Robert S. Kerr
Environmental Research Laboratory

Revised

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Compiled by
Robert S. Kerr Environmental Research Laboratory

Office of Environmental Processes and Effects Research
Office of Research and Development
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

Contents

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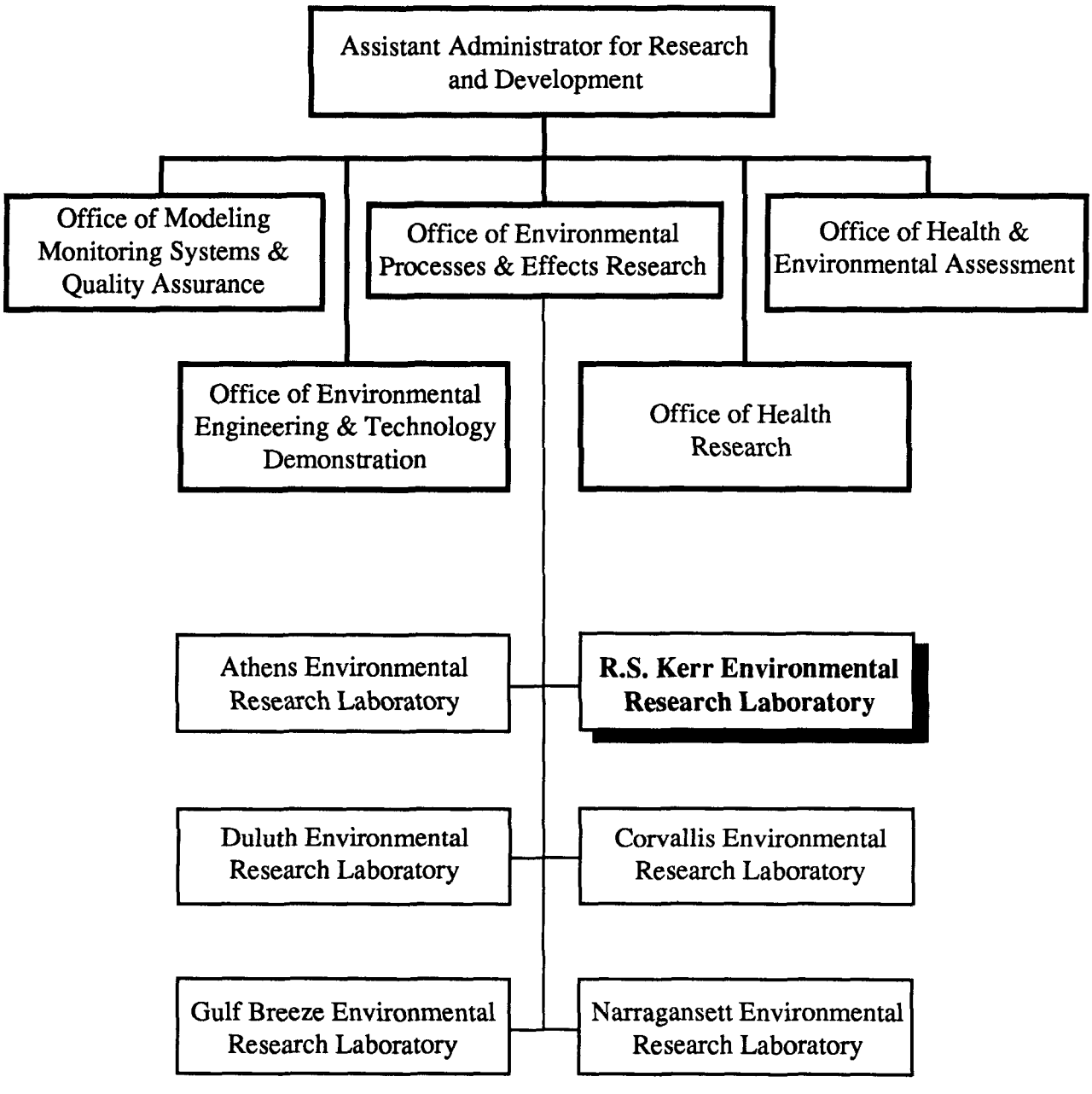
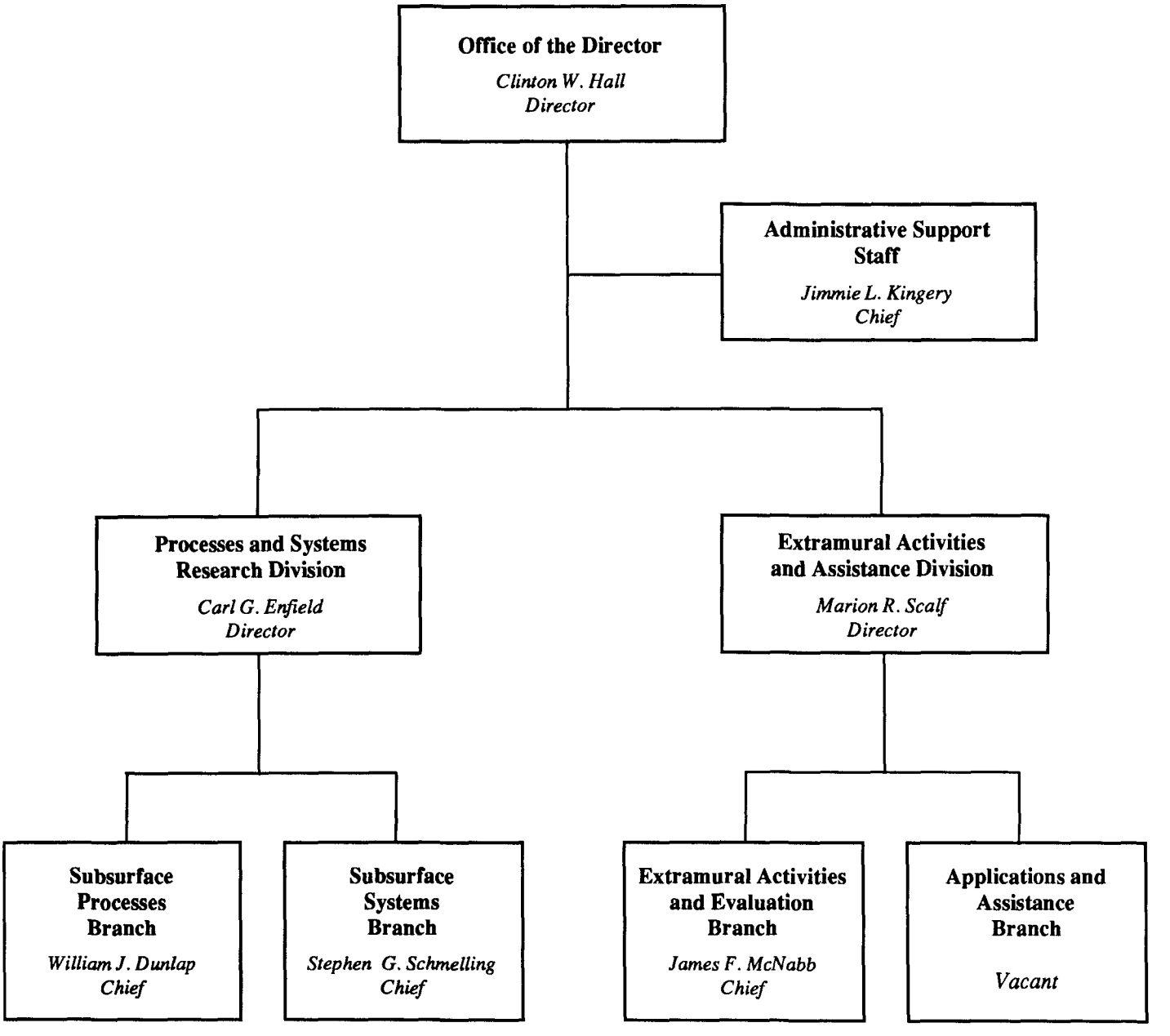


Robert S. Kerr Environmental Research Laboratory

Organizational Chart



Background

The Robert S. Kerr Environmental Research Laboratory in Ada, Oklahoma, is one of 14 national research laboratories of U.S. EPA's Office of Research and Development. Dedicated in 1966, RSKERL began as a U.S. Public Health Service laboratory responsible for providing research, technical assistance and training on water pollution problems to the south-central region of the U.S., including the states of Arkansas, Texas, Louisiana, New Mexico and Oklahoma. By 1970, when the U.S. EPA was established, the research programs at RSKERL were directed toward solving environmental problems national in scope and importance.

