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**INVESTIGATION OF THE GEOKINETICS HORIZONTAL
IN SITU OIL SHALE RETORTING PROCESS**

Quarterly Report for July–September 1983

**By
K. B. Henderson**

**January 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

July, August, September 1983

by

Kenneth B. Henderson

GEOKINETICS INC.

**391 Chipeta Way, D-2
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Date Published - January 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.

THIRD 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 Retort #27 and #28 off gas processing plant. Retort #27 was ignited on August 11, 1983 with a new ignition procedure. By September 30, 1983, the retort had completed 47 days of operation.

Re-entry drilling on Retort #28 continued from January through March. The construction of production and observation wells was begun in April and completed in June. Air injection and off gas piping and manifolding was begun in June and, along with the installation of electrical and instrumentation wiring, was completed in September.

Wet weather during May and June hampered work on the evaporation pond for Retort #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 has taken place since the first part of April. To date, the oil storage tanks, demister tanks, air coolers, ammonia absorber and stripper, the afterburner stack (the afterburner stack has been converted to a low NO_x burner), the H_2S absorber and stripper, the ammonia stripper-reboiler and a small heat exchanger have been installed. The two process vessels associated with the sulfur plant modification were installed 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 complete. All injection, vacuum, and spare blowers are all operational. The entire plant was completed and put through an initial shakedown run during August. All the system performed according to design. As of September 30, 1983, the toxic emissions off Retort #27 were not high enough to warrant operating the plant.

DESCRIPTION OF THIRD QUARTER 1983 TECHNICAL PROGRESS

I. RETORT #27

As of July 1, 1983, the beginning of the third quarter, final preparations had been made to ignite Retort #27. However, the decision was made not to ignite pending completion of the off gas processing facility that serves both Retorts #27 and #28.

Retort #27 was ignited on August 11, 1983. The ignition began by using the "charcoal point ignition" technique in the air injection wells. This technique provides for the dumping of several pounds of hot charcoal down each air injection well to create an ignition point at the bottom of the well. After dumping, the air flow rates into the retort are gradually increased.

This particular procedure has been used for most previous ignitions with excellent success. However, in the present case, within a few hours of dumping the hot charcoal down the wells, it became obvious that the ignition was not proceeding normally. The expected temperature rise in the retort was not observed, nor did the off gas analysis indicate the retort was burning properly.

It should be noted that the ignition problems were not completely unexpected and are probably best understood when viewed in terms of what happened during the Retort #27 blast. The blast design for Retort #27 resulted in an exceptionally efficient lateral motion in the "W" round. This large lateral motion created a void approximately 30 feet wide at the last row of "W" holes. The overburden subsequently slumped into that void, which was to be the ignition area.

The first response to the situation was to simply by-pass this "slumped zone" and reduce the size of the retort. However, an analysis of the core samples from that area showed the presence of low grade (6-8 GPT) shale that had been reduced to only large diameter rubble. Any rubbing in this zone would be due mostly

to slumping or caving in of overburden into the void. The decision was made to use the opportunity to study fire-front propagation through poorly rubblized, ultra low grade shale. Therefore, the original plan was followed, and the air injection wells, and consequently the ignition wells, were installed in this zone.

When it became apparent the ignition would not proceed normally, plans were made to use a back-up procedure which would permit the application of more intense heat for a longer period at the ignition point. The new procedure is actually a variation of the "charcoal point ignition" technique, where a 20 pound charge of charcoal is dropped to the bottom of each ignition well and ignited with several hot briquettes. A vacuum is also drawn on the well to help pull the fire front in the proper direction. A one-half inch pipe is lowered to within a few inches of the hot coals, and diesel fuel is injected through it into the hot coals at approximately one liter of fuel per minute. Air is injected into the retort and the flow gradually increased, in the present case, to 4,434 scfm by the end of the first seven day period.

During the second week, temperatures began to rise slowly at the first row of thermocouples. The vacuum blower, expected to be used only during the initial ignition procedures, has been used continuously since ignition to insure that the fire front propagate at the elevation of the main shale bed. A thin seam of shale in the overburden that slumped into the retort was richer in kerogen than the lower strata, and at first, had a tendency to draw the fire front upward. The vacuum blower apparently overcame that problem because the fire front held at the proper elevation.

Fire front propagation through the "slumped zone" was slow and difficult to control because of the low grade shale and the large void spaces left by poor rubbling in the area. Consequently, oil production from Retort #27 began later than with previous retorts. However, from day 24, production improved at an steadily increasing rate (see Figure 1).

