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**ENVIRONMENTAL RESEARCH PLAN FOR THE GEOKINETICS INC.
INVESTIGATION OF THE HORIZONTAL IN SITU OIL SHALE
RETORTING PROCESS**

Research Program Outline

By
Hilding K. L. Spradlin
David L. Hutchinson
Steve G. Mankowski

November 30, 1979

Work Performed Under Contract No. FC20-78LC10787

Geokinetics Incorporated
Concord, California

U. S. DEPARTMENT OF ENERGY

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HILDING K. L. SPRADLIN
DAVID L. HUTCHINSON
STEVE G. MANKOWSKI

GEOKINETICS INC.
280 Buchanan Field Road
Concord, CA 94520

November 30, 1979

PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY

Under Cooperative Agreement #DE-FC20-78LC10787

RESEARCH PROGRAM OUTLINE

Table of Contents

<u>Section</u>	
I.	Introduction 1
II.	Program Background and Philosophy. 4
III.	Environmental Research Program Outline 7
A.	Atmospheric Resource Research. 7
A1.	Meteorological and Climatological Investigations. 7
A2.	Air Quality Investigations. 14
B.	Hydrological Resource Research 22
B1.	Hydrology 22
B2.	Effluent Water Handling 29
C.	Ecological Resource Research 31
C1.	Introduction. 31
C2.	Vegetation Research 32
C3.	Wildlife Research 33
C4.	Land Research 34
C5.	Risk Assessment and Mitigation. 35
C6.	Reclamation 36
D.	Cultural-Economic Resource Research. 38
D1.	Historical Investigations 41
D2.	Social and Economic Investigations. 44
D3.	Recreational Resources. 51
D4.	Permits 52

I. INTRODUCTION

In 1975 Geokinetics Inc. (GKI) began lab and field testing of a horizontal in situ shale retorting process. In July of 1977 a cooperative agreement was entered into with the United States Energy Research and Development Administration (now a division of the United States Department of Energy) to develop the process to commercial viability.

The process under development involves the explosive fracturing of shallow and relatively thin oil shale beds which causes minor uplift of the overburden. This is then followed by in situ retorting using a horizontally moving flame front. The development plan being followed is a phased, five year program designed to optimize blasting and retort burn techniques. Simultaneously, the retort sizes will be increased to their practical limits in order to benefit from the economies of scale which are expected to be realized as this practical limit is neared or attained.

In the course of developing the horizontal in situ retorting process, GKI is working on the frontier of knowledge, both technically and environmentally. The primary goal of the project is to overcome the obstacles inherent in the development of a viable horizontal in situ oil shale retorting technology; however, GKI also recognizes that the process being developed may have significant impacts upon valuable environmental resources. Since many of the impacts may be dependent upon and unique to the new technology and thereby not entirely foreseeable, it is essential

that the advances in technical knowledge be paced by simultaneous advances in environmental knowledge. To this end, GKI has developed and organized a concurrent environmental research program to identify, assess and minimize the adverse environmental impacts which may result from the research activities of GKI. Upon completion of the technical research project, the environmental research program will also have acquired the knowledge essential to valid assessment and mitigation of the environmental impacts that will be associated with a commercial horizontal in situ shale oil operation.

This environmental research plan has been prepared and submitted to propose the scope and intent of GKI's environmental research and to comply with the environmental provisions set forth in the Cooperative Agreement, number DE-FC20-78LC10787 (formerly ET-76-A-03-1787 and earlier EF-76-A-04-3789).

In broad form, GKI's environmental goals are to:

1. describe the environment as it existed prior to disturbance by GKI.
2. determine the nature and extent of environmental changes caused by GKI.
3. develop and implement measures to minimize the adverse impacts of GKI.
4. develop and implement reclamation procedures which will return the affected land to its original level of productivity and environmental durability, and
5. coordinate measures to protect the health and safety of persons and animals which may be affected by the activities of GKI.

GKI recognizes that the environmental research program must be dynamic to meet the demands that will be put upon it by a

technical research program developing a new technology. To this end, the program has been designed to promote flexibility in meeting this challenge.

II. PROGRAM BACKGROUND AND PHILOSOPHY

The GKI environmental program has grown along with the technical research program. Prior to 1977, the field research program was limited in scope and environmental concerns were adequately addressed by periodic environmental assessments. In 1977, it was determined that a formal environmental research plan was needed to systematically assess the impacts that the enlarged technical research program could impose upon the local environment.

In November of 1977, the first complete "Environmental Research Plan for the Geokinetics Oil Shale Group Investigation of the Horizontal In Situ Oil Shale Retorting Process" was published. This document provided for an exhaustive and comprehensive examination and evaluation of the impacts that GKI could create. It was recognized that as a research study, the environmental program would have to be flexible in order to continue to address the significant impacts of the retorting process and its appurtenant facilities. In order to assure such flexibility it was explicitly provided that revisions would be made to the Environmental Research Plan (ERP) as they became appropriate.

Subsequently, the ERP was revised in December of 1977 and February of 1978. It readily became apparent that the format selected was functional and flexible but could provide the requisite flexibility only in exchange for an inordinate cost in labor to revise the document each time.

The difficulties experienced in keeping the ERP current

finally resulted in a decision to restructure the document. The revised version would be required to outline the goals and direction of the environmental research program in a concise, comprehensive and understandable manner, but at the same time had to be readily amenable to dropping, adding and modifying research programs as program goals were achieved, as new knowledge obsoleted certain research approaches and necessitated new ones, and as research programs reached planned completion. It was decided that these goals could best be served by a two part document. One section, the Program Outline, would define the environmental research program goals and objectives and the second section, the Research Record, would describe the actual research conducted, modifications thereto and conclusions therefrom.

Experience has shown that in the case of GKI's in situ operation the environmental concerns can be addressed most effectively and logically with four general topical categories or sets: air, water, ecology and culture. Other ostensibly independent environmental concerns have been found to constitute subsets of the four primary categories since they do not stand by themselves but instead contribute to the goals of one or more primary sets or are heavily dependant upon the results from a primary.

This discovery has led to the environmental program as described herein to be classified into four major categories, Atmospheric Resource Research (meteorology and air quality), Hydrological Resource Research (geohydrology, hydrology, and effluent handling), Ecological Resources Research (flora, fauna,

pedology, geomorphology, and reclamation), and Cultural-Economic Resource Research (archeology, history, economics, sociology, industrial health and environmental health).