Today, RSKERL serves as U.S. EPA's center for ground-water research, focusing its efforts on studies of the transport and fate of contaminants in the subsurface, development of methodologies for protection and restoration of ground-water quality, and evaluation of the applicability and limitations of using natural soil and subsurface processes for the treatment of hazardous wastes. The Laboratory has a long history of research responsibilities related to the use of soils and the subsurface for waste treatment and to the protection of the soil, ground water and surface water. These responsibilities have, in the past, included the development and demonstration of cost-effective methods for land treatment of municipal wastewaters, animal production wastes, and petroleum refining and petrochemical wastes, as well as the development of technologies for the protection of ground-water quality.

RSKERL carries out research through in-house projects and cooperative and interagency agreements with universities, national laboratories, and other research centers. RSKERL currently has over 50 ongoing or planned extramural projects at approximately 25 research institutions in 20 states.

Current Activities

An examination of the environmental legislation (including RCRA, SDWA, CERCLA, and TOSCA) that relate to ground-water quality protection reveals four common regulatory and/or management requirements:

1. Establishment of criteria for location, design, and operation of waste disposal activities to prevent contamination of ground water or movement of contaminants to points of withdrawal or discharge.

2. Assessment of the probable impact of existing pollution on ground water at points of withdrawal or discharge.

3. Development of remediation technologies which are effective in protecting and restoring ground-water quality without being unnecessarily complex or costly, and without unduly restricting other land use activities.

4. Regulating the production, use, and/or disposal of specific chemicals possessing an unacceptably high potential for contaminating ground water when released to the subsurface.

These requirements translate into a need by the Agency, other regulatory entities and industry, for a definitive knowledge of the transport and fate characteristics of contaminants in subsurface environments. Without sufficient knowledge of the behavior of contaminants in the subsurface, there is a risk of (1) under-control, resulting in excessive ground-water contamination, or (2) over-control, resulting in uneconomical under-utilization of the subsurface as a treatment media.

The mission of the Robert S. Kerr Environmental Research Laboratory is to develop that knowledge base.

Processes Research

Most of the research conducted at RSKERL is directed at the processes that control the transport and fate of contaminants in the subsurface. For organizational purposes RSKERL divides this work into the areas of hydrologic, abiotic, and biotic processes research. Hydrologic processes are those processes that act to influence the movement of water, the primary vehicle for contaminant transport. Abiotic processes are the chemical and physical interactions that cause contaminants to move at rates different than those of the water or which change the concentrations of the contaminants. Biotic processes refer to microbially-mediated transformations of contaminants in the subsurface to other compounds. In the subsurface these three types of processes are inseparable and simultaneous, and the ultimate goal of all research is to integrate the influence of these processes into a unified understanding of contaminant behavior in the subsurface.

Hydrologic Processes

The lack of understanding of how contaminants move in the subsurface severely restricts the ability to protect ground-water quality or to design effective systems to "cleanup" contaminated ground water. Although the physics of water flow in uncontaminated homogeneous media is reasonably well understood, the processes involved in contaminant transport in heterogeneous media is poorly understood. Hydrologic processes research at RSKERL is directed at three areas: (1) expanding our understanding of the physics of fluid flow through porous media, (2) developing methodology for evaluating the spatial variability of hydrologic processes in the subsurface, and (3) advancing the mathematical techniques for predicting the spatial and temporal distribution of contaminants.

Current RSKERL research aimed at understanding the physics of fluid flow through porous media includes studies on how immiscible fluids move through porous media, the impact of the immiscible fluids on the physical properties of porous medium, fluid movement in heterogeneous formations, and delineation of the physical basis of dispersion.

RSKERL's efforts to develop methodology to evaluate the heterogeneity of the hydrologic system include the evaluation of measurement methods to determine the variability in hydraulic conductivity and the development of statistical techniques for sampling strategies and risk analysis.

RSKERL has an extensive program to develop, evaluate, and improve mathematical models for use in predicting the transport and fate of contaminants in the subsurface. Model development includes work on advective and dispersive models for contaminant transport in the vadose zone and ground water. The principal avenue for model information transfer is the International Ground Water Modeling Center (IGWMC) at Holcomb Research Institute in Indianapolis, Indiana. The IGWMC maintains and evaluates mathematical models designed to simulate ground-water movement and contaminant transport, maintains annotated data bases of these models, maintains data sets for model evaluation, offers hands-on training courses, and conducts research to develop benchmark methods for the intercomparison and validation of existing models.

Abiotic Processes

Abiotic processes research at RSKERL is focused on five major areas of concern: (1) sorption processes; (2) facilitated transport phenomena; (3) behavior of complex wastes; (4) abiotic transformations; and (5) spatial variability implications. The objectives of research projects in these areas include defining and understanding the chemical and physical mechanisms responsible for the observed phenomena and evaluating the implications of these processes. Laboratory and field work on abiotic processes is coordinated with the refinement of mathematical models that simulate processes affecting the mobility and fate of contaminants in ground water.

Sorption processes retard the movement of contaminants relative to the movement of the water in which the contaminants are being transported. Understanding and quantitating these sorption processes is important for risk assessment and for designing systems to remediate contaminated ground water. An understanding of sorption of non-polar organic molecules in low-carbon subsurface environments typical of many aquifers is emerging, although the capability to accurately forecast

pollutant transport is still lacking. RSKERL work in the sorption area includes: (1) studies to determine the environmental factors that control the sorption of polar and ionic organic contaminants and the subsequent impact of these contaminants on the mobility of non-polar organic compounds; (2) laboratory studies on sorption and retardation in the complex matrices typically present at contaminated sites; (3) studies to determine the effects and importance of sorption kinetics for pollutant transport; and (4) studies to determine the environmental factors controlling vapor phase sorption in the vadose zone.

Facilitated transport is a generic term encompassing phenomena that enhance contaminant mobility. Evidence of mobility enhancement has been observed at a number of contaminated sites, but the processes responsible for this enhanced mobility have yet to be clearly identified. Facilitated transport research conducted by RSKERL includes studies of: (1) enhanced transport of organic compounds of low solubility by dissolved organic carbon; (2) particulate transport; (3) enhancement of metals transport by the formation of organo-metallic complexes; and (4) mixed-solvent transport. These research areas involve many different chemical and physical mechanisms, but are linked by their common effect of enhancing the transport of pollutants in the subsurface.

