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

Quarterly Report for the Period January-March 1981

By
David L. Hutchinson

May 1981
Date Published

Work Performed Under Contract No. FC20-78LC10787

Geokinetics Inc.
Concord, California

U. S. DEPARTMENT OF ENERGY

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INVESTIGATION OF THE GEOKINETICS
HORIZONTAL IN SITU OIL SHALE
RETORTING PROCESS

QUARTERLY REPORT
JANUARY, FEBRUARY, MARCH 1981

by
DAVID L. HUTCHINSON

GEOKINETICS INC.
280 Buchanan Field Road
Concord, CA 94520

Date Published - May 1981

PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY
Under Cooperative Agreement #DE-FC20-78LC10787

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION.	1
SUMMARY	2
SITE PREPARATION.	4
RETORT FRAGMENTATION.	4
RE-ENTRY DRILLING	5
RETORT PROCESS FACILITIES	5
RETORT BURN	8
OIL PRODUCTION AND HANDLING	9
POST-BLAST AND POST-BURN EXAMINATIONS	10
SEPARATE EXPERIMENTS.	10
ENVIRONMENTAL RESEARCH.	10
ANALYTICAL LABORATORY	15
KAMP KEROGEN FACILITIES	16
SUPPORT ACTIVITIES.	16
GENERAL AND ADMINISTRATIVE.	17
SECOND QUARTER 1981 FORECAST.	17

LIST OF FIGURES

	<u>Page</u>
FIGURE 1 - GEOKINETICS INC. FIELD SITE.	20
FIGURE 2 - RETORT #25 - RE-ENTRY AIR, PRODUCTION AND OBSERVATION WELL LOCATIONS	21
FIGURE 3 - RETORT #23 - WATER MONITORING WELL LOCATIONS . .	22
FIGURE 4 - RETORT #23 - SURFACE FACILITIES LAYOUT (SANDIA). .	23
FIGURE 5 - RETORT #23 - RE-ENTRY WELL LOCATIONS	24
FIGURE 6 - RETORT #24 - RE-ENTRY AIR, PRODUCTION AND OBSERVATION WELL LOCATIONS	25
FIGURE 7 - RETORT #24 - SURFACE FACILITIES LAYOUT	26
FIGURE 8 - RETORT #24 - THERMOCOUPLE WELL LOCATIONS	27
FIGURE 9 - RETORT #24 - OIL PRODUCTION - FIRST QUARTER 1981	28
FIGURE 10 - RETORT #16, #17, & #18 - POST-BURN CORE HOLE LOCATIONS	29
FIGURE 11 - NATIVE GROUNDWATER SAMPLING WELL LOCATIONS . . .	30
FIGURE 12 - RETORT #24 - WATER MONITORING WELL LOCATIONS . .	31
FIGURE 13 - LOCATION OF METEOROLOGICAL TOWERS.	32
FIGURE 14 - REVEGETATION TEST AREAS.	33

APPENDICES

	<u>PAGE</u>
APPENDIX A - PROGRESS REPORT - FOREST SERVICE REVEGETATION STUDY.	A-1
APPENDIX B - IRRIGATION EXPERIMENTS WITH PRODUCED WATERS FROM THE RETORTING OF OIL SHALE.	B-1

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.

1981 FIRST QUARTER SUMMARY

Retort #23 has been heavily instrumented by Sandia National Laboratories. We expect this instrumentation to give valuable data relative to the in situ combustion processes. Retort #23 was ignited on March 16, 1981. The retort is relatively small, measuring 100 feet long by 50 feet wide by 24 feet thick. The charcoal point ignition technique was used at both of the air injection wells. Ignition points expanded to produce a burn front with vertical distribution. Gas analysis and thermocouple data indicated that the combustion front was moving into the retort zone as expected. By the end of the quarter the burn front was approaching the first row of thermocouples, located 15 feet downstream of the air injection wells. Small amounts of oil were evident in the product emulsion. The production of meaningful quantities of shale oil from Retort #23 is expected to begin in April.

A total of 6,588 barrels of shale oil have been recovered from Retort #24 to date. Approximately 6,057 barrels of oil were recovered during the quarter, an average of 65 barrels per day. Channeling of the Retort #24 fire front along the north and south edges of the retort became evident in February. Air injection flows were reduced in efforts to control the fire front; this resulted in a significant decrease in the oil recovery rate. Steady improvement in the oil production rate followed the implementation of increased air injection and off gas flow rates after a damaged off gas vacuum blower was replaced in March.

Approximately 4,909 barrels of shale oil were shipped by tanker truck to the WESRECO refinery in Salt Lake City, Utah, during the quarter. A shipment of 511 barrels of shale oil was made to the Sun Oil Company for research purposes.

Drilling of re-entry process and instrumentation wells on Retort #25 was completed. A post-burn core sampling program for Retort #18 was developed and implemented. Eight post-burn core holes were drilled, with depths ranging from 45 feet to 62.5 feet. Two post-blast core holes were drilled on Retort #13. As expected, very little breakage was observed in those post-blast core holes. Retort #13 will be burned in 1981 to develop techniques for recovering shale oil from a low-void retort.

Designs for the water and sewage disposal systems for the new trailer camp were approved by health officials. Trenches for sewer and gas lines were constructed and sewer pipe was installed and bedded. Fabrication of the natural gas line was nearly 80 percent complete by the end of the quarter. Excavation of a trench for the water lines was underway. Most of the trailers in the present camp will be relocated to the new site, just north of

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the existing site. This move is necessary to bring Kamp Kerogen into compliance with Utah health regulations. Preparations for the installation of new laboratory and office buildings began during the quarter.

Project Manager Jim Lekas outlined Geokinetics' research progress in a presentation at the DOE/LETC-sponsored Fourth Annual Oil Shale Conversion Symposium. Several other staff members also attended the symposium in Denver.

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STATUS OF MAJOR TASKS AND SIGNIFICANT ACCOMPLISHMENTS

SITE PREPARATION:

The site for the new trailer camp was cleared in February. Survey markers for rods and utility lines (water, sewer, electrical and natural gas) were staked in place. Holes for the septic tanks were excavated and two cement septic tanks were moved into place. Trenches for sewer and gas lines were completed and the sewer line was installed and bedded. Gas line installation was nearly complete by the end of the quarter. Actual sewage line and gas line locations were determined by survey and included on a one inch = 40 feet scale development plan map.

Locations for three additional production wells on Retort #25 were staked for drilling. The wells are located closer to the air injection wells than previously designed production wells on the retort. Eight instrumentation wells were also staked in January for drilling on Retort #25. Actual collar locations and elevations for Retort #25 re-entry process and instrument wells were determined by survey and included on a plan map. The surface of Retort #25 was then cleared in preparation for the construction and assembly of retort process equipment. Retort locations are shown in Figure 1. Retort #25 re-entry air, production and observation well locations are shown in Figure 2.

Locations for fourteen water monitoring wells surrounding Retort #23 were staked for drilling. The locations of the water monitoring wells are shown in Figure 3. Grid points for the Retort #24 fugitive emissions monitoring program were also staked.

The electrical cable from power generation facilities to Retort #23 was bedded and buried through rocky areas. A right-of-way was cleared in preparation for excavation of a trench for the natural gas line which will service Retorts #23, #24, and #25. A control survey from the current retort development area to the new trailer camp site was conducted.

An updated geologic map of the project site was developed. The map includes structure contours of the top of the Mahogany oil shale zone and thickness contours of the overburden.

RETORT FRAGMENTATION:

Geokinetics worked with blasting consultants and contacted explosives manufacturers to plan for blasting experiments related to Retort #26. Suggestions were received from IRECO Chemicals and a meeting was held to finalize designs for the blast experiments.

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The Chicago Pneumatic C-700 drill rig was received at the field site and underwent shakedown testing prior to an initial servicing by the supplier. ICM representatives visited the project site to explain operation and maintenance procedures to the Geokinetics drillers and maintenance supervisor. Drilling accessories for the rig were designed during the quarter.

RE-ENTRY DRILLING:

Re-entry drilling on Retort #25 continued during January and February and was completed in March. Nine production wells, six observation wells, sixty-three instrument wells and two test wells were drilled during the quarter by a contract driller. In addition, eight air injection wells and sixteen off gas recovery wells were previously drilled into the retort zone. Retort #25 process wells consist of 8-inch diameter holes equipped with 6-5/8-inch outside diameter casing. Retort #25 instrument wells are 4-inch diameter holes with casings installed to the total depth of each well. Each instrument well is equipped with a 1-inch diameter steel casing; thirty instrument wells are also equipped with a 1/2-inch diameter casing which is perforated in the bottom stand (21 feet) of pipe. The 1-inch diameter casings will be used as thermowells; four 1/16-inch type K thermocouples will be installed in each thermowell prior to retort ignition for the purpose of monitoring fire front configuration and movement during the retort burn. The perforated casings will serve as retort pressure monitoring pipes and a source of retort gas for analysis purposes. Retort #25 re-entry air, production (PW) and observation (OB) well locations are shown in Figure 2. Re-entry drilling performed during the quarter is summarized in Table 1.

RETORT PROCESS FACILITIES

The fabrication and installation of process equipment for Retort #23 were completed during the quarter. Most of the equipment from Retort #18 was reworked for use on Retort #23. This included 10-inch diameter pipe, air-in and off gas manifolds, mist elimination equipment and the heat exchanger for cooling recycle gases. The Retort #24 afterburner was reworked and installed on Retort #23; refractory lining and Gunitite insulation were replaced and installed inside the vessel where necessary. Skids for the product separation tank were fabricated and the tank was moved into place on the retort. Plumbing of oil lines was completed and overflow alarms were installed. A 150-barrel capacity tank was received from DOE and installed as a product separation tank on Retort #23. The Retort #23 surface facilities layout is shown in Figure 4.