III. ENVIRONMENTAL RESEARCH PROGRAM OUTLINE

A. ATMOSPHERIC RESOURCE RESEARCH

A1. Meteorological and Climatological Investigations

A1.01 Introduction

Most of the environmental research investigations, currently under consideration by GKI, will be successful only after a reasonable understanding of the local microclimate has been acquired. Without this precursory understanding, inter-relationships existing between the process research and the surrounding environment cannot be assessed. Furthermore, changes in the local microclimate suspected of being related to the activities of GKI can not be evaluated, let alone substantiated.

In order to attain a reasonable understanding of the local microclimate and evaluate project induced impacts upon it, a meteorological and climatological investigation of the immediate locale will be required.

A1.02 Research Goals

The specific goals of the meteorological and climatological investigation are to collect, reduce and analyze meteorological and microclimatological data for the purpose of:

1. obtaining knowledge of the structure and flexibility of the local microclimate;
2. evaluating any trends associated with the locale; and
3. monitoring for project induced changes in the local microclimate.

A1.03 Parameters

All meteorological and microclimatological

parameters to be continuously monitored and investigated are listed in Table A1. The parameters were chosen carefully with consideration given to the amount of study needed to attain the goals of the investigation and to the cost effectiveness of the study. The investigation has been designed to minimize over-study without prostituting the quality of study.

A1.04 Collection - Monitoring Network

Continuous monitoring and data collection of microclimatological parameters will be conducted utilizing a network of electrical and mechanical weather collection and monitoring instrumentation. All instrumentation will be located at either a permanently based electrical station, an easily transportable electrical station or at a series of smaller, easily movable meteorological stations containing mechanical instrumentation.

In order to insure that the meteorological goals are attained, the instrumentation network will be modified or expanded as needed as the scope and location of project operations changes over time. For example, simultaneous extensions of retorting into areas of varying topography with dissimilar microclimates may require the utilization of additional or different instrumentation.

The meteorological instrument networks will consist of both electrical and mechanical instrumentation. Due to the savings in labor costs inherent in the devices, electrical instrumentation will be used as much as possible. Mechanical

TABLE A1

**Meteorological Parameters
to be Monitored**

<u>Parameters</u>	<u>Units</u>
Air temperature at 100 feet	degrees Farenheit
Air temperature at 30 feet	degrees Farenheit
Air temperature at 10 feet	degrees Farenheit
Soil temperature at surface	degrees Farenheit
Relative humidity	percent
Barometric pressure	inches of mercury
Wind velocity at 30 feet	miles per hour
Wind velocity at 100 feet	miles per hour
Total wind travel	miles per day
Wind direction at 30 feet	degrees azimuth
Wind direction at 100 feet	degrees azimuth
Precipitation at surface	inches
Evaporation at surface	gallons per square foot
Solar radiation at 100 feet	calories per in ² per minute
Solar radiation at surface	calories per in ² per minute
Sunshine duration	hours per day

instrumentation will be used only when comparable electrical instruments are not available, data is needed for special purposes over short periods of time, or when backup data collection to the electrical instruments is needed.

The networks of instrumentation will be configured to provide quality assured data on all of the parameters listed in Table A1. It is expected that data representative of the entire section upon which GKI will operate and data for point source specific ambient air dispersion path modeling will be obtained largely by electrical instrumentation. Microclimatological data of a particular area requiring specific monitoring and collection will be collected using a combination of mechanical and electrical instrumentation.

The mechanical instrumentation will include but will not be limited to:

1. hygrothermograph: to obtain relative humidity and temperature data;
2. evaporation recorder: to analyze net evaporation rates;
3. pyrheliometer: to assess solar intensity;
4. sunshine recorder: to obtain daily solar duration;
5. totalizing anemometer: monitoring total surface wind run;
6. microbarograph: to collect barometric pressure data; and
7. maximum-minimum thermometers: measuring temperature in degrees fahrenheit.

Whenever possible, the mechanical instrumentation will be powered by solar batteries to enhance system reliability and decrease maintenance time.

In addition to the regular microclimatic monitoring and collection network, a series of ecoclimatological stations (eco-logs) have been installed on the project site. They are specifically designed to obtain microclimatological data pertinent to the vegetation and soil erosion investigations.

Each eco-log is a self-contained unit continuously monitoring the following parameters during the growing season: surface air temperature, soil surface temperature, and precipitation.

The eco-logs are located in areas of differing vegetation types with two eco-logs in each vegetation type. One eco-log in each vegetation area is intended as a control unit and the other monitors for retorting process effects upon that particular vegetation type.

All instrumentation will be inspected on a weekly basis, and data will be examined for anomalies indicative of malfunction. Complete records will be kept of maintenance, malfunctions and correlative actions. All instrumentation will be calibrated quarterly and as accurately as field conditions permit. Calibration reference instruments will include a suitable observatory mercury-column barometer, thermometer, max-min thermometer and a psychrometer.

A1.05 Data Reduction and Analysis

Reduction and analysis of raw data will be conducted in-house by the environmental department and by consulting agencies as appropriate. Both automatic data processing (ADP) and manual reduction procedures will be utilized to meet

the goals of this investigation.

Statistical and correlative analyses will be conducted on all collected data in order to obtain monthly, seasonal and yearly representations of the local microclimate.

A1.06 Reporting

Technical reports with respect to the meteorological and climatological investigations will be written and submitted semi-annually. One covering the first six months of the year will be submitted by the first of October of that year, and the second covering the later six months of the year will be submitted the first of April of the following year.

A1.07 Equipment Site Selection

There exists the possibility of obtaining perfidious data that will in turn falsely represent the local microclimate. In order to minimize this problem, it is imperative that equipment installation sites are chosen carefully. Therefore the following rule will be followed so as to avoid this problem:

All equipment will be installed well above or a great distance away from any man-made or topographical feature that can alter or limit the efficiency of the equipment unless the equipment is specifically designed to be so affected.

A1.08 Upper Air

After considering the relative size of the entire research program being conducted by GKI, and maximizing all possible impacts that the program could have on the environment, it is now generally felt that an upper air investigation at the

research level would be unproductive. However, if the need for upper air data becomes imperative, an attempt will be made to obtain such data from the National Weather Service and the National Oceanic and Atmospheric Administration. If additional research is required, the permanently based electrical weather station may be extended and additional parametric sensors utilized to collect data between one hundred and two hundred feet. A possibility does exist that a program utilizing radio-sonde, tether-sonde or other aerially-derived data acquisition may be conducted.