The behavior of complex wastes is emerging as a focal point of abiotic processes research. Complex wastes frequently contain separate immiscible phases in which organic compounds are dissolved and behave differently than those dissolved in water. Research at RSKERL is investigating the movement of relatively insoluble organic compounds partitioned into the immiscible fluid matrix and the chemical processes involved in the dissolution and weathering of the separate phase. Both of these areas are closely related to questions about the efficacy and efficiency of pump-and-treat technologies for remediation of aquifers contaminated by complex wastes.

The fourth area of abiotic processes research is the study of chemical transformations. RSKERL research projects are investigating subsurface environmental factors which are expected to change the importance of naturally occurring chemical transformations in ground water relative to that observed in surface waters. These factors include the presence of abundant mineral surfaces, the absence of oxygen, and the long residence times during which even slowly occurring reactions may become important. Other RSKERL research projects are investigating the efficacy of inducing abiotic chemical transformations as a remediation technique, particularly in the vadose zone.

The final area of abiotic processes research is on the spatial variability of those parameters that affect abiotic processes. Most subsurface formations are heterogeneous, and the impact of this variability, with respect to important subsurface parameters in the transport and fate of contaminants, is only beginning to be investigated. The fractured porous rock that underlies many contaminated sites is an example of a situation where spatial heterogeneity plays an important role in the rate at which abiotic processes take place. In unconsolidated media, the lack of complete mixing may play a major role in the rate at which chemical and biological reactions take place and may limit attempts to remediate contaminated ground water. RSKERL is pursuing research, in both laboratory and modeling studies, in this area.

Biotic Processes

The biotic processes research effort was initiated on a very limited scale in the late 1960's when RSKERL scientists postulated, on the basis of both field observations and environmental considerations, that subsurface environments were likely to harbor significant populations of microorganisms potentially capable of degrading pollutants. In the ensuing years this effort has continued to grow in intensity as the result both of research findings and increasing recognition of the magnitude of ground-water pollution problems. Considerable progress has been made by RSKERL and its extramural associates in developing effective methods for obtaining uncontaminated samples of subsurface material for biological studies, in developing new techniques and procedures for enumerating and characterizing subsurface biota, and in developing technology for studying biological transformations of contaminants in the subsurface.

Historically, the primary effort of the RSKERL biotic processes research program has been directed toward the development of fundamental process information required for the development of mathematical models for predicting the transport and fate of pollutants in subsurface environments. However, in recent years the need for applications research pertaining to the development of biologically based methodologies for the restoration of contaminated subsurface environments has exerted an impact of increasing significance on the research effort. While the development of basic process information remains a principal goal of the biotic processes research program, much of the research directed toward this goal is currently conducted within the framework of bioremediation technology development activities.

The current RSKERL biotic processes research program is comprised of three principal research elements which represent the breadth of activities from fundamental subsurface biological process delineation to applied bioremediation technology development.

1. Process discovery - initial discovery and definition (usually qualitative) of specific biological processes which transform and/or degrade pollutants in subsurface environments. The development of information concerning the occurrence and behavior of microorganisms responsible for subsurface biological processes is included in this area.

2. Process evaluation - careful quantitative evaluation at laboratory scale of subsurface biological processes.

3. Process Demonstration - evaluation of specific subsurface biological processes in pilot plant or field-scale studies in relation to biorestoration technology development. The validation of mathematical models of biotic processes is included in this element.

For naturally-occurring organic contaminants, such as petroleum hydrocarbons, the state-of-knowledge is fairly advanced, and therefore, the work is mainly in the area of process application. Computer models that predict the course of biorestoration of contaminated soils as well as contaminated aquifers are being developed and evaluated in the field. But for xenobiotic compounds such as trichloroethylene and dioxin, most of the work is at the level of process definition. A field study is in progress to determine the extent to which a novel biotechnology can remove trichloroethylene from an aquifer. Parallel studies in the laboratory are adapting this biotechnology to treat water from contaminated wells. The microbial communities that degrade trichloroethylene are being characterized biochemically to allow comparisons of their community structure and nutritional status. This should allow a determination of whether the organisms in cultures, laboratory microcosms, and field studies are similar and can be expected to behave the same way, or if they are significantly different.

The knowledge of anaerobic biotransformation of contaminants is expanding rapidly. Anaerobic fate studies, with contaminated subsurface material have revealed a number of unsuspected biotransformations. This work is now moving to the level of process definition, and these newly discovered anaerobic processes may form the basis for restoration biotechnologies. Denitrification, a well characterized anaerobic biotic process, is being applied to restoration of ground water contaminated with nitrates. Hydrologic influences on the basic biotic process are being evaluated at pilot scale.

Human pathogens are important contaminants of ground water. RSKERL has focused its efforts since 1976 on studying the transport and survival of viruses in the subsurface. Important data on the fate and transport of important human pathogens, such as Rotavirus, Hepatitis A, poliovirus, and other enteroviruses, has been collected and compared to the fate and transport of bacterial indicators. Current work is focused on the development of a regional screening model of virus transport in soils and ground water to be used in decisions related to disinfection variance and wellhead protection zones.

Applied Research

In addition to processes research, the scientific foundation of all research and other activities conducted by RSKERL, there is also considerable effort to support the immediate needs and activities of EPA's operating programs.

Underground Injection Control Program

Both the Safe Drinking Water Act of 1974 and the Hazardous and Solid Waste Amendments of 1984 address the question of protection of ground-water quality as a result of injection of waste into the subsurface by means of deep wells. EPA regulations in support of this legislation have been based on assuring that the use of injection wells for the disposal of waste will not endanger the human health or the environment.

Research in support of the underground injection control program is basically in three areas: (1) mechanical integrity of the injection well -- methodologies for determining that waste injection is into the intended zone and no others; (2) the injection zone and confining bed -- methodologies for determining that the waste will stay in the injection zone; and (3) the fate and transport of injected waste in the injection zone. RSKERL supports research projects in each of these areas. RSKERL has constructed research wells near Ada for the purpose of finding more effective ways of determining the mechanical integrity of injection wells. The test facility, which consists of one injection well, two cement evaluation wells, one fiberglass calibration well, three monitoring wells, and necessary surface equipment, is designed to evaluate the integrity of cement behind both steel and fiberglass casing; test a variety of methods for detecting leaks in tubing, casing and packers; evaluate the capability for detecting fluid movement behind casing; and detect the movement of fluids in the subsurface away from the injection well. This Mechanical Integrity Test Facility provides EPA with a unique research facility unmatched in government, academia or industry.

Office of Solid Waste

RCRA mandated Land Treatment Regulations promulgated July 26, 1982, require that all hazardous waste land treatment facilities obtain a Part 264 Operating Permit. These permits are intended to insure that land treatment units are designed, managed and closed in an environmentally acceptable manner. RCRA Amendments of 1984 require a fixed schedule of decisions pertaining to whether or not land treatment should be prohibited as a waste management alternative for specified hazardous wastes. RSKERL is actively developing technical information and associated decision models needed by regulatory authorities to make economically, technically and environmentally acceptable decisions pertaining to land treatment prohibition determinations, permit responses/ issuances, site closure/post closure plans, no migration petitions, and corrective actions.

Office of Ground-Water Protection

Section 1428 of the Safe Drinking Water Act Amendments of 1986 calls for states to establish wellhead protection (WHP) programs on a voluntary basis. The Amendments give EPA no regulatory authority to require states to implement WHP programs, but do charge EPA with providing guidance and leadership to the states.

RSKERL supports the Office of Ground-Water Protection (OGWP) and the WHP program in two areas: (1) the evaluation and refinement of methods for delineating WHP areas, and (2) development of delineation methods to account for the ability of aquifers to dilute, retard, or otherwise attenuate the concentrations of contaminants moving toward public drinking water wells.