The first trace amounts of oil were recovered from Retort #27 during the first week of September; by month's end (day 47), production had increased to nearly 50 bbls/day (see Figure 1). Retort #26, by comparison, was producing 120-130 bbls/day after the same elapsed time. By September 30, 1983, a total of 756 barrels of oil had been produced.

Several adjustments to the air-in and off gas flow rates were required to stabilize the fire front during the retorting of the low quality zone. The most persistent problem, as evidenced by thermocouple data, appeared to be preferential flow along both edges of the retort. Even though the data gathered during the last week of the period was sporadic because of computer problems, the indications were that the fire front was still leading along both edges of the retort.

The fire front control problems experienced during September should be less persistent as the fire front moves from the low grade material it is currently in, into good, properly rubblized shale. (See Figure 3 for plot of air-in, off gas, and production wells for Retort #27).

II. RETORT #28

Retort #28 is scheduled to be burned simultaneously with Retort #27. The ignition of Retort #28 will most likely be sometime in October.

Re-entry drilling into Retort #28 was substantially complete by the end of the second quarter. Piping and manifolding for the air injection system was begun in June and completed in July; off gas piping and manifolding was started in July and along with electrical wiring installations continued into the first week of September. The instrumentation package was completed by the second week of September.

Air-in and off gas flow rate measurements made early in September indicated the need to enhance the permeability of the retort at the off gas wells. Permeability is improved by explosive springing; that is, by setting off a small explosive charge at the bottom of each well. After springing, permeability is rechecked; a few wells required up to three shots before adequate permeability was achieved (see Figure 4 for a plot of air-in and air-out wells for Retort #27).

III. GAS PROCESSING FACILITY

A major part of Geokinetics' efforts during the third quarter were concentrated on completing and testing the off gas processing facility for both Retorts #27 and #28.

The scope of work for this investigation for 1983 proposed that two large retorts be operated simultaneously. It was determined that this operation would result in a substantial increase in SO_x and NO_x emission levels as specified in the original Prevention of Significant Deterioration (PSD) approval order. That order requires notification of the Utah Bureau of Air Quality of any intent to modify the specified conditions. Part of the notification included submitting to the Air Quality Conservation Committee enough actual site data to demonstrate the impact the increased retort size would have on the environment. Geokinetics submitted this information and subsequently, a new order was issued by the state specifying the emissions limit to which Geokinetics must comply. It was further determined that the off gas processing facilities at the site would need to be upgraded and enlarged, and therefore, most of Geokinetics' efforts during the first three quarters of 1983 have been concentrated on erecting and bringing this off gas processing facility on line.

By the end of the second quarter, most of the off gas cleanup facility had been erected. The gas dewatering equipment was in place, as were the air-in and off gas compressors, and the ammonia removal system. There was some delay in completing the H_2S

removal system because of the decision to modify the original Stretford plant so that a less toxic catalyst (the ARI Lo-Cat™ Catalyst) could be used.

The major change, as well as the major delay in completion, was the design and late delivery of stainless steel oxidizer tanks. The tanks were delivered during July and final installation of piping and pumps continued into August.

A decision was made to convert the facilities afterburner to a low NO_x type burner. The change was made to determine whether the ammonia removal system could be by-passed. The low NO_x system controls high temperatures in the afterburner stack to prevent the formation of NO_x compounds. By controlling the quantity of water and primary and secondary air injected into stack, the temperature can be controlled such that the ammonia in the gas will dissociate to nitrogen, water vapor and hydrogen. The modification included removing a section of the refractory lining around the inside circumference of the stack, about half way up, installing the process piping and controls and relining the exposed surfaces.

During August, the hydrogen sulfide removal plant was put through a shakedown run at a flow rate of 1,100 gpm of water. Under these shakedown conditions, all the pressure drops and flow rates within the system were found to be well within design expectations. The 150 psig steam boiler was operated for an inspector to obtain the Certificate of Boiler Inspection and Permit to Operate.

The gas processing (cleanup) facility will be brought on line when the hydrogen sulfide and ammonia contaminate levels in the off gas become high enough to operate the system efficiently.

IV. EVAPORATION POND

Unusually wet weather during most of the spring and summer months hampered work on the evaporation pond, but during the last part of July and August, work on the pond was completed, including

installation of plastic lining. The pond was inspected and put into service simultaneous to the ignition of Retort #27.

V. ENVIRONMENTAL RESEARCH

A. ECOLOGIC RESEARCH

1. Land Rehabilitation - Visual observations of the U.S. Forest Service revegetation plot study on Retort #24 were made by Geokinetics personnel during July and by both U.S. Forest Service and Geokinetics personnel during August. This study is a cooperative effort between Geokinetics and the Intermountain Forest and Range Experiment Station (USFS), and was designed to yield information on alternative cultural revegetation methods and suitable herbaceous and shrubby species for establishing a level of vegetative cover adequate to meet government reclamation requirements.

