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INVESTIGATION OF THE GEOKINETICS HORIZONTAL IN SITU OIL SHALE RETORTING PROCESS

Quarterly Report for July—September 1982

By
Steven Bartlett
Lee Wege

November 1982
Date Published

Work Performed Under Contract No. FC20-78LC10787

Geokinetics Inc.
Salt Lake City, Utah

U. S. DEPARTMENT OF ENERGY

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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 means of 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 at the off gas wells.

OVERVIEW OF THE GEOKINETICS' IN SITU RETORTING PROCESS

This section of the report is to aid readers who are unfamiliar with the Geokinetics in situ retorting process to help them understand the quarterly report and the various processes and terminology.

In the Geokinetics Process, a pattern of blastholes is drilled from the surface, through the overburden, and into the oil shale bed. The holes are loaded with explosives and fired, using a carefully planned blast system. The blast results in a fragmented mass of oil shale with high permeability. The void space in the fragmented zone comes from lifting the overburden, producing a small uplift of the surface.

The fragmented zone constitutes an in situ retort. The bottom of the retort is sloped to provide drainage for the oil to a sump where it is lifted to the surface by a number of oil production wells. Air injection holes are drilled at the other end. The oil shale is ignited at the air injection wells and air is injected to establish and maintain a burning front that occupies the full thickness of the fragmented zone.

The front is moved in a horizontal direction through the fractured shale towards the off gas wells at the far end of the retort. The hot combustion gases from the burning front heat the shale ahead of the front, driving out the oil, which drains to the bottom of the retort where it flows along the sloping bottom to the oil production wells. As the burn front moves from the air in to the off gas wells, it burns the residual carbon in the retorted shale as fuel. The combustion gases are recovered at the off gas wells. This gas is combustible and could be used for power generation.

After the detonation, core samples are taken to evaluate the effectiveness of the blast and the quality of fracturing.

The next phase is re-entry drilling. Wells are drilled into the retort for air injection, off gas removal and oil production. A fire is ignited at one end of the retort and its horizontal progress through the bed is monitored by a series of thermocouple wells. Progress of the fire front is regulated by varying the air injection rates through a row of air-in wells located at one end of the retort.

Upon completion of the burn when the fire front has reached the far end of the retort, the retort is shut in and the process wells and equipment are removed. The surface is recontoured and revegetated to restore the aesthetic and ecological value of the landscape. In addition to these activities, prior to, during and after retort burn, environment studies are conducted in such areas as air quality, fugitive emissions, hydrology, wildlife and ecology to assess the impact of the project of the project upon the ecosystem and mitigate adverse effects.

In the following sections of the report, the various aspects of the project are reported in fuller detail with a description of activities, experiments, data and findings.

1982 SUMMARY

This section of the report is a summary of Geokinetics' activities during 1982.

The Retort #25 burn was terminated in June after 243 elapsed days. Total oil production was 20,956 barrels with an average production of 86 barrels per day for this eight month period. Final oil recovery was 59%, Geokinetics' highest yield for a retort of this size. Retort #25 has been dismantled and recontoured, and post-burn environmental studies are continuing.

Re-entry drilling was done for process and instrumentation holes on Retort #26 during January through March. Instrumentation and process manifolding installation began in March. Surface manifolding was completed in May. Instrumentation installation was completed by early July and the retort was ignited on July 8. Total oil production for Retort #26 reached 8,767 barrels by the end of September.

The Retort #27 site was drilled and prepared for blasting during the months of January and February and the retort was detonated on February 25. Retort #27 was Geokinetics' first 2 acre retort and post blast coring was done in March and April to determine the blasts' success. Recontouring and compacting of the retort's surface was completed in May and June, and re-entry drilling began in July and continued into August.

Preliminary site preparation for Retort #28, Geokinetics' second 2 acre retort, began in May, and blast hole drilling started in June and was finished by August. Detonation of the retort occurred on August 18, and presently post blast contouring and coring is being accomplished to determine the effects of the blast.

THIRD QUARTER 1982 SUMMARY

Retort #26 was ignited on July 8 and July 9. Oil production began on July 20, and total oil production reached 238 barrels by the end of July. AIr injection rates were increased during the month as a fire front was established within the retort. Oil production from Retort #26 for August was 3,949 barrels, an average of 127 barrels of oil per day. August's average air injection rates were maintained at approximately 5,600 standard cubic feet per minute. By the end of August, the fire front had reached a position 55 feet from the air injection wells. Oil production from Retort #26 for September was 4,580 barrels, an average of 153 barrels per day. This total and average production was the highest ever recorded by Geokinetics. Air injection rates into the retort averaged 5,358 standard cubic feet per minute. By the end of September, the fire front had reached a location 130 feet downstream from the air injection wells. All monthly reported emissions for Retort #26 were below the PSD and UBAQ permit stipulations.

Re-entry drilling began on Retort #27 in July on air-in and air-out process holes and continued throughout August.

Blast hole drilling continued on Retort #28 throughout July. Approximately 17,000 feet of blast holes were completed in July and detonation of the retort occurred on August 18. Explosive loading occupied two days and the procedure and shot were completed without any hinderance. Initial analysis of the retort indicated that the shot was successful. Recontouring and post blast coring began on Retort #28 during September.

Retort #25 surface piping was dismantled during July and the retort was subsequently recontoured.

Testing was done by Geokinetics, LETC and Pedco on a Stretford pilot plant that removes H_2S from the process gas stream during September.

DESCRIPTION OF THIRD QUARTER TECHNICAL PROGRESS

I. RETORT #25

Retort #25 completed its operation in June, and the surface equipment dismantling began in July. The removal of all instrumentation and process well casing was completed by mid-July. By the end of the third week, all surface equipment had been removed from Retort #25 and surface recontouring was completed.

II. RETORT #26

A. Introduction - The total oil production for Retort #26 during the quarter was 4,580.2 barrels. Retort #26 was ignited on July 8 and 9, and completed 72 days of actual oil production during the quarter (oil production began on July 20.) Water production was 9,470.4 barrels for a 79 day production period. Total off gas production for the third quarter equalled 650 million standard cubic feet. Air injection rates were gradually increased during July until a uniform fire front was achieved. The quarterly average rate of injection was 5,028 standard cubic feet per minute and a total of 575 million standard cubic feet of air was injected. The fire front by the end of the reporting period had reached a position 130 feet downstream from the air injection wells. All air quality, process and stack gas studies show that the afterburner on Retort #26 operated efficiently, and all emissions were within EPA and UBAQ permit stipulations.

B. Oil, Water and Gas Production

1. Oil Production - The retorting of oil shale produces oil and water in both a liquid and mist form, and numerous gases. Each of these products is analyzed to determine its nature, constituents and abundance in order to characterize retorting conditions and efficiency. Table 1 gives a summary of oil, oil mist

and water production for July through September, and an average for the third quarter of 1982.

Retort #26 was ignited on July 8 and 9 using Geokinetics' charcoal ignition technique. Oil production began on July 20, 12 days after ignition.

Oil production for August gradually increased during the month except for a 10 day interval (elasped 40-50) where air injection rates were reduced for the Retort #28 blast. Oil production rates dropped slightly during the middle of the week when the air injection system was temporarily shut down because of loosened surfaced piping seals caused by the blast.

Oil production for September was outstanding. The average oil production for the month was 153 barrels per day. Production rates were stable except for September 14 when oil production soared to 292 barrels (Figure 1). The total oil production for September reached 4,580 barrels. This total is the highest monthly oil production during Geokinetics' history.

The percent oil yield loss to coking and burning within the retort gives indications of retorting efficiency. This is calculated weekly using the alkene/alkane ratio. Percent oil yield, as determined indirectly by extrapolation of gas chromatographic data, is the percentage of oil yielded by retorting of the theoretical amount of oil that could be produced from the kerogen if retorting was carried out under ideal conditions, i.e., no oil loss to coking or burning. Table 2 gives the quarterly summary of percent oil yield and loss for Retort #26. (Note: Percent oil loss to coking and burning for production oil and oil mist analysis are approximate figures. Percent coked + % burned + % yield equals approximately 100%).

2. <u>Water Production</u> - Water production for the third quarter (both liquid and mist portions combined) was 9,470 barrels

with an average of 119.9 barrels per day. Monthly water production for July, August and September was 901, 4,001, and 4,568 barrels respectively.

3. Gas Production - The numerous gases produced by retorting are analyzed daily to determine the constituents and their relative abundance. Table 3 shows the process gas for ten day intervals and also a monthly and third quarterly average.

Total process gas volume or off gas volume for the various gas constituents can be calculated indirectly from the percent abundance of the process gas constituents and the off gas flow rates recorded at the air-out well heads. The average air-out flow rate (off gas flow rate) in standard cubic feet per minute (scfm) and total off gas volume for each month during the third quarter is given in Table 4. Table 5 also presents the average high heating value in BTU per standard cubic feet for July through September. Also included with Table 5 is the total BTU produced.

C. Air Injection and Fire Front Advance - Air injection rates typically show a good correlation with production rates and fire front advance rates and therefore are critical in process control. A summary of the air injection has previously been given in Table 4.

In July, the air injection rates were monitored carefully and increased according to a predetermined schedule until a rate of approximately 6,000 standard cubic feet per minute was reached (see Figure 1). This rate of 6,000 scfm was maintained during the majority of the Retort #25 burn and has proven to be an optimum rate for high oil yield. Air injection and oil yield data from both Retort #25 and Retort #26 will be compared and utilized to assess optimum air injection rates and also more precisely define the relationship between air injection rates and oil production.

Air injection rates remained constant through the month of August except for a brief period following the Retort #28 blast (Figure 1).

Air injection rates also remained somewhat stable through most of September, but were slightly decreased during the final days of the month. On September 21, the air injection rates was decreased to an average of 5,128 standard cubic feet per minute to test the effect on oil production. In addition, air injection rates were decreased at the north end of the retort during mid September to inhibit the fire front advance and produce a more uniform front.

The rate of fire front advance and fire front location were impossible to determine during July because the fire front had not reached the first row of thermocouples.

By August 4, the fire front was uniform and was situated between the first and second rows of thermocouples. By August 11, the fire front had advanced to a location between the second and third row of thermocouples (approximately 45 feet downstream of the injection wells). As of August 25, the fire front had reached a position 55 feet from the air injection wells. Figures 2-4 show the fire front location for end of month intervals during the third quarter.

At the beginning of September, the fire front was 62 feet downstream from the air injection wells. During the remainder of the month, it progressed 68 feet to a location 130 feet downstream from the air-in wells.

D. Air Quality - Geokinetics is required by the existing Prevention of Significant Deterioration (PSD) permit, issued by the EPA, and the State Air Construction permit, issued by the Utah Bureau of Air Quality, to measure specific pollutants emitted by the afterburner on Retort #26 and also the estimated emissions from ancillary sources including the electrical generator and vehicle traffic on the unpaved service roads at the site. The emissions from the ancillary sources are based on established emission factors set forth in the PSD permit application. These individual pollutants and their respective emission rates are listed in Table 6 on a monthly and quarterly basis.

The emissions presented for Retort #26, which is the primary source of emissions, are determined by measurements of the effluent gas stream at a point ahead of the afterburner and also at the top of the afterburner after combustion. The quarterly average emission rates, maximum emission rates and maximum allowable rates as stipulated the existing air quality permit were below the allowable limits for July, August and September.

A comparison of total emissions measured in tons for all sources and the total allowable emissions set forth by the PSD permit is given in Table 7 for the third quarter of 1982.

E. Process/Stack Gas - Process gases are those gases which are produced by retorting, whereas stack gases are the resultant gases produced after the combustion of the process gas have been combusted in the afterburner. The process and stack gas analyses are routine tests performed by the Analytical Laboratory to determine the concentration of pollutants in both gas streams and test the efficiency of the afterburner. Results of these analyses are given in Table 8 and 9.

III. RETORT #27

Re-entry drilling on Retort #27 began in July. During the first week of the month, all air-in and air-out holes were surveyed and staked. Drilling began the second week of July and continued into August. By the end of the third week of August, all injection wells and off gas recovery wells had been completed. Figure 5 presents a schematic view of Retort #27 process wells.

IV. RETORT #28

Retort #28 was Geokinetics' second 2 acre retort. Blast hole drilling, which began in June, continued on Retort #28 during July. During July, approximately 17,000 feet of blast hole was completed.

The detonation of the retort was significant because it tested Geokinetics' capability to blast a large size retort in an area with significant topographical changes and a non-uniform overburden. Since much of Geokinetics' based land is found in terrain with varying topography, the capability and technology required for successfully blasting and retorting such areas will be vital for good land utilization and will increase the usable oil shale reserves.

A small hill located on the southwest section of the retort provided both topographical and overburden variance.

Blast hole drilling was completed on Retort #28 by the 11th of August with a total footage of 43,388.6 feet. The blast holes were then measured in order to determine the amount of water and drill cuttings that had filled the holes so as to verify actual hole depths before explosive loading. Final blast hole measuring was conducted on August 12-14. On August 15, the blast hole priming systems were installed. The explosive loading began on August 16. 354,349 pounds of Ireco aluminum nitrate slurry was loaded into 266 blast holes. By the morning of August 18, all holes had been loaded and stemmed to the surface, and the surface detonation systems were subsequently wired.

The blast was detonated at approximately 3:00 pm, August 18. Initial analysis indicated that the shot was successful. Post blast surveying began on August 26 in order to assess the amount of surface displacement. This data will be correlated with high speed photography and other data to more fully evaluate the blast.

During the first week of September, post blast surface contouring began on Retort #28. Contouring and leveling of the retort's surface was done so that the drill rigs could begin post blast coring and re-entry drilling (i.e. drilling of retort process holes). By September 20, Geokinetics had begun coring various locations within the retort to assess the fracturing characteristics produced by the retort blast.

V. ADDITIONAL ACTIVITIES

A. Retort #25 Soil Temperature Study - Soil temperatures at various depths on Retort #25 and at a control location (Figure 6) were monitored during the burning process of the retort. Elevated soil temperature due to retorting has a direct influence and could affect vegetation growing on the retort surface.

With this in mind, the study was designed to obtain data that would allow for a preliminary evaluation of the retorting effect upon soil temperature, as well as allow for the design of future studies to determine the effect of increased soil temperature upon revegetation practices.

The study was initiated in October 1981 during the first week of the Retort #25 burn. Soil temperature probes (type "T" thermocouples) were placed along the soil profile at 10, 50, 100 and 150 centimeter depths. Soil temperature data were collected automatically on a daily basis with the use of a data logging system. In order to avoid the effect of solar radiation upon soil temperature, data were collected during the early morning hours. Temperature data were recorded from the data logger to a magnetic tape which was transferred to a computer system for storage and analytical reduction.

Results:

Retort #25 burned for a period of 243 days (October-June). Average monthly soil temperatures during this period are given in Table 10. In addition, difference among means per depth are graphically represented in Figures 7a-7d.

As shown, difference between mean temperatures occurred during March or approximately 150 days into the burn. Comparison of retort temperatures and control temperatures over time at each depth are graphically presented in Figure 8. Again, the separation in temperature curves displays the change between locations during March.

Soil temperatures recorded on Retort #25 and at the control site were subjected to statistical analysis in order to assess any significant difference between locations. The student's t-test was performed for the period before and after March. The results of these tests are given in Table 11.