Technical Assistance & Information Transfer

The Robert S. Kerr Environmental Research Laboratory has long been involved in technical assistance and information transfer with EPA Regional Offices and state and other federal agencies. The terms "technical assistance" and "information transfer" identify a multitude of activities. In general, "technical assistance" is used to describe an activity initiated by a specific request that requires significant RSKERL personnel resources. Information transfer activities may require significant resources but are generally items that are initiated without a specific request.

Superfund Subsurface Remediation Technology Support Program

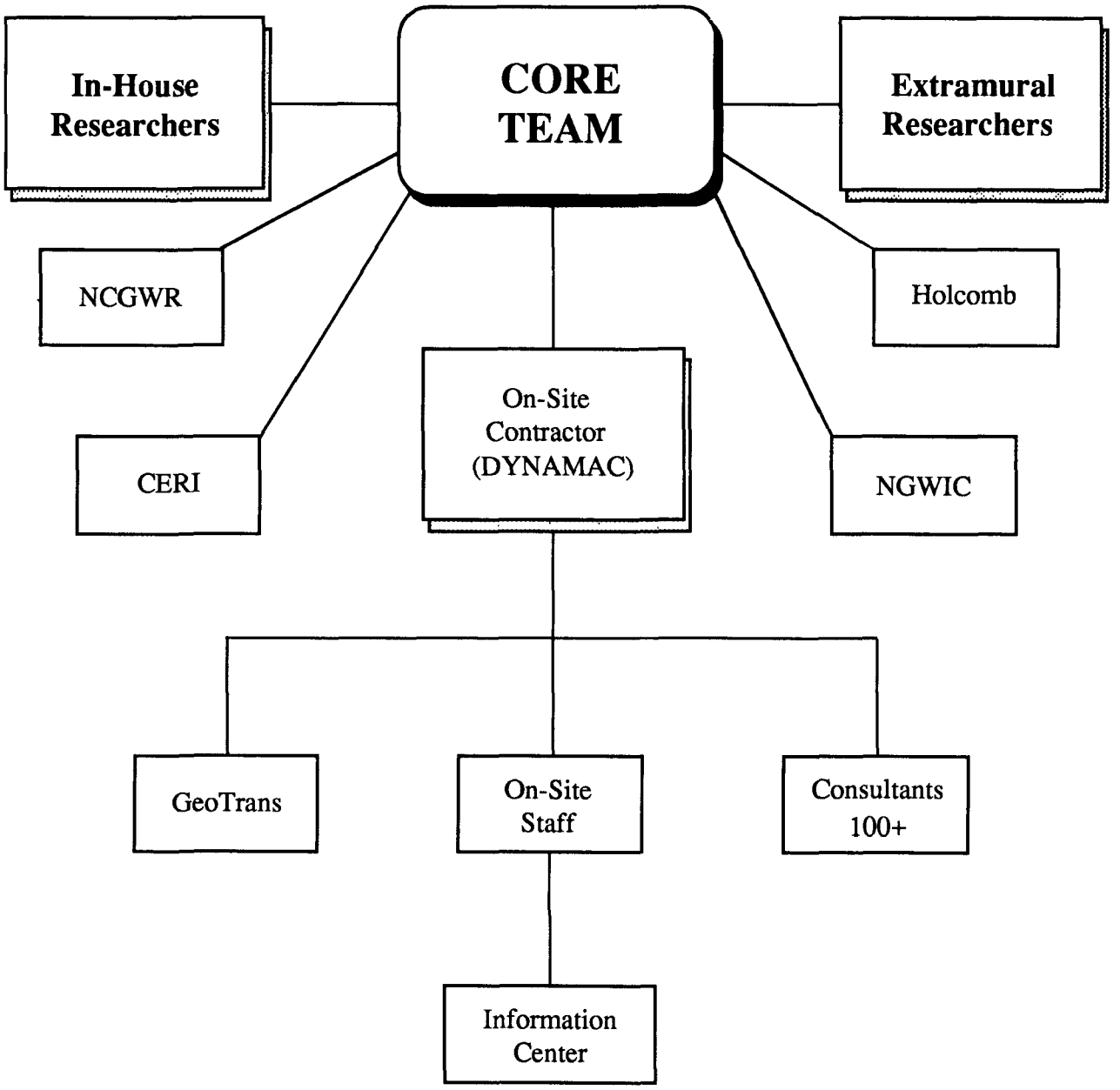
The Superfund Amendments and Reauthorization Act of 1986 (SARA) directs the EPA, as part of the overall Superfund site clean-up program, to conduct a program of research, evaluation and demonstration of alternative or innovative technologies for response actions that will achieve more permanent solutions than in the past.

Superfund site decision-makers must evaluate, approve, and plan an appropriate combination of cost effective remediation activities that will protect human health and the environment. Selection of appropriate ground-water remediation technology is dependent on an understanding of fate and transport characteristics of hazardous chemicals in subsurface environments--a highly specialized, rapidly developing scientific field. The Office of Solid Waste and Emergency Response (OSWER) and the Office of Research and Development (ORD) have established a Subsurface Remediation Technology Support Program under RSKERL that provides decision-makers with a source of easily accessible, up-to-date subsurface fate and transport information and the associated expert assistance required to effectively use this information. Components of the program include:

- Subsurface Remediation Technology Support Core Team -- RSKERL scientists and engineers provide a readily available source of technical support with assistance from an on-site contractor and a cross-section of ground water scientific expertise available as consultants;
- RSKERL Research Program -- expertise on subsurface processes and systems from more than forty in-house scientists and thirty-five universities and research institutions provides the scientific basis for the Technology Support Program;
- On-Site Contractor -- provides support to Core Team in the form of on-site scientific staff, a Subsurface Remediation Information Clearinghouse, subcontract to GeoTrans, Inc., and over one hundred consultants from the ground-water research and consulting community;
- National Center for Ground Water Research -- a consortium of Oklahoma, Oklahoma State and Rice universities charged with developing and conducting long-range exploratory research to help anticipate and solve the Nation's emerging ground-water problems;
- International Center for Ground Water Modeling -- Holcomb Research Center, Indianapolis, clearinghouse for ground-water modeling software, providing research, short courses, seminars and educational activities;
- National Ground Water Information Center -- National Water Well Association, Dublin, Ohio, repository of ground water quality information accessible to scientists, government agencies, business and the public; and
- Center for Environmental Research Information (CERI-Cincinnati) -- provides support to Technology Support Program in the development of seminars, conferences, training, publications, and other technology transfer materials.

RSKERL - ADA

Technology Support Center



LIST OF ACTIVE PROJECTS

Site Characterization

Transformation

Transport

Subsurface Exposure Assessment

Subsurface Reclamation

Underground Injection Control

Wellhead Protection

Drinking Water

Superfund

ACTIVE PROJECTS

Swelling Properties of Soil Organic Matter

Institute:	NSI (Carl Enfield/Roger Cosby, P.O.)
Task No:	1036
Project Period:	09/89 - 09/90
Principal Investigator:	Bill Lyon (FTS 743-2277) Fred Busche (FTS 743-2302)

Abstract: This project is aimed at the development of methods for measuring the swelling properties of soil organic matter. Three variations of the basic technique published by Green et.al., 1984, for measuring the swelling properties of powered coals will be explored. These are:

1. Reduction of necessary sample size through the use of melting point capillaries for the swelling measurements;
2. Direct use of the measurement technique on very organic rich, whole soil samples; and
3. Use of the technique on fractions of soil organic matter separated by means of ultra-sonification and heavy liquids such as methylene chloride.