A striking difference between the irrigated half of the spring seeding and the non-irrigated half is evident. Predictably, there was little growth observed on the non-irrigated side because insufficient precipitation had occurred since seeding on May 23, 1983 (see Figure 5). Also, there is greater weed competition on the straw mulched treatments as compared to the wood fiber or no-mulch treatments. This is also predictable because of the amount of weed seed carried by the straw mulch.

Designated irrigation continued during August as planned, but will be discontinued in September near the end of the growing season. Personnel from the USFS will be on-site in late October to implement the fall seeding program.

2. Wildlife Monitoring - A report of the second year's wildlife monitoring data was completed by Dr. Robert E. Stoecker (Stoecker-Keammerer and Associates - Boulder, Colorado) during September. The report period extended from May 1981 through June 1983.

The principal objectives of the wildlife monitoring program are to obtain data that will permit detection of substantial changes in important animal populations due to retorting or reclamation, and because monitoring studies are in a preliminary stage, an important additional objective is a critical evaluation of the efficacy of each component of the monitoring program. Three wildlife studies are discussed in the accompanying text: 1) pellet transect studies, 2) pellet count on revegetated surfaces, and 3) road counts.

SUMMARY OF FIRST TWO YEAR'S RESULTS

Pellet Transect Studies. Pellet transect studies are designed to obtain abundance data twice each year (spring-summer and fall-winter) on mule deer, elk, cottontails, coyotes, and pocket gophers, and also on the occurrence of domestic cattle. Eight pellet transects in close proximity to Kamp Kerogen were set-up for the study (see Figure 6). The main objective of the pellet transect study is to check for indication of relative differences in animal abundance between areas located near retorting activities and areas located some distance away.

Mule Deer. Results of mule deer pellet counts conducted over the past 2 years are shown in Tables 1 and 2. These data are presented graphically, along with baseline data, in Figures 7 and 8. There are two conspicuous features of Figures 7 and 8 that are particularly relevant to impact analysis. Namely, transect W6 tends to have high deer pellet-group densities, yet is located nearest to active retorting facilities. Pellet count data obtained during June 1981, at the start of monitoring (Table 1), are not presented graphically because counts made at that time were of pellets of unknown age (undoubtedly some of the pellets counted were from the previous season, as is indicated by the high densities shown). These data are useful for evaluating W6 relative to other transects of that time period. Again W6 has a high value; only one other transect, W9, is higher. These results strongly suggest that deer

are not being displaced from the project site. A statistical evaluation of these findings, although possible at this time, seems premature in view of the relatively short time span involved.

The second aspect of Figures 7 and 8 which is particularly relevant to future impact analyses, concerns the obvious correlation of the data points. In both habitats during the baseline and the past year, deer usage of local sites is very similar. The correlation between baseline and the first year's monitoring results is highly significant ($r=0.84$; $df=8$; $P<0.002$). The correlation was graphically presented in last year's report (DOE, 1982*) and is shown here again in Figure 9. The correlation between the first and second year's monitoring results, for the winter period only, is significant but only at the 90% level ($r=0.69$; $df=6$). Only the winter periods were compared because deer apparently were virtually absent from the Seep Ridge area during the summer (May through October) of 1982.

Elk. Elk sign were infrequently observed during the baseline period and during the first year of monitoring, however, a small group of elk was seen within the Seep Ridge study area during the fall of 1982. Pellet transect studies were successful in recording the presence of these elk; the data are shown in Table 3. Continued monitoring of elk near the Seep Ridge site is highly recommended.

Other Wildlife and Cattle. Although pellet transect studies were designed primarily to obtain information on big game, the method is suited to evaluating relative abundance information on other species as well. For cottontail, coyote, pocket gopher, and cattle, only presence-absence data are obtained (evidence that the animal is recorded as being present or not present). Also, in the case of cottontails, only half the number of quadrats along each transect are examined and the quadrat size is reduced to an inner circle within each quadrat of $3m^2$.

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*Department of Energy, Investigation of the Geokinetics' Horizontal In Situ Oil Shale Retorting Process. Third Quarter report, 1982, DOE/LC-10787-104.

Data obtained on elk, cottontail, coyote, pocket gopher, and cattle for the first year of monitoring are presented in Table 4. Data for the second year of monitoring, excluding elk, are presented in Table 5. Data obtained thus far on cottontails, coyotes, pocket gophers, and cattle have little utility at this time apart from providing information on general levels of abundance, habitat affinities, and seasonal differences in population sizes. In the future, however, these data could become useful for evaluating differences between revegetated and control sites.