Electrical power to Retort #23 was activated after Sandia National Laboratories instrumentation monitoring trailers were wired in. Instrumentation was then wired into the monitoring

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Table 1

RETORT #25 RE-ENTRY DRILLING

<u>Well Designation</u>	<u>Depth (Feet)</u>	<u>Well Designation</u>	<u>Depth (Feet)</u>	<u>Well Designation</u>	<u>Depth (Feet)</u>
PW-4	112	TC-12	81	TC-38	103
PW-5	110	TC-13	79	TC-39	103
PW-6	107	TC-14	79	TC-40	100
PW-7	122	TC-15	79	TC-41	102
PW-8	120	TC-16	79	TC-42	99
PW-9	117	TC-17	86	TC-43	99
Test #1	115	TC-18	85	TC-44	98
Test #2	111	TC-19	83	TC-45	105
OB-1	112	TC-20	84	TC-46	104
OB-2	112	TC-21	82	TC-47	103
OB-3	108	TC-22	82	TC-48	110
OB-4	123	TC-23	81	TC-49	103
OB-5	120	TC-24	94	TC-50	102
OB-6	118	TC-25	95	TC-51	99
TC-1	80	TC-26	94	TC-18.5	84
TC-2	80	TC-27	94	TC-24.5	94
TC-3	77	TC-28	92	TC-30.5	98
TC-4	79	TC-29	92	TC-31.5	99
TC-5	78	TC-30	90	TC-11	80
TC-6	75	TC-31	98	TC-21	80
TC-7	76	TC-32	99	TC-31	77
TC-8	75	TC-33	97	TC-41	78
TC-9	83	TC-35	95	TC-51	78
TC-10	83	TC-36	95	TC-61	76
TC-11	81	TC-37	94	TC-71	75
				TC-81	74

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trailers by Sandia personnel. Retort #23 production well pumps were activated to dewater the retort for pre-ignition air flow tests. Air injection well AI-1 on Retort #23 was sprung with 2.5 pounds of 75 percent gel dynamite. The purpose of the shot was to remove mud from fractures in the well, thereby increasing the air flow rate into the well. Air flow was increased from 450 scfm at 4 psi to 1,752 scfm at <1 psi. Air flow tests were later conducted at air injection and off gas recovery wells. Maximum air flows of 1,752 scfm and 1,700 scfm were measured at air-in wells AI-1 and AI-2, respectively. Maximum flows of 1,097 scfm and 993 scfm were measured at the two off gas wells. Later, well stimulation was successfully carried out on Retort #23 to improve vacuum capability. Off gas well AO-2 was sprung with 10 pounds of 40 percent gelatin dynamite in March. The explosive was detonated in the well casing at a point corresponding to the medium rubble zone, according to the drill log. Permeability in AO-2 was increased significantly as a result of the shot. Static pressure dropped from greater than two pounds to less than one-half pound. Retort #23 re-entry well locations are shown in Figure 5.

Retort #24 production well pumping performance improved significantly after heavy-duty oil field pumps were installed in January. Oil production rates increased and lower fluid levels within the retort were noted. Retort #24 production well pumps were serviced routinely throughout the quarter. Pumps were permanently removed from production wells PW-1 and PW-2 in February because of the proximity of the approaching fire front. Production pumps were installed in observation wells OB-5 and OB-6 to enable their use as production wells. Retort #24 re-entry air, production and observation well locations are shown in Figure 6.

Installation of a new air-out blower for Retort #24 was completed in January. This blower was damaged early in March. The 300 horsepower Sutorbilt 400S blower was installed to replace the damaged unit. The afterburner vessel intended for Retort #25 was received during the quarter. Stainless steel hangers for securing Gunitite insulation were welded inside the afterburner. Gunitite was then applied to the vessel, which was mounted on skids to enable moving it to retorts. Due to a failure of the Retort #24 afterburner, the vessel intended for Retort #25 was installed on Retort #24. Walkways and safety rails were installed on Retort #24 during the quarter. The Retort #24 surface facilities layout is shown in Figure 7.

Construction of a retort wastewater line from the tank battery to the new 1.5-acre evaporation pond began in January. The new evaporation pond was put into use in February; a tanker truck was used to transport retort water from the tank battery to the evaporation pond. Unusually dry winter weather conditions at the field site made it necessary to apply retort water to roads as a dust control measure.

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Engineering and final design of process equipment for Retort #25 began in March. Fabrication of equipment and procurement of materials for the retort began.

RETORT BURN

The burn of Retort #23 was initiated on March 16, 1981. The charcoal point ignition routine was used at both of the air injection wells. Retort #23 measures 100 feet long by 50 feet wide by 24 feet thick. Sandia National Laboratories instrumentation was very useful in monitoring thermocouple data on a 30-minute basis and process conditions every 10 minutes. Ignition points expanded to produce a burn front which moved into the retort zone as expected. By the end of the quarter the Retort #23 fire front was approaching the first row of thermocouple wells, about 15 feet downstream of the air injection wells. Temperatures exceeding 800° Fahrenheit were recorded at several monitoring points in the first row of thermocouples. Retort #23 thermocouple well locations are shown in Figure 5.

The burn of Retort #24 continued into its second month in January; the retort had burned for 120 days at the end of the quarter. In January, thermocouple data indicated a channeling of the Retort #24 fire front. A channel or tongue on the north edge of the retort was leading the rest of the fire front by approximately 15 feet. Immediate action was taken to curtail the irregular fire front: off gas recovery wells AO-7, AO-8, AO-15 and AO-16 were closed and the air injection rate at air-in wells AI-7 and AI-8 was decreased. As a result, the process gas was forced to flow towards the center of the retort, thereby directing the fire front in that direction. This was successful in slowing the advance rate of the north tongue.

Using thermocouple data, a channel soon became evident on the south edge of Retort #24. Retort #24 thermocouple well locations are shown in Figure 8. It was surmised that in spite of the process control modifications, the path of least resistance for the process gas was along the edges of the retort. When the southern leading edge was detected, the entire fire front had moved down the retort bed such that the leading edges were past the center row of off gas wells. Corrective measures were taken immediately; the far set of off gas wells were all closed, leaving only off gas wells AO-3, AO-4, AO-5, and AO-6 open. Air-in flows at air-in wells AI-1 and AI-2 were reduced to approximately 124 scfm. Total air-in flow was decreased to approximately 2,500 scfm, while total off gas flow was about 3,000 scfm. On February 27, off gas wells AO-4 and AO-5 were shut due to the proximity of the fire front. Well casing in AO-3 and AO-6 were perforated to increase the flow of off gas out of the wells. By the end of February, most movement of both the north and south tongues down the length of the retort had been stalled as a result of control efforts and the unique air flow schedule.

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The operation of Retort #24 was generally smooth during March, except for the loss of off gas vacuum capability while the damaged off gas recovery blower was replaced. During that time off gas wells A0-11, A0-12 and A0-13 were opened in addition to A0-3 and A0-6 at mid-retort. Off gas recovery vacuum capability was restored on March 7. Efforts to control movement and configuration of the Retort #24 fire front through air injection and off gas flow rate variations continued through the end of the quarter. Thermocouple data indicated that the fire front had stabilized in an irregular configuration, with the main part of the fire front at the fourth row of thermocouples and leading edges along both sides of the retort. On March 31, the Retort #24 air injection rate was increased to 3,000 scfm and the off gas recovery rate was increased to 3,500 scfm.

Retort #24 gas analysis data summary tabulations have been included in each monthly report during the quarter.

OIL PRODUCTION AND HANDLING

Retort #23 was ignited on March 16, 1981, and burned for two weeks during the quarter. Oil production in that time was insignificant. Small amounts of oil were observed in the product emulsion. Recovery of measurable quantities of shale oil from Retort #23 is expected to begin early in the next quarter. The Sandia instrumentation is working well, and is already yielding valuable data.

A cumulative total of 6,588 barrels of shale oil has been recovered from Retort #24 to date. The retort has burned for 120 days since ignition. Oil production during the quarter totaled 5,817 barrels, an average of 65 barrels per day. Oil production averaged 88 barrels per day in January and reached an average of 113 barrels per day in mid-February. Daily oil production peaked at 148 barrels on February 17. Air flow rate reductions were successful in stalling movement of the fire front down the length of the retort, but this caused a significant decrease in oil production rates to occur late in February. Further decreases in oil production resulted from lower air flow rates which accompanied the loss of off gas vacuum capability early in March. Daily oil production dropped to an average of 24 barrels per day during that period. Off gas recovery vacuum was restored on March 7, after which oil production rates began to increase. Retort #24 oil production averaged 40 barrels per day during March, with an average of 45 barrels per day during the last week of the month. Retort #24 daily oil production rates for the quarter are shown in Figure 9.

Approximately 4,909 barrels of shale oil were shipped by tanker truck to the WESRECO refinery in Salt Lake City, Utah,

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during the quarter. A shipment of 511 barrels of oil was sent to the Sun Oil Company for research purposes.

POST-BLAST AND POST-BURN EXAMINATIONS

A post-burn core sampling program for Retort #18 was developed by the Retort Branch. Drilling began on February 17 and was completed on February 21. The program consisted of eight core holes with depths ranging from 45 feet to 62.5 feet.