A2. Air Quality Investigations

A2.01 Research Goals

The horizontal in-situ process presently being developed by GKI generates gaseous and aerosol contaminants and emits them to the atmosphere. The ramifications associated with these contaminants and their effects upon the environment are a major concern of GKI. The goals of the air quality investigations are therefore to:

1. determine the nature and extent of the contaminants;
2. determine the types of emission control devices and methods suitable for use with the process at project levels and eventually at commercial levels; and
3. identify and eliminate conditions that could evolve on a project level where certain contaminants might exceed standards protective of human and/or environmental health.

The criterion for determining the types of contaminants to be investigated is the standard federal regulatory definition of air pollution; defined as the presence in the ambient air of one or more air contaminants in such quantities and duration and under conditions and circumstances, as is or tends to be injurious to human health or welfare, animal or plant life or property, or would unreasonably interfere with the enjoyment of life or use of property.

A2.02 Research Categories

Potential types of air contamination to be investigated are process gases, stack gases, fugitive dust, aerosols and background sound levels. Each type will be addressed in one or more of the three following correlative research

categories. The research categories are: process gases, stack gases and ambient air.

A2.03 Process Gas

Gases produced during retorting travel from the retort, through a demister and thence to the stack eliminator. Daily monitoring of these gases for composition and heating value is essential in determining process efficiencies, selecting pollution control measures and for future resource recovery considerations. All unburned gases produced through retorting will be hereafter referred to as process gases.

From a direct environmental standpoint, regular monitoring and the subsequent analysis of the process gas stream is equally important. Basic source-strength data on chemical compositions of gases, concentrations of various constituents of the gases, flow rates and temperatures will be determined. Comparisons between process gas and stack gas can then be made for the purpose of assessing stack efficiencies and subsequently, air contamination at the stack.

As a second consideration, monitoring and analysis of process gas is essential in evaluating health hazards associated with possible leakage of process gas from retort surfaces or faulty equipment.

Process gas analysis will be performed in-house using gas chromatography and ASTM analysis methods on a regular basis. Any constituents of the process gases warranting either correlative analysis or requiring special instrumentation for analysis

will be contracted to an outside laboratory.

Extensive investigations by the Department of Energy (DOE) and other research organizations have been conducted on process gas with respect to oil shale. They have reported on all known contaminants that exist in process gas, and have made assessments of their significance.

GKI will conduct an investigation of all known significant contaminants to determine if they actually exist in the process gas. Those found to have significant concentrations will then be monitored on a regular basis and those found to have insignificant concentrations will be deleted from the monitoring program. Special periodic investigations will be performed to evaluate all known contaminants to insure that no new contaminants have developed nor that the previously found contaminants have changed in significance of concentration.

Preliminary studies have indicated that hydrocarbons, carbon monoxide, hydrogen sulfide, sulfur dioxide and oxides of nitrogen will have significant concentrations warranting periodic monitoring.

Nitrosamines, polynuclear aromatics and carbonyl sulfide (COS) are potentially dangerous health hazards requiring special attention. Outside laboratories will conduct investigations to determine if any of the three exist in the process or stack gases, and will assess their significance.

General parameters to be monitored in the process gas stream are listed in Table A2.

A2.04 Stack Gas

The last opportunity to control process induced contamination of ambient air lies in the efficiency of the stack eliminators. In order to evaluate the efficiency of the stack eliminator and the extent of process induced contamination into the atmosphere, a program of monitoring and analysis of stack gases must be initiated.

Initial monitoring and analysis of stack gases will be performed in-house using gas chromatography and ASTM analysis methods. From the obtained data, stack gas contaminants and their concentrations will be evaluated for significance. Conclusions will be verified by independent outside laboratory investigations.

The extensiveness of the stack gas investigations will be dependent upon the significance of the concentrations and the amount of contaminants found. Monitoring and analysis of stack gases will begin with periodic sampling using the in-house methods as described for process gas analysis. If any contaminants warrant more frequent study, schedules of monitoring will be stepped up. Furthermore, if the emission of any contaminant approaches or exceeds 100 tons per year, approved E.P.A. methods of monitoring and analysis will be implemented.

The monitoring program will also obtain effluent temperature and volumetric flow rate data for use in ambient air dispersion modeling.

General parameters to be determined from stack gas analysis are given in Table A2.

A2.05 Ambient Air

The ambient air investigations will be a multifaceted study with varying durations and extensiveness. In general, all contaminants emitted to the atmosphere whose source is directly or indirectly associated with the existence of GKI on the project site will warrant study.

The investigations will be designed to determine the air quality baseline, identify sources of project induced contamination, determine their impacts upon the ambient air quality and to design and implement suitable methods or devices for controlling whatever contamination is found.

Ambient air baseline data will be obtained for two reasons:

1. To use as a comparative value in assessing the level of impact that the project will have on ambient air quality in the future.
2. To determine if any contaminants of significance are present in ambient air under natural conditions.

The baseline investigations will consist of periodic sampling of the air for constituent analysis, photographically determining a visibility baseline and evaluating the ambient air scattering coefficient.

Stack eliminators will be continuous point sources of contamination generating nearly all of the air pollution associated with the project. Although other sources of contamination exist, their combined impacts should be minor in comparison with stack gas emissions. The extensiveness and direction of the ambient air monitoring program will therefore be largely governed by the findings obtained from stack gas analyses.

The monitoring program will initially consist of periodic sampling and analysis of ambient air which will become more frequent as the amounts of pollutants released approach the maximum yearly tonnages as defined by federal and state air quality regulations

Types of monitoring equipment will also vary with increased monitoring frequency. Initial periodic investigations will be performed with equipment previously described for process gas analysis. If conditions warrant continuous monitoring of specific contaminants, E.P.A. approved continuous monitoring devices will be utilized.

Langrangian diffusion modeling techniques will be used to assess dispersion paths and to determine placement of ambient air monitoring stations.

Process gas leakage will be investigated daily using carbon monoxide, sulfur dioxide or other appropriate gases as an indicator. The investigation will initially consist of monitoring for excessively high concentrations of carbon monoxide as defined by OSHA on and about retorts and processing equipment. Carbon monoxide comprises 2 to 10% of the retort off gas and is also the greatest amount of toxic substance per unit volume of gas, therefore if carbon monoxide in the ambient air is within acceptable limits then it would be safe to assume that all other toxic contaminants are within limits as well. Through relative dilution calculations, reasonably good estimates of concentrations of other contaminants can also be obtained. Monitoring for other

gases will be added or substituted as is found appropriate in the future.