Status: A new ashing technique has been developed which allows for an accurate determination of soil organic matter and mineral content. Interference of wax and resin components to swelling determinations on Michigan peat samples has been overcome by using the soxhlet extraction. Wax and resin tended to melt during the drying procedure thus interfering with swelling determinations. A review of the microcalorimetric method for studying sorption of organic solvents by earth materials was completed. This method appears to have many advantages over other methods currently in use to study sorption.

Field Evaluation of the Conjunctive Use of Mathematical Models and Laboratory Microcosms

Institute:	U.S. Geological Survey - Reston (John Wilson, P.O.)
Task No:	1043
Project Period:	06/89 - 06/92
Principal Investigator:	Stephen Ragone (FTS 959-5720)

Abstract: The project will determine whether the distribution of reductive products of trichloroethylene in an actual plume of contamination can be predicted by incorporating biodegradation rates of trichloroethylene and cis-dichloroethylene (determined in anaerobic laboratory microcosms) into a solute transport model. Cores, used to construct laboratory microcosms, will be taken from a flow path exhibiting reductive dechlorination at the Picatinny Arsenal in New Jersey. Rates of degradation will be incorporated into a comprehensive solute transport model of the site and the predictions will be compared to the actual disposition of daughter products along the flow line in the field.

Status: Microcosms to simulate DCE and TCE biotransformation have been constructed and rate determinations are underway.

Methods for Estimating Spatial Variability of Subsurface Environments

Institute:	U.S. Geological Survey - Boston (Robert Puls, P.O.)
Task No:	2005
Project Period:	04/88 - 12/90
Principal Investigator:	Stephen Garabedian (FTS 835-6861)

Abstract: The object of this project is to develop methods for dealing with the spatial variability of the properties of subsurface environments and its impact on the prediction of contaminant transport and fate. Predicting the transport and transformation of chemicals in the subsurface environment requires a knowledge of the spatial and temporal variability of parameters used as input data to transport and transformation models. It is not economically feasible to measure each of the parameters for every element in the problem domain. Also, methods are required to select the next most advantageous sample point and estimate the confidence gained from this additional data. This project addresses methods of determining spatial variability, its impact on predictions of contaminant distribution in the subsurface, and an evaluation of statistical techniques for determining how many samples are required to adequately describe a hydrologic system.

Status: A paper titled "Evaluation of Hydraulic Conductivity Measurements from a Multiple Port Permeameter" is undergoing final revision. It describes the permeameter method for measuring hydraulic conductivity and compares the results with other techniques. Analysis continues on data collected during the summer of 1989, but it is still too early to assess if it will be sufficient to resolve the three-dimensional structure of the hydraulic conductivity distribution. A two-dimensional analysis of permeameter data and the first set of borehole flowmeter data has been completed. An article, "Macrodispersion Estimates from Hydraulic Conductivity Measurements," is being written. It incorporates the two dimensional structure of the hydraulic conductivity distribution into a stochastic theory to predict macrodispersion, and compares the results with natural-gradient tracer tests. Another article, based on laboratory measurements associated with the project, suggests a significant adsorptive capacity of the weathered feldspar minerals in the sediments at the Cape Cod site.

Scanning Electon Microscopy - Energy Dispersive X-Ray Studies of Ground Water Colloids

Institute:	U.S. Geological Survey - Denver (Robert Puls, P.O.)
Task No:	2034
Project Period:	09/89 - 07/90
Principal Investigator:	Terry Rees (303) 236-4053

Abstract: The characterization of ground-water colloids at a Globe, Arizona, copper mine will contribute to an improved understanding of contaminant transport mechanisms for heavy metals in ground water. Colloidal material, collected on nucleopore filters, will be analyzed for particle size and number distribution, mineral identification, and possible heavy metal sorption on individual mineral particles. This will be accomplished using scanning electron microscopy with energy dispersive X-ray analyses.

Status: A journal article has been prepared on colloid characterization at a site with heavy metal contamination. The techniques are now being applied to other projects.

Vertical Profile Characterization of Microbiological Activity in an Aviation Gasoline Plume

Institute:	RSKERL	
Task No:	3021	
Project Period:	03/89 - 05/90	
Principal Investigator:	Don Kampbell	(FTS 743-2358)
	Guy Sewell	(FTS 743-2232)
	John Wilson	(FTS 743-2259)

Abstract: This project is to provide a descriptive assessment of microbial activity in the remediation of gasoline contaminated subsurface material at the Traverse City project site. The microbial activities associated with biodegradation of gasoline components present in the profile of a plume will be identified and quantified. Characterization phenomena will be determined on core material for fuel carbon, dehydrogenase activity, bacteria count, microcosm rate of degradation, and total biomass by fatty acid profile.

Status: The field and microcosm work has been completed along with data analysis. The first draft of the report is being reviewed.

Chemical Relationship between Soil, Gas, Core Material, and Water Quality at an Aviation Gasoline Plume Site

Institute:	RSKERL	
Task No:	3022	
Project Period:	09/89 - 06/90	
Principal Investigator:	Don Kampbell	(FTS 743-2358)
	David Ostendorf	(FTS 743-2232)
	John Wilson	(FTS 743-2259)

Abstract: The project aim is to define the relative importance of soil gas measurements, core material analyses, and water quality on the transport and transformation processes taking place in a specific contamination plume. Soil gas measurements and core analyses have been obtained at different depths and locations in an aviation fuel plume at the U.S. Coast Guard Air Station in Traverse City, Michigan. Analytical data from ground-water monitoring wells at the site are available. The chemical parameters to be emphasized are aviation gasoline constituents, oxygen, methane, and carbon dioxide. The results of the investigation will aid in corrective action decisions at other hazardous sites for the selection of methodology and the evaluation of remediation.

Status: The final report is nearing completion.

Anaerobic Metabolism of Organic Pollutants in Subsurface Environments

Institute:	NCGWR /University of Oklahoma (Guy Sewell/Dick Scalf, P.O.)
Task No:	1010
Project Period:	06/86 - 10/90
Principal Investigator:	Herb Ward (713) 527-4086 Joe Suflita (405) 325-5734

Abstract: The object of this project is to provide information on the biodegradation of selected classes of organic pollutants by anaerobic microorganisms indigenous to the subsurface, including: the physical, chemical, and biological factors which limit or stimulate biodegradation; the predominant pathways; and the microorganisms and associated degradative enzymes involved. Indigenous microflora from anoxic subsurface environments will be biologically characterized. Classes of organic compounds which are susceptible to anaerobic degradation in such environments will be identified and the environmental conditions which control the rate and extent of such degradation will be elucidated. Biodegradation pathways for selected compounds will be determined and the isolation of the responsible enzymes will be attempted. If possible, the appropriate techniques to assess anaerobic biodegradation in the field will be developed.

Status: The dehalogenating bacterium DCB-1 has been characterized phylogenetically through 16S ribosomal RNA analysis, which indicates that the bacterium belongs to a new genus of sulfate reducing bacteria. Crude extracts of the dehalogenating bacterium strain DCB-1 reductively dehalogenated contaminants with a preference for 3-iodobenzoate; 3,5 dichlorobenzoate; and 3-chlorobenzoate. In resting cell experiments, aryl dehalogenation was stimulated in the presence of formate, pyruvate and hydrogen. It was inhibited in the presence of sulfate, thiosulfate, molybdate, selenate, diphenylamine, and metrinidazole. Hydrogen was evaluated as an electron donor to help clarify the relationship between dehalogenation and sulfate reduction. The rate of hydrogen consumption was about four times faster during the reduction of sulfur oxyanions compared to reductive dehalogenation. The dehalogenation of PCE by the same cell extracts was enhanced in the presence of methyl viologen and was proportional to the amount of protein in the extract. The presence of 3-chlorobenzoate had no effect on the dehalogenation rates of either PCE or 3-chlorobenzoate, suggesting that the two dehalogenation processes are unrelated.