PELLET COUNTS ON REVEGETATED SURFACES

Wildlife Monitored. Pellet counts conducted on revegetated surfaces are similar in purpose to the pellet transect studies described above. Because of the small areas sampled, however, and the significance of the presence of certain species, emphasis is placed on mule deer, cottontail, and pocket gopher.

Methods. At the present time there are only two small plots (approximately .03 ha each) that have been retorted and revegetated. Five quadrats (10m^2 each) have been placed on each of these plots; one quadrat in the approximate center of the plot, and four 5m away in each of the cardinal directions (Figure 10). Two additional quadrat clusters with the same quadrat arrangement are located nearby in areas that were disturbed only by equipment operation. Sampling intervals are the same as described above for transect studies.

Results and Discussion. At the time the quadrat clusters were established (May 1981), a relatively large number of deer pellet-groups were counted on the retort areas (Table 6). This was probably due to the new growth of grasses planted during the fall of 1979. As was pointed out previously, pellet-counts on newly established quadrats are of unknown age, consequently the data

for the May 1981 period are inflated because of this time factor. Usage by deer of the retort and access areas was much less the year following initial revegetation (Table 6), and during the second year of monitoring no deer pellet groups were found on any of the quadrats. It is not clear why deer were apparently absent from these areas during the second year of monitoring, although it seems likely that it was due to increased human activity in the area.

Other Wildlife and Cattle. No evidence of cottontails was obtained from quadrats located on the revegetated areas during the first year of monitoring, and only seven quadrats showed evidence of cottontails the second year (2 at station 14B, 1 at 14D, and 4 at 15B). See Table 6. One would expect new growth of annuals to attract cottontails. Also, no evidence of pocket gophers within the revegetated areas has been observed for the 2-year monitoring period. Because pocket gophers are common in the surrounding vicinity, it will be of some interest to monitor their usage of revegetated areas, and particularly to see if they utilize disturbed access areas as readily as retort areas.

Usage by cattle was evident for the winter period of 1982, but evidence of cattle was found during the second year. The extent to which cattle are deleterious to the revegetation process is being evaluated by investigators working the revegetation studies.

Road Counts

Wildlife Monitored. Road count studies are being conducted primarily to record numbers of deer and deer road kills in the vicinity of the Seep Ridge site. Sightings of raptorial birds also are recorded. Additionally, information is obtained whenever possible on elk, grouse, bobcats, coyotes, and any unusual or rare wildlife species.

Methods. A fixed route of 5 miles north and 5 miles south of the Seep Ridge site is routinely traveled (Figure 11). Counts are

performed twice each month throughout the year and always within 2 hours of sunset. The direction of travel is randomly chosen prior to each count. All sightings are recorded in terms of 1-mile intervals, and sightings of deer are recorded and associated with habitat type (pinyon-juniper or sagebrush).

Results and Discussion. Road count information on deer is particularly useful for determining whether important road crossings occur. Potential road kill problems and hazards to motorists could thereby be more meaningfully evaluated.

The results of road counts conducted for the past two years of monitoring (see Table 7 and 8), suggest only moderate numbers of deer in the vicinity of the Seep Ridge site, and these findings are consistent with the estimates of deer pellet-group densities. No important road crossings were found. One road-killed deer was identified approximately 5 miles south of the Seep Ridge site on June 3, 1981 during the first road count performed. No other road kills were observed during the following 46 counts conducted over a 2-year period.

Raptorial birds were observed on five road counts the first year, and on eleven road counts the second year (Table 7 and 8). Three species identified were the rough-legged hawk (a winter resident), redtailed hawk (permanent resident), and the bald eagle (also a winter resident). This was the first sighting of a bald eagle in the count area. The bird was observed in flight on May 12, 1982, approximately 5 miles north of the Seep Ridge site.

B. ATMOSPHERIC RESEARCH

1. Air Quality - During the operation of Retorts #24 and #25, a tabulated summary of retort emissions was routinely provided as part of the monthly progress reports, but, with the ignition of Retort #27 in August, a new reporting approach was implemented to

conform to conditions set forth in the new air quality approval order issued by the Utah Bureau of Air Quality (UBAQ).