Periodic monitoring of fugitive dust and aerosols will be performed using integrating nephelometers and photographic visibility studies. If fugitive dust emissions become excessive, control programs will be initiated in addition to the regular revegetation and soil stabilization programs.

Ambient background sound levels will be monitored if conditions warrant doing so. On a research level this contaminant is not expected to be significant. Occasional verification will be taken with a precision sound level meter with industry-standard A-weighting and slow ballistic features.

General parameters to be monitored in ambient air are listed in Table A2.

TABLE A2

Air Quality Parameters to be Monitored by Source.

(Determinations will include, but not necessarily be restricted to, the constituents listed in the respective tables.)

(1) PROCESS GAS STREAM

Temperature	Elemental Gases
Common Gases	Hydrogen (H ₂)
Ammonia (NH ₃)	Nitrogen (N ₂)
Carbon Dioxide (CO ₂)	Oxygen (O ₂)
Carbon Monoxide (CO)	Hydrocarbons
Hydrogen Sulfide (H ₂ S)	C ₁ through C ₆
Nitrogen Oxides (NO _x)	Carbonyl Sulfide (COS)
Sulfur Dioxide (SO ₂)	Organometallics
Mercaptans	Trace Elements

(2) STACK GAS STREAM

Temperature	Elemental Gases (as above)
Solid Particulates	Hydrocarbons (as above)
Common Gases (as above)	Organometallics
Ozone (O ₃)	

(3) AMBIENT AIR

Gross Particulates	Hydrocarbons (as above)
Common Gases	Oxidants (ozone)
Ammonia (NH ₃)	
Carbon Monoxide (CO)	
Hydrogen Sulfide (H ₂ S)	
Nitrogen Oxides (NO _x)	
Sulfur Dioxide (SO ₂)	
Sulfur Trioxide (SO ₃)	

B. HYDROLOGICAL RESOURCE RESEARCH

B1. Hydrology

When a particular resource in an environment becomes limiting, the eco-system becomes correspondingly less stable and more vulnerable to damage. In a desert biome such as the one encompassing the GKI research site, water is a limiting resource. Recognizing this, GKI intends to devote considerable attention to the effects its process may have on the abundance and quality of that resource.

B1.01 General Background

The baseline hydrologic framework for any region is a function of the climate, the vegetative cover and the geology of that particular region. Process effects leading to significant transfigurations of one or more of the governing factors will inevitably alter the baseline hydrologic framework.

From existing literature, those factors governing the hydrologic framework of the region are only generally known, but that which is known is highly typical of a high desert biome. The annual net evaporation rate is approximately 40 inches per year, total annual precipitation is 8 to 12 inches, the winters are dry and cold with some snow, the summers are hot and dry with intermittent thunder shower activity and the vegetation is predominantly pinyon pine, juniper and sagebrush.

From a geomorphological standpoint, bench land topography predominates in this arid to semi-arid region. The land rises gently to the crest of the Roan Plateau in the south. Continuity

of this surface is interrupted by deep narrow canyons of the larger tributaries of the Green and White Rivers.

Water is present in the ground immediately below the surface of the project site, but it has been found to be of poor quality. It appears to be perched on the mahogany bed with the water flowing in fractures in the rock. This subsurface region above the mahogany will be referred to as the shallow aquifer.

The mahogany oil shale zone is a relatively impermeable bed approximately 30 feet thick beneath the research site. This bed is gray to very dark brown, has a relatively low specific gravity and is very resistant to weathering.

Even less is known of the interlaying region between the mahogany bed and the deep aquifer at 1300 feet. Various sandstone beds are found throughout the interlaying region with the upper beds containing significant amounts of bituminous material and the lower sandstone beds lacking bituminous material.

The deep aquifer is noted throughout the entire region. The water is of good quality and contains the only potable water found to date on the research site.

It is suspected that the modified in situ process will have a significant impact upon the geological structure within the retort zone, but minimal effect by comparison upon the local microclimate or the vegetative system. The hydrology and water resource investigation will therefore be approached from a geological perspective and will exclude the more insignificant impacts upon the microclimate and the vegetation. Any significant process

related perturbations that may arise in the local microclimate or in the vegetative system that could alter the hydrological framework will be discovered by concurrent meteorological and ecological investigations. Conversely, any impact that hydrological perturbations may have on the local ecosystem will also be addressed as part of the ecological research program.

B1.02 Research Goals

As previously stated, significant alterations to the geology will impact the hydrologic framework. It is conceivable that by fracturing the mahogany, vertical communication between the shallow aquifer and the formations below the mahogany will be improved. This in turn could result in degradation of water below the mahogany.

Secondly, the actual retorting process can have various chemical impacts upon the hydrology. Process water is produced through combustion that can add to the groundwater volume, flow to areas outside the retorting area and contaminate subsurface waters.

Another conceivable chemical impact upon the groundwater quality could be leachables from a retort being transported to other water bearing formations and thereby contaminating subsurface waters.

In view of the possible impacts to the subsurface hydrology and water resources in the general vicinity of the research site, the following objectives have been formulated pursuant to attainment of the goal of the hydrological research program

i.e. determine if the development of the GKI modified horizontal in situ retorting process will adversely and significantly impact water resources in the region. The hydrological research objectives are as follows:

1. Characterize, identify and quantify the chemical constituents in surface water, groundwater, process water, and leached water.
2. Determine the configuration of the geological formations that will be affected by the retorting process or which may be open to contamination by the retort effluent.
3. Assess the perturbations to natural water movement that may be caused by process operations and the significance of such perturbations.
4. Determine the environmental fate and significance of solutes released to surface and subsurface waters.

B1.03 Research Categories

The impacts of retorting will be assessed for both surface water and groundwater. However, since there are no streams or ponds on the project site and surface drainage on the site is intermittent and present only as snowmelt or runoff from rainstorms, it is anticipated that the process will have negligible effect upon surface waters. This has resulted in both types of water being addressed together under the topical categories of hydrogeology/hydrogeomorphology and water characterization rather than under physical categories of surface and subsurface water. This approach is expected to permit study of surface water without overemphasizing its importance while permitting future increases in surface water study intensiveness should it prove necessary.