Chemical Kinetics of Heterogeneous and Homogeneous Solution Phase Decomposition of Haloaliphatic Compounds

Institute:	Stanford University (Stephen Hutchins, P.O.)
Task No:	1019
Project Period:	04/88 - 09/90
Principal Investigator:	Martin Reinhard (405) 723-0308

Abstract: The goals of this project are to define the role of the geologic matrix (containing iron minerals), and the solution chemistry (reduced sulfur species), on the abiotic transformation of halogenated aliphatic compounds. Fe(II) containing minerals, such as magnetite and biotite, will be characterized with respect to surface area, bulk elemental composition, and other parameters which are expected to affect reactivity. Sorption of haloaliphatics, such as hexachloroethane, on these materials will be measured prior to transformation studies. Transformation studies will be conducted to determine reaction rates, stoichiometry, and activation energies to allow for the development of a kinetic and mechanistic model for the reduction of haloaliphatics by Fe(II) and the nucleophilic substitution reactions between sulfur compounds and haloaliphatics.

Status: Experiments have been conducted to assess whether the abiotic transformation of carbon tetrachloride (CT) in the presence of Cysteine (CS), sulfide (HS-), and Fe(II) was facilitated with and without a solid mineral phase, represented by zeolite. Tests with low Fe concentrations demonstrated no enhancement in reaction rate with zeolite, probably due to sequestering of Fe within the zeolite structure. At high Fe concentrations, iron oxyhydroxide precipitates occurred without zeolite present and led to a high transformation rate; therefore, zeolite was not a good choice for this type of system. For CS and HS-, the presence of zeolite clearly accelerated the abiotic transformation of CT, therefore it appears that mineral surfaces are necessary or advantageous for promoting abiotic transformation rates of CT. Future work will focus on evaluating other model minerals such as aluminum oxides and silica gels instead of zeolite, and including iron sulfide minerals such as pyrite and marcasite.

Oxy-Radical Processes for Abiotic In Situ Destruction of Organic Pollutants in Aquifer

Institute:	Illinois State Water Survey/RSKERL (Stephen Hutchins, P.O.)
Task No:	1023
Project Period:	09/88 - 03/90
Principal Investigator:	Gary Peyton (217) 333-5905

Abstract: The goal of this research is to evaluate the feasibility of chemical in situ aquifer reclamation using free-radical abiotic processes for the degradation of organic contaminants. The radical processor agents will be introduced into columns containing aquifer materials and several organic contaminants. At the end of the experiments the aquifer material will be extracted to determine residual contaminant concentrations. Free radical effects on the aquifer material will be evaluated through measurement of aquifer material TOC before and at the end of the experiments. The data will be evaluated for feasibility of using free radicals for in situ remediation.

Status: A series of four miscible displacement experiments have been performed and consistent results obtained by using azide to suppress microbial activity. Naphthalene transformation and average persulfate residence time yielded a good correlation. An extrapolation of these results indicates that about 17 hours of persulfate/napththalene contact would be required for complete napththalene transformation.

Biodegradation of Pesticides in Aquifers

Institute:	RSKERL/NSI (John Wilson/Roger Cosby, P.O.)
Task No:	1033
Project Period:	07/88 - 01/92
Principal Investigator:	Jim Sinclair (FTS 743-2302) Fred Busche (FTS 743-2302)

Abstract: The objective of this project is to develop methods to predict the biological degradation of pesticides in aquifers and to correlate the hydrologic and geologic properties of aquifers to their capacity to degrade pesticides. More specifically, the object is to determine if differences in subsurface sediment characteristics are related to differences in the biodegradation potential. Cores having different textures will be obtained from drilling at a site having several desired characteristics. Some cores will be tested for the ability of their microbial populations to degrade atrazine to CO_2 by adding ^{14}C labeled atrazine and measuring the amount of $^{14}CO_2$ released. Other portions will be tested by HPLC analysis for the degradation of atrazine even if it is partial degradation not resulting in CO_2 formation. Finally, bacteria from the samples will be characterized for metabolic capabilities and diversity in an attempt to link microbial type to sediment type and biodegradation potential.

Status: Aseptic cores have been acquired from two sites in a water table aquifer in Oklahoma. Ground water at one of the sites contains residues of atrazine, while the other site is uncontaminated. The cores have been used to construct microcosms. Some of the microcosms were spiked with radio-labelled atrazine and are being monitored for the production of radio-labelled carbon dioxide. Some were spiked with stable atrazine and are being monitored by HPLC for the removal of atrazine and appearance of transformation products. Some of the microcosms were sterilized to separate the contribution of biological and abiotic transformations.

Degradation of Monoaromatic Hydrocarbons by Aquifer-Derived Microorganisms under Various Types of Anaerobic Conditions

Institute:	Stanford University (Stephen Hutchins, P.O.)	
Task No:	1034	
Project Period:	05/89 - 08/91	
Principal Investigator:	Dunja Grbic-Galic (415) 723-3668	Martin Reinhard (415) 723-0308

Abstract: This project has been established to determine the capacity of microorganisms in aquifers to transform monoaromatic hydrocarbons, including BTX, in the absence of oxygen. This information will be used to predict the influence of the geochemical environment on the biotransformation of hazardous organic compounds in subsurface materials. Microcosms will be constructed from subsurface material contaminated with monoaromatic hydrocarbons. Enrichment cultures will also be derived from contaminated subsurface materials. The microcosms and cultures will be used to determine the potential for biotransformation of the predominant aromatic hydrocarbon contaminants of the subsurface. In the first year of the project, emphasis will be placed on methanogenic and sulfate-reducing conditions.

Status: Experiments are continuing with aquifer material from Seal Beach and Traverse City. Different activities are observed in the two systems indicating heterogeneities in microbial populations from the two sites. Only toluene degradation has been observed in Seal Beach microcosms and it occurs with and without Fe (III). Activity ceases with time and efforts to renew activity through vitamin, acetate/benzoate, or yeast extract addition have been unsuccessful. In the Traverse City material toluene and ethylbenzene are degraded with preferential activity toward the latter. Traverse City material also shows activity toward propylbenzene in methanogenic and sulfate reducing microcosms but only under conditions using media supplemented with organics. In all cases co-metabolism may be the mechanism affecting the fate of the compounds. Some replicate microcosms are inactive, indicating heterogeneity in subsurface populations. Future work will include the continuation of these tests with a emphasis on maintaining activity and the initiation of tests using material from the Patuxent River.

Biodegradation of PCB's in Complex Oily Wastes

Institute:	RSKERL/NSI (John Wilson/Roger Cosby, P.O.)	
Task No:	1035	
Project Period:	07/88 - 09/90	
Principal Innvestigator:	Susan Gibson (FTS 743-2325)	Fred Busche (FTS 743-2320)

Abstract: The objective of this investigation is to evaluate the effects of different treatment scenarios, including alternating aerobic/anaerobic treatment, on PCB congeners in a mixed oily waste. Biodegradation of PCB congeners will be evaluated in a mixed oily waste under a variety of conditions including: (1) aerobic; (2) aerobic with an initial biphenyl supplement; (3) anaerobic; (4) anaerobic with a periodic butyrate supplement; (5) alternating aerobic/anaerobic; and (6) anaerobic with sulfate or nitrate as alternate electron acceptors. If a suitable PCB contaminated waste cannot be obtained, an oily waste without PCB contamination will be spiked and evaluated. In either case, some samples will be spiked with known congener mixtures or with an Aroclor mixture.