Previous, in place of daily direct stack measurements, daily concentrations of hydrogen sulfide and ammonia in the unburned retort off gas were used to calculate the resultant sulfur dioxide and nitrogen dioxide emissions from the incinerator. These daily calculated emissions, along with the semi-monthly direct stack measurements, were the basis for determining permit compliance. However, the new air quality approval order for Retorts #27 and #28 stipulates that permit compliance will be determined by a "properly performed compliance test" using appropriate EPA reference methods, and this compliance test must be performed no later than 19 weeks after the ignition of Retort #27. Therefore, before the end of calendar year 1983, the compliance test will be conducted by Geokinetics with UBAQ personnel in attendance. Events leading up to the test, as well as the preliminary and final results, will be a part of future progress reports to replace the former emissions tables.

It is expected that daily measurements of H_2S and NH_3 in the retort off gas will continue and will be reported with other retort off gas constituents as part of the off gas characterization study. Whenever in-house direct stack measurements are taken, the results will be included in the appropriate reports. This change does not alter the proposed air quality work described in the statement of work for 1983; rather it allows for reporting the same information required by the UBAQ.

2. Fugitive Emissions - During August, authorization was given to TRC Environmental Consultants, Inc., to develop the field study plan (test protocol) for a Retort #27 Fugitive Retort Emissions Study. The purpose of the study is to quantify potential fugitive hydrocarbon and carbon monoxide emissions through cracks and fractures on the retort surface. A draft and final study plan submitted by the contractor for Retort #27 was received by Geokinetics.

During the operation of Retort #17, a small pilot retort, in 1979, Monsanto Research Corporation gathered samples to determine surface fugitive emissions of hydrocarbons (HC) and carbon monoxide (CO). Measurements were made at numerous locations on the surface of the retort to determine the rate of seepage of HC and CO due to excess pressure caused by the combustion process occurring in the shale bed within the retort. Since the 1979 pilot operation, improvements have been made in methods of operation and the preparation of the ground surface above a retort. The size of the retort also has been increased. One of the most significant differences between the 1979 pilot test and the current operation, for which the above stated testing program is to be employed, is that a small negative pressure is maintained in the retort by the operation of air-in and gas out blowers. With this difference in operating conditions, it is expected that surface fugitive emissions from Retort #27 will be lower than for previous operations.

The Retort #27 fugitive emissions study sets forth the approach, test methods, quality assurance procedures, and analytical methods to be used for measuring and reporting emissions data. Fugitive emissions from Retort #27 will be measured during the early, middle, and late periods of the burn. The initial burn sampling is scheduled for the first part of October when the fire front location is expected to be between the first and second row of thermocouples. Subsequent sampling has tentatively been scheduled for early March and June for the middle and late burn periods, respectively.

C. HYDROLOGIC RESEARCH

1. Infiltration Tests - Soil infiltration testing on both disturbed retort surface areas and other undisturbed sites was begun during June 1983 and completed during August 1983. The objective of the study was to characterize the hydrologic properties of the retort surface in comparison to natural, undisturbed

locations typical of the Geokinetics in situ retorting operation. The study was conducted by the Utah State University Foundation under the direction of Professor Richard H. Hawkins, and a report on his findings is expected to be submitted sometime during the fourth quarter of 1983.

Some specific goals of the study are as follows:

- a. Determine point infiltration rates and parameters on at least two different land types using two different methods; and
- b. Synthesize hydrologic loss rate parameters for the sites from the infiltration rates; and

Both ponding and sprinkling infiltrometer tests were conducted. The ponding rings were 12 and 18 inches in diameter, and the sprinkling infiltrometer was a rotating drop former, approximately 2 ft² with a fall height of about 6 feet. Runs were made for a duration of at least 60 minutes. Sprinkler intensity was relatively constant at approximately two inches per hour. Sampling was made in clustered groups consisting of a sprinkler plot with two ponding plots on either side.

Data reduction will include parameter fitting using the Green-Amp infiltration equation, which should provide an estimate of the saturated hydraulic conductivity (K_s) at a location for the depth of water penetration. Also, sixty (60) minute infiltration rates can be predicted.

From the reduced infiltration data, rainfall-runoff relationships can be predicted from the synthesis of runoff curves numbers (CN) for a series of designed storm durations and return periods. In addition, any relationships between the sprinkler infiltration rates and ponding ring data will be defined.

2.   Surface Water Monitoring - In addition to soil infiltration data, two surface water monitoring stations were constructed during August, 1983 (see Figure 12). The stations are designed to monitor surface runoff events, and will collect data on the frequency and magnitude of runoff events along with water quality. These data are to be used with infiltration data to predict effects of surface impacts on the quality and quantity of runoff events. This should help develop mitigation methods that may be required during future retorting operations (culverts, sediment, dams, etc.).