Discussion:

An increase in soil temperatures seems to be occurring on Retort #25 as compared to the control location, although statistically there is no significant difference at the 95 percent confidence interval for the tested periods. The analysis is somewhat misleading to the point that substantial differences did not occur until the latter two months, at which time the limited number of samples precludes statistical analysis. As represented by Figures 7a-7d and 8, differences between locations seems to be increasing over time. Significant differences will most likely occur during post-burn recovery. Soil temperatures will continue to be monitored during this period to determine if differences are occurring, as well as if the retort location begins to return to normalcy.

The recorded effect to date of the retorting process upon soil temperatures indicates that a more in depth evaluation of this effect may be required prior to finalizing revegetation practices. Further analysis of post-burn data will determine this need.

B. Wildlife Monitoring Report and Field Manual - A draft report of the first year's wildlife monitoring data was completed by Dr. Robert E. Stoecker (Stoecker-Keammerer and Associates) during July. The report period extended from May 1981 through June 1982. Baseline Investigations at the Seep Ridge site were conducted from May 1978 through May 1979. Some of the data obtained during the baseline period are presented in the report for purposes of comparison.

The main objectives of the wildlife monitoring program are to obtain data that will permit detection of substantial changes in important animal populations due to mining or reclamation. Since 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.

Six wildlife studies are discussed in the accompanying text:

- Pellet transect studies
- Pellet counts on revegetated surfaces
- Road counts
- Impact studies of open water impoundments
- Raptor observations
- Threatened and endangered species

In addition to the monitoring report, a field manual detailing the procedures for each of the component studies was presented to Geokinetics. This manual will be published along with the first year report, and copies of the report will be presented to the DOE.

Summary of First Year 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, pocket gophers and also on the occurence of domestic cattle. Eight pellet transects in close proximity to Kamp Kerogen were set up for the study (see Figure 9). The main objective of the pellet transect study is to check for indications of relative differences in animal abundance between areas located near retorting activities and areas located some distance away.

Mule Deer - First year results of mule deer pellet counts suggest that deer are not being displaced from the project site. Wildlife pellet transect #6 (W-6) had the highest deer pellet group density (Figures 10 and 11) yet it is located nearest to active retorting facilities. In view of the relatively short time span involved with the results, a statistical evaluation of the findings was not performed, although it would be entirely possible to do so. A different pattern could occur next year due merely to changing habitat conditions resulting from grazing or other causes.

An obvious correlation of data points between 1978-79 and 1981-82 periods suggest that deer usage of local sites is very similar. The correlation is highly significant (r=.84; df=8; PL.002). This is graphically shown in Figure 12.

Other Wildlife and Cattle - Data obtained on elk, cottontail, coyote, pocket gopher and cattle for this past year are presented in Table 12. Comparable data are not available from the baseline period.

Elk have rarely been observed near the Seep Ridge site, and it is somewhat surprising that two occurrences of the elk pellet groups were identified along the transects. Data for the remaining species have little utility at this time apart from providing information on general levels of abundance, habitat, affinities and seasonal differences in polulation sizes. In the future, however, these data will be useful for evaluating differences between revegetated and control sites.

Road Counts:

Wildlife Monitoried - Road count studies are being conducted primarily to record numbers of deer and deer road kills in the vicinity of the Seep Ridge site (Figure 13). Sightings of raptorial birds are also recorded. Additionally, information is at least potentially available on elk, grouse and other wildlife species of interest such as bobcats and coyotes. All sightings of unusual or rare wildlife are also recorded.

The results of road counts conducted this year (Table 13) suggest only moderate numbers of deer in the vicinity of the Seep Ridge site. These findings are consistent with the estimates of deer pellet group densities. No indications at this point suggest important road crossing locations. One road killed deer was identified approximately five miles south of the Seep Ridge site on June 3, 1981. This was the first road count performed. No other road kills were observed during the following 22 counts of this past year.

Raptorial birds were observed on only five road counts. Three species were identified: the rough legged hawk (a winter resident), red-tailed hawk (permanent resident) and the bad eagle (also a winter resident). This was the first sighting of a bad eagle in the vicinity of the Seep Ridge site. The bird was observed in flight on May 12, 1982, approximately five miles north of the Seep Ridge site.

Impact Studies of Open Water Impoundments - The wildlife species searched for near open water impoundments include dead specimans of birds and small mammals (Figures 14 and 15).

During the course of the investigations (a total of 20 separate observations) only one specimen was found. One unidentified bird (a passerine) was found dead in Pond #2. No other evidence of hazards to wildlife from these two open water impoundments was obtained.

In view of the almost total absence of observed mortalities near the two impoundments, it is decided unnecessary to continue these studies. However, unstructured observations in the course of other activities will be performed as a check on any conditions that are hazardous to wildlife.

Raptor Observations - In May 1981, attempts were made during mornings to locate nesting ratorial birds. The Seep Ridge site (Section 2 and a surrounding zone of approximately one mile) was searched on foot and from a vehicle. No nesting raptors were located. Similarly, results of baseline investigations indicated no active raptor nests on the site. One red-tailed hawk was seen during the course of observations made during 1981. It is possible that this bird nested nearby, but since so few raptor observations are made by personnel working at the site, it seems unlikely that nesting raptors are at all common in the immediate vicinity of the retorting facilities.

Threatened and Endangerd Species - Observations for threatened or endangered wildlife species conducted during the baseline period and during this past year have resulted in only one sighting, which was mentioned previously in the section on road counts. Namely, one wintering bald eagle was observed in flight on May 12, 1982, approximately five miles north of the Seep Ridge site. No reports of bald eagle winter roost sites are known of for the vicinity. Bald eagles regularly occur during winter in this region, even at distances well away from large rivers. There is no reason to believe, however, that habitats are present within the one mile study area surrounding the Seep Ridge site that are of particular importance to bald eagles, or to any other endangered wildlife species currently on the Federal list.

C. <u>USFS Plant Survival Study</u> - During September, plant survival and growth measurements were taken on Retorts #10 and #18, and #11 following their second and third growing seasons, respectively.

The plant survivial study is a cooperative effort between Geokinetics and the USFS Intermountain Forest and Range Experiment Staton, Provo, Utah. The main objective of the study is to provide information on the adaptability of several species of plants (trees, shrubs, forbs and grasses) established by transplanting container-grown planting stock. This information will be beneficial for the development of a successful and economically viable revegetation plan on burned in situ retorts.

<u>Results/Discussion</u> - Plant survivial and growth measurements for Retorts #10 and #18, and Retort #11 are given in Tables 14 and 15, respectively. The tables depict the overall survival and growth measurements since the species were planted. A frequency distribution of overall plant survival for all the retorts is given in Figure 16.

The majority of the plant species alive during the spring sampling (refer to June monthly) survived during the growing season. The only significant loss (>10 percent) occurred with the Oregon grape (Berkeris fremontii) species. These plants were observed to be unhealthy during the spring sampling, and their loss may be contributed to low precipitation amounts occurring during the early growing months (see Figure 17).

As shown in Figure 16, of the 59 species planted, 31 of them have a survival rate greater than 50 percent, while only 11 of the species have a survival rate of 80 percent or greater.

As yet, an acceptable survival rate has not been established, but species with less than 50 percent survival will most likely be questionable as for utilization on retort surfaces.

Further analysis over longer periods of time will be necessary before final selections of the tested species are made. However, a preliminary evaluation will be conducted following the 1983 fall sampling in order to select favorable species for future studies.

Planted retorts will be sampled again in the spring of 1983 in order to determine if any loss occurred during the winter months.

D. Process Water Characterization - Process water (water collected from the shale oil-winter separation process) was sampled periodically during the burn of Retort #25. Five samples were taken and analyzed by the in-house laboratory. The purpose of the study is to characterize, identify and quantify the chemical constituents in process water.

The investigation was initiated in November 1981, one month into the burn of the retort. Samples were gathered from the water wash tank within the tank farm compound. Chemical analysis was performed by the laboratory in accordance with standard methods and other methods adapted for retort wastewater.

Results/Discussion:

General statistical analysis was performed on the data as given in Table 16.

As shown, the water contains amounts of inorganic and organic compounds. This comes as no surprise since the analysis is similar to past work on site as well as other outside laboratory results (Mercer, 1981; Ray, 1981). A comparison of analytical results from Geokinetics and Monsanto Research Corporation is given in Table 17. A visual comparison of the data shows the wide variability in results, especially between the respective analyses by Geokinetics. The variability is the results of many factors of which numerous researchers have reported upon (Fox, 1980; Farrier, 1979).

In order to decrease the variability within our own results, additional sampling was planned and is being carried out during the burn of Retort #26. Three samplings were taken during this quarter, and chemical analysis will be performed on the samples by Geokinetics' in-house laboratory except for the following parameters:

- Biochemical Oxygen Demand (BOD)
- Total Organic Carbon (TOC)
- Total Inorganic Carbon (TIC)
- Total Kjeldahl Nitrogen (TKN)

These parameters will be analyzed by an outside laboratory. Data reduction of the analysis will be performed once all samples have been completed. In addition, variability overtime will be addressed and other in-depth analysis made once the studies of Retorts #25 and #26 are completed.

Retort Peripheral Well Water Quality Studies - Retorts #23 and #24:

On July 28, 1982, water samples were taken from the peripheral wells surrounding Retorts #23 and #24. This sampling was the fourth gathered during the post-burn phase of the retorts.

Chemical analysis will be performed by the in-house laboratory according to standard methods and others specifically designed for retort process waters. Results of the peripheral well water analysis will be presented at the completion of studies in January of 1983.

Stretford Plant:

During September, a pilot Stretford plant was operated at the field site. The pilot plant was provided by the EPA, and operated by an

EPA contractor, Pedco, Inc. The Laramie Energy Technical Center provided funding for the test, and also provided on-site analytical services. A Stretford plant is designed to remove hydrogen sulfide from the process gas. Results of the testing are now under evaluation.

Thermosludge Boiler and Ammonia Stripper:

Geokinetics is investigating the use of a Thermosludge boiler as a means of upgrading waste water from the retorts, and providing process steam. A meeting between Geokinetics and KTI personnel was held on September 20. Thermosludge boiler and ammonia stripping column were discussed. At the end of September, a bench scale ammonia stripper was constructed. The stripper will test the efficiency of ammonia removal from Retort #26 process water utilizing stream stripping methods.

Retort Simulation Research:

Retorting tests were carried out utilizing a steel retort simulator. A detailed report covering 3 runs executed in December and January of 1982 was submitted to LETC. The tests indicated that recovery of oil from Utah shale used in the tests was much less than in Colorado shale used in similar tests carried out int 1974. The unexpected results may be due to equipment problems and will be checked with additional tests.

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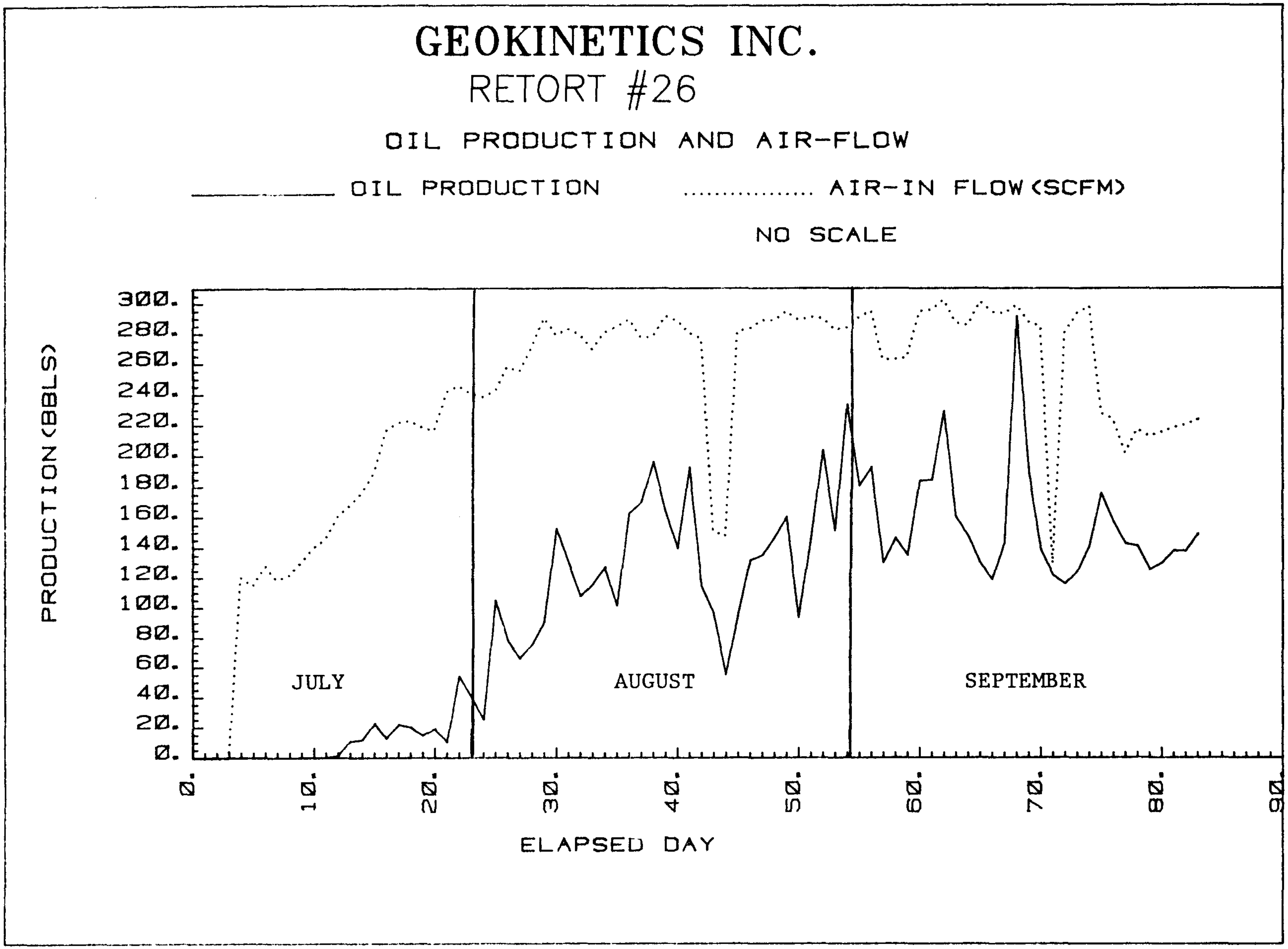