B1.04 Hydrogeology/Hydrogeomorphology

Research will be conducted under this category to develop an understanding of the geological structures underlying the test site. Items of particular interest will be wet and dry aquifers and aquacludes with respect to their porosities, water content, structure and relationships to each other. It is expected that core drilling, gamma logging, remote sensing and field mapping will be the tools of choice.

A second avenue of investigation will be to determine the hydrologic flow patterns on the project site prior to and after retorting. Well level monitoring plus chemical and isotopic tracing are the research tools most likely to provide the information needed.

Finally, gross alterations in the drainage pattern due to GKI activity will be identified and their impact assessed as necessary. Erosional and ecological impacts due to detailed changes in the drainage pattern are addressed as a facet of the ecological research program.

B1.05 Water Characterization

Water from aquifers determined to be of interest, the various retort water process streams and such runoff streams as can be found will be analyzed to determine their dissolved and suspended constituents. Initially, all samples will be analyzed for an extensive suite of parameters which have been identified as potential trace constituents in retort process water or are basic indicators of water quality. Table B1 lists the parameters

TABLE B1

Regular or Routine

Alkalinity as CaCO_3
 Hardness, total
 pH
 Specific conductance
 Temperature
 Turbidity

 Chemical oxygen demand

 Carbon, total organic
 Dissolved solids, total
 Suspended solids, total

 Dissolved solids, volatile
 Suspended solids, volatile

 Ammonia as $\text{NH}_3\text{-N}$
 Bicarbonate as HCO_3
 Carbonate as CO_3
 Nitrate as $\text{NO}_3\text{-N}$
 Nitrite as $\text{NO}_2\text{-N}$
 Sulfate as SO_4

 Calcium as Ca
 Potassium as K
 Silica as SiO_2
 Sodium as Na

 Arsenic as As
 Boron as B
 Fluorine as F
 Magnesium as Mg
 Mercury as Hg
 Molybdenum as Mo
 Selenium as Se

Quarterly

(In addition to all routine parameters examined)

Hydroxide as OH
 Barium as Ba
 Chloride as Cl
 Copper as Cu
 Iron as Fe
 Manganese as Mn
 Nickel as Ni

 Cyanide as CN
 Phosphate, total, as $\text{PO}_4\text{-P}$
 Orthophosphate, as $\text{PO}_4\text{-P}$

 Coliform, total
 Coliform, fecal

 Sulfur as S
 Zinc as ZN

 Oil and grease
 Phenols
 Surfactants
 Carbon, dissolved organic

 Gross alpha
 Gross beta
 BOD, 5-day
 Trace elements

which have been considered to be of initial interest from the standpoint of the environmental research program. The analysis results will be evaluated regularly to determine which test parameters are best dropped from the test suite as insignificant, not appropriate or generally not cost effective. In addition, new parameters judged to be important will be added to the test suite as necessary.

Standard ASTM methods will be used to conduct the analyses whenever possible but may be subject to modification to improve their accuracy when experience indicates that the ASTM method is not adequate due to peculiarities of the sample water. The overriding goal is accuracy but it is also important that the analysis methods be standard to the maximum extent possible.

Whenever possible, the GKI on-site lab will be used to conduct the analyses to insure standardization of analysis, minimize changes in the sample characteristics due to temporal delay, and to minimize analysis costs. Periodically, samples will be sent out to commercial laboratories to check the results from the on-site lab and thus insure the quality of results obtained.

B2. Effluent Water Handling

B2.01 Introduction

The GKI horizontal in situ retorting process produces an oil water emulsion and free water. The water is derived from groundwater in the retort, connate water released by the retorting process heat, and water generated when hydrogen in the kerogen and retorted oil is oxidized at the flame front. This water is pumped as an emulsion or as free water from the retort production wells and is recovered as both emulsion and free water from the exhaust gas recovery system. The water is separated from the emulsion, combined with the free water stream and is then disposed of.

Currently, the water is pumped into an evaporation pond lined with an impermeable membrane. The pond has been constructed large enough to allow for complete evaporation as a means of disposal.

Variations in the retorting process may enable part of this water to be reused in the retorting process, e.g. steam injection into the retort. However, it appears that the retorting process will always be a net producer of water and will require some method of effluent water disposal or purification to be used.

B2.02 Goals

GKI's water effluent disposal goal is to identify or develop, evaluate and select a method of disposing of effluent water and/or its solutes in a manner that is:

1. environmentally acceptable
2. cost effective

3. recovers as many useful resources from the effluent water as is economically feasible (including agricultural or potable water if practicable).

B2.03 Implementation

Beyond effluent characterization as described in B1.05, the GKI effort will largely consist of maintaining close contact with the research efforts of DOE in this field. Such research would be beyond the resources of this environmental research program and thanks to the current efforts of DOE in this field, largely redundant. GKI will evaluate and comment on the efforts of DOE and will provide whatever support to the research effort that is practicable.

The effluent water handling approaches that GKI considers potentially viable include but are not limited to:

1. evaporation (natural or enhanced)
2. purification and discharge
3. partial purification and discharge
4. deep well injection
5. reinjection into spent retorts

Selection of an approach will be dependent upon the results of research by both DOE and GKI. The viability of the purification approaches will be largely dependent upon the efforts of DOE in this area while the viability of the remainder will be highly dependent on GKI's environmental research in hydrology and ecology.

C. ECOLOGICAL RESOURCE RESEARCH

C1. Introduction and Goals

C1.01 Introduction

Ecology is the science concerned with the interrelationships among living things and with their non-living environment. GKI realizes that its operations will have an impact upon this local fabric of interrelationships. However, it is not known where GKI activity will impact this fabric nor how severely it will be impacted.

The more salient aspects of the local ecosystem are its plant and animal interrelationships. Preliminary observation reveals that the project site is in an arid region and supports a vegetational regime dominated by grasses, sage, pinyon pine and juniper. The vegetation and topography can be expected to support a diverse array of fauna. Wildlife species observed to date include elk, deer, coyote, occasional raptors and a diverse collection of small birds and mammals.

GKI is committed to minimizing its impact on this ecosystem so that avoidable permanent damage does not result and so that the process of reclamation is as simple and straightforward as possible.

C1.02 Goals

The general ecological goals which GKI will pursue are designed to provide an understanding of the local ecosystem so that measures may be taken to insure its minimal disturbance and the maximum probability that it can be restored to a

state of equal or greater useability or productivity than existed before disturbance. GKI's ecological goals are therefore to:

1. Develop a solid understanding of the local ecosystem interrelationships, that is, its structure and function.
2. Define the operational and post operational ecological impacts which can occur as a result of GKI operations and implement measures to mitigate those impacts.
3. Develop and implement effective reclamation procedures for lands disturbed by operational activities.