Status: Microcosms have been constructed to simulate the fate of PCB during the land farming of a mixed oily waste. Other microcosms simulate the degradation of PCB in an anaerobic compost supplemented with a fatty acid. A few microcosms also simulate PCB degradation in an aerobic soil slurry reactor.

TCE Biotreatment Demonstration Project

Institute:	RSKERL/NSI (Dennis Miller/Roger Cosby, P.O.)		
Task No:	3016		
Project Period:	10/88 - 09/90		
Principal Investigator:	Randy Callaway (FTS 743-2319)	Fred Busche	(FTS 743-2249)

Abstract: The purpose of this research is to design, construct, and demonstrate a mobile treatment system to remove chlorinated solvents from contaminated ground water. The work will consist of three phases. The first will include literature reviews and bench scale experiments to develop and confirm design parameters. Phase two will include the construction of the treatment system and verification of its removal efficiency. Phase three will include transporting the system to a predetermined site and demonstrating removal under field conditions.

Status: The evaluation of the bioreactors has been completed for three TCE loading rates. In addition, the unit design of the air stripper is complete as is the redesign of second phase bioreactors. The design for the hydrocarbon concentration unit has been initiated.

Regional Screening Model of Virus Transport in Soils and Ground Water

Institute:	U.S. Department of Agriculture (Dave Walters, P.O.)
Task No:	1015
Project Period:	03/89 - 02/91
Principal Investigator:	Scott Yates (714) 787-5145

Abstract: The objective of this project is to improve an existing model of virus transport in soils and ground water. EPA's Office of Drinking Water is required, by 1991, to promulgate regulations that would require the disinfection of all ground water used as public water supplies. Variances may be granted if it can be shown that the water is likely to be free from viral contamination. A regional model of virus transport in ground water has been developed incorporating geostatistical techniques which has the potential for use as an aid in granting variances from the disinfection regulation. The model may also be used in the delineation of wellhead protection zones that would minimize the contamination of drinking water by enteric viruses. It will not only calculate wellhead protection zones, but will also provide an estimate of the probability that virus contamination will not occur in the well if that zone distance is imposed. The model, as currently written, is very simple in that it only considers the horizontal movement of viruses under regional ground-water flow conditions. In order for the model to be more realistic, and therefore more useful, several improvements are necessary. These include the transport of viruses through the unsaturated zone and the influence of pumping wells on the flow characteristics of the area. A screening model which could be used by regulators to help determine areas with a higher probability of virus contamination of ground-water supplies will be developed. It will have the capability of delineating protection zones within which sources of contamination should not be placed if contamination by viruses is to be avoided. Every effort will be made to limit data input requirements to information available from local water utilities.

Status: Work is underway on the initial model format. A paper, "The Use of Models for Granting Variances from Mandatory Disinfection of Ground Water Used as a Public Water Supply," has been completed.

Biological Colonization of Hazardous Waste Sites

Institute:	Cornell University (John Wilson, P.O.)
Task No:	1016
Project Period:	10/87 - 02/91
Principal Investigator:	Martin Alexander (607) 255-1717

Abstract: It has recently become apparent that certain classes of hazardous organic wastes are being treated in situ in aquifers and in deeper regions of the unsaturated zone, through naturally-occurring biotransformations. Techniques are being developed that evaluate the contribution of this natural biorestoration on a site-specific basis. These techniques presume that the contaminated aquifer, or deeper unsaturated environment, already harbors organisms that are capable of biotransforming the contaminant. Site specific information is needed that can be used to evaluate the prospects for colonization of a contaminated aquifer or the unsaturated zone by these microorganisms. The object of this project is to develop an understanding of the properties of microorganisms as well as the properties of the subsurface materials which determine whether a particular contaminated site will be colonized by microorganisms capable of degrading wastes. The effort will emphasize laboratory and pilot scale field studies. Information collected will be appropriate for incorporation into mathematical models describing the transport of microbes through geological material.

Status: A number of bacterial strains have been isolated that are capable of degrading hazardous organic substances. These strains have been screened for transportability through soil, and they fall into two classes. Some of the strains are easily transported while others are strongly retained in the soil. Work continues to build a larger collection of strains, and when the collection is large enough to make statistically valid comparisons, the strains will be characterized to determine the physiological or chemical basis for transportability. An internal report, "Biodegradation of Organic Wastes at Hazardous Waste Sites," has been forwarded to the appropriate Program Office.

Facilitated Transport of Hydrophobic Organic Pollutants by Dissolved/Colloidal Organic Macromolecules

Institute:	RSKERL
Task No:	1020
Project Period:	02/88 - 04/90
Principal Investigator:	Candida West FTS 743-2257

Abstract: This project has four main goals, which are to: (1) provide further evidence and understanding of size exclusion of macromolecules as a mechanism of contaminant transport; (2) examine whether synthetic model macromolecules simulate transport by naturally occurring macromolecules; (3) determine whether experimental breakthrough curves involving this mechanism of facilitated transport may be adequately described by the mathematical expressions used in models; and (4) determine whether the level of significance played by size exclusion for any particular soil may be calculated using common soil characteristics. Specifically this project will determine: (1) if there is a range of break through velocities for synthetic macromolecules which can be corrected by molecular weight; (2) if the velocities of different organic macromolecules of the same "apparent" molecular weight are constant in a given soil column; (3) the range of pore sizes from which the macromolecules are being excluded; and, (4) if given the empirically derived effective porosity for a macromolecule (relative to that of water) and the partition coefficients of selected organic molecules, if the observed movement of the hydrophobic organics can be adequately predicted by existing transport equations.

Status: Column studies of polyethylene oxides (PEO's) through a sand have been completed which indicated transport up to a molecular weight of 900,000. There was no evidence of size exclusion, although this is not surprising since PEO's are linear chains of small size in one direction. Experimental work is complete and data analysis is underway for column studies where humate colloids were passed through the same sand. Concentrations as high as 300 ppm humate have broken through at 95-100 percent of the initial concentrations. Particle size analyses have indicated that these particles were stable throughout the experiment and averaged approximately 300 nanometers in diameter. Work is now underway to determine the effect of humates on contaminant transport.

Partitioning of Hydrophobic Compounds between Soils and Solutions Effects of Dissolved Organic Carbon and Surfactants

Institute:	RSKERL
Task No:	1022
Project Period:	06/87 - 04/90
Principal Investigator:	Fred Pfeffer FTS 743-2311

Abstract: The purpose of this project is to determine the effects of dissolved organic carbon (DOC) and surfactants on the distribution coefficients of two hydrophobic compounds between; (1) water and soil, (2) water and natural dissolved organic carbon and surfactant, and (3) soil and water containing natural DOC and surfactant. Specific materials studied are two hydrophobic compounds, hexachlorobenzene and benzo-a-pyrene, and three natural DOC sources: landfill leachate; nonionic surfactant (Triton X-100) and a cationic surfactant (sodium lauryl sulfate). Studies consist of batch sorption isotherm and equilibrium measurements conducted in a special apparatus where compounds partition to two aqueous reservoirs connected by a head space.