Figure 1. Retort #26 - Oil Production and Air Flow

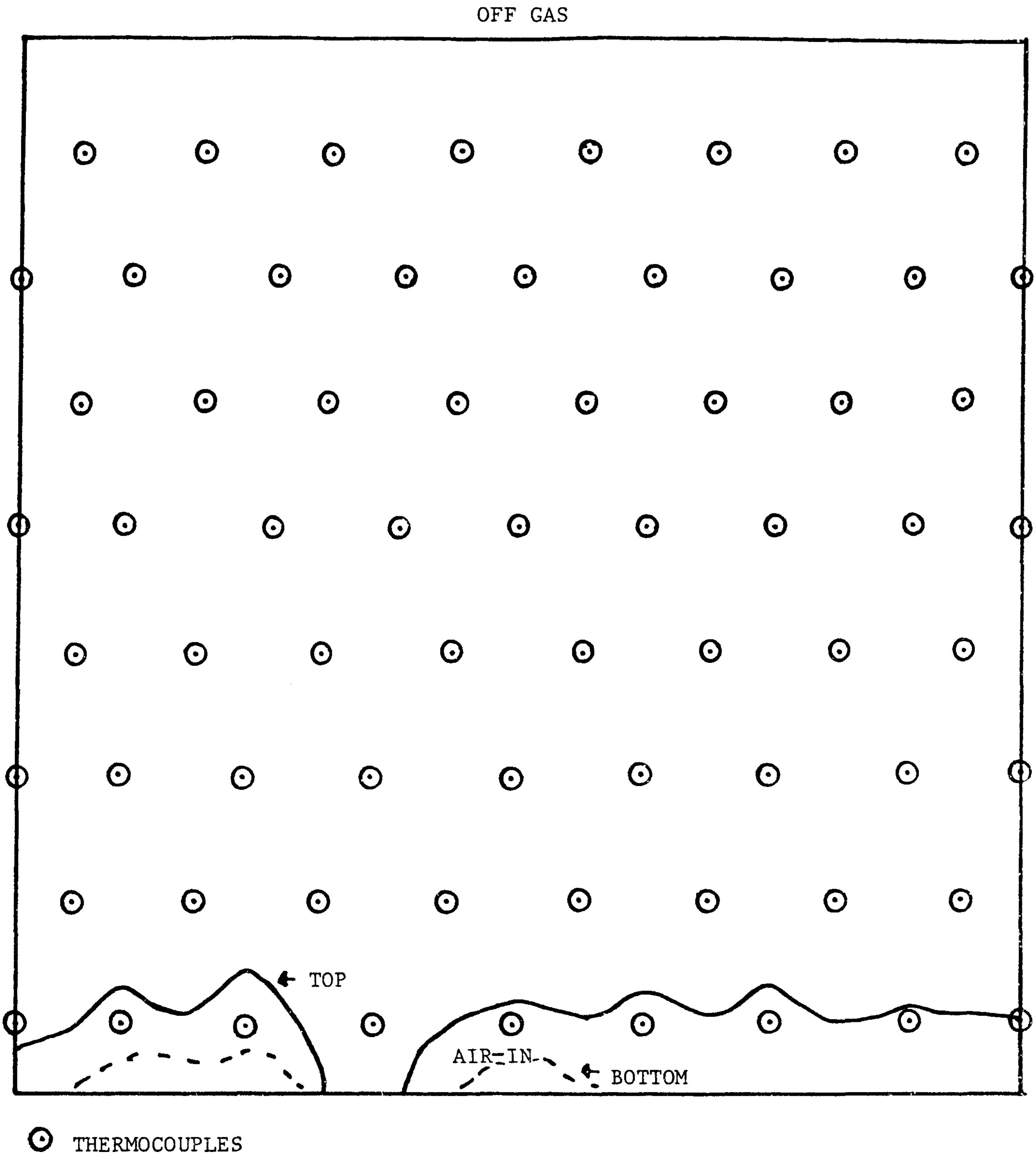


Figure 2. Retort #26 - Fire Front Location
800° Isotherms - End of July, 1982

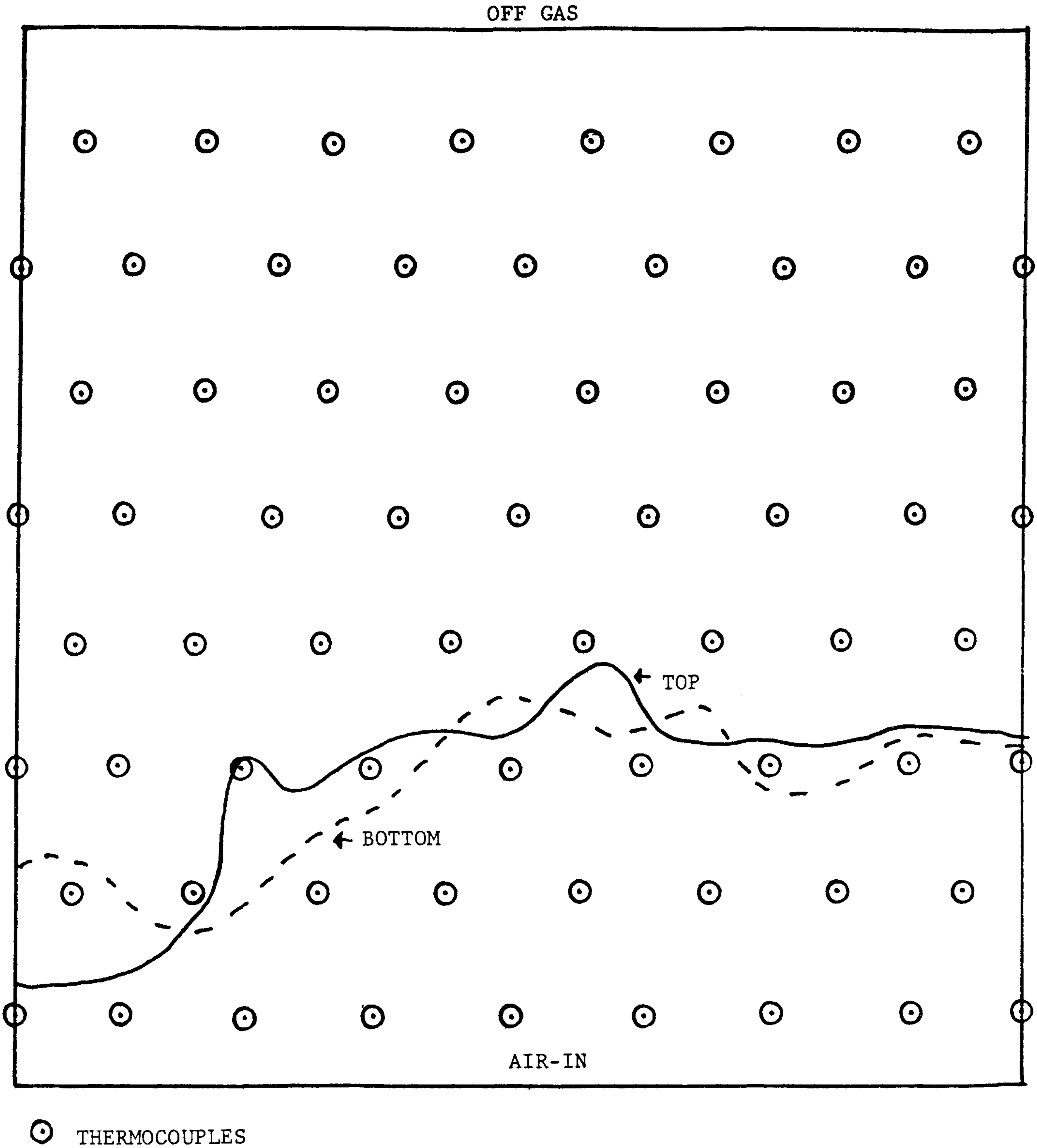


Figure 3. Retort #26 - Fire Front Location
800° Isotherms - End of August, 1982

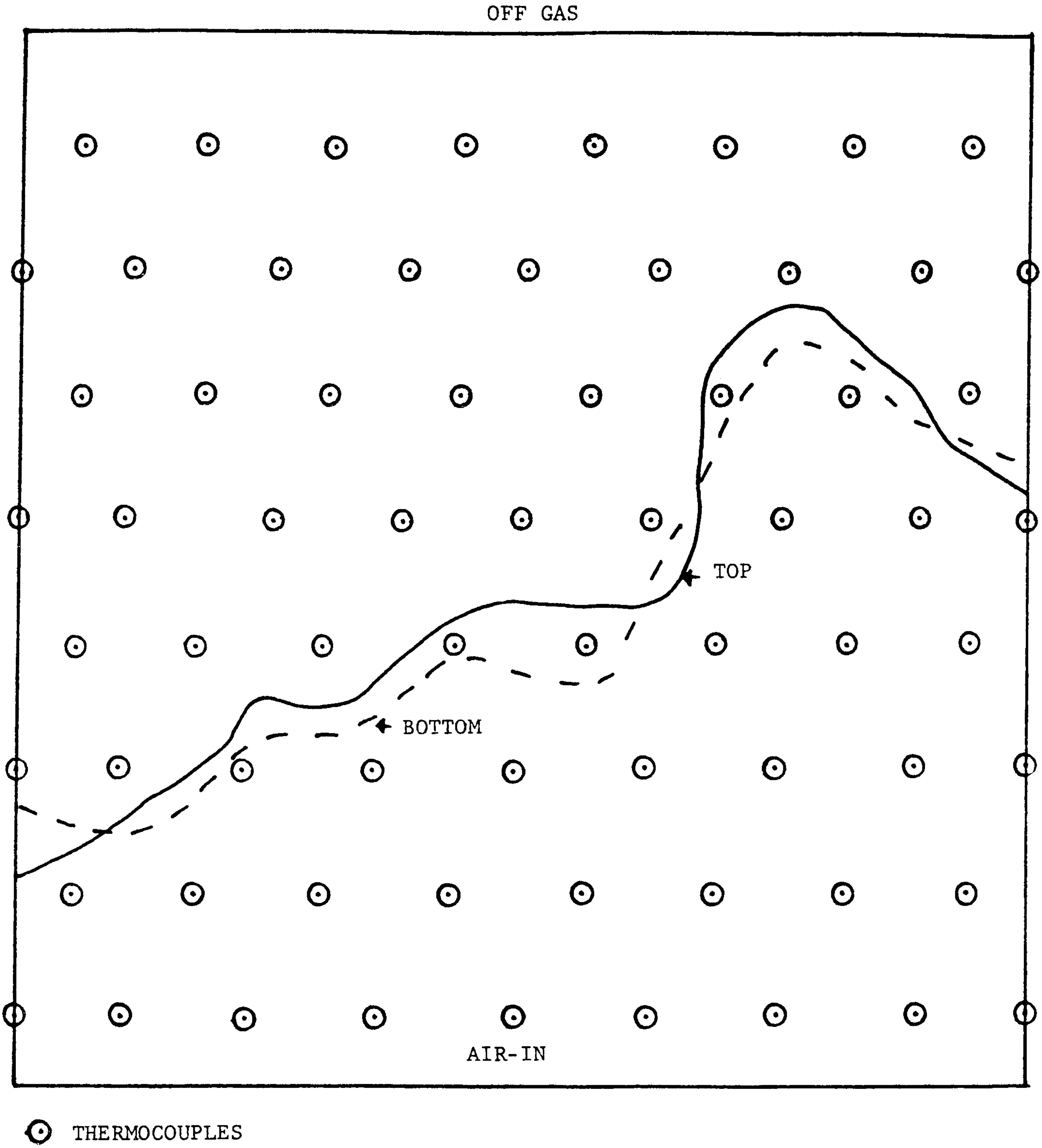


Figure 4. Retort #26 - Fire Front Location
800° Isotherms - End of September 1982

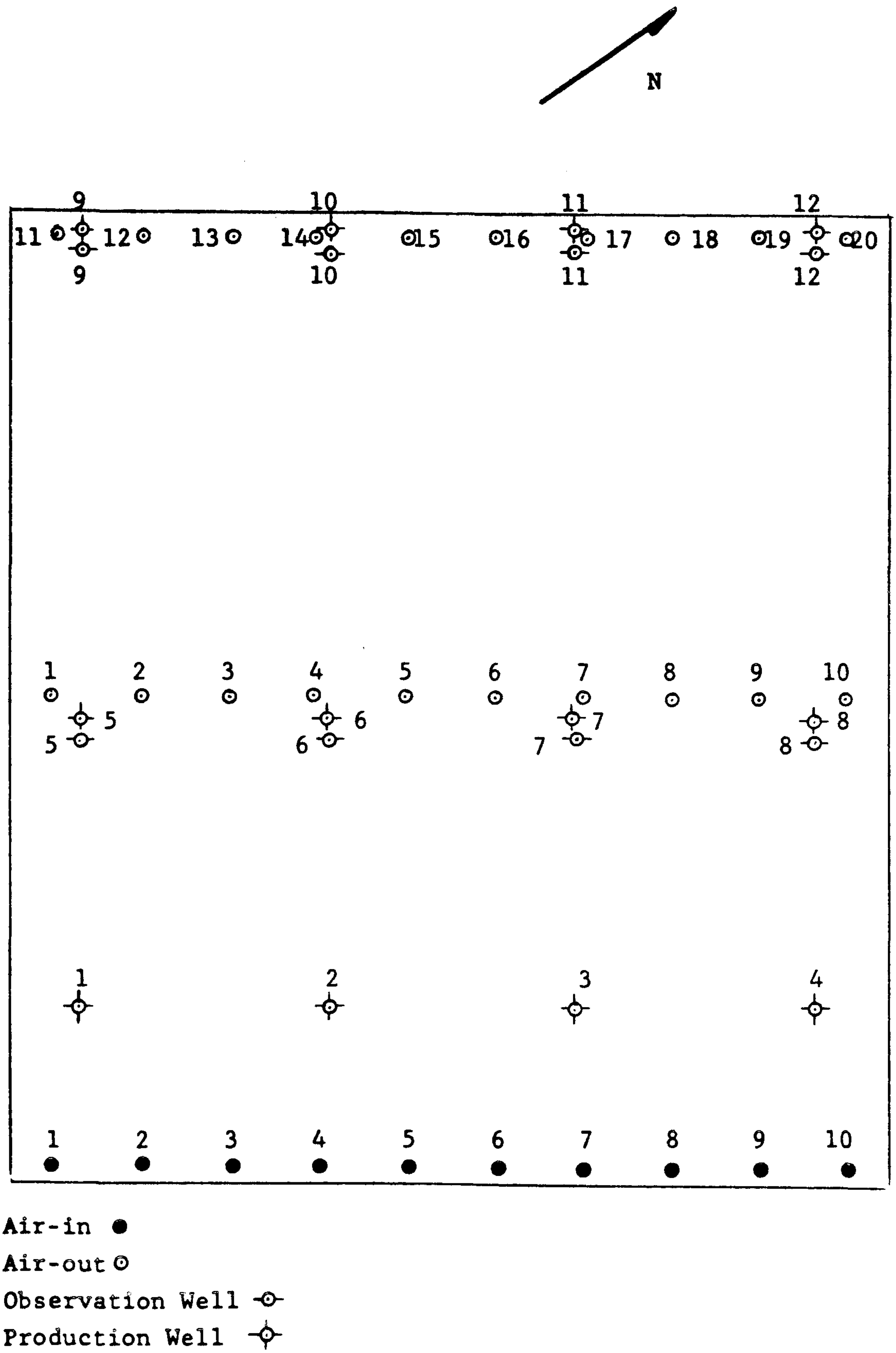
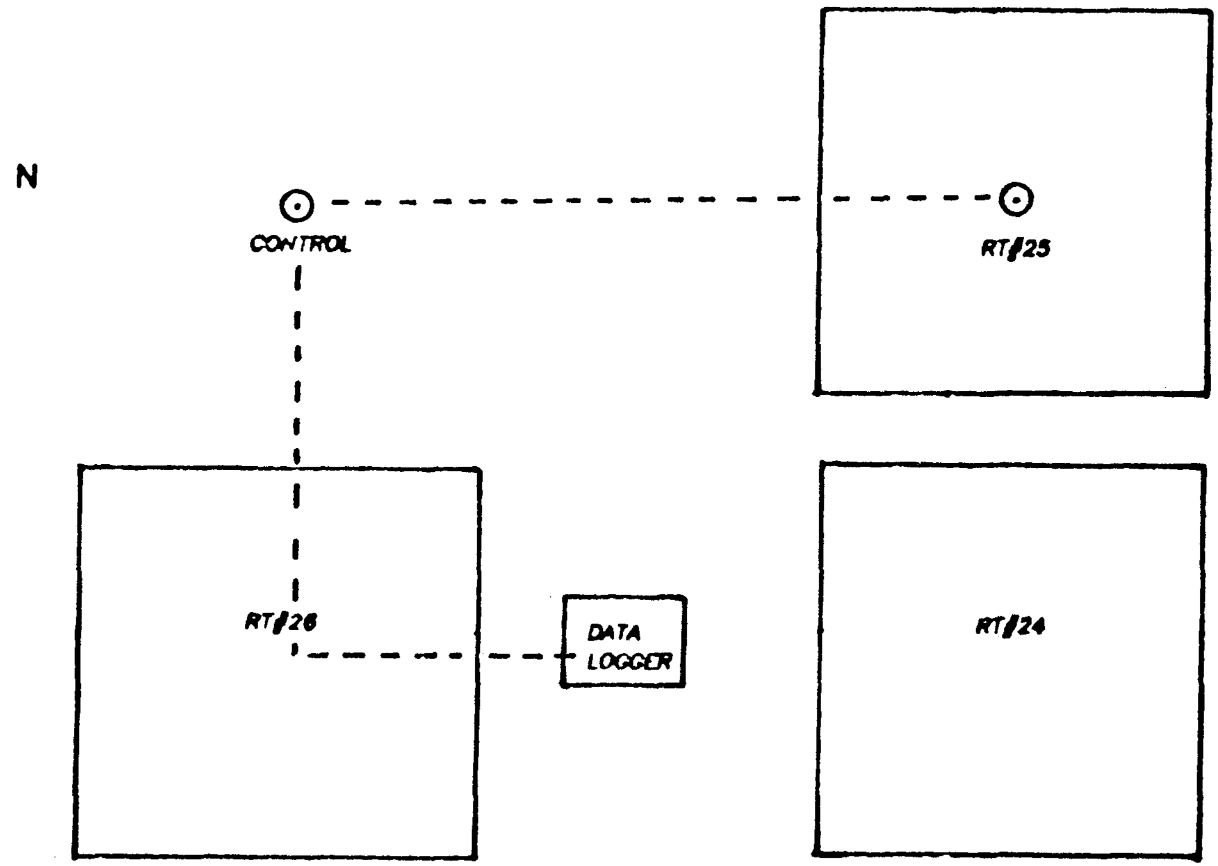