Each surface water station consists of an H-Type flume with a crest gage and single stage sediment sampler. Station 1 has a continuous water level recorder. Each flume is to be calibrated with an open channel flow meter during several events to establish stage flow relationships. As yet, the flumes have not been calibrated due to equipment problems. Water and sediment samples were gathered during two (2) runoff events at various stages, and the samples are being analyzed in the Geokinetics laboratory. A list of parameters to be analyzed are shown in Table 9. Preliminary results of this study will most likely be released with the surface impacts study during the fourth quarter of 1983.

3.   Subsurface Impact Studies - During September, groundwater monitoring studies were initiated to characterize the site geohydrology in detail and to make accurate predictions of the impacts of in situ retorting. The studies are designed to fill existing data gaps from past subsurface impact studies. The studies consist of rock coring, packer testing, and the installation and testing of 18 wells at the test site (see Figure 12).

The study includes the completion of wells above and within the upper portion of the Mahogany zone and below the Mahogany zone. These wells should identify the lateral and vertical movement of groundwater associated with the targeted oil shale zone before and after retorting operations. In addition, wells are to be completed in the upper portion of the Douglas Creek Member of the Green River Formation but below the zone of rich tar sands. These deeper wells are designed to identify the degree of separation of shallow groundwater from the underlying Douglas Creek Aquifer.

Monitoring wells are to be completed in six clusters of three wells each, and these clusters are arranged around the projected areas of retorting operations. This configuration should insure that the lateral movement of groundwater can be quantified and that the impacts of site operations can be monitored.

In addition to the above wells, four more wells will be completed in the shallow alluvial materials at the site. These wells will serve to monitor the limited alluvial deposits on or near the site.

Preliminary results from rock coring and packer testing completed to date indicate the presence of zones of low permeability below the Mahogany Zone. Completion of the proposed monitoring program and associated geohydrologic testing should serve to quantify the significance of these zones in determining the movement of groundwater at the site.

4. Effluent Water - During September, one water sample from Retort #27 was taken for chemical analysis. The sample is to be analyzed in the Geokinetics laboratory for parameters listed in Table 10.

OIL PRODUCTION TO E.D. 47
RETORT #27 - 755.5 RETORT #28 - 0.0

Figure 1. Oil Production to Elapsed Day 47

WATER PRODUCTION TO E D. 47
RETORT #27 - 10007 6 RETORT - #28 0

Figure 2. Water Production to Elapsed Day 47

Air-in ●

Air-out ○

Observation Well ⊕

Production Well ⊕

Figure 3. Retort #27 - Process Wells

Figure 4. Retort #28 - Plan View, Instrumentation Wells

WEEKLY PRECIP WITH IRRIGATION

IRRIGATED Vs. NON - IRRIGATED

Figure 5. Weekly Precipitation with Irrigation
Irrigated vs. Non-Irrigated

Figure 6. Location of Pellet Transects

Figure 7. Mule deer pellet-group densities for three summer periods. Data are means $\pm$ 95 percent confidence intervals.

Figure 8. Mule deer pellet-group densities for three winter periods. Data are means $\pm$ percent confidence intervals.

Fig. 9. Between-year correlation of mule deer pellet-group counts. The points plotted are transect values—the number of pellet-groups per hectare for the same transect for the 2-year period. Transect location and season (S=summer; W=winter) is shown alongside the dots. The graph demonstrates a significant correlation ($r=0.84$; $df=8$; $P<0.002$) in pellet-group counts for the ten transect locations, suggesting similar habitat usage for both years. The ellipse is the 95% confidence region.

Figure 10. Pellet Count Study on Revegetated Surfaces

Figure 11. Road Count Route

Scale: 1.3" = 1,000'
Section 2

Figure 12. Location of Groundwater Monitoring Wells
Section 2.

Table 1. Mule deer pellet-group density estimates, 1980-1982. The first column shows counts along unswept transects (the pellet-groups counted were of unknown age). Columns 2 and 3 are the results of counts along transects swept free of pellets the previous sampling period.