Stratigraphic sections for each of the eight post-burn core holes on Retort #18 were developed. The individual section illustrations were then combined on several longitudinal cross-section drawings to show the relationship of the burn to key marker beds, the oil shale section and blasthole powder column positions. The locations of the Retort #18 post-burn core holes are shown in Figure 10.

Two post-blast core holes were drilled to depths of 43.6 feet and 45 feet on Retort #13. As expected, very little breakage was observed in the cores obtained. Retort #13 will be burned in 1981 to test the possibility of extracting oil from a low-void retort.

The report on blast-induced fracturing of Retort #24 and #25 as determined by post-blast drilling was drafted and reviewed by management. Data from re-entry process and instrumentation well drilling performed on Retort #25 during February and March was included. Information from blast consultants contributing to the report was obtained and work on the final draft began.

SEPARATE EXPERIMENTS

Preparations for a trial burn of the horizontal in situ retort simulators were made. A shakedown run was conducted to check out retorting and burn monitoring equipment.

ENVIRONMENTAL RESEARCH

The native groundwater sampling study was extended to 1981 and the seventh suite of samples was collected in January. Samples were collected from supplemental series wells #10, #12, and #13. The eighth suite of three six-liter native groundwater samples was collected from wells #12, #13 and #222. The program is designed to produce additional data for the characterization of native groundwater existing above the Mahogany oil shale zone at the project site. Every other month, a six-liter sample is collected from each of three sampling wells chosen randomly from the twelve wells shown in Figure 11. These wells are at least

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200 yards from any retort. The current sampling program was initiated in January 1980. Evaluation of the data obtained in 1980 is underway. Preliminary interpretation supports the earlier groundwater characterization that native groundwater on Section 2 is of a variable but generally poor quality.

The Retort #23 water monitoring program was designed and fourteen hydrologic monitoring wells were drilled around the retort. The Phase I (pre-burn) samples for the program were collected in March. Thirteen six-liter samples were collected from the monitoring locations shown in Figure 3. The Retort #23 water monitoring program is similar in objective and design to the Retort #24 monitoring plan.

Phase II of the Retort #24 water monitoring program was initiated in January. Phase II consists of taking three suites of thirteen six-liter samples from the monitoring locations shown in Figure 12. The first Phase II sampling suite was collected in January, one month after Retort #24 was ignited. The second suite of samples for Phase II was collected in March. Another suite will be collected one month prior to the end of the Retort #24 burn.

A grid system for the surface of Retort #24 was designed for use as a reference frame to randomly select sampling points for the fugitive emissions monitoring program. Two samples will be taken from each row of the 10 feet by 10 feet grid every month. Trial samples of fugitive gas emissions were collected from the Retort #24 surface in March following the fabrication and calibration of sampling equipment. Sample collection will use a technique developed by the Monsanto Research Corporation.

Retort #24 process gas and stack emissions investigations continued during the quarter. Emissions were reported each month and are summarized for 1981 to date in Table 2.

The burn of Retort #23 did not progress far enough to produce any measurable atmospheric emissions during the quarter.

Quarterly maintenance of all mechanical meteorological instruments was performed in January. Two snow boards were added to the meteorological data collection system to provide additional accuracy in measuring snow depths and water equivalency. Quarterly maintenance of electrical weather stations at the field site was performed by West Aq in February. The locations of the meteorological towers are shown in Figure 13. Routine meteorological data collection continued throughout the quarter.

The first draft of the meteorological and climatological report covering January through June of 1980 was completed in March. The report is undergoing review and final revision.

Table 2
First Quarter 1981 Air Emission Rates
(Pounds per hour)

<u>Location</u>	<u>Actual SO₂ (Average)</u>	<u>Maximum Allowable SO₂</u>	<u>Peak SO₂</u>
Retort #24	27.05	135.30	84.10
Retort #23	Nil	26.70	Nil

<u>Location</u>	<u>Actual NO_x (Average)</u>	<u>Maximum Allowable NO_x</u>	<u>Peak NO_x</u>
Retort #24	13.49	45.10	44.70
Retort #23	Nil	8.90	Nil
650 KW Generator	At 1/2 Load 19.50	At Full Load 38.90	N/A

<u>Location</u>	<u>Actual Hydrocarbons (Average)</u>	<u>Maximum Allowable Hydrocarbons</u>	<u>Peak Hydrocarbons</u>
Retort #24	Nil	1.40	Nil
Retort #23	Nil	Nil	Nil
650 KW Generator	At 1/2 Load 0.7	At Full Load 1.50	N/A

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Table 2 (Continued)

Location	Actual Pariculates (Average)	Maximum Allowable Pariculates	Peak Pariculates
Retort #24	Nil	1.00	Nil
Retort #23	Nil	Nil	Nil
650 KW Generator	Nil	Nil	N/A
Haul Roads	1.00	1.00	N/A

<u>Location</u>	Actual CO (Average)	Maximum Allowable CO	Peak CO
Retort #24	Nil	Nil	Nil
Retort #23	Nil	Nil	Nil
650 KW Generator	At 1/2 Load 1.5	At Full Load 2.90	N/A

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John Dale (U. S. Environmental Protection Agency - Region VIII), Roger Tucker (U. S. Geologic Survey - Area Oil Shale Office), William McMichael and Ralph Roberson (both of Research Triangle Institute) visited Kamp Kerogen in January as part of a data gathering survey on the oil shale industry. The survey information regarding shale oil development and production processes and related technologies will be assessed and applied to the promulgation of future air emissions standards.

Utah state health officials approved the designs for new water and domestic wastewater disposal systems for Kamp Kerogen. Construction of the new trailer camp began, as detailed in the Site Preparation category. Existing trailers will be relocated to a site adjacent to the present camp. This move is necessary to bring Kamp Kerogen into compliance with Utah health codes. Soil at the proposed leach field site for the new office/laboratory complex was examined and found suitable for wastewater absorption. A consultant from Ashley Engineering visited the field site to assist in the preparation of design plans for a wastewater disposal system for the new laboratory and offices.

Geokinetics personnel met with Bill Weaver of DOE/LETC and Radian Corporation personnel at Vernal to review the Geokinetics Environmental, Safety and Health Plan. Radian Corporation was hired by DOE to assist in establishing a suitable and effective program for the project. The meeting was held in conjunction with audits of DOE oil shale projects regarding compliance with the Environmental, Safety and Health Plan designed by DOE.

Ed Mead and Trudy Phillips of DOE/LETC visited Kamp Kerogen to meet with the Environmental Branch to review and coordinate ongoing and future environmental research.

Ken Hargis and Dr. Greer of Los Alamos Scientific Laboratory accompanied a representative of the University of Utah's Rocky Mountain Center for Occupational and Environmental Health on a visit to the project site to discuss plans for a medical study to be conducted as part of an industrial hygiene monitoring program. In March, approximately 30 Geokinetics employees and field site residents participated in the voluntary study. Participants gave blood samples, completed a medical history questionnaire and underwent a physical examination. The data obtained will be filed in an oil shale workers' registry and will contribute to health studies conducted for DOE's Oil Shale Task Force.

Hilding Spradlin and Bill Sharrer attended a public information seminar on regulations regarding the identification, manifesting and disposal of hazardous wastes. The seminar was sponsored by the Uintah Basin District Health Department and featured a group from the Utah Hazardous Waste Committee. The State of Utah has received interim authorization from the U. S. Environmental Protection Agency to operate its own program of hazardous wastes in lieu of the Federal Hazardous Waste Program. Permits

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related to the new hazardous waste program will be issued by the Utah Hazardous Waste Committee.

Jim Lekas and Hilding Spradlin represented Geokinetics at a meeting in Vernal between district Bureau of Land Management (BLM) officials and local energy development companies. The objective of the meeting was to review BLM permitting procedures and discuss future plans of the companies represented. Jim Lekas presented an overview of the Geokinetics process.

A meeting was held with Bob Ferguson of the U. S. Forest Service (USFS) Shrub Sciences Laboratory in Provo. Plans for the revegetation study to be conducted by the USFS at the field site in 1981 were discussed. Retorts #10 and #18 will be used for the study, which will be similar in scope to previous work conducted on Retorts #5 and #11. Revegetation test areas are shown in Figure 14. A progress report on the first year's results of the USFS study is attached as Appendix A. A report on two retort water irrigation experiments is attached as Appendix B.

Environmental Branch staff members met with ecological consultants Dr. Erik Olgeirson and Dr. Robert Stoëcker in Colorado to discuss vegetation and wildlife research plans. No changes were planned for the vegetation program. Dr. Olgeirson will visit the project site later in 1981 to conduct annual plant productivity and phytosociological studies. It was also resolved to develop and implement a detailed wildlife research plan in 1981 which will continue throughout the remainder of the research project.

Bill Sharrer represented Geokinetics at a public meeting in Vernal conducted by the Bureau of Land Management. The BLM presented proposals for oil shale leasing and the management of Wilderness Study Areas. The discussions covered proposed changes in BLM land use plans involving the Bookcliff and White River Resource Areas, and the possible addition of the Bull Canyon Area to the National Wilderness System. A proposed oil shale leasing program schedule including tract delineation and selection criteria was outlined. Public comments on the proposals were solicited.

ANALYTICAL LABORATORY

The second full suite of retort gas samples from 21 locations on Retort #24 was taken by the laboratory staff. The gas samples were analyzed by gas chromatography in January.