These goals will be implemented through efforts in ecological subcategories. These have been selected as functional divisions which will permit an effective research program to be mounted on a very broad and diversified subject. The categories consist of but are not necessarily limited to the following:

1. Vegetation Research
2. Wildlife Research
3. Land Research
4. Risk Assessment and Mitigation
5. Reclamation

C2. Vegetation Research

C2.01 Introduction

Vegetation is the primary producer in an ecosystem. Impacts on vegetation will have consequential impacts throughout the ecological community. For example, plants convert sunlight into energy which may then be potentially available to herbivores. If a particular vegetative species is removed from an area, animals dependent upon that plant will be secondarily impacted by reduced food sources. Predators of

such animals will likewise be impacted, and so on throughout the food web. In addition to food, vegetation provides other important habitat requirements such as cover and microclimate diversity.

C2.02 Implementation

GKI will conduct a vegetation study on Section 2 in order to:

1. Determine the types, location and relative abundance of vegetation on Section 2;
2. Develop an estimate of annual plant productivity on the project site;
3. Determine whether any rare, endangered or threatened species of plants are likely to be present on the project site; and
4. Determine whether populations of important plant species are endangered by GKI activities at the project site.

This descriptive data will be applied to the objectives of GKI's ecological investigations and will provide comparative data and a point of reference for future research and monitoring programs and impact assessment efforts.

C3. Wildlife Research

C3.01 Introduction

Preliminary reconnaissance of the project site by a professional ecologist indicates that operations will not affect any habitat critical to the survival of any wildlife species. It has been decided therefore to conduct a reasonably simple and short study of the local wildlife commensurate with the expected importance of the wildlife habitat on the project site. The program will be constructed so that it may be expanded

if the research results indicate that such would be appropriate.

C3.02 Implementation

GKI will conduct a wildlife study on the project site to determine the following:

1. Probable usage of the project site by mammals, birds, amphibians and reptiles;
2. Whether any rare, endangered or threatened species of animals are likely to be present on or make seasonal use of the project site; and
3. Whether populations of important animal species or critical habitat thereof are endangered by GKI activities at the project site.

Data collected will be applied to the ecological investigation objectives; it will enable an assessment of probable impacts of GKI operations on wildlife near the project site, and provide a comparative baseline for future wildlife monitoring programs.

C4. Land Research

C4.01 Introduction

This category of research shall be devoted to the diverse aspects of the direct process impacts upon the soils and geomorphology of the project site. Indirect impacts upon the ecosystem through the soils or geomorphology may, if appropriate, be addressed through this section but usually shall be better addressed in the section appropriate to the impacted entity i.e. plants, wildlife, air quality, hydrology, archeology, etc.

C4.02 Implementation

The studies to be conducted under this category

shall be designed to accomplish the following:

1. Describe the characterization and distribution of soils on the project site.
2. Assess the impact of project operations upon the local soils and implement measures to mitigate those impacts deemed unacceptable.
3. Assess the impact of project operations upon the local geomorphology and implement measures to mitigate adverse impacts such as erosional enhancement, drainage pattern modification, etc.

C5. Risk Assessment and Mitigation

C5.01 Introduction

Ecology is a complex, imperfectly understood and subtle science which often discovers important relationships among apparently unrelated entities and conversely can reveal new and subtle meaning to previously "well understood" inter-relationships. Due to this ecological characteristic this section has been instituted to provide an overt forum to periodically examine the environmental research program data base in an integrative light.

C5.02 Implementation

A meeting of all environmental personnel and other interested parties will be held semi-annually. A review of the research results from the previous six months will be given by each environmental department and an effort will then be made to identify previously unforeseen environmental problems occasioned by normal process operations, changes to process operations, and potential process failures or accidents. Problems identified will be dealt with by instituting new research programs if necessary, assessing the impact potential of the

problem, and devising and implementing appropriate mitigation measures.

C6. Reclamation

C6.01 Introduction

Reclamation is in many ways the culmination of the environmental research program. After all the environmental impacts have been identified and mitigated it is still necessary to restore the environment to a state which does not readily betray the fact that mineral extraction has taken place on the site. To accomplish this, it is necessary that there be no process debris left on the site, no major land scars left and a vegetational regime reestablished that resembles the natural one. Finally, it is important that the vegetation planted be as productive or more productive than the original vegetation so that wildlife and livestock carrying capacity is not adversely affected.

C6.02 Implementation

GKI defines reclamation as actions performed during or after project operations to shape, stabilize, revegetate, or otherwise treat disturbed areas in order to restore stable, and safe environmental conditions, consistent with the historical use of the land. Reclamation of the project site will thereby be accomplished in a manner designed to:

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

3. Minimize or prevent future hazards to public safety and welfare.

Pertinent environmental baseline and operational data, local Bureau of Land Management (BLM) experience and other sources will provide a basis for determining revegetation test strategies. On-site test areas for retort and support areas will be designated and experiments conducted. The results of test experiments will be applied to refining and standardizing reclamation methods and determining timetables for overall site rehabilitation.

D. CULTURAL-ECONOMIC RESOURCE RESEARCH

D0.01 Introduction

The existence of a mining camp and the corresponding development of GKI's horizontal in situ oil shale retorting process (LOFRECO) could have varying degrees of impact on the historical resources, social and economic conditions, and recreational resources of the Uintah Basin. In the past, energy related development has often led to "boom towns": communities which have experienced rapid population growth in an unplanned or uncoordinated manner. The result has often been the inability of a community to fulfill social and economic needs in safe, healthful, productive, and esthetically and culturally pleasing surroundings.