Transect	Mean Pellet-groups per Hectare +/- SE (n)*		
	Summer & Winter 1980-81 (approx.)	Summer 1981	Winter 1981-82
<u>Pinyon-Juniper</u>			
W8	450 +/- 89 (80)	100 +/- 34 (80)	38 +/- 21 (80)
W10	313 +/- 77 (80)	175 +/- 46 (80)	50 +/- 30 (80)
W14	313 +/- 68 (80)	50 +/- 25 (80)	125 +/- 54 (80)
W15	388 +/- 90 (80)	38 +/- 21 (80)	50 +/- 30 (80)
Combined:	366 +/- 33 (4)	91 +/- 31 (4)	66 +/- 20 (4)
<u>Sagebrush</u>			
W6	475 +/- 75 (80)	213 +/- 55 (80)	200 +/- 80 (80)
W9	513 +/- 107 (80)	175 +/- 50 (80)	25 +/- 18 (80)
W11	388 +/- 70 (80)	25 +/- 18 (80)	75 +/- 35 (80)
W16	113 +/- 36 (80)	0 +/- 0 (80)	13 +/- 12 (80)
Combined:	372 +/- 90 (4)	103 +/- 53 (4)	78 +/- 43 (4)

- * n = The number of 10m² quadrats sampled, except for combined results where an unweighted analysis of means (transects, not quadrats, are considered to be the sample unit) is used.

Table 2. Mule deer pellet-group density estimates, 1982-1983.

Transect	Mean Pellet-groups per Hectare +/- SE (n)*	
	Summer 1982	Winter 1982-83
<u>Pinyon-juniper</u>		
W8	13 +/- 12 (80)	75 +/- 30 (80)
W10	0	25 +/- 18 (80)
W14	0	163 +/- 45 (80)
W15	0	125 +/- 51 (80)
Combined:	3 +/- 3 (4)	97 +/- 30 (4)
<u>Sagebrush</u>		
W6	13 +/- 12 (80)	138 +/- 39 (80)
W9	0	88 +/- 41 (80)
W11	0	75 +/- 30 (80)
W16	0	13 +/- 12 (80)
Combined:	3 +/- 3 (4)	79 +/- 26 (4)

* n = The number of 10m² quadrats sampled, except for combined results where an unweighted analysis of means (transects, not quadrats, are considered to be the sample unit) is used.

Table 3. Elk pellet-group density estimates, 1982-1983.

Transect	<u>Mean Pellet-groups per Hectare +/- SE (n)*</u>	
	Summer 1982	Winter 1982-83
<u>Pinon-juniper</u>		
W8	0	0
W10	13 +/- 12 (80)	0
W14	0	0
W15	0	25 +/- 18 (80)
Combined:	3 +/- 3 (4)	6 +/- 6 (4)
<u>Sagebrush</u>		
W6	13 +/- 12 (80)	13 +/- 12 (80)
W9	125 +/- 48 (80)	50 +/- 25 (80)
W11	488 +/- 85 (80)	125 +/- 37 (80)
W16	0	0
Combined:	156 +/- 114 (4)	47 +/- 28 (4)

* n = The number of 10m² quadrats sampled, except for combined results where an unweighted analysis of means (transects, not quadrats, are considered to be the sample unit) is used.

Table 4. Pellet transect results for species other than mule deer, 1981-1982. For cottontails, 40 quadrats, 3m² each, were sampled per transect; for other species, 80 quadrats, 10m² each, were sampled per transect. All quadrats had been cleaned the previous sampling period.

Number of Quadrats with Animal Sign Present										
Transect	<u>Elk</u>		<u>Cottontail</u>		<u>Coyote</u>		<u>Pocket Gopher</u>		<u>Cattle</u>	
	S	W*	S	W	S	W	S	W	S	W
<u>Pinon-juniper</u>										
W8	1	0	0	24	0	0	0	0	5	3
W10	0	0	0	24	0	0	0	0	5	1
W14	0	0	0	14	0	0	3	2	1	7
W15	0	0	0	2	0	0	0	0	22	14
<u>Sagebrush</u>										
W6	0	0	4	26	0	0	0	2	7	2
W9	1	0	3	7	0	0	10	6	11	22
W11	0	0	1	9	0	0	27	32	18	41
W16	0	0	1	9	0	0	4	7	25	24
* S = Summer period (counts conducted in the fall, October 1981) W = Winter period (counts conducted in the spring, May and June 1982)										

Table 5. Pellet transect results for species other than mule deer and elk, 1982-1983. For cottontails, 40 quadrats, 3m² each, were sampled per transect; for other species, 80 quadrats, 10m² each, were sampled per transect. All quadrats had been cleaned the previous sampling period.

Transect	Number of Quadrats with Animal Sign Present							
	<u>Cottontail</u>		<u>Coyote</u>		<u>Pocket Gopher</u>		<u>Cattle</u>	
	S	W*	S	W	S	W	S	W
<u>Pinon-Juniper:</u>								
W 8	2	26	0	0	0	0	0	4
W 10	1	18	0	0	0	0	0	5
W 14	0	12	0	0	1	5	0	6
W 15	0	24	0	0	2	1	0	29
<u>Sagebrush:</u>								
W 6	22	35	0	0	0	3	0	4
W 9	11	27	0	0	12	3	0	45
W 11	13	29	0	0	40	38	1	40
W 16	6	26	0	0	7	11	0	45

* S = Summer period (counts conducted in the fall, October 1982).