Two samples of Retort #24 off gas condensate were collected from the air-out line downstream of the mist elimination system in January. These were preliminary samples for a study to characterize the amount of heavy oil (greater than C₁₀) which passes

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through the off gas mist eliminators. Additional samples were collected in February.

Analysis of the fifth and sixth suites of native groundwater samples was completed in February. These samples were collected in September and November of 1980. The raw data obtained was included in the February monthly report. Analysis of the Phase I (pre-burn) water samples from the Retort #24 water monitoring program was completed in March. The raw data obtained was included in the March monthly report.

A new laboratory technician was hired and trained during the quarter. Additional methods of analysis for hydrogen sulfide and ammonia were investigated for quality assurance and back-up method purposes. A gas standards generator for use with permeation tubes was received at the end of March. It will be very helpful in calibrating gas analysis instruments.

Routine analyses of oil, gas and water samples continued during the quarter.

KAMP KEROGEN FACILITIES

Work on utility lines for the new trailer camp began in February and continued in March, as outlined in the Site Preparation category. Kamp Kerogen roads were bladed in March.

A mobile home was moved into place near the warehouse/shop facility and utility hook-ups were installed. Placement of the trailer at this location will enhance security for the shop and equipment yard.

SUPPORT ACTIVITIES

Service was performed on welding machines, backhoes and other equipment prior to assembly of Retort #23 process equipment. A seldom-used wrecker truck was modified for use in fabricating retort equipment.

Routine vehicle maintenance was conducted throughout the quarter. Tool boxes and racks were built for the Chicago Pneumatic C-700 drill rig and several trucks.

A central air compressor starting system was added to the Kamp Kerogen electrical power generation facilities. The system is tied to the natural gas generator as well as the back-up diesel generators. Warranty work and other servicing was performed on the natural gas generator.

An upper-level deck was constructed in the warehouse to increase storage space and efficiency.

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GENERAL AND ADMINISTRATIVE

Utah Technical College safety instructors presented a four-hour training session on welding safety and proper ventilation of work areas.

The Hewlett-Packard 1000 computer was installed. An entry-way and electrical wiring were installed in the trailer housing the computer system.

Project Manager Jim Lekas outlined research progress in a presentation at the DOE/LETC-sponsored Fourth Annual Oil Shale Conversion Symposium. Several other staff members also attended the symposium in Denver. Mr. Lekas also attended the Industrial Advisory Committee meeting in Vernal, and met with Brad Barber of the State of Utah to discuss planning for oil shale development impacts. Television news reporter Kathleen Phelan of ABC-affiliate KTVX (Channel 4, Salt Lake City, Utah) filmed a special report and interview with Mr. Lekas at the project site.

Geokinetics President Mitchell A. Lekas gave a presentation at a science teachers workshop in Vernal. He described the horizontal in situ retorting process and outlined research progress to date.

SECOND QUARTER 1981 FORECAST

SITE PREPARATION

An updated structure contour map and isopach map of the Mahogany oil shale zone in the north half of Section 2 will be completed based on geologic data obtained to date.

Actual water line and electrical line locations for the new trailer camp will be determined by survey. Work on the new trailer camp will continue. An updated map of the new site will be drawn up. This map will incorporate survey control points which can be used to expedite future maintenance of utility systems.

Site development for the new office/laboratory complex will begin.

RETORT FRAGMENTATION

Blasting experiments related to Retort #26 will be conducted in April. Drilling of blastholes for Retort #26 will begin.

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RE-ENTRY DRILLING

None.

RETORT PROCESS FACILITIES

Fabrication and assembly of process equipment for Retort #25 will begin.

RETORT BURN

Operation of Retorts #23 and #24 will continue.

OIL PRODUCTION AND HANDLING

Production of oil from Retort #23 will begin. Production of oil from Retort #24 will continue. Shipments of shale oil to the WESRECO refinery in Salt Lake City, Utah, will continue.

POST-BLAST AND POST-BURN EXAMINATIONS

Analysis of data from post-burn coring on Retort #18 will continue. Stratigraphic sections will be developed for the post-burn cores that were collected from Retort #17 in 1980. These illustrations will be compared to those developed from the Retort #18 post-burn cores.

SEPARATE EXPERIMENTS

Another burn of the horizontal in situ retort simulator will be conducted in May.

ENVIRONMENTAL RESEARCH

Routine collection of hydrologic and meteorological data will continue.

ANALYTICAL LABORATORY

Routine analyses of gas and water samples will continue.

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KAMP KEROGEN FACILITIES

Preparation of the new trailer camp site will continue.

SUPPORT ACTIVITIES

Routine service and repair of equipment will continue.

GENERAL AND ADMINISTRATIVE

None.

Figure 1. Geokinetics Inc. Field Site

Figure 2. Retort #25 - Air, Production and Observation Well Locations

SCALE: 1" = 60'

LEGEND

- SHALLOW WELLS
- ⊙ DEEP WELLS

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KG

Figure 3. Retort #23 - Monitoring Wells

Figure 4. Retort #23 - Surface Facilities Layout (Sandia)

- ⊕ PRODUCTION WELL
- ⊕ OBSERVATION WELL
- ⊙ AIR-IN WELL
- ⊗ AIR-OUT WELL
- △ THERMOCOUPLE WELL

SCALE: 1" = 20'

1/6

Figure 5. Retort #23 - Re-Entry Well Locations

- ✕ PRODUCTION WELL
- ⊗ OBSERVATION WELL
- ⊙ AIR-IN WELL

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Figure 6. Retort #24 - Re-Entry Air, Production and Observation Well Locations

Figure 7. Retort #24 - Surface Facilities Layout

PLAN VIEW

LEGEND

- △ THERMOCOUPLE WELL
- ⬡ PRESSURE WELL

SCALE: 1" = 50'

Figure 8. Retort #24 - Instrument Well Locations

GEOKINETICS INC. RETORT #24

1981 FIRST QUARTER OIL PRODUCTION

Figure 9. Oil Production - First Quarter 1981

Figure 10. Retorts #16, #17, and #18 - Post-Burn Core Hole Locations

SECTION 2, T14S, R22E, UINTAH COUNTY, UTAH

GEOKINETICS INC.

0 500' 1000'
SCALE

Figure 11. Location of Native Groundwater Wells on Section 2

Figure 12. Retort #24 - Water Monitoring Well Locations

SEC. 2, T14S, R22E, UTAH COUNTY, UTAH

GEOKINETICS INC.

0 500' 1000'
SCALE

Figure 13. Location of Meteorological Towers

Figure 14. Revegetation Test Areas

APPENDIX A

PROGRESS REPORT - FOREST SERVICE

REVEGETATION STUDY

RECLAMATION
REVEGETATION RESEARCH - 1980
Progress Report
Forest Service Revegetation Study

by
LINDA KENNY
WILLIAM L. SHARRER

GEOKINETICS INC.
280 Buchanan Field Road
Concord, CA 94520

January 1981

PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY
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CONTENTS

	<u>Page</u>
ABSTRACT.	A-5
INTRODUCTION.	A-6
SITE DESCRIPTION.	A-6
STUDY METHODS	A-8
Experimental Design	A-8
Data Collection	A-8
RESULTS	A-11
Plant Survival.	A-11
Plant Growth.	A-14
DISCUSSION.	A-14
RECOMMENDATIONS	A-19
LITERATURE CITED.	A-20

ILLUSTRATIONS

	<u>Page</u>
Figure 1 - Plant Species Planted on Retorts #11 and #5. . .	A-7
Figure 2 - Planting Design for Retort #5.	A-9
Figure 3 - Planting Design for Retort #11.	A-10
Figure 4 - Retort #5 Growth Measurements.	A-17
Figure 5 - Retort #11 Growth Measurements	A-18
Table 1 - Retort #11 Plant Survival Rates	A-12
Table 2 - Retort #5 Plant Survival Rates.	A-13
Table 3 - Retort #11 "ON" and "OFF" Retort Comparison . .	A-15
Table 4 - Retort #5 "ON" and "OFF" Retort Comparison. . .	A-16

ABSTRACT

This report presents first-year results of the Forest Service revegetation study at the Geokinetics research site. The study is designed to provide information on alternative methods for revegetating retort areas, and those areas immediately adjacent to retort sites. Retorts #5 and #11 were selected for the study, and planting took place on April 24, 1980, using 21 species of plants (14 shrubs, 4 forbs, 2 grasses, and 1 tree). The report evaluates the first-year survival and growth of the plants and also presents a discussion of the results and recommendations for future study.

INTRODUCTION

The specific goals of the revegetation research on the Geokinetics Inc. (GKI) field research site, Kamp Kerogen, in Uintah County, Utah, are to develop an economical revegetation scheme that will:

1. Reestablish a vegetational regime that resembles the natural one prior to its disturbance; and
2. Be as productive, or more productive, than the original vegetation.

In order to help bring about these specific goals, GKI, in cooperation with the USDA Intermountain Forest and Range Experiment Station Shrub Science Laboratory, is presently engaged in a revegetation study that is designed to provide information on alternative methods for revegetating retort areas and those areas immediately adjacent to retort sites.

The research reported here includes the first-year results of the revegetation study at GKI. The research was initiated during the spring of 1979, and plantings were made on the site in April 1980. The objective of this study is to evaluate the survival and growth of 21 species of plants (14 shrubs, 4 forbs, 2 grasses, and 1 tree) established by transplanting container-grown planting stock. (See Figure 1.)

Subsequent reports of this study will be completed each year until planting data no longer provides useful information.