Status: Distribution coefficients have been determined for surfactants and water. In addition, data from experiments using a Danish leachate and Lula aquifer material were incorporated in a paper which was presented by Carl Enfield in Denmark in August, 1988. All of the experiments using Danish leachate and Lula aquifer material are complete. A re-evaluation of all of the soil and leachate equilibrium distribution coefficient study data is being made to describe partitioning between all of the possible "sinks" for adsorption of the hydrophobic compounds being studied. These sinks in the experimental protocol are the aqueous, soil, soluble organic and inert surface (glass and Teflon) phases. The results of these tests will be combined with findings by researchers in Denmark for a final report.

Transport of Inorganic Colloids in "Undisturbed" Subsurface Systems

Institute:	RSKERL
Task No:	1025
Project Period:	11/88 - 06/91
Principal Investigator:	Robert Puls FTS 743-2262

Abstract: The objective of this project is to use "undisturbed" soil blocks to quantify the mobility and reactivity of secondary clay minerals and hydrous oxides by using laser light scattering techniques, or other acceptable methods, which quantify the amount of colloids in aqueous suspension and also provide a distribution of size.

Status: The stability of previously synthesized radio-labelled Fe_2O_3 colloids (spherical, 150 nm) were investigated over the pH range of 3-11 using various ionic strengths (0 to 0.05) and electrolyte compositions ($NaClO_4$, $CaSO_4$, and $CaCl_2$). Non-radioactive colloids were stable over the pH ranges 3-6 and 8-11, and generally less than 0.03 M ionic strength. The radioactive colloids however were unstable at the higher pH range. Analyses are underway to determine the possibility and implications of radiolytic induced instability. Column studies were performed at pH 3.6 and 10.4 using aquifer material recovered from a copper mining site near Globe, AZ. There was no detectable breakthrough of the colloids at the low pH where the particles are oppositely charged to the aquifer matrix. However, at high pH, where electrostatic repulsive effects are operative, there was breakthrough and it occurred at the same time as the added tritium. The colloids only attained a quasi-stable condition at this higher pH with the particle size ranging from 500-700 nm. Future work will focus on understanding and attempting to control radiocolloid stability. If successful, additional column experiments at the higher pH range will be performed. The equal charged nature of the iron colloids in this pH range is analogous to the behavior of clay particles in the less than 4 pH range.

Survival and Transfer of Genetic Elements in the Subsurface Environment

Institute:	RSKERL	
Task No:	1042	
Project Period:	03/89 - 09/91	
Principal Investigator:	Guy Sewell (FTS 743-2232)	Stephen Hutchins (FTS 743-2327)

Abstract: The purpose of this project is to define the environmental factors affecting the survival and transfer of recombinant genetic elements in the subsurface environment and in using this information to develop methods for predicting the fate of recombinant microorganisms and genetic elements for use with bioremediation techniques. Core samples from Traverse City will be used to create simulated aquifer environments into which recombinant microorganisms or genetic elements will be introduced. The survival, persistence, and propagation of these organisms or sequences will be determined under different environmental conditions.

Status: Work continues on the isolation, screening, and characterization of bacteria from fuel contaminated cores. No success has been obtained to date in the isolation of a nitrate reducing organism capable of degrading toluene, but efforts will continue. Two bacterial isolates from the high peroxide region in the BioDeg I area at Traverse City are also being screened for plasmids and novel degradative capabilities. The arrival of a DNA analysis system will facilitate the plasmid comparisons from environmental isolates.

Movement and Transformation of Contaminants in Soils and Ground Water

Institute:	NCGWR (Dick Scalf, Carl Enfield, P.O.)	
Task No:	1046	
Project Period:	09/89 - 12/90	
Principal Investigator:	Herb Ward (713) 527-4086	Roland Lindquist (FTS 743-2231)

Abstract: This project is designed to support experimental studies on transport processes currently being recognized as central to understanding the movement and transformation of contaminants in the subsurface. There is a pressing need to identify and understand the transport processes discovered in recent field studies so that these can be incorporated in predictive models, the use of which will result in a more effective and cost efficient approach to protecting and restoring the subsurface environment, including ground water. The items of work to be addressed are: sorption of nonpolar organic contaminants to whole and amended low-carbon sediments, including primarily aquifer materials; effects of naturally occurring or synthetic catalysts on the degradation of organic contaminants in soil and ground water; and the mobility of hydrophobic contaminants in soils and ground water that are associated with macromolecules such as natural humic and fulvic materials. The work will be carried out with the facilities, equipment and staff at both the RSKERL and participating Center universities. As methods and technology are developed, specific portions of the work will be carried out at the universities in cooperation with RSKERL scientists and under the guidance of established peer review procedures.

Status: Dr. Lindquist, from the University of Lund in Sweden, has initiated laboratory studies at RSKERL. He is part of a visiting scientist program set up between RSKERL, the NCGWR, and the University of Lund.

Sorption and Transport of Hydrophobic Organic Chemicals in Complex Solvent Systems

Institute:	University of Florida (Lynn Wood, P.O.)
Task No:	2008
Project Period:	10/87 - 02/91
Principal Investigator:	P.S.C. Rao (904) 392-1951

Abstract: Complex systems, those having multiple solutes and solvents, are found at many hazardous waste disposal sites. Examining the chemodynamics of complex mixtures is, therefore, essential for predicting the environmental impact of hazardous waste disposal. The primary objective of this project is to determine the effects of miscible and immiscible solvents on the solubility, sorption, and transport of contaminants in soils and aquifers. Data collected in this project will be used to develop and evaluate theoretical approaches for estimating solubility and sorption in complex wastes. The results of this project are expected to be used by state regulatory agencies, industry, and EPA for developing simulation models and for educational and management applications.

Status: The solubility and sorption of several organic solutions in a variety of complex solvents have been measured. Solutes examined include anthracene, fluoranthene, napthalene, diuron, and pyrene. Solvents include methanol, acetonitrile, acetone, nitrobenzene, n-octanol, DMSO, o-cresol, and TCE. Predictions of the effect of partially immiscible organic solvents (PMOS) on the solubility of hydrophobic organic chemicals (HOC) by the log-linear approach and UNIFAC are in general agreement with experimental data up to fc=0.5. Recent investigations have been focused on two major areas. The first concerns "negative cosolvency" which has been reported for a few organic solvents. The second deals with a theoretical and experimental examination of solvent-solvent interactions which help explain the apparent differences in the cosolvencies of completely and partially miscible organic solvents.

Multiphase Chemical Transport in Porous Media

Institute:	Virginia Polytechnic Institute (Jong S. Cho, P.O.)
Task No:	2017
Project Period:	04/88 - 04/91
Principal Investigator:	J.C. Parker (703) 961-5775

Abstract: The three major goals of this research are to: (1) develop a mathematical model for multiphase organic chemical transport with gas phase movement and biodegradation in a two dimensional computer code; (2) numerically verify the code and perform experiments to obtain data demonstrating the influence of multiphase flow systems on the transport and fate of toxic organic substances in the subsurface; and (3) develop a multiphase fate and transport model of toxic organic compounds in the subsurface which will investigate alternative regulatory and management methods for waste disposal, monitoring system design, and the development of remedial action plans.

Status: A simplified scheme has been adopted to save memory requirements and computational effort considering the minor effects of hysteresis on flow. Refinements in the transport model have been implemented to obtain a better accuracy while requiring minor additional storage and computational effort over the non-hysteresis model. The simulation results showed the importance of oil phase entrapment. The density of the oil phase is also an important property that could influence the magnitude of fluid entrapment. Work has continued on the development and testing of alternative and innovative numerical formulations to improve solution accuracy and efficiency. Study has