W = Winter period (counts conducted in the spring, May 1983).

Table 6. Mule deer pellet-group counts on revegetated surfaces, 1980-1982. The first column shows counts along newly established quadrat clusters (the pellet-groups counted were of unknown age). Columns 2 and 3 are the results of counts within quadrats swept free of pellets the previous sampling period.

Quadrat Cluster	<u>Mean Pellet-group per Hectare +/- SE (n)</u>		
	Summer & Winter 1980-81 (approx.)	Summer 1981	Winter 1981-82
14 B	1600 +/- 678 (5)	0 +/- 0 (5)	200 +/- 200 (5)
14 D	0 +/- 0 (5)	0 +/- 0 (5)	0 +/- 0 (5)
15 B	600 +/- 600 (5)	0 +/- 0 (5)	0 +/- 0 (5)
15 D	600 +/- 245 (5)	0 +/- 0 (5)	0 +/- 0 (5)

n = The number of 10m² quadrats sampled.

B = Blasted area (retort areas).

D = Disturbed area (access areas).

Table 7. Results of road counts conducted along a 10-mile route, 1981-82.

<u>Number of Animals Observed</u>					
	Deer	Elk	Grouse	Deer Road-kills	Raptors
<u>1981</u>					
JUN 3 28				1	
JUL 10 29					
AUG 9 25					
SEP 7 28					1 rough-legged hawk(?)
OCT 19 28	5				1 red-tailed hawk
NOV 12 24					
DEC 14 29					
<u>1982</u>					
JAN 12 26	5 3				
FEB 12 26					
MAR 15					1 red-tailed hawk and 1 rough-legged hawk
24	13				
APR 9	14				1 red-tailed hawk and 1 hawk (sp?)
MAY 12 27					1 bald eagle

Table 3. Results of road counts conducted along a 10-mile route, 1982-83.

<u>Number of Animals Observed</u>				
	Deer	Elk	Grouse	Deer Road-kills Raptors
<u>1982</u>				
JUN 10				1 hawk (sp?)
23				1 red-tailed hawk
JUL 6				1 great horned owl (?)
18				2 owls, 1 hawk (sp?)
AUG 9				1 owl, 2 hawks (sp?)
23				1 red-tailed hawk
SEP 7				1 red-tailed hawk
23				
OCT 7				
27	19	7		
NOV 7	17			
22				
DEC 6				
20				1 red-tailed hawk
<u>1983</u>				
JAN 12				
28				
FEB 8				
23				
MAR 7				1 red-tailed hawk
28	4			
APR 12	22			
28				
MAY 9				2 hawks (sp?)
26				1 red-tailed hawk

TABLE 9

WATER QUALITY PARAMETERS FOR SURFACE MONITORING PROGRAMMajor Cations

Calcium
Magnesium
Sodium
Potassium
Lithium
Strontium

Other Quality Indicators

pH
Conductivity
Total Dissolved Solids
Chemical Oxygen Demand
Alkalinity
Total Suspended Solids*

Major Anions

Chloride
Carbonate-Bicarbonate
Sulfate

Indicators

Thiosulfates
Thiocyanates
Ammonia
Ammonium
Alkyl Pyridines
Cyanide
Sulfides
Total Sulphur
Carbonyl Sulfide
Fluoride

Trace Metals

Boron
Iron
Silica
Arsenic
Antimony
Lead

Organics

Oil and Grease
Total Organic Carbon
Total Organic Nitrogen
Phenols

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*Surface water samples only.

TABLE 10**Chemical and Physical Parameters for Analysis
of Retort Process Wastewater (Retort Water)**

<u>Major Cations</u>	<u>Major Anions</u>	<u>Trace Elements</u>	<u>Organics</u>
Sodium	Fluoride	Antimony	Oil & Grease
Potassium	Chloride	Arsenic	Phenols
Magnesium	Bromide	Boron	BOD
Calcium	Phosphate	Cadmium	TOC
Strontium	Nitrate	Copper	TIC
	Sulfate	Iron	TKN
	Bicarbonate	Lead	
	Carbonate	Nickel	
		Selenium	
		Silicon	
		Molybdenum	
		Vanadium	
<u>Indicators</u>		<u>Quality Indicators</u>	
Ammonia		Alkalinity	
Ammonium		COD	
Cyanide		Conductivity	
Sulfide		pH	
Total Sulfur		TDS	
Thiocyanate		TSS	
Thiosulfate			