SITE DESCRIPTION

Kamp Kerogen is an in situ oil shale retorting experimental research site located in the southern Uintah Basin, Uintah County, Utah. The research site occupies Section 2 of Township 14 South, Range 22 East, approximately 70 miles south of Vernal, Utah.

Elevation at the site is approximately 6,700 feet. The natural vegetation of the area reflects the annual precipitation of about 10-12 inches. The site consists primarily of open pinyon-juniper woodlands and sagebrush-dominated shrublands (Olgeirson, 1979). The soils are all relatively deep, well drained, and are primarily of a shale and sandstone origin (Olgeirson, 1979).

Figure 1

Plant Species Planted on Retorts #11 and #5

The following plant species were planted on April 24, 1980.

RETORT #11

ACMI	-	<u>Achillea millefolium</u> (southern Idaho)
ATBO	-	<u>Atriplex bonnevillensis</u> (Desert Exp. Range/ Sand Wash)
ATID	-	<u>Atriplex idahoensis</u> (southwest Idaho)
ATOB	-	<u>Atriplex obovata</u> (Hatch Trading Post, Utah)
ATOB ²	-	<u>Atriplex obovata</u> (northern Arizona)
ATTR	-	<u>Atriplex tridentata</u> (White River; East of Ouray, Utah)
CAMO	-	<u>Camphorosma monspeliaca</u> (Russia)
CELA	-	<u>Ceratoides lanata</u> (Myton, Utah)
CEPA	-	<u>Ceratoides papposa</u> (Russia)
HEBO	-	<u>Hedysarum boreale</u> (Salt Lake County, Utah)
KOPR	-	<u>Kochia prostrata</u> var. <u>villosissima</u> (Russia)
ORHY	-	<u>Oryzopsis hymenoides</u> (Ouray, Utah)
PEPA	-	<u>Penstemon palmeri</u> (Alton, Utah)
POCO	-	<u>Poa compressa</u> (Jacklin Seed Company)
SWSA	-	<u>Swainsonia salsula</u> (Russia; PI-314641)

RETORT #5

AMUT	-	<u>Amelanchier utahensis</u> (Rio Blanco, Colo.)
CHNA	-	<u>Chrysothamnus nauseosus</u> (Meeker, Colo.)
EPVI	-	<u>Ephedra viridis</u> (central Utah)
PUTR	-	<u>Purshia tridentata</u> (Mt. Pleasant, Utah)
QUGA	-	<u>Quercus gambelli</u> (Cannonville, Utah)
RHTR	-	<u>Rhus trilobata</u> (Enterprise, Utah)

STUDY METHODS

Experimental Design

The experimental design used in this revegetation study was developed by Robert B. Ferguson of the Forest Service Shrub Science Laboratory and was implemented at the Geokinetics site in cooperation with the Forest Service, under the direction of Mr. Ferguson.¹

The sites selected for study were experimental Retorts #5 and #11. The disturbed area directly over and immediately adjacent to Retorts #5 and #11, equals approximately 1,925 square feet and 3,375 square feet, respectively.

At Retort #5, a rectangular area 35 feet by 55 feet was used to plant five species of shrubs and one tree species that normally grow to a relatively large size. Ten rows of 15 plants were planted along the axis of the study area. Plants were spaced 44 inches apart within the row, and rows were spaced 42 inches apart.

On Retort #11, a rectangular area 45 feet by 75 feet was used to plant nine species of shrubs, four species of forbs, and two species of grasses which normally grow 3 feet or less in height and diameter. Fifteen rows of plants were planted along the axis of the study area. Plants were spaced 36 inches apart within the row, and rows were spaced 36 inches apart.

The experimental design for each retort area consisted of five blocks, with each test species represented by five plants in each block. Species location within blocks was random. The planting design for Retort #5 is shown in Figure 2 and the design for Retort #11 is shown in Figure 3.

Data Collection

First-year survival and growth data were collected from each retort according to the following schedule and methods:

1. Survival data was recorded periodically throughout the growing season. (See Tables 1 and 2.)
2. Plants were considered "dead" when they showed no signs of growth (only brown leaves and dry brittle stems) at the time of sampling.

¹ Much of the information in the Experimental Design Section was provided by Robert B. Ferguson, Range Scientist, USDA Forest Service Shrubs Sciences Laboratory, Provo, Utah.

Figure 2
Planting Design for Retort #5

Figure 3
Planting Design for Retort #11

BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5
Pepa	Hebo	Swsa	Pepa	Cela
Cela	Atob	Hebo	Attr	Acmi
Atbo	Atbo	Acmi	Atbo	Atob
Cepa	Cela	Atid	Atid	Poco
Camo	Atid	Atob ²	Atob	Hebo
Kopr	Cepa	Attr	Poco	Atob ²
Acmi	Atob ²	Poco	Kopr	Atid
Hebo	Attr	Atob	Hebo	Kopr
Swsa	Pepa	Cela	Camo	Cepa
Poco	Camo	Cepa	Orhy	Camo
Orhy	Kopr	Atbo	Swsa	Pepa
Atob ²	Swsa	Kopr	Atob ²	Attr
Atob	Acmi	Pepa	Acmi	Swsa
Atid	Poco	Camo	Cela	Orhy
Attr	Orhy	Orhy	Cepa	Atbo

3. Growth measurements were made at the end of the growing season.
4. Plant heights were measured from the soil surface to the apical bud of the plants.
5. Plant widths were measured across the widest portion of the plants.

RESULTS

Plant Survival

First-year plant survival data collected on Retort #11 was good, with an average species survival rate of 80% at the final sampling date (Table 1). Russian thistle (Salsola iberica) plants were removed periodically during the growing season if they appeared to be in direct competition with the test species. However, several annual and perennial grasses and forbs were left undisturbed even if they seemed to be in indirect competition with the planted shrubs. Many of the Swainsonia salsula plants listed as alive at the time of the first sampling (June 11) did not look healthy and as shown on Table 1, the survival rate decreased from 88% on June 11 to 32% on September 15. Three other species: Achillea millefolium, Hedysarum boreale, and Penstemon palmeri, also exhibited a low survival rate. Their poor showing may have been due to a difference in planting location. This difference will be discussed later.

The survival and growth data were similar for the two types of Antriplex obovata. The Arizona plants, however, had slightly higher growth measurements, and were observed to be much healthier. The Penstemon palmeri did not generally do well, but a few plants set seed, and it may be worth planting again to see if the Penstemon will reestablish itself from its own seed. Survival rates for all other species on Retort #11 were considered good.

Plant survival data collected on Retort #5 during the growing season revealed generally poor results. (See Table 2.) The average survival rate on June 11 was good with 95% still alive; however, at the final sampling date, September 12, the average survival rate was only 34%. Only one species, Ephedra viridis, was growing satisfactorily with a survival rate of 80%. All other species had poor survival rates of 52% or less. Russian thistle growth was quite thick on Retort #5, but only those plants that appeared to be in direct competition were removed or crushed down.

During the sampling period, differences in survival and growth were noticed between plant species on and off the retorts.

TABLE 1
Retort #11 - Plant Survival Rates
During the 1980 Growing Season (Apr 24 - Sept 20)¹

DATE	6/11/80		7/10/80		8/11/80		9/15/80	
SPECIES (Abbrev.)	DEAD/ PLANTED (#)	SURVIVAL (%)	DEAD/ PLANTED (#)	SURVIVAL (%)	DEAD/ PLANTED (#)	SURVIVAL (%)	DEAD/ PLANTED (#)	SURVIVAL (%)
ACMI	0/25	100	3/25	88	11/25	56	13/25	48
ATBO	0/25	100	0/25	100	0/25	100	0/25	100
ATID	1/25	96	1/25	96	1/25	96	1/25	96
ATOB	1/25	96	1/25	96	1/25	96	1/25	96
ATOB ²	0/25	100	0/25	100	2/25	92	2/25	92
ATTR	0/25	100	0/25	100	3/25	88	2/25	92*
CAMO	2/25	92	2/25	92	3/25	88	2/25	92*
CELA	1/25	96	1/25	96	1/25	96	3/25	88
CEPA	0/25	100	2/25	92	5/25	80	5/25	80
HEBO	5/25	80	7/25	72	11/25	56	10/25	60*
KOPR	0/25	100	0/25	100	0/25	100	0/25	100
ORHY	0/25	100	1/25	96	6/25	76	5/25	80*
PEPA	0/25	100	0/25	100	7/25	72	12/25	52
POCO	0/25	100	0/25	100	2/25	92	2/25	92
SWSA	3/25	88	7/25	72	15/25	40	17/25	32
TOTAL	13/375	96.5	25/375	93.3	68/375	81.9	75/375	80

¹ Planting Date: April 24, 1980

* The discrepancy in survival rates between 8/11 and 9/15 occurred because one of the plants listed as "dead" on 8/11 revived, and was relisted as "alive" on 9/15.

TABLE 2

Retort #5 - Plant Survival Rates
 During the 1980 Growing Season (Apr 24 - Sept 20)¹

DATE	6/11/80		7/10/80		9/12/80	
SPECIES (Abbrev.)	DEAD/ PLANTED (#)	SURVIVAL (%)	DEAD/ PLANTED (#)	SURVIVAL (%)	DEAD/ PLANTED (#)	SURVIVAL (%)
AMUT	0/25	100	10/25	60	19/25	24
CHNA	2/25	92	4/25	84	12/25	52
EPVI	1/25	96	2/25	92	5/25	80
PUTR	0/25	100	2/25	92	20/25	20
QUGA	1/25	96	10/25	60	21/25	16
RHTR	3/25	88	11/25	56	22/25	12
TOTAL	7/150	95.3	39/150	74	99/150	34

¹ Planting Date: April 24, 1980

To determine if there was a difference due to location, the data was broken down into two parts, designated as "ON RETORT" and "OFF RETORT", as shown in Tables 3 and 4 (the areas of raised ground are considered "ON RETORT", and are circled in Figures 4 and 5 by a dotted line). There were no distinguishable differences in survival rates either "ON" or "OFF" Retort #5. However, when Retort #11 survival rates were broken down into "ON RETORT" and "OFF RETORT", marked differences were noted. The "OFF RETORT" survival rates climbed to 89%, while the "ON RETORT" rate fell to 69%, with the combined overall rate at 80%.

