	41.2	1155.1	80.2	8256.1	3316	6684
58	45.1	1200.2	78.0	8334.1	4690	6028
59	49.7	1249.9	52.0	8386.1	4690	6684
60	45.3	1295.2	55.0	8441.1	4779	7096
61	168.7	1463.9	72.5	8513.6	4599	6227
62	113.4	1577.3	80.2	8593.8	4690	6740
63	116.5	1693.8	64.9	8658.7	4690	6740
64	120.7	1814.5	43.9	8702.6	4779	6394
65	126.6	1941.1	52.9	8755.5	4953	6627
66	132.7	2073.8	76.7	8832.2	4779	7149
67	114.9	2188.7	76.0	8908.2	3902	4605
68	126.4	2315.1	61.3	8969.5	4779	5074
69	119.9	2435.0	52.2	9021.7	4779	6453
70	75.1	2510.1	42.2	9063.9	4779	6740
71	206.0	2716.1	64.4	9128.3	5363	8209
72	163.6	2879.7	92.5	9220.8	6101	9372
73	156.3	3036.0	78.8	9299.6	5363	5504
74	132.9	3168.9	58.2	9357.8	5714	7646

TABLE 3
Off Gas Constituents by 10-day Averages

Retort #27

E. D.	NITROGEN	CARBON DIOXIDE	OXYGEN	HYDROGEN	CARBON MONOXIDE	METHANE	C1-C6 HYDROCARBONS
1- 10	72.733	18.032	13.317	.868	.756	.509	.950
11- 20	73.691	13.280	9.736	1.229	.691	.848	1.454
21- 30	73.097	10.535	9.783	2.018	1.753	1.319	2.508
31- 40	65.926	17.945	6.787	2.468	5.111	.909	1.737
41- 50	64.702	19.125	6.403	3.710	3.987	1.038	1.780
51- 60	66.009	15.245	8.652	3.994	4.263	.951	1.623
61- 70	61.209	18.584	5.721	6.533	5.806	1.287	2.072
71- 80	61.851	19.653	4.584	5.947	5.868	1.162	1.895
81- 90	62.277	17.467	5.153	7.192	5.576	1.274	2.094
91-100	60.731	19.274	2.500	7.640	7.151	1.500	2.439
101-110	60.393	21.270	2.289	6.841	6.577	1.297	2.172
111-120	61.711	18.981	4.144	6.169	6.213	1.334	2.273
121-130	62.862	17.760	3.812	6.792	6.171	1.432	2.263
131-140	59.217	21.629	1.604	7.819	6.709	1.509	2.454

TABLE 4
Off Gas Constituents by 10-day Averages

Retort #28

E. D.	NITROGEN	CARBON DIOXIDE	OXYGEN	HYDROGEN	CARBON MONOXIDE	METHANE	C1-C6 HYDROCARBONS
1- 10	71.819	14.214	8.230	2.632	1.681	.711	1.244
11- 20	67.669	18.673	5.727	3.430	2.388	1.113	1.908
21- 30	63.791	19.334	5.102	5.135	4.245	1.231	2.110
31- 40	63.342	19.114	3.941	5.756	5.406	1.319	2.261
41- 50	62.730	16.392	4.343	6.247	7.206	1.744	2.546
51- 60	63.163	17.915	4.785	6.076	5.520	1.239	1.985
61- 70	61.399	20.380	2.789	7.163	5.587	1.353	2.180
71- 80	63.359	18.305	3.894	6.212	5.722	1.264	2.003

TABLE 5
RETORTS #27 and #28 HEATING VALUES
(BTU/SCF)

Elapsed Day	Average High Heating Value RETORT #27	Average High Heating Value RETORT #28
*1-10	23.840	33.358
11-20	31.112	50.242
21-30	57.272	65.608
31-40	55.551	75.620
41-50	54.381	82.144
51-60	53.864	69.752
61-70	72.688	77.111
71-80	67.937	71.467
81-90	75.543	
91-100	87.404	
101-110	79.923	
111-120	80.698	
121-130	78.170	
131-139	88.300	

* Ignition Date : Retort #27 - August 11, 1983
Retort #28 - October 18, 1983

H₂S and NH₃ Concentration of Process Gas
Retorts #27 and #28

Elapsed Day		H ₂ S	NH ₃
#27	#28	Concentrations	Concentrations
1-10		NA	NA
11-20		12	20
21-30		16	8
31-40		25	13
41-50		35	24
51-60		35	71
61-70	1-5	40	189
71-80	6-15	51	61
81-90	16-25	26	NA
91-100	26-35	30	199
101-110	36-45	150	317
111-120	46-55	305	136
121-130	56-65	329	162
131-139	66-74	546	210

TABLE 6

Sampling - Replication Design

	Ponding		Rainfall		:	Total
	Dry	Wet	Dry	Wet		
Sage	20	20	10	10	:	60
Retorts	20	20	10	10	:	60
TOTAL	40	40	20	20	:	120

TABLE 7

SUMMARY OF INFILTRATION DATA

I PONDING RUNS

	- - - - - DRY - - - - -			- - - - - WET - - - - -		
	Mean	Stdv	Skew	Mean	Stdv	Skew
Sage	4.70	1.88	0.94	2.16	0.97	1.05
Retorts	0.55	0.47	2.14	0.11	0.09	1.33