Figure 5 . Retort #27 - Process Wells



THERMOCOUPLE PROBES

EXTENSION WIRE

SCALE : NONE

Figure 6. Location of Temperature Sensors

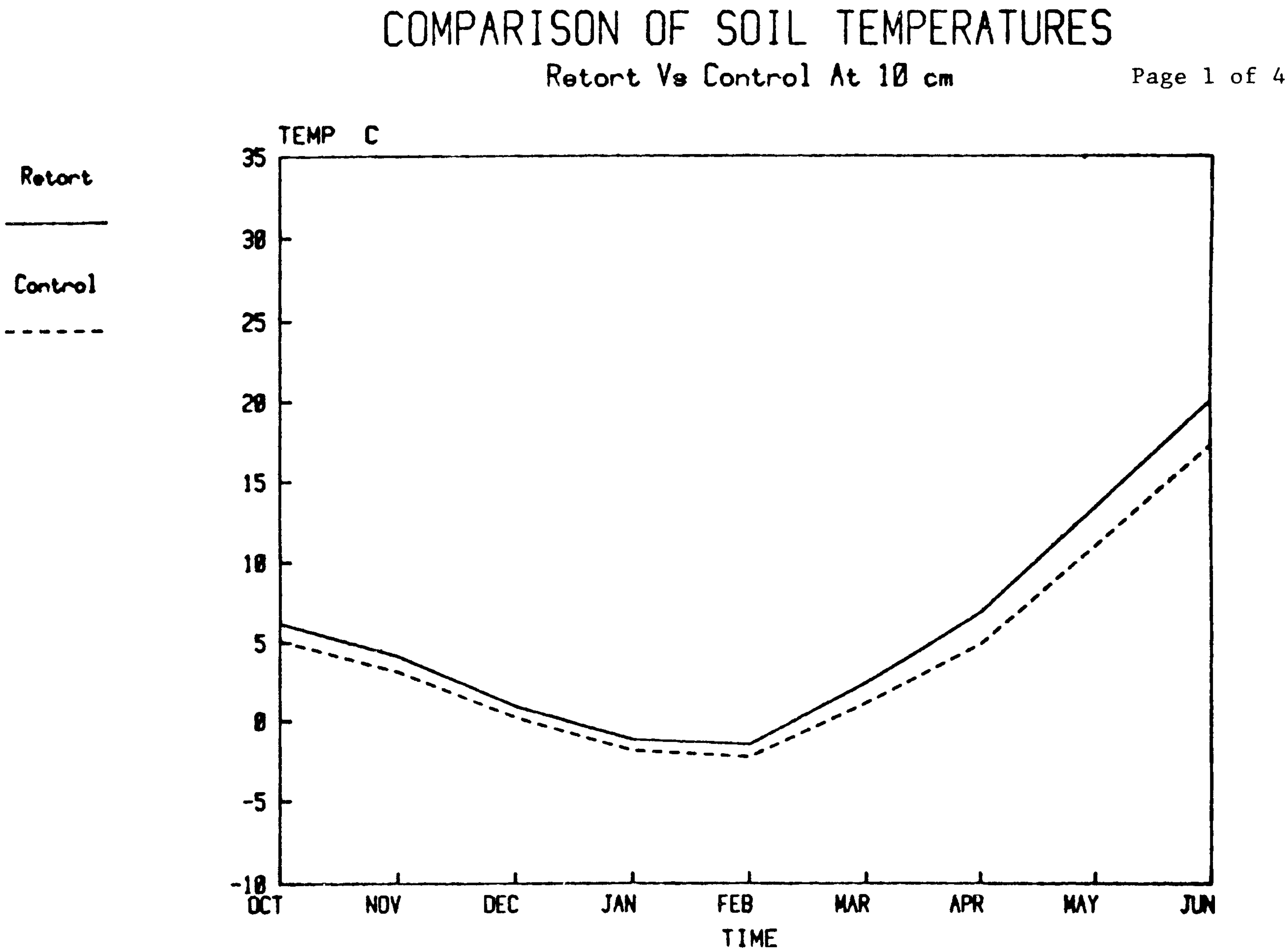


Figure 7a. Comparison of Retort #25 and Control Soil Temperatures at Recorded Depths Over time

COMPARISON OF SOIL TEMPERATURES

Retort Vs Control At 50 cm

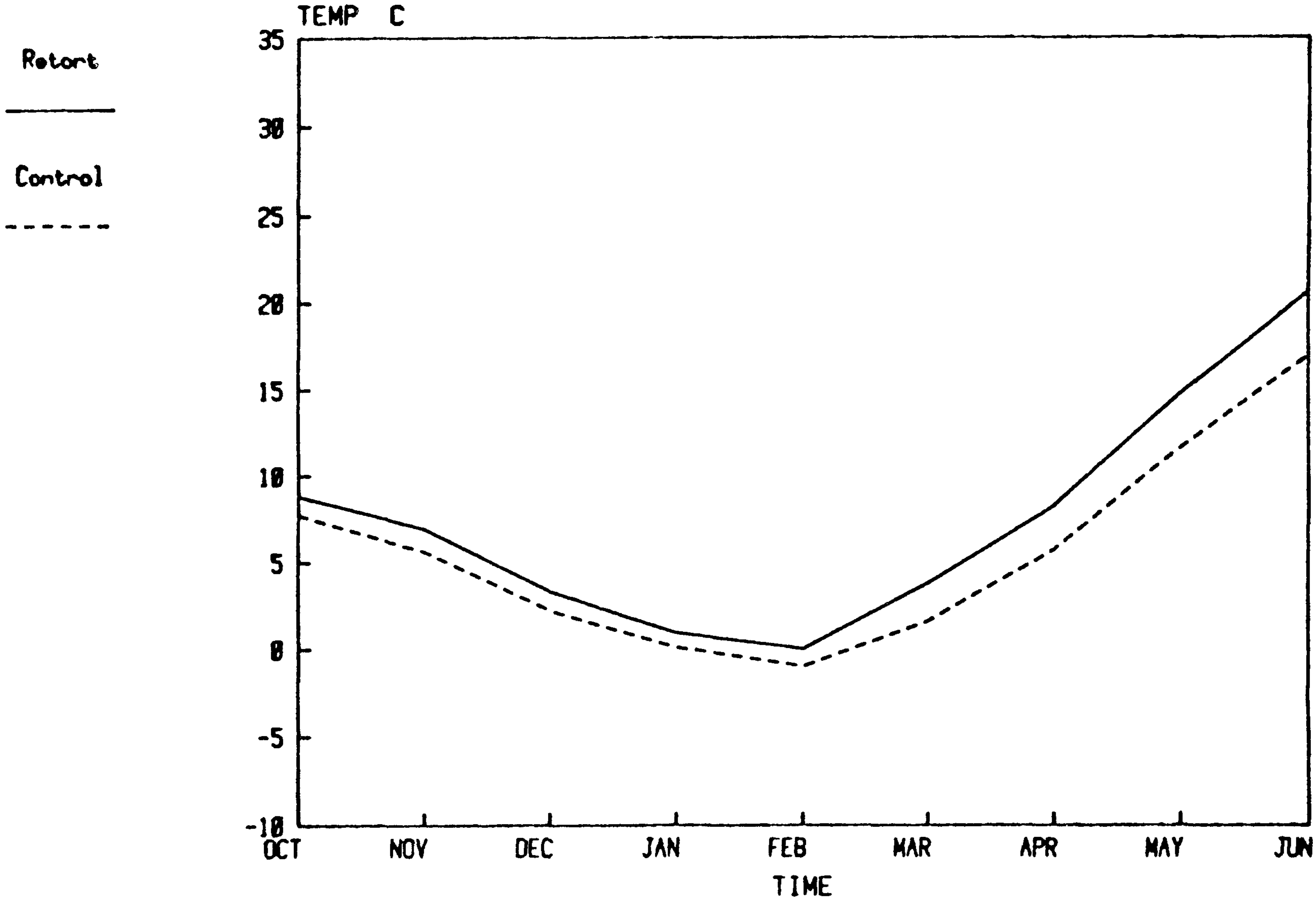


Figure 7b.

COMPARISON OF SOIL TEMPERATURES

Retort Vs Control At 100 cm

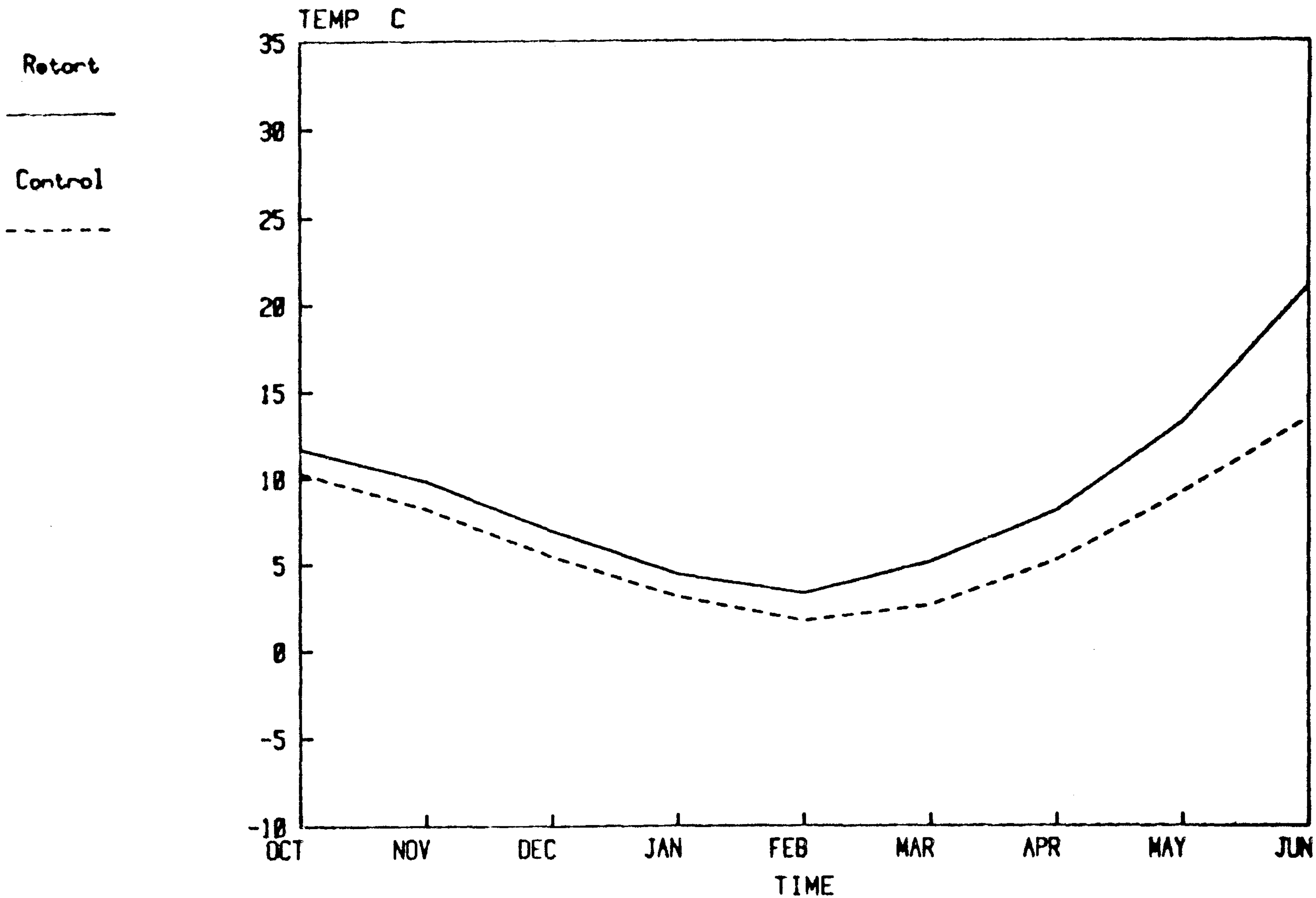


Figure 7c.