Plant Growth

Height and width measurement were taken on September 20, 1980. Measurements for Retort #5 and #11 are shown in Figures 4 and 5 respectively. This data was also broken down into "ON" and "OFF" RETORT. While there were no marked differences between "ON RETORT" and "OFF RETORT" data for Retort #5, height and width measurements for Retort #11 were generally greater "OFF RETORT". It was also noted that these "OFF RETORT" plants appeared much healthier than the "ON RETORT" plants.

A statistical analysis was conducted between "ON RETORT" height and width measurements, and "OFF RETORT" measurements, to determine if the data actually represented the general findings. Overall, no significant differences in growth occurred between planting locations. However, it must be noted that the original study was not designed to depict location differences; and in many cases, the data was inadequate for comparable statistics.

DISCUSSION

This study was designed to provide information on alternative methods for revegetating retort areas, and those areas immediately adjacent to retort sites. These first-year results do not conclusively indicate the most desired methods of revegetation, since more time will be required for such a conclusion. However, the data does indicate what species might be more compatible with the retort areas and are discussed in the Results.

There was some indication on Retort #11 that plant location, "ON" or "OFF" RETORT, may affect the survival and growth of certain test species. One factor which influenced this observation is discussed as follows:

1. The area on the retort was not contoured to prevent runoff or enhance water retention. When precipitation fell, or when water was applied, excessive runoff occurred on the uplifted surface of the retort, and probably only small amounts of water

TABLE 3

Retort #11 - Comparison of Survival Rates and
Growth Measurements Between "ON RETORT" and "OFF RETORT"

SPECIES (Abbrev.)	ON RETORT				OFF RETORT			
	DEAD/ PLANTED (#)	SURVIVAL (%)	AVERAGE ¹ Height (cm)	Width (cm)	DEAD/ PLANTED (#)	SURVIVAL (%)	AVERAGE ¹ Height (cm)	Width (cm)
ACMI	10/10	0	ALL DIED		3/15	80	8	14
ATBO	0/9	100	11	14	0/16	100	20	26
ATID	0/0	NONE PLANTED			1/25	96	13	23
ATOB	0/5	100	5	8	1/20	95	8	10
ATOB ²	1/10	90	12	10	1/15	93	10	13
ATTR	1/9	89	11	18	1/16	94	15	25
CAMO	2/18	89	17	23	0/7	100	19	25
CELA	3/10	70	14	15	0/15	100	11	20
CEPA	4/11	64	25	28	1/14	93	22	27
HEBO	4/5	20	5	6	6/20	70	8	13
KOPR	0/10	100	24	39	0/15	100	50	65
ORHY	4/19	79	22	28	1/6	83	19	31
PEPA	10/14	29	6	12	2/11	82	10	14
POCO	0/10	100	7	20	2/15	87	7	23
SWSA	13/14	7	5	10	5/11	55	11	19
TOTAL	52/154	66			24/221	89		

¹ All height and width measurements for live plants in each species were added together and divided by the number of live plants to obtain the average height and width.

TABLE 4

Retort #5 - Comparison of Survival Rates and
Growth Measurements Between "ON RETORT" and "OFF RETORT"

SPECIES (Abbrev.)	ON RETORT				OFF RETORT			
	DEAD/ PLANTED (#)	SURVIVAL (%)	AVERAGE ¹ Height (cm)	Width (cm)	DEAD/ PLANTED (#)	SURVIVAL (%)	AVERAGE ¹ Height (cm)	Width (cm)
AMUT	9/11	18	5	6	10/14	29	5	3
CHNA	6/11	46	12	12	6/14	57	13	14
EPVI	5/15	67	13	8	0/10	100	15	10
PUTR	11/12	8	5	10	9/13	31	6	8
QUGA	10/12	17	4	5	11/13	15	3	4
RHTR	4/7	43	10	5	18/18	0	ALL DIED	
TOTAL	45/68	34			54/82	34		

¹ All height and width measurements for live plants in each species were added together and divided by the number of live plants to obtain the average height and width.

Figure 4
Retort #5 - Growth Measurements
Taken on September 20, 1980¹

	CHNA					EPVI					PUTR				
ht	10	*	11	12	23	14	20	13	6	10	*	11	1	*	*
wdt	11		9	13	20	11	15	10	6	4	*	9	1		
	RHTR					QUGA					AMUT				
ht	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
wdt	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	PUTR					QUGA					AMUT				
ht	6	*	*	*	*	*	*	*	3	3	*	*	3	*	*
wdt	8					*	*	*	5	3			3		
	RHTR					CHNA					EPVI				
ht	*	*	*	*	*	6	10	15	*	14	22	14	13	20	20
wdt	*	*	*	*	*	15	12	20	*	15	12	4	6	20	10
	PUTR					RHTR					AMUT				
ht	7	*	*	*	*	*	*	8	10	11	4	*	*	*	*
wdt	12					*	*	5	6	3	5	*	*	*	*
	QUGA					EPVI					CHNA				
ht	*	*	*	*	*	*	27	20	10	13	*	15	*	8	8
wdt	*	*	*	*	*	*	8	7	5	13	*	13	*	8	9
	RHTR					CHNA					PUTR				
ht	*	*	*	*	*	*	*	*	12	*	*	5	*	*	*
wdt	*	*	*	*	*	*			15			10	*	*	*
	AMUT					EPVI					QUGA				
ht	*	*	6	4	6	*	9	11	10	7	*	*	3	*	*
wdt	*	*	2	3	7	*	4	9	9	9	*	*	4	*	*
	CHNA					EPVI					QUGA				
ht	*	*	*	*	15	*	*	*	11	14	*	*	4	*	*
wdt	*	*	*	*	11	*	*	*	8	10	*	*	6		
	RHTR					PUTR					AMUT				
ht	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
wdt	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

1) Height and width measurements are in centimeters (cm).

* Dead

--- Approximate location of retort, identified by ground heave.

Figure 5
Retort #11 - Growth Measurements
Taken on September 20, 1980¹

	PEPA	HEBO	SWSA	PEPA	CELA
ht	6 14 6 6	9 5 10 *	12 15 14 7 6	11 5 20 9 *	7 13 14 23 21
wdt	13 * 11 17 17	15 10 15 *	25 42 14 9 13	15 14 13 9 *	10 21 24 21 20
	CELA	ATOB	HEBO	ATTR	ACMI
ht	18 20 19 14 25	4 4 8 8 7	6 9 5 6	16 15 10 14 21	6 11 7 3
wdt	16 16 21 14 11	9 4 8 7 7	8 15 9 10 *	28 21 23 27 32	* 15 10 14 5
	ATBO	ATBO	ACMI	ATBO	ATOB
ht	8 12 28 10 19	16 15 18 22 28	3 8 7 5 5	25 30 25 21 29	14 10 8 10 5
wdt	10 15 33 11 27	23 22 30 30 18	14 16 23 11 14	30 47 38 37 28	11 10 7 14 5
	CEPA	CELA	ATID	ATID	POCO
ht	21 20 27 20	20 32 26 40 30	10 18 * 7 10	21 20 23 13 15	3 9 11 9 8
wdt	20 24 19 21	33 29 23 24 21	24 24 * 13 13	28 37 31 45 29	6 26 33 25 24
	CAMO	ATID	ATOB ²	ATOB	HEBO
ht	15 9 17 17 11	6 18 15 16 16	9 4 15 13 15	10 6 12 14 7	4 7 12 7 8
wdt	23 15 25 28 18	10 28 33 38 36	16 3 20 22 35	15 12 16 20 5	8 16 14 16 13
	KOPR	CEPA	ATTR	POCO	ATOB ²
ht	64 36 55 60 52	16 27 23 6 21	17 20 17 29 15	6 7 7 13 6	9 3 10 20 6
wdt	65 29 60 60 43	14 25 35 30 47	22 33 40 47 55	23 35 28 29 25	10 5 10 9 9
	ACMI	ATOB ²	POCO	KOPR	ATID
ht	16 * 10 15 *	10 16 13 18 10	9 10 9 10 3	45 70 56 72 60	7 12 3 5 12
wdt	22 * 13 11 *	14 11 10 14 13	36 33 30 29 9	30 87 70 52 75	22 17 14 10 22
	HEBO	ATTR	ATOB	HEBO	KOPR
ht	* * * 11 *	9 * 7 9 15	7 5 4 1 9	5 * * * *	45 39 62 15 20
wdt	* * * 15 *	9 * 11 15 18	10 8 7 6 8	6 * * * *	38 59 75 67 65
	SWSA	PEPA	CELA	CAMO	CEPA
ht	* * * *	3 * * *	17 * 14 14 *	5 * * 30 16	10 23 15 36 28
wdt	* * * *	13 * * *	17 16 20 *	10 * * 35 20	10 22 22 32 34
	POCO	CAMO	CEPA	ORHY	CAMO
ht	* 7 3 3 *	15 14 7 32 23	* 28 28 19 16	22 20 44 23 25	17 23 30 29 35
wdt	* 20 11 10 *	20 25 17 30 20	* 22 37 21 18	26 31 60 35 35	34 37 29 35 34
	ORHY	KOPR	ATBO	SWSA	PEPA
ht	25 15 11 20	21 37 26 3 23	6 10 17 7 8	* * * * 5	* * * 8 10
wdt	33 30 42 20	33 60 65 50 30	7 10 11 15 17	* * * * 10	* * * 16 17
	ATOB ²	SWSA	KOPR	ATOB ²	ATTR
ht	7 13 * 9 8	* * * *	23 34 22 23 29	10 * 8 13 9	10 8 10 18 10
wdt	6 10 * 11 10	* * * *	30 26 22 40 36	11 * 7 5 9	25 28 11 23 11
	ATOB	ACMI	PEPA	ACMI	SWSA
ht	5 * 7 4 10	* * * *	* * 5 * 7	* * * * *	* * * * 114
wdt	12 * 5 6 12	* * * *	* * 10 * 10	* * * * *	* * * * 111
	ATID	POCO	CAMO	CELA	ORHY
ht	12 19 14 16 9	3 5 3 10 5	11 15 10 10 9	10 3 16 * 23	20 30 * 28 25
wdt	18 4 22 16 16	7 15 12 14 17	14 20 20 15 21	8 23 10 * 13	25 22 * 35 20
	ATTR	ORHY	ORHY	CEPA	ATBO
ht	12 10 6 10 *	14 16 25 11 *	* 15 * 20 20	* * * 25 32	9 13 10 21 10
wdt	11 10 11 7	15 16 32 15	19 30 30	* * * 27 29	2 15 10 33 12