II RAINFALL RUNS

	- - - - - DRY - - - - -			- - - - - WET - - - - -		
	Mean	Stdv	Skew	Mean	Stdv	Skew
Sage	1.91	0.73	0.83	1.54	0.77	1.40
Retorts	0.67	0.15	-0.12	0.50	0.17	-0.32

Notes: Data in cm/hr

SUMMARY OF INFILTRATION DATA
(Logarithmic)I PONDING RUNS

	- - - - - DRY - - - - -			- - - - - WET - - - - -		
	Mean	Stdv	Skew	Mean	Stdv	Skew
Sage	1.48	0.38	0.40	0.69	0.43	0.31
Retorts	-0.90	0.86	-0.84	-2.82	1.73	-2.86 ¹

II RAINFALL RUNS

	- - - - - DRY - - - - -			- - - - - WET - - - - -		
	Mean	Stdv	Skew	Mean	Stdv	Skew
Sage	0.58	0.41	-0.87	0.32	0.54	-0.95
Retorts	-0.42	0.23	-0.39	-0.77	0.43	-0.56

Notes: Logarithms to natural base of data in cm/hr

1. Includes one point of zero infiltration set to a value of 0.0001 cm/hr for calculation purposes.

Table 8. Curve Number Summary

"SAGE"

Storm Duration (hr)		RP=10 yr				RP=100 yr		
		P (in)	CN			P (in)	CN	
			FF	B			FF	B
1		0.98	94.6	91.7		1.56	94.1	91.5
2		1.06	89.6	87.3		1.65	90.0	85.2
4		1.19	79.4	81.7		1.77	81.3	79.2
6		1.28	68.5	74.7		1.88	72.4	74.6
12		1.47	58.3	59.2		2.13	51.5	57.2
24		1.68	*	*		2.51	*	45.2

Notes: *Q=0.CN indeterminate

"RETORTS"

Storm Duration (hr)		RP=10 yr				RP=100 yr		
		P (in)	CN			P (in)	CN	
			FF	B			FF	B
1		0.98	99.7	99.7		1.56	99.7	99.7
2		1.06	99.3	99.3		1.65	99.3	99.3
4		1.19	98.6	98.6		1.77	98.7	98.7
6		1.28	97.9	97.8		1.88	97.9	97.9
12		1.47	96.4	95.3		2.13	96.0	95.7
24		1.68	94.1	91.4		2.51	93.5	90.9

TABLE 9
Consensus Curve Numbers
Geokinetics Site

Storm Duration (hr)	Curve Number	
	Sage	Retorts
1	93.0	99.7
2	88.0	99.3
4	80.4	98.7
6	72.6	97.9
12	56.6	95.8
24	*	92.5

* Indeterminate. $Q=0$, where Q = inches of runoff

TABLE 10
AVERAGE PERMEABILITIES OF GEOLOGIC FORMATIONS
WITHIN AND BELOW RETORTED AREAS¹

<u>Elevation (feet above msl)</u>	<u>No. of Samples</u>	<u>Average Permeability (cm/sec)</u>	<u>Lithology</u>
6740-6760	8	9×10^{-6}	PARACHUTE CREEK MEMBER:
6720-6740	7	2×10^{-5}	kerogenous marlstones with
6700-6720	7	4×10^{-5}	tuff interbeds
6680-6700	7	9×10^{-6}	
6680-6700	7	1×10^{-5}	-----
6640-6660	9	4×10^{-6}	GKI "Mahogany Zone"
6620-6640	9	2×10^{-4}	-----
6600-6620	8	2×10^{-5}	
6580-6600	8	8×10^{-7}	UPPER DOUGLAS CREEK MEMBER:
6560-6580	6	1×10^{-7}	interbedded lar sands and
6540-6560	3	3×10^{-7}	massive limestone

¹Permeabilities are based on packer tests in coreholes PTH-1 through PTH-5.

TABLE 11

PERMEABILITY DATA FOR COREHOLE 12
(located 1000 feet from the nearest retort)

Depth Interval* (ft)	Permeability (cm/sec)	Lithology
20 - 30	0	Parachute Creek Member: Kerogenous marlstone with tuffaceous interbeds
30 - 40	0	
40 - 50	3.7×10^{-5}	GKI "Mahogany Zone"
50 - 60	3.1×10^{-4}	
60 - 70	0	
70 - 80	0	
80 - 90	1.5×10^{-6}	
90 - 100	7.4×10^{-7}	sandy tuff

*Ground surface elevation is 6740 feet above msl.

TABLE 12

Quarterly Emissions Data
October - December 1983

(all values in lbs/hr)

	<u>SO₂</u>	<u>NO₂</u>	<u>CO</u>	<u>HC</u>	<u>Particulates</u>
Quarterly Average	19.9	16.0	<2.1	<1.2	<2.2
Maximum during Quarter	61.1	38.5	<2.1	<1.2	<2.2
Permitted limit	65.7	44.3	2.1	1.2	2.2