COMPARISON OF SOIL TEMPERATURES

Retort Vs Control At 150 cm

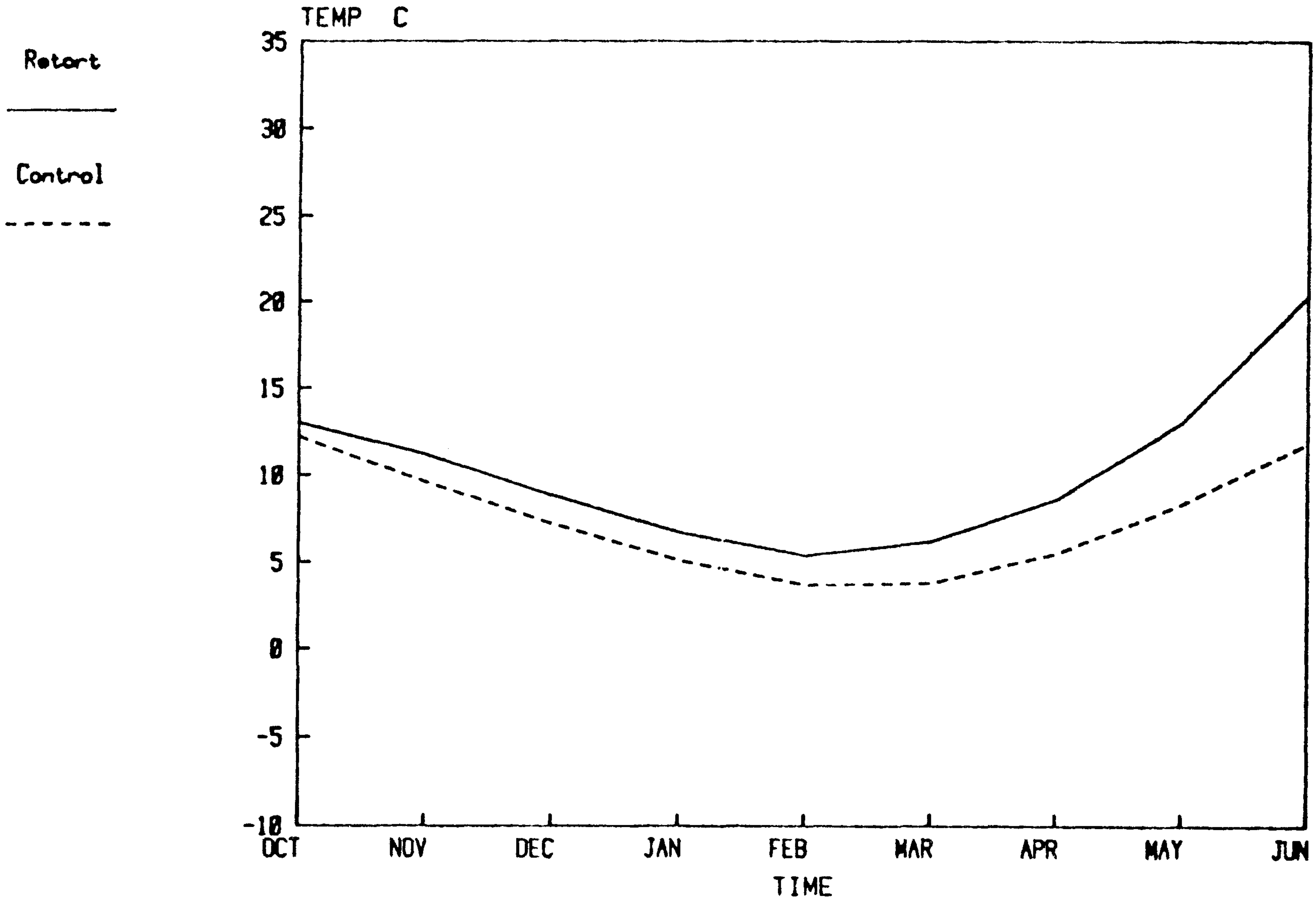


Figure 7d.

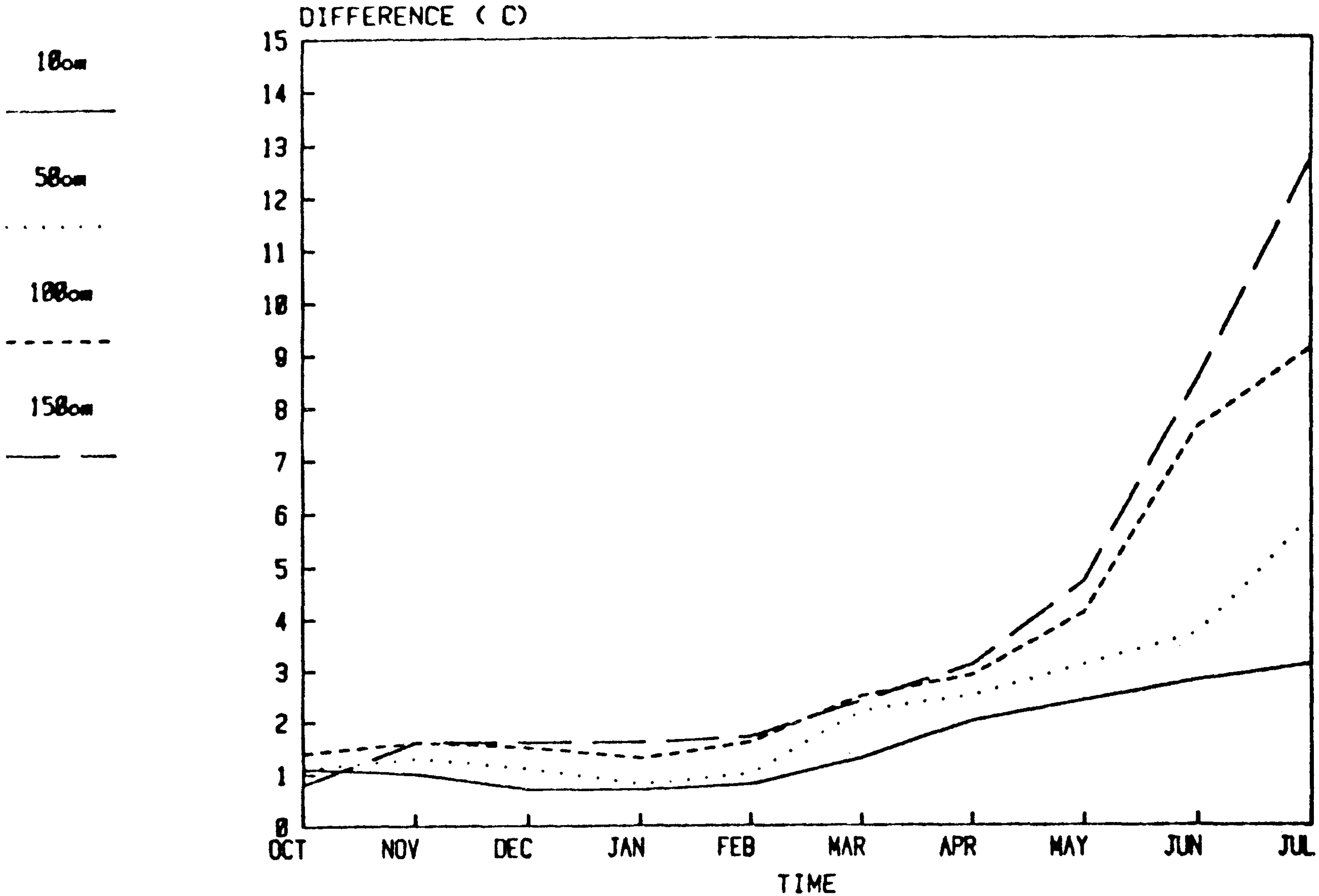


Figure 8. Differences in Soil Temperature Means Between Retort and Control Sites

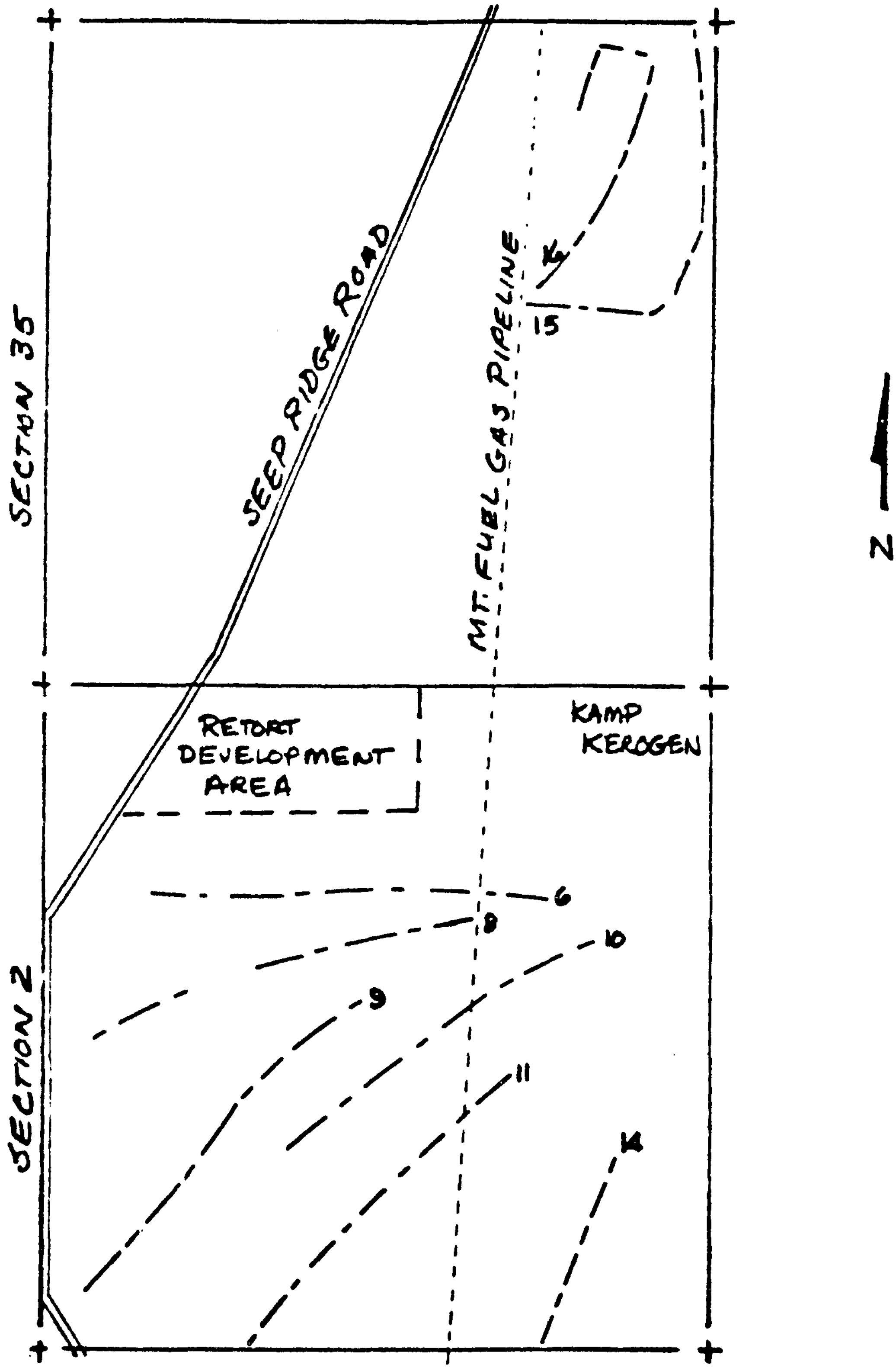


Figure 9. Locations of Pellet Transects

— - — PELLET TRANSECTS

0 1000' 2000'
SCALE

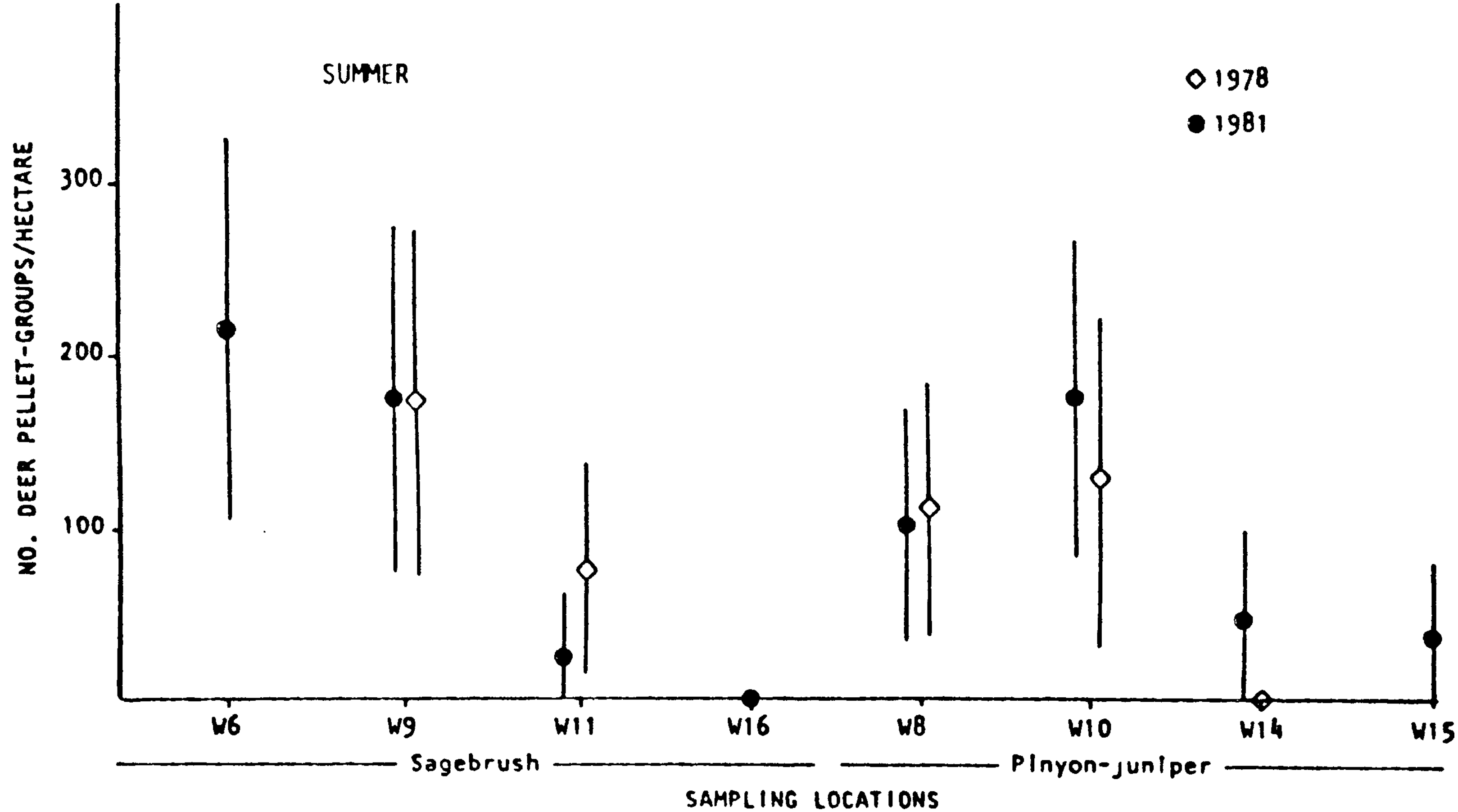


Figure 10. Mule deer pellet-group densities for two summer periods. Data are means ± 95 percent confidence intervals.