1) Height and width measurement are in centimeters (cm).

* Dead

--- Approximate location of Retort, identified by ground heave.

were retained by the soil and available to the "ON RETORT" plants.

The survival rate on Retort #5 was quite poor. (See Table 2.) The low survival rate can probably be attributed to two factors: (1) the Russian thistle competition was overwhelming, and (2) three of the species; Amelanchier utahensis, Quercus gambelli, and Rhus trilobata were not native to the research site.

Two variables that possibly affected the "ON RETORT" survival and growth were the lack of water storage on the uplifted retort areas, and possible soil temperature differences between "ON" and "OFF" RETORTS due to postburn activity associated with the retort process.

The soil temperature difference and its effect, beneficial or detrimental, upon plant growth is not known for the retort sites. However, it is known that soil temperatures are higher on the retorts than off the retorts (snow-melt has been observed to occur earlier on the retorts than off the retorts); but the temperature difference should decrease as postburn activity decreases. Retorts #5 and #11 were planted on April 24, 1980, approximately 2.5 years after the burn ended for both retorts. This would indicate that the effect of temperature differences upon plant growth for Retorts #5 and #11 were probably minimal. However, the residual time of the post burn activity is not known, and there is little data available to verify such a conclusion.

Future revegetation plans include retorts that will have greater postburn activity. In order to meet the objectives of this study, variables including soil temperature differences, and any other that may arise, will have to be contained, or their effects defined, so that the results of the study will be clear and interpretable.

RECOMMENDATIONS

The following recommendations have been formulated from the first-year results and observations:

1. Delete Amelanchier, Quercus, Rhus, and Swainsonia from the study due to their poor growth and survival rates, and substitute other species known to be on the site, or adapted to similar conditions, such as Artemisia tridentata, Artemisia frigida, and Pinus edulis.
2. Control Russian thistle growth, or remove the plants from the retort sites to eliminate their competition with the test species.

3. Contour retort sites, and incorporate small basins around each plant into the planting design in order to increase water retention on the retorts.
4. Examine the possible differences in planting location, "ON" or "OFF" RETORT, in order to determine what factors, such as soil temperature, are creating, or contributing, to such differences.

LITERATURE CITED

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APPENDIX B

IRRIGATION EXPERIMENTS WITH PRODUCED WATERS FROM THE RETORTING OF OIL SHALE

IRRIGATION EXPERIMENTS WITH PRODUCED
WATERS FROM THE RETORTING OF OIL SHALE

by

DAVID L. HUTCHINSON

GEOKINETICS INC.
280 Buchanan Field Road
Concord, CA 94520

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CONTENTS

	<u>Page</u>
SUMMARY	B-4
INTRODUCTION.	B-4
NATIVE VEGETATION EXPERIMENT.	B-5
TREE EXPERIMENT	B-6

TABLES & FIGURES

Table I - Statistical Characterization of Retort Water.	B-10
Figure 1 - Native Vegetation Irrigation Experiment Location.	B-11

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SUMMARY

The research described herein was conducted by Geokinetics to qualitatively assess the tolerance of native and certain introduced species of vegetation to irrigation with produced water from the retorting of oil shale. Two separate experiments were conducted at the Kamp Kerogen field site in Uintah County, Utah. The results indicate possible effects on vegetation that a prolonged exposure to produced water would have.

The two simple experiments were initiated during the summer of 1979. It was expected that irrigation with produced water would eventually result in detrimental effects to the plants receiving it; the concentrations of boron, molybdenum, arsenic, oil and other constituents in untreated production waters are high enough to likely cause damage to plants.

In one experiment a 27 foot by 27 foot plot of native vegetation was irrigated with one inch of produced water per week for five weeks using a lawn sprinkler. Grasses and shrubs within the test plot appeared to have died; germination of annual plants was greatly inhibited.

In the other experiment, 30 container-grown seedlings ranging in height from 0.3 feet to 3.0 feet were transplanted. Six species of broadleaf, deciduous trees not native to the test site were represented by five seedlings each. All 30 trees received well water irrigation for one month, after which four trees of each species were irrigated with produced water for seven weeks.

One tree of each species continued to receive well water throughout the experiment; only two of those trees survived the summer of 1979. All six species appeared to have been adversely affected by produced water. The horse chestnut trees were the hardiest of the species planted. Most of the 30 trees, including those irrigated with well water, did not survive the winter season.

INTRODUCTION

The Geokinetics In Situ Oil Shale Project is a cooperative venture between Geokinetics Inc. and the U. S. Department of Energy. 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

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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 the burn front moves from the air-in to the air-out wells, residual coke serves as the primary fuel source to sustain the moving burn front. Combustion gases are recovered at the off-gas wells.

This retorting process requires no water, but produces water at a volume approximately equal to oil production. The oil-water emulsion is pumped out of the retort and is then separated. A representative characterization of retort water is shown in Table I.

NATIVE VEGETATION EXPERIMENT

A 27 foot by 27 foot plot was established at the location shown in Figure 1. A plot of equal dimensions with similar vegetation was established as a control plot. The control plot was located just north of the irrigated test plot. Both plots were marked with laths, survey tape and string.

One inch of produced water per week was applied to the irrigated plot using a spray-type lawn sprinkler placed in the center of the test plot. This amount of watering was recommended by ecological consultant Dr. Erik R. Olgeirson; he indicated that sagebrush and other native vegetation should tolerate irrigation with one inch of normal water per week. The quantity of water applied was monitored using a glass beaker placed in the path of the sprinkler. Produced water was applied on August 23, 1979; August 30, 1979; September 6, 1979; September 12, 1979; and September 20, 1979.

Color slides of the plots were taken prior to irrigation, during the program and at the completion of the experiment. The slides and frame records are on file at Kamp Kerogen.

Irrigated plants began drying up and showing discoloration within three weeks after the program began. The plots were left undisturbed through the winter of 1979 and spring of 1980. Geokinetics botanist Linda Kenny examined the plots on July 16, 1980. Grasses and shrubs within the test plot appeared to be dead. Several small groups of cactus were alive but brown and shriveled in spots. Germination of annual plants within the test plot was greatly inhibited. The control plot and areas surrounding the test plot were thickly populated with cheat grass, an

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annual grass. None had grown in the test plot. A few perennial grasses had sprouted in one small area in the test plot.

A small pinyon pine was located on the boundary of the test and control plots. The south side of the tree, which was in the test plot, was in the path of the produced water spray. The north side of the tree was not hit by the water. Needles on the northern side of the pinyon were all green. The needles on the south side were dead, but there was some new growth at the tips of the branches. This may indicate that produced water is most toxic to plants when it contacts the leaves.