Quality of life is degraded when demands on basic public services and facilities, health services, housing and recreational and cultural opportunities outstrip the supply of these amenities. Community and personal disorganization evidenced by an increase in divorce and family instability, crime, and mental illness is likely to occur. Researchers have noted "that in fairly remote areas where labor must be attracted and retained from elsewhere, quality of life may become a critical factor of production."¹ Rapid population growth can also affect the physical environment in ways that have quality of life implications. Surveys have revealed that residents of the Uintah Basin place a high value on their rural lifestyle and ready access to an attractive outdoor environment.² Aesthetic deterioration

resulting from uncoordinated rapid population growth will have undesirable effects on the attractiveness and quality of that outdoor environment. Further, it is the National Environmental Policy of the United States "to create and maintain conditions under which man and nature can exist in harmony, and fulfill the social, economic and other requirements of present and future generations..." This policy (NEPA) includes the goal of assuring "safe, healthful, productive, and esthetically and culturally pleasing surroundings" and the responsibility "to preserve important historic, cultural, and natural aspects of our national heritage, and maintain wherever possible, an environment which supports diversity, and a variety of individual choice." In addition, Section 102 (b) requires Federal agencies to insure that unquantified environmental amenities and values be given appropriate consideration in decision-making along with economic and technical considerations.

GKI will examine its activities in relation to historical resources, social and economic conditions, and recreational resources, and will cooperate with local, state and federal authorities in an effort to minimize adverse impacts.

REFERENCES

1. Logan, R., A. Wiseman, S. Albrecht, and B.D. Gardner;
Anticipated Socio-Economic Impacts In The Uintah Basin
of Utah Resulting from Oil Shale Development, in the
area with matching support from Utah State University;
p. 72.
2. Gilmore and Duff, cited by Logan, et. al.; p. 72.

D1. Historical Resources

D1.01 Introduction

GKI recognizes historical resources as valuable and irreplaceable cultural assets that often merit preservation and protection. Archeological, anthropological and paleontological resources are a nonrenewable source of scientific data and information which, when neglected, desecrated or destroyed result in an irreplaceable loss.

Much can be learned about the past by studying these resources: e.g., how the earth was formed and developed; how, when and where certain mineral resources were deposited; how social systems have developed; and how people have adapted to environmental change through time.

The public has an interest in the preservation, protection and study of these resources. This is evidenced by federal and state antiquities statutes, public support of museums and historical sites, and by support of historical research.

GKI recognizes that its activities could disturb or destroy historical resources. The value of an historical resource would be diminished by incompatible development adjacent to the resource or could be destroyed by process operations on the site occupied by the resource.

The types of resources that might be impacted by GKI activities definitely include antiquities: historic and prehistoric sites, buildings, ruins and other objects; and materials of paleontological interest.

D1.02 Goals

In order to adequately assess potential impacts and avoid or mitigate disruption or destruction of historical resources, GKI has adopted the following goals:

1. Locate and identify historical resources that may exist on land used by GKI;
2. Determine the relative value or significance of these resources; and
3. Take appropriate measures to preserve or protect important resources.

D1.03 Implementation

The goal of locating and identifying historical resources that may exist on a site is achieved by the following procedure:

1. Consult national and state historical registers to determine if any such resources have already been identified and recorded;
2. Consult the Utah Division of State History
 - a. to obtain known information about the site and historical resources likely to exist on it, and
 - b. to obtain permits and clearances needed to conduct further study or process operations;
3. Direct inquiries to local persons familiar with the area in question to obtain information about the site and historical resources likely to exist on it; and
4. Commission surface surveys by qualified parties approved by the Division of State History prior to operations having potential for resource disturbance.

The goal of determining the value or significance of historical resources that are found to exist will be achieved through evaluation by the parties conducting the surface surveys. Such evaluation will then be reviewed by the Division of State History.

The goal of preserving or protecting important resources will be achieved by consulting with the Division of State History to design and implement preservation or protection measures appropriate to the value of the resource. These measures may include strategies to avoid or mitigate disruption or destruction, state-supervised excavation of the resource, or non-development of the specific site involved.

To insure that additional findings (made after the initial investigations and surveys) are reported, identified, and if valuable, preserved or protected, GKI will instruct its employees to report such finds to their supervisors. Significant finds will be promptly reported to the parties that conducted the original survey and to the Division of State History. Appropriate measures will be taken to preserve to protect such resources until they can be evaluated by competent authorities.

D2. Social and Economic Conditions

D2.01 Introduction

Two facets of potential socio-economic impacts may result from GKI activities, they are:

1. Possible socio-economic impacts of GKI activities on the Uintah Basin, and
2. Social and psychological impacts upon GKI employees; related to maintaining a remote, somewhat isolated field camp.

D2.02 Regional Impact Goals

GKI recognizes that uncoordinated rapid population growth can have devastating impacts on the socio-economic structure and public service delivery system of a community.

Therefore, GKI's goals are to:

1. Assess the potential socio-economic impacts GKI activity could have on the Uintah Basin, and
2. Develop and implement strategies to avoid or mitigate significant adverse impacts.

GKI will thus insure that its activities will not contribute to negative impacts on the community.

D2.03 Implementation

These goals will be achieved in the following manner:

1. Assemble socio-economic data pertaining to the Uintah Basin;
2. Generate projections of GKI activities, especially employment and expenditure information;
3. Evaluate the above information in terms of potential impacts of GKI activity;
4. Determine whether significant impacts will result from GKI activity; and

5. Consult and cooperate with local government planning agencies to develop mitigation strategies, if needed.

The principal planning agency concerned with growth in the Uintah Basin is the Uintah Basin Association of Governments (UBAG). UBAG has established an Energy Planning Office to assist in managing energy development-related growth and mitigating adverse socio-economic impacts. GKI will continue to work with these authorities to eliminate potential negative impacts and contribute positively to growth and well-being in the Uintah Basin.

D2.04 Internal Impacts

Some socio-psychological impacts upon GKI employees are unavoidable in a situation wherein they must live and/or work at a remote, isolated field camp. These impacts are of immediate and direct significance to the individuals affected and are of indirect importance to GKI due to their potential for increasing employee turnover and decreasing worker productivity.

Of the spectrum of socio-economic impacts that could be precipitated by GKI activities, the social and psychological impacts upon employees are likely to be the most significant. As a result, GKI expects to devote most of its socio-economic impact alleviation efforts to this area of concern.

Most GKI employees are housed at the project site in trailers provided by the company. The field camp is approximately 70 miles or 2 hours from all basic and emergency services. Retail and grocery stores, gasoline service stations, postal service, organized recreation facilities, schools, health and medical services and county fire-fighting aid are among the facilities and

services that field camp residents do not have ready access to.

In general, when conveniences and amenities that people normally take for granted are not readily available, negative reactions to the situation may arise and can range from mild dislike of the situation to various types of psychological disturbance. Effects of these impacts could be manifested in a multitude of ways ranging from snappishness toward others to familial disintegration and mental illness.