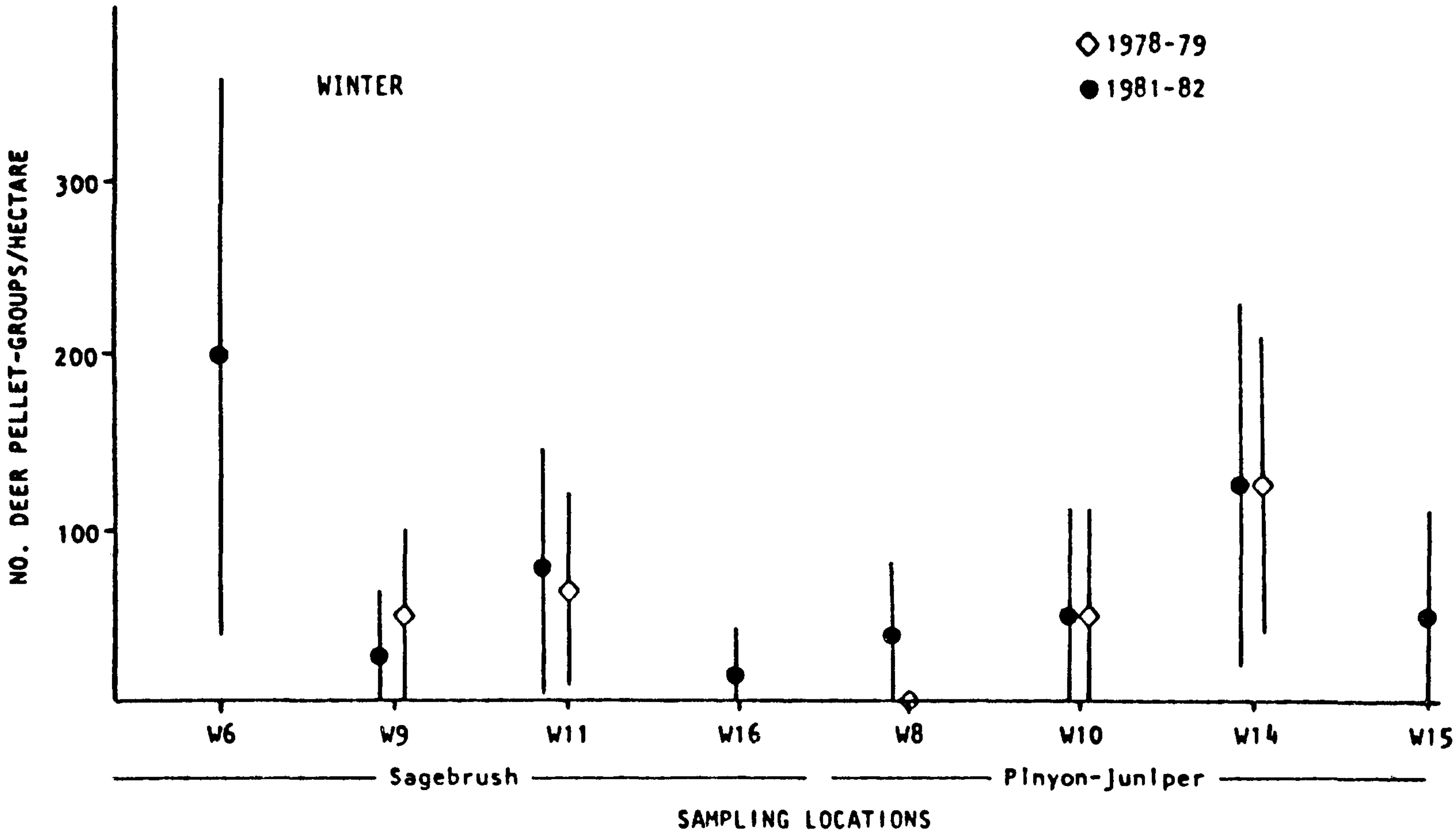


Figure 11.Mule deer pellet-group densities for two winter periods. Data are means ± 95 percent confidence intervals.

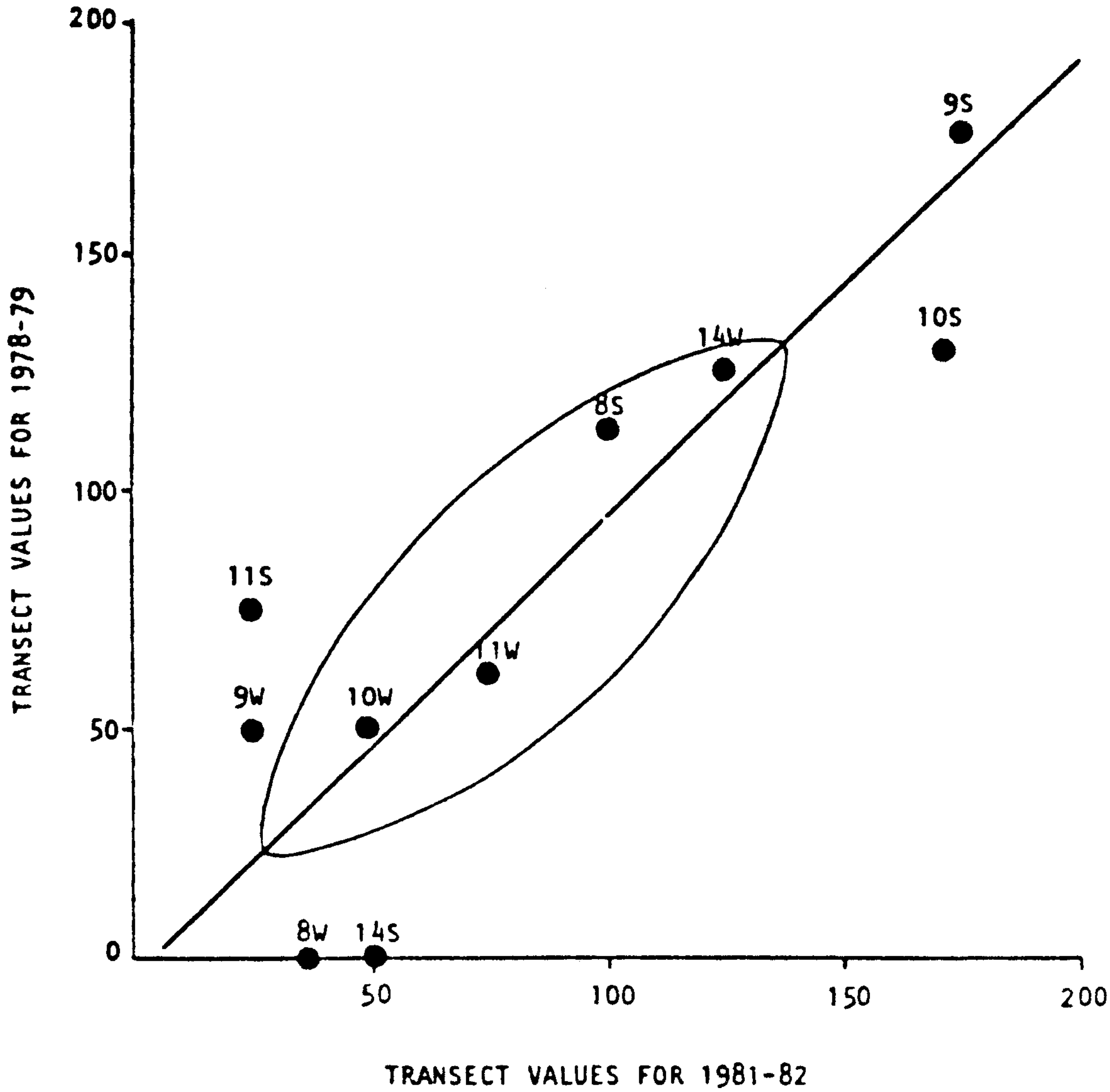


Figure 12. Between-year correlation of mule deer pellet-group counts. The points plotted are transect values—the number of pellet-groups per hectare for the same transect for the 2-year period. Transect location and season (S=summer; W=winter) is shown alongside the dots. The graph demonstrates a significant 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.