TREE EXPERIMENT

This experiment was initiated to determine if several species of trees selected by the U. S. Forest Service (USFS) would grow at the field site if irrigated with produced water. Thirty small, container-grown trees were transplanted on July 13, 1979. The height of the seedlings ranged from 0.3 feet to 3.0 feet. Five trees each of the following six species were planted:

1. Aesculus hippocastanum (Horse Chestnut)
2. Quercus macrocarpa (Bur Oak)
3. Acer grandidentatum (Bigtooth Maple)
4. Celtis occidentalis (Common Hackberry)
5. Fraxinus amonala (Singleleaf Ash)
6. Five Hybrid Poplars:
 - NE-53: Populus masimowiczii x P. Caudina
 - NE-9: P. nigra x P. trichocarpa ("Roxbury" Poplar)
 - NE-302: P. betulifolia x P. trichocarpa
("Andover" Poplar)
 - NE-32: P. angulata x P. berolinensis
 - NE-388: P. maximowiczii x P. trichocarpa
("Androscoggin" Poplar)

The trees were watered with approximately one gallon every two weeks, as prescribed by USFS personnel. All 30 trees were watered with Kamp kerogen well water at the time of planting and through July 26, 1979. Kamp water was applied on July 13, 15, 18, 21, and 26, in quantities totaling the prescribed amount. By July 30, 1979, four trees of each species were watered with produced water and one tree of each species was watered with Kamp water. The trees were watered in this manner on July 30; August 9, 12, 18, 23, 25, and 30; and September 2, 6 and 20. No water-

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ing took place after September 20, 1979. The trees were left undisturbed through winter and spring, and were examined by botanist Linda Kenny on July 16, 1980. The following observations were made regarding each of the species planted:

Aesculus hippocastanum (Horse Chestnut) - The leaves of all five trees began turning brown almost immediately after transplanting. Each plant had lost some leaves and one had lost all leaves by July 26, 1979, while all were still being irrigated with Kamp water. The Horse Chestnut trees continued to brown and lose leaves after watering with produced water began. By September 2, the four trees receiving produced water had no leaves and the tree receiving Kamp water had only one browning leaf left. At the time that watering was discontinued, it did not appear that the Horse Chestnut trees would survive. However, when the trees were evaluated in July 1980, the Horse Chestnut trees appeared healthier than the other species planted. Three of the four Horse Chestnut trees watered with produced water and the tree that received Kamp water were alive with a few small new leaves.

Quercus macrocarpa (Bur Oak) - These trees appeared to remain in good condition through July 1979, with one tree exhibiting some wilting (loss of turgidity after five days but recovering). One week after produced water irrigation began, all of the trees except one (which received produced water) began showing leaf discoloration and drying. By August 12 all of the oak trees had browning at the tips of some or all leaves. The tree receiving Kamp water had lost a few leaves and may have been affected by produced water leaking from the spigot of the plumbing system. Observations on September 2 indicated that three of the oak trees watered with produced water had browning leaves. This included the tree which had wilted earlier; the leaves had curled and then crumpled at the tips. The other oak tree irrigated with produced water had no leaves at that time. The tree watered with Kamp water showed browning at leaf edges and signs of possible windburn (which may have resulted from the leaking water contacting the leaves). When the trees were examined in July 1980, only the one that had received Kamp water appeared to have survived the winter. It had only a few small leaves at that time.

Acer grandidentatum (Bigtooth Maple) - All five maples did quite well through July 1979. By August 9, two of the trees receiving produced water showed browning at the tips of some leaves. On August 12, all five maples showed browning on some leaves. Observations on September 2 noted that all leaves were brown on three of the maples receiving produced water; the other tree receiving produced water showed leaves slightly brown at the tips. The maple receiving Kamp water looked healthy with deep green leaves in September 1979. None of the maples had any live

leaves or showed any signs of new growth when examined in July 1980. Apparently none survived the winter.

Celtis occidentalis (Common Hackberry) - Within two days after transplanting, two trees had lost some leaves and another showed some browning of leaves. By the fifth day, all of the hackberries had dry leaves with another tree also showing browning of leaves. On August 9, it was noted that two of the trees receiving produced water had brittle leaves; the other three trees showed some browning at the tips of leaves. On August 12, the two trees with brittle leaves showed a slight browning at tips of leaves. Observations on September 2 noted that trees receiving produced water had browning, yellowish leaves that were brittle or very brittle. The tree receiving Kamp water had no leaves. None of the hackberry trees appeared to have survived the winter when observed in July 1980.

Fraxinus americana (Singleleaf Ash) - Although two of these trees lost some leaves on top shortly after transplanting, the ash trees appeared to be in good condition through July. One week after being watered with produced water, one tree was turning brown at the tips of leaves and two other trees had brittle leaves. On August 12, leaves on the two trees with brittle leaves were curling and the other two trees receiving produced water had some leaves turning brown at the tips. The tree receiving Kamp water showed slight browning of some leaves. In September 1979, none of the trees receiving produced water had any live leaves; one tree had lost all leaves. The tree receiving Kamp water looked healthy in September 1979, none of the trees receiving produced water had any live leaves; one tree had lost all leaves. The tree receiving Kamp water looked healthy in September 1979 and had deep green leaves. None of the ash trees appeared to be alive when examined in July 1980.

The five hybrid poplars are referred to here by the designations preceding the scientific descriptions listed above. Poplars NE-53, NE-9, NEW-302 and NE-32 were irrigated with produced water; NE-388 received Kamp water.

NE-32 showed some signs of browning two days after being transplanted and NE-53 showed some yellowing five days after transplanting. Generally, however, all five poplars were in good condition when irrigation with produced water began. On August 9, the poplar trees were still in fair condition, with browning at the tips of some leaves on all five plants. Observations made in September 1979 indicated the following: NE-53 had some new growth with most of the new leaves turning black at the tips. All of the original leaves had fallen off. All leaves on NE-9 were very brittle; there appeared to have been some new growth which was brittle and blackened. The original leaves on NE-302 were almost totally brown while new growth was slightly black at tips of leaves. The original leaves on NE-32 were brown, but

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there were some healthy-looking new leaves as well as some new leaves with black tips. NE-388, which received Kamp water, looked healthy and had some new growth. On September 20, 1979, when the trees were watered for the last time, the leaves on NE-388 had begun to dry out. None of the poplars showed evidence of being alive when examined in July 1980.

TABLE I

STATISTICAL CHARACTERIZATION OF RETORT WATER

(All Concentrations Expressed as mg/l,
Unless Otherwise Noted)

Parameter	Mean	Deviation	Variance	High	Low
Alkalinity as CaCO ₃	17,836.36	4,373.39	17,387,768	30,300	15,000
Hardness as CaCO ₃	153.72	85.75	6,684.20	303	28
pH units	8.56	0.34	0.10	9.08	8.14
Conductivity $\mu\text{ohms}/\text{cm}^{-1}$	34,035.91	10,968.05	109,362,003	64,800	24,600
COD	3,682.36	650.57	384,764	4,420	2,000
Ammonia as NH ₃ -N	1,270.68	779.52	552,415	2,400	65.2
Bicarbonate as HCO ₃	17,174.91	7,152.98	46,513.803	36,996	11,346
Carbonate as CO ₃	2,825.45	1,567.70	2,234,261	4,560	0
Chloride as Cl	3,016.36	4,292.25	16,748,550	15,000	800
Cyanide as CN	13.31	9.55	82.89	25.3	0.94
Nitrate as NO ₃ -N	34.16	28.15	720.25	76	2.5
Nitrite as NO ₂ -N	1.33	1.13	1.17	3.6	0.18
Phenol	11.56	11.84	127.50	26.48	00.10
Phosphate-Total	2.1	1.22	1.34	3.82	0.50
Phosphate-Ortho	1.07	0.80	0.58	2.26	0.02
Sulfate as SO ₄	609.09	361.71	118,942	1,020	184
Sulfide as S	447.36	280.72	71,641.55	816	34.8
Oil & Grease	103	202.00	37,095.68	697.8	7.9
Surfactants as MBAS	23.20	34.39	1,075.35	110	0
Total Dissolved Solids	22,144.64	7,133.03	46,254,620	23,500	16,052
Gross Alpha ± 3.5 pCi .l ⁻¹	8.29	4.21	16.13	14	3.8
Gross Beta ± 5.0 pCi .l ⁻¹	26.45	6.74	41.34	38	21
Antimony as Sb	0.011	0.003	0.000006	0.015	0.008
Arsenic as As	2.55	3.92	13.96	13.485	0.21
Barium as Ba	0.54	0.18	0.03	0.82	0.30
Beryllium as Be	0.009	0.006	0.00003	0.016	0
Bismuth as Bi	0.059	0.017	0.0002	0.088	0.046
Bromide as Br	0.18	0.10	0.01	0.4	0.1
Boron as B	60.55	67.63	4,157.52	175	0.51
Cadmium as Cd	0.084	0.088	0.007	0.2	0.001
Calcium as Ca	32.58	33.25	1,005.19	101.7	0.12
Chromium as Cr	0.078	0.039	0.001	0.144	0.046
Cobalt as Co	0.56	0.30	0.08	1.272	0.246
Copper as Cu	0.209	0.167	0.025	0.504	0.026
Fluoride as F	35.15	6.47	38.10	44.3	25.0
Germanium as Ge	0.044	0.096	0.008	0.28	0
Iron as Fe	13.99	25.46	589.10	88.20	1.54
Lead as Pb	0.642	0.924	0.776	2.24	0.015
Lithium as Li	0.179	0.117	0.012	0.378	0.070
Magnesium as Mg	17.49	7.75	54.56	26.4	6.86
Manganese as Mn	0.937	1.876	3.20	4.74	0.038
Mercury as Hg μg .l ⁻¹	3.78	11.35	117.18	38	0
Molybdenum as Mo	11.91	8.74	69.49	24.4	2.05
Nickel as Ni	1.62	2.06	3.85	5.21	0.067
Potassium as K	121.43	21.16	407.10	147.8	99.2
Selenium as Se	0.215	0.470	0.20	1.238	0
Silica as SiO ₂	17.95	4.15	15.65	25	13.5
Silver as Ag	0.135	0.123	0.014	0.316	0.004
Sodium as Na	9,392	2,951.0	7,916,720	17,800	7,281
Strontium as Sr	0.002	0.003	0.000008	0.007	0
Tin as Sn	0.168	0.454	0.187	1.5	0
Vanadium as V	0.43	0.25	0.056	0.82	0.12
Zinc as Zn	0.095	0.067	0.004	0.242	0.03

FIGURE 1
NATIVE VEGETATION IRRIGATION
EXPERIMENT LOCATION