Employees residing in Vernal or Roosevelt and commuting to the field site are also not immune to these impacts. Married couples will be left with a minimum of time together as the worker spends most of the day at work and in transit. This may strain the marital relationship or cause difficulties in child raising.

D2.05 Mitigation

Total avoidance of these socio-psychological impacts related to living and/or working at a remote, isolated field camp is impossible. However, GKI feels that given careful and sensitive employee selection, education, and management, these potential problems are manageable. GKI proposes to mitigate such impacts by implementation of the following program:

1. Inform prospective employees of camp living conditions;
2. Provide as many civilized amenities, work opportunities, and social events as possible;
3. Conduct safety and emergency training periodically; and
4. Periodically review management policies, procedures, and activities related to the field operation in order to find ways of maintaining and improving morale among employees and their dependents.

One of the most effective means of mitigating impacts on those living and working at the field camp is by insuring that prospective employees know what to expect. A prospective employee is given a chance to visit the field camp and talk to others at the site about general working and living conditions. GKI also attempts to acquaint them with the options available for educating school-age children which can present special problems since the nearest school bus stop is 40 miles away at Ouray, Utah and even a one-room school cannot be obtained at the site unless 25 to 30 students are living at camp. The only reasonable option for some time will probably be to enroll school-age youngsters in certified correspondence courses. If offered a position, a person is encouraged not to accept unless they feel that they and their families can accept and adjust to the camp working and living problems. Flexibility and the ability to adapt lifestyles to circumstances are important qualities that GKI tries to find in prospective employees and their dependents.

GKI provides as many amenities as practicable to make the field camp a reasonably pleasant place to live. Clean, safe and comfortable mobile homes are provided at company expense. Utilities and furnishings are also provided. GKI provides laundry facilities, and certain company tools and equipment are available for personal employee use.

Transportation to and from Vernal is provided as frequently as possible. Employee mail is taken to and delivered from Vernal several times a week, and employees are permitted to have their

mail delivered c/o GKI. A company telephone is available to employees at the field camp, but toll charges are the responsibility of the caller.

GKI provides an indoor recreation facility at the project site. It is used as a camp meeting hall as well. Pool (billiards), TV, board games and ping-pong are available activities. Company parties are sponsored periodically, as are other group activities.

GKI attempts to offer part-time employment to worker's dependents as much as possible. This provides an opportunity for involvement in company operations, a break from a possibly boring routine, and supplemental income.

Since recreation is largely an individual matter, field camp residents accustomed to urban-type recreational facilities will be more severely impacted than those who require less in the way of "organized" activity. Extensive outdoor recreation opportunities are available in the area surrounding the camp.

GKI recognizes that maintaining a remote field camp entails responsibilities related to emergency situations. The GKI Health and Safety Branch maintains a periodically updated industrial safety plan, a camp fire prevention plan and an emergency medical treatment and evacuation plan as well as conducting training in occupational and household safety, accident prevention and first aid. Periodic safety meetings also cover fire prevention and procedures for fire detection and extinguishment. All camp residents will be given first aid training. All may be certified at the Red Cross basic level and selected employees may be certified

at the Red Cross advanced level as appropriate.

GKI will periodically review matters related to maintaining the field camp. This will include but will not be limited to examining GKI policies, procedures, and activities related to camp working and living conditions and consequential social and psychological impacts. In addition, GKI will continue to encourage suggestions from employees and other camp residents as to means of improving the camp living and working conditions.

Interpersonal problems that may arise are dealt with by the individuals involved. Problems involving a company policy or procedure are discussed with an employee's supervisor, or with the person responsible for that policy, to resolve difficulties.

GKI will remain alert to other potential impacts and will continue to make every effort to provide safe, healthful, productive, and esthetically and culturally pleasing surroundings for its employees and their dependents.

D3. Recreational Resources

D3.01 Discussion

GKI interprets recreational resources to be those elements of the environment which provide people any pleasurable interest or amusement, or refresh them physically or mentally by means of relaxation or enjoyment.

GKI recognizes the value of recreational resources and realizes that its activities could have potentially adverse impacts on recreational opportunities in the Uintah Basin. Potential impacts of GKI activities on recreation provided by businesses or public facilities may be considered direct socio-economic impacts, and are addressed in Section D2 of this ERP. Potential impacts on outdoor recreation opportunities near the project site are addressed here.

The types of activities that could be impacted by GKI operations are numerous. The region provides opportunities for solitude, aesthetic appreciation, photography, wildlife observation, hiking, camping, rock-hounding, four-wheeling and hunting. Winter opportunities for snowmobiling and cross-country skiing also exist.

The most significant potential impacts that GKI activity could have are the displacement of game animal herds and the elimination of public access to operations areas.

GKI will study the potential for displacement of game animal herds in environmental baseline studies and ecological investigations carried out under Section C3 of this ERP.

Public access to operations areas will be restricted due to safety considerations.

These potential impacts would affect only a limited number of people, and are of a temporary nature. Recreational resources in the area of the project site are not heavily used by Uintah Basin residents or tourists most of the year because of the area's general inaccessibility and the availability of more attractive and less arid areas such as the Uintah Mountains and Flaming Gorge Reservoir to the north. The only time that there is any significant recreational use of the area near the project site by the public is during deer hunting season. It is not expected that this use will be adversely affected by GKI activity.

The unavailability of operations areas for recreational use will be temporary since project use of the land is temporary and GKI will return operations areas to the recreational resource base after the extraction of the shale oil resource. This will be achieved through the design and implementation of reclamation and revegetation strategies to return the land to its original aesthetic appeal and carrying capacity for wildlife and stock.

D4. Permits

D4.01 Discussion

Part of the cultural environment that GKI functions in consists of the body of national, state and local law. Among this body of law are requirements that governmental permission be obtained for various and sundry aspects of process operations such as land use, construction, emission release, etc. It is essential that GKI identify the various permit limitations under which it must function and insure that these requirements are met.

To this end, GKI has instituted a procedure whereby all permits obtained by the company are reviewed quarterly to insure that they are still needed and are current. Close liason is maintained with the pertinent governmental agencies to insure that GKI is aware of new permits as they become necessary. Finally a record of all permits needed by GKI presently and in the near future will be listed in the Research Record to this Environmental Research Program. These permit records will list the following information as appropriate:

1. Name of Permit
2. Governmental Agency issuing
3. Enabling and pertinent statutes and regulations
4. Conditions for procurement and maintenance
5. Status of permit
6. Where the actual permit documents may be found.