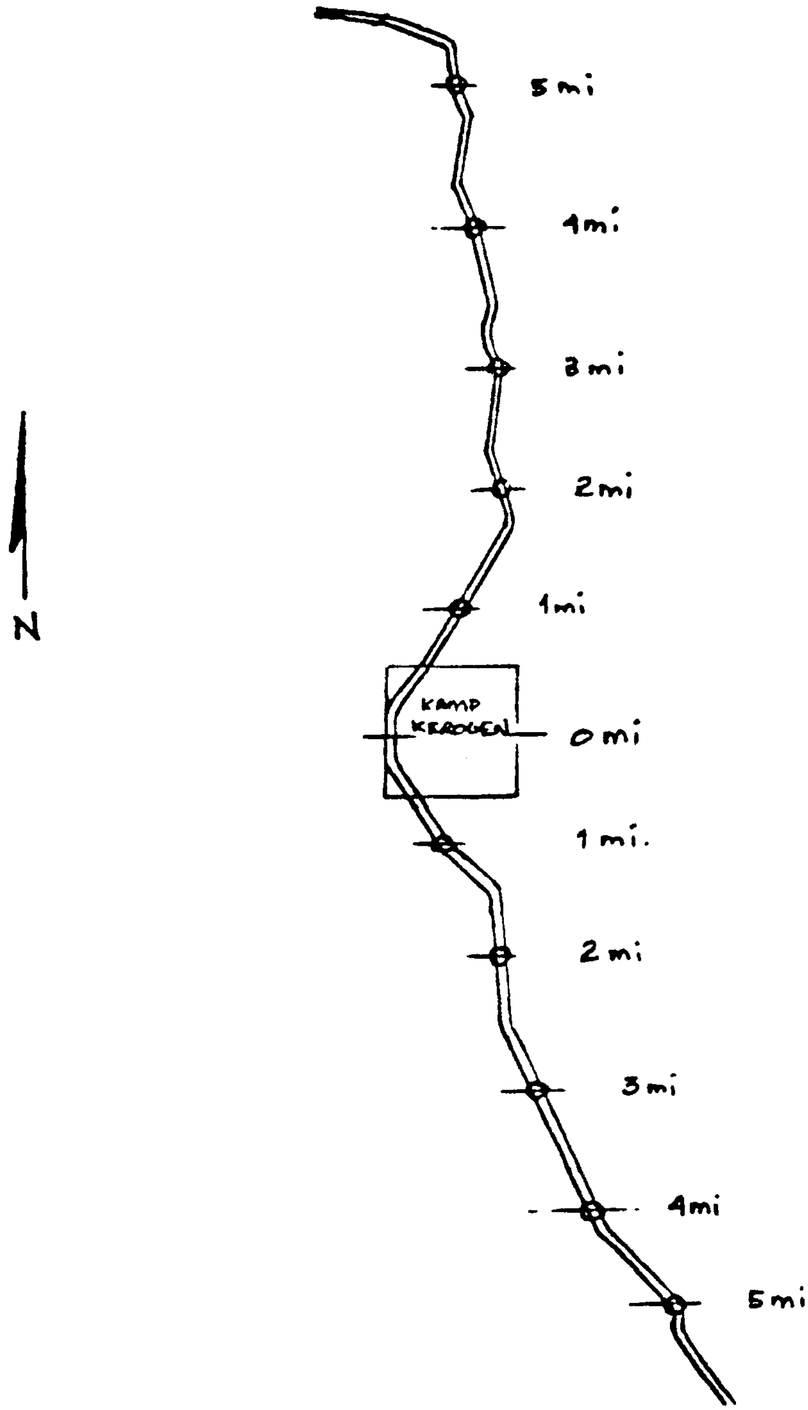


Figure 13. Road Count Route

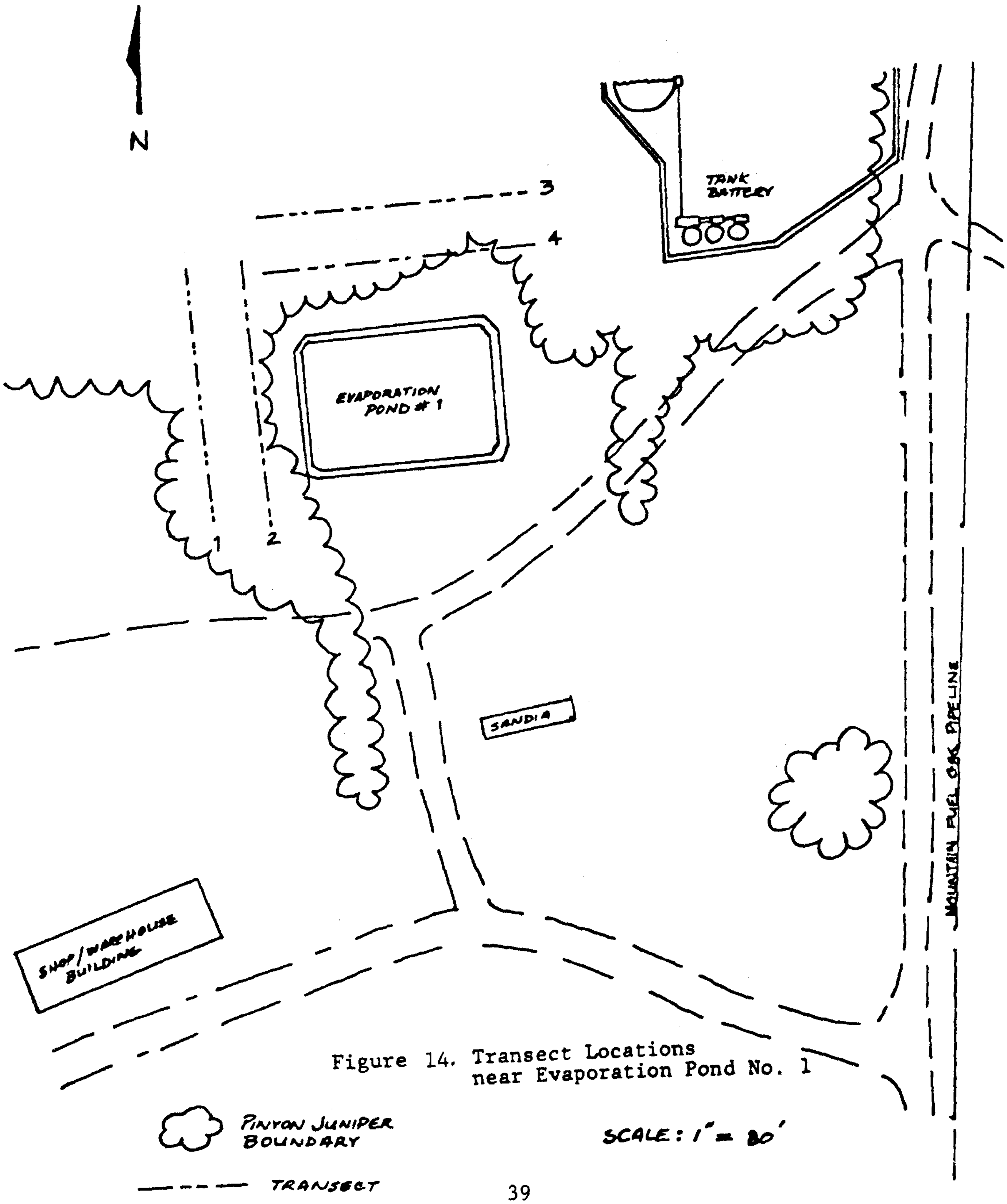


Figure 14. Transect Locations near Evaporation Pond No. 1

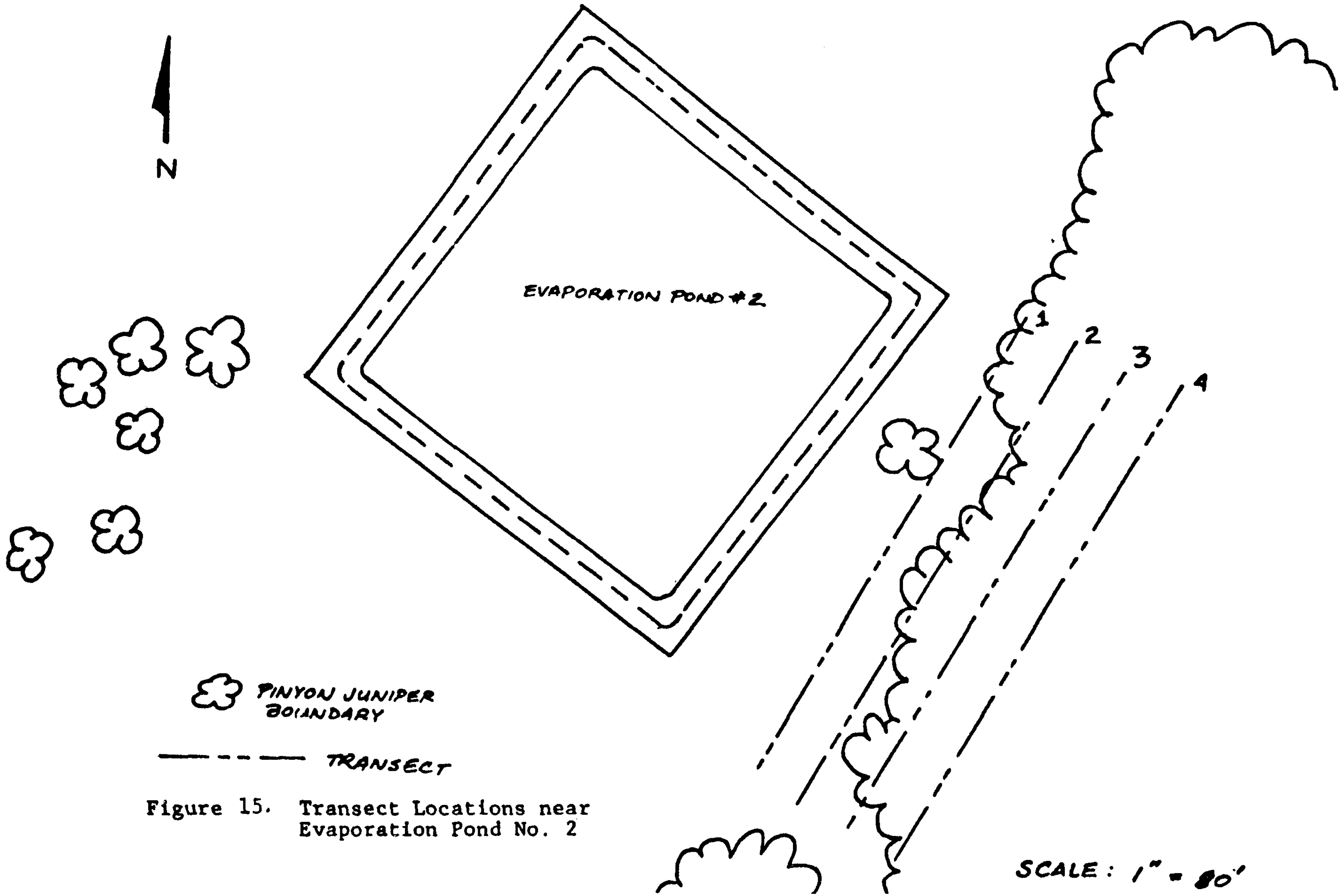


Figure 15. Transect Locations near Evaporation Pond No. 2

PERCENT SURVIVAL DISTRIBUTION OF PLANTED SPECIES
(RETORTS 10, 11, AND 18)

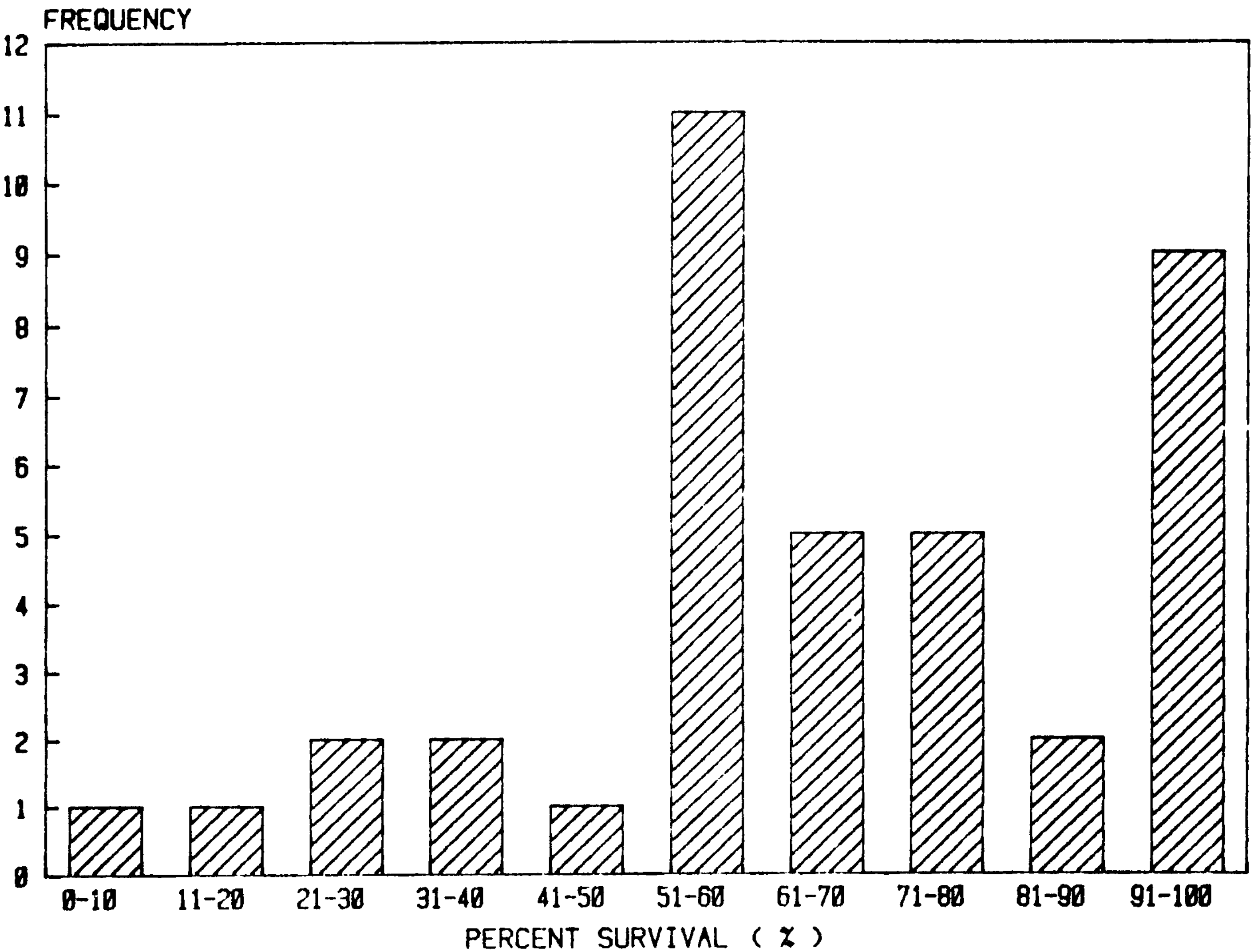


Figure 16

COMPARISON OF SPRING PRECIPITATION AMOUNTS (1982)
WITH LONG TERM RECORDS

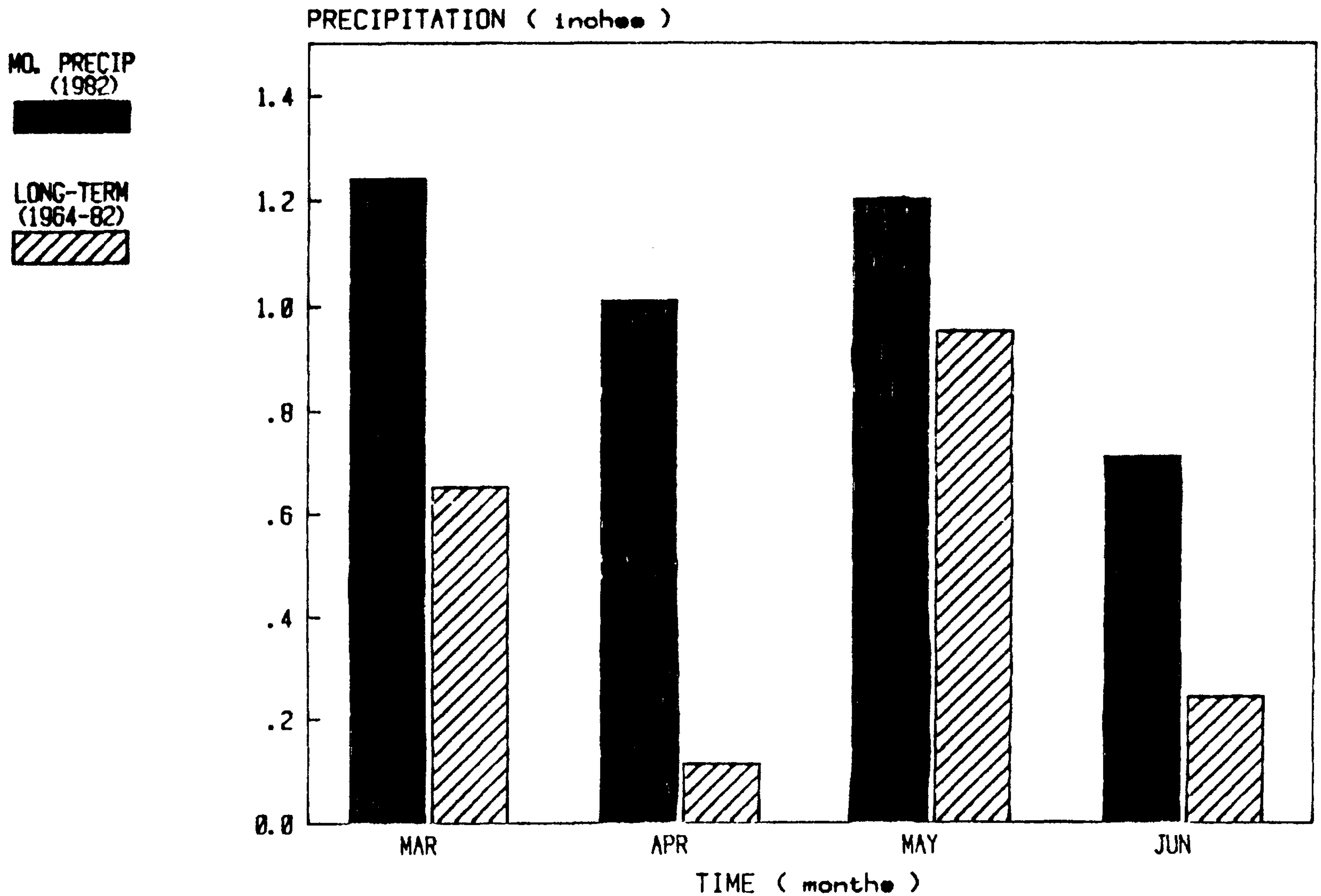


Figure 17

TABLE 1

Summary of Oil and Water Production

THIRD QUARTER - 1982

Retort #26

Oil Production

Month	Liquid	Mist	Total
*July	238.1	0.0 bbls	238.1 bbls
August	3,946.2 bbls	2.3 bbls	3,948.5 bbls
September	4,494.9 bbls	85.3 bbls	4,580.2 bbls
3-MONTH TOTAL	8,679.2 bbls	87.6 bbls	8,766.8 bbls

Average Oil Production

Month	Liquid	Mist	Total
*July	21.7 bbls/day	0.0 bbls/day	21.7 bbls/day
August	127.3 bbls/day	0.1 bbls/day	127.4 bbls/day
September	149.8 bbls/day	2.8 bbls/day	152.6 bbls/day
3-MONTH AVERAGE	99.6 bbls/day	.96 bbls/day	100.6 bbls/day

Water Production

Month	Total	Average/day
**July	901.2 bbls	50.1 bbls/day
August	4,001.2 bbls	129.1 bbls/day
September	4,568.0 bbls	152.3 bbls/day
3-MONTH AVERAGE	3,156.8 bbls	110.5 bbls/day

* Retort #26 produced oil for only an eleven day period during July.

**Water production began on July 13 and is based on an 18 day period.

TABLE 2

Oil Analysis/Production Oil - Retort #26

THIRD QUARTER - 1982

Date	Percent Oil Loss*		Percent Oil Yield
	Coked	Burned	
JULY	12.1	51.9	42.3
AUGUST	15.2	36.3	53.8
SEPTEMBER	15.8	36.0	54.3

* Percent oil loss to burning and coking are approximate figures. (% coked + % burned + % yield is approximately 100%)

TABLE 3

Retort #26 - Gas Analysis, 10-day Averages

THIRD QUARTER 1982

E.D.	NITROGEN	HYDROGEN	PROPANE	PROPENE	CARBONYL SULFIDE	ISOBUTANE	BUTANE	1-BUTENE	TRANS-BUTENE-2	CIS-BUTENE-2	1,3-BUTADIENE
1- 10	63.130	6.462	.121	.144	.007	.012	.032	.055	.008	.002	.018
11- 20	63.992	5.992	.173	.126	.008	.017	.040	.042	.006	.003	.007
21- 30	58.895	7.290	.204	.114	.005	.020	.051	.055	.010	.004	.003
31- 40	54.778	9.936	.272	.142	.006	.029	.058	.046	.007	.002	.002
41- 50	58.307	8.589	.165	.087	.004	.016	.040	.040	.006	.004	0.00
51- 60	59.286	7.576	.177	.094	.005	.017	.043	.042	.008	.004	.002
61- 70	58.615	8.069	.194	.109	.004	.019	.051	.049	.008	.005	.003
71- 80	62.960	7.122	.173	.078	.003	.017	.035	.034	.006	.003	.000
81- 84	62.182	7.927	.210	.087	.001	.014	.039	.033	.005	.004	0.00
Quarter Average	60.392	7.474	.181	.118	.006	.018	.043	.046	.007	.003	.006

E.D.	2 METHYLBUTANE	PENTANE	1-PENTENE	OXYGEN	METHANE	CARBON MONOXIDE	CARBON DIOXIDE	ETHENE	ETHANE	ISO-HEXANE	HEXANE	1-HEXENE
1- 10	.004	.000	.001	1.624	1.247	3.113	23.415	.353	.206	.009	.022	.001
11- 20	.004	.000	.005	5.219	1.117	2.807	19.958	.230	.239	.082	.012	0.00
21- 30	.006	.004	.010	2.389	1.422	5.787	23.287	.139	.260	.007	.034	.002
31- 40	.008	.004	.027	2.168	1.422	7.019	23.356	.218	.337	.062	.039	.014
41- 50	.006	.001	.010	3.864	1.134	6.068	21.306	.111	.218	.003	.014	.001
51- 60	.006	.002	.008	4.124	1.865	5.411	17.910	.155	.213	.010	.015	.002
61- 70	.007	.002	.013	5.532	1.284	6.387	18.944	.197	.296	.006	.020	.002
71- 80	.007	.001	.003	7.022	.890	4.446	16.546	.097	.216	.004	.016	.000
81- 84	.010	0.00	.009	6.200	.711	4.038	17.995	.147	.212	.001	.016	.000
Quarter Average	.006	.002	.009	3.929	1.285	4.889	20.712	.199	.246	.012	.021	.003

TABLE 4

Average Air-in, Air-out Flow Rates
and Total Air-in, Off gas Volume
for Retort #26 Process Gases

THIRD QUARTER - 1982

Month	Air Injection Rate	Off-Gas Flow Rate
	(in standard cubic feet/min)	
July	3840	4051
August	5583	6088
September	5128	6040
* Quarterly Average	5028	5625

Month	Total Volume Air Injected	Total Volume Off Gas
	(in million cubic feet)	
July	94	117
August	249	272
September	232	261
Quarterly Total	575	650

* Weighted averaged based on a 78 day air injection period.

TABLE 5

COMBUSTION GASES

RETORT #26

THIRD QUARTER
1982

E.D.	AVERAGE HEATING VALUE (BTU/SCF)	TOTAL BTU PRODUCED (MM BTU)	H_2S CONCENTRATION (ppm)	NH_3 CONCENTRATION (ppm)
	HIGH			
1-84	75.0	44,568.2	6,697.0	4,716.0

RETORT #26

E.D.	AVERAGE HEATING VALUE (BTU/SCF)	TOTAL BTU PRODUCED (MM BTU)	H_2S CONCENTRATION (ppm)	NH_3 CONCENTRATION (ppm)
	HIGH			
1-10	65.3	1,774.5	28.0	22.0
11-20	60.0	3,445.1	12.0	16.0
21-30	79.1	5,935.5	27.0	69.0
31-40	100.9	8,103.9	85.0	277.0
41-50	75.9	6,159.1	353.0	561.0
51-60	80.6	6,712.4	1,418.0	828.0
61-70	82.6	7,010.4	1,840.0	674.0
71-80	62.9	4,738.3	1,505.0	1,215.0
81-84	64.4	1,886.4	1,399.0	1,054.0
QUARTERLY AVERAGE	74.5	14,626.4	709.0	523.0

TABLE 6

Geokinetics Emissions Rates

THIRD QUARTER 1982

(all values in lbs/hr)

SOURCE	ACTUAL-AVERAGE	ACTUAL-PEAK	ALLOWABLE-PEAK
	SO_2	SO_2	SO_2
Retort #26			
JULY	1.30	2.40	135.30
AUGUST	18.80	78.20	135.30
SEPTEMBER	93.00	134.80	135.30
	NO_x	NO_x	NO_x
Retort #26			
JULY	0.6	2.10	45.10
AUGUST	16.0	44.7	45.10
SEPTEMBER	38.4	45.0	45.10
650 KW Generator			
JULY	NA	12.97	38.90
AUGUST	NA	28.01	38.90
SEPTEMBER	NA	29.2	38.90
	HYDROCARBONS	HYDROCARBONS	HYDROCARBONS
Retort #26			
ENTIRE QUARTER	BDL	BDL[a]	1.40
650 KW Gen.[b]			
JULY	NA	.50	1.50
AUGUST	NA	1.00	1.50
SEPTEMBER	NA	1.1	1.50
	PARTICULATES	PARTICULATES	PARTICULATES
Retort #26			
ENTIRE QUARTER	BDL	BDL	1.00
650 KW Gen.			
ENTIRE QUARTER	NA	NIL	NIL

SOURCE	ACTUAL-AVERAGE	ACTUAL-PEAK	ALLOWABLE-PEAK
	PARTICULATES	**PARTICULATES**	**PARTICULATES**
Access Roads[c] ENTIRE QUARTER	NA	1.00	1.00
	CARBON MONOXIDE	**CARBON MONOXIDE**	**CARBON MONOXIDE**
Retort #26 ENTIRE QUARTER	BDL	BDL	NIL
650 KW Gen.			
JULY	NA	.97	2.90
AUGUST	NA	2.09	2.90
SEPTEMBER	NA	2.2	2.90

a) Below Detection Limit

b) Emissions from the exhaust of the electrical generator are not directly measured - maximum values given are based on manufacturer's emission factors for selected operating conditions.

c) Fugitive dust emissions from all unpaved access roads are not monitored - maximum value given is based on EPA emission factor for unpaved roads.

TABLE 7

TOTAL MONTHLY EMISSIONS

THIRD QUARTER 1982

(all values in tons)

	SO_2	NO_x	HC	Particulates	CO
JULY					
Total Emissions	0.5	0.2	0.2	0.4	0.4
Total Allowable	50.3	16.8	1.1	0.4	1.1
AUGUST					
Total Emissions	7.0	6.0	0.4	0.4	0.8
Total Allowable	50.3	31.2	1.1	0.4	1.1
SEPTEMBER					
Total Emissions	33.5	24.3	0.4	<0.7	0.8
Total Allowable	48.7	30.2	1.0	0.7	1.0
QUARTER					
Total Emissions	41.0	30.5	1.0	<1.5	2.0
Total Allowable	149.3	78.2	3.2	1.5	3.2

TABLE 8

Process Gas Data

RETORT #26

(Pre Combustion in Afterburner)

(all values in % volume)

	JULY	AUGUST	SEPTEMBER	QUARTERLY MEAN
N_2	63.56	57.49	60.44	60.50
O_2	3.42	2.65	6.35	4.14
CO_2	21.69	22.50	17.82	20.67
CO	2.96	6.54	5.71	5.01
Methane	1.18	1.30	0.05	0.84
NMHC*	0.95	0.06	6.81	0.91
H_2S	0.004	0.032	0.167	0.068
NH_3	0.002	0.038	0.095	0.045

*Non Methane Hydrocarbons

TABLE 9

Stack Gas Data

RETORT #26

(Post Combustion in Afterburner)

MONTH	N_2 (% vol)	O_2	CO_2	HC*	CO (ppm)	TSP** (ug/m^3)
JULY	77.8	7.9	14.3	BDL	BDL	<3
AUGUST	78.2	7.6	14.2	BDL	BDL	300
SEPTEMBER	73.44	4.75	21.79	BDL	BDL	16,500
QUARTERLY MEAN	76.48	10.13	16.76	BDL	BDL	5,600

Note: A minimum of two samples are collected each month as required by the PSD permit.

BDL = Below Detection Limit

* Hydrocarbons
** Total suspended particulates

TABLE 10 -- AVERAGE MONTHLY SOIL TEMPERATURES (^{o}C) FOR RT #25 AND CONTROL SITES

	10 cm		50 cm		100 cm		150 cm	
	Rt.	C	Rt.	C	Rt.	C	Rt.	C
OCT	6.2	5.1	8 8	7.7	11.7	10.3	13.0	12.2
NOV	4.1	3.1	6.9	5.6	9.8	8.2	11.2	9.6
DEC	0.9	0.2	3.3	2.2	6.9	5.4	8.8	7.2
JAN	-1.2	-1.9	0.9	0.1	4.4	3.1	6.7	5.1
FEB	-1.5	-2.3	0.0	-1.0	3.3	1.7	5.4	3.7
MAR	2.4	1.1	3.8	1.6	5.1	2.6	6.2	3.8
APR	6.9	4.9	8.3	5.8	8.1	5.2	8.6	5.5
MAY	13.4	11.0	14.7	11.6	13.2	9.1	13.0	8.3
JUN	20.1	17.3	20.7	17.0	21.0	13.4	20.3	11.8

TABLE 11 -- RESULTS OF t-TEST FOR DIFFERENCES BETWEEN SOIL TEMPERATURES AT RECORDED DEPTHS ON RT #25 AND CONTROL SITES

OCTOBER - FEBRUARY

DEPTH	t-STATISTIC	CRITICAL t-VALUE [1]
10	0.41	2.35
50	0.45	2.35
100	0.66	2.35
150	0.70	2.35

MARCH - JUNE

DEPTH	t-STATISTIC	CRITICAL t-VALUE
10	0.59	2.92
50	0.58	2.92
100	1.01	2.92
150	1.32	2.92

[1] t-Test was perfomed at the 0.05 level

Ho: $U_1 - U_2 = 0$

Ha: $U_1 - U_2 > 0$

TABLE 12

Pellet transect results of species other than mule deer. 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									
	Elk		Cottontail		Coyote		Pocket Gopher		Cattle	
Transect	S*	W	S	W	S	W	S	W	S	W
Pinyon-Juniper										
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
Sagebrush										
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 13

Results of road counts conducted along a 10-mile route.

	Number of Animals Observed				
	Deer	Elk	Grouse	Deer Road-kills	Raptors
1981					
JUN 3				1	
28					
JUL 10					
29					
AUG 9					
25					
SEP 7					
28					1 rough-legged hawk(?)
OCT 19					1 red-tailed hawk
28	5				
NOV 12					
24					
DEC 14					
29					
1982					
JAN 12	5				
26	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					1 bald eagle
27					

TABLE 14

RETORT PLANT SURVIVAL AND GROWTH MEASUREMENTS - FALL 1982

RETORT NO. 18

SPECIES (abbrev.)	NUMBER PLANTED	MEAN SURVIVAL (%)	MEAN HT. (cm)	MEAN DIA. (cm)
Arfr	40	70	9.5	11.8
Arno	40	60	6.0	4.1
Artr v.	39	69	8.6	6.9
Atca[1]	40	95	18.1	23.2
Atca[2]	40	60	6.3	9.0
Atca x Atcu	40	60	13.0	15.8
Befr	40	33	2.9	3.2
Chna	40	53	10.8	11.7
Cune	40	0	--	--
Epne	40	65	7.3	9.3
Erco	37	57	8.0	10.2
Lemo	40	53	19.8	20.3
Pest	37	51	5.8	7.1
Pied	40	40	3.1	2.9
Rhtr	40	45	16.6	7.1
Spam	40	55	7.5	8.1

RETORT NO. 10

SPECIES (abbrev.)	NUMBER PLANTED	MEAN SURVIVAL (%)	MEAN HT. (cm)	MEAN DIA. (cm)
Agsp x Agre	30	93	17.8	8.0
Bogr	30	100	8.7	4.7
Cost	40	73	6.7	3.4
Hija	30	77	8.8	4.8
Orhy	30	97	17.3	5.7
Putr	40	28	2.4	2.7
Sihy	30	100	11.4	5.8
Spai	30	93	21.3	7.7

TABLE 15

RETORT PLANT SURVIVAL AND
GROWTH MEASUREMENTS - FALL 1982

RETORT NO. 11

SPECIES (abbrev.)	NUMBER PLANTED	MEAN SURVIVAL (%)	MEAN HT. (cm)	MEAN DIA. (cm)
Acmi	25	60	13.7	12.4
Atbo	25	100	13.0	20.0
Atid	27	92	9.0	14.4
Atob [1]	25	80	6.0	6.9
Atob [2]	25	60	11.1	11.9
Attr	25	76	12.3	20.0
Camo	25	84	7.4	11.6
Cela	23	83	11.1	12.4
Cepa	25	80	9.2	9.6
Hebo	25	52	4.9	6.4
Kopr	25	100	19.1	17.0
Orhy	25	64	13.6	5.8
Pepa	25	20	23.4	12.4
Poco	25	68	8.6	7.6
Swsa	25	28	16.4	14.6

TABLE 16

RETORT #25 PROCESS WATER QUALITY
Based On n=5 Unless Otherwise Noted
All Concentrations Expressed As Mg/l,
Unless Otherwise Noted

PARAMETER	n-SIZE	MEAN	STD. DEV.	MIN.	MAX.
Sodium		4,886	2,483	2,924	9,036
Potassium		103.5	55.3	65.3	196.0
Magnesium		4.5	1.7	3.6	6.2
Calcium		7.8	3.1	4.5	7.4
Strontium		1.6	0.8	0.9	2.8
Fluoride		24.1	9.5	8.3	33.0
Chloride		944	325	510	1,328
Bromide		4	2	2	5
Phosphate		8	4	3	10
Nitrate		118	72	5	419
Sulfate		393	178	159	616
Bicarbonate		14,584	2,989	11,660	19,099
Carbonate		2,747	789	1,723	3,616
Antimony		0.39	0.22	0.20	0.47
Arsenic	4	27.11	9.15	15.31	37,63
Boron		354	109	223	522
Iron	4	1.35	0.71	0.48	2.05
Lead		0.072	0.049	0.05	0.16
Silicon		6.2	1.2	5.1	8.1
Molybdenum		1.85	1.32	0.74	4.13
Selenium	4	0.015	0.003	0.013	0.019
Oil & Grease		287	79	200	400
Phenols		58	20	27	80
TOC	4	1,816	190	1,533	2,063
TKN	4	4,352	896	3,515	5,480
BOD	4	2,140	454	1,512	2,598
Ammonia		1,036	294	640	1,439
Ammonium		2,674	608	1,760	3,360
Cyanide		73.5	87.0	20.2	227.0
Sulfide	3	150	74	65	197
Thiocyanate		303	114	178	432
Thiosulfate		2,137	744	1,281	3,081
Alkalinity		16,535	2,622	12,430	19,568
COD		7,355	2,938	2,410	9,565
TIC	4	2,465	342	2,155	2,821
Conductivity umhos·cm^{-1}		18,620	1,526	16,800	20,900
pH units		9.08	0.16	8.92	9.27
TDS		16,117	6,809	9,857	27,100
TSS	4	122.8	87.3	32.3	208.7

TABLE 17 COMPARISON OF GEOKINETICS RETORT WATER QUALITY ANALYSIS AMONG RESULTS FROM GEOKINETICS AND AN OUTSIDE LABORATORY

Mean Values In Mg/l Unless Otherwise Noted

PARAMETER	GEOKINETICS RT. #25	OTHER [1]	MONSANTO [2]
Sodium	4,886	9,392	3,030
Potassium	103.5	121.4	281
Magnesium	4.5	17.49	3.4
Calcium	7.8	32.6	4.43
Strontium	1.6	0.002	0.20
Fluoride	24.1	35.2	1.8
Chloride	944	3,016	2,057
Bromide	4	0.18	
Phosphate	8	2.1	1.6
Nitrate	118	34.2	
Sulfate	393	609	
Bicarbonate	14,584	17,174	12,800
Carbonate	2,747	2,825	3,800
Antimony	0.39	0.01	
Arsenic	27.11	2.55	9.23
Boron	354	60.6	107
Iron	1.35	13.99	1.59
Lead	0.07	0.64	0.34
Silicon	6.2	17.95	0.62
Molybdenum	1.85	11.91	1.19
Selenium	0.02	0.22	0.07
Phenols	58	11.56	
TOC	1,816		
TKN	4,352		1,120
BOD	2,140		
Ammonia	1,036	1,270	2,590
Ammonium	2,674		
Cyanide	73.5	13.31	0.004
Sulfide	150	447	
Thiocyanate	303		
Thiosulfate	2,137		
Alkalinity	16,535	17,836	16,600
COD	7,355	3,682	
TIC	2,465		
Conductivity umhos·cm $^{-1}$	18,620	34,036	
pH units	9.08	8.56	
TDS	16,117	22,145	25,684
TSS	122.8		322

[1] Environmental Assessment, Geokinetics Inc. Oil Shale Research Project, Uintah County, Utah D.O.E. 1979.

[2] Oil Shale Wastewater Analysis And Characteristics. Monsanto Research Corporation 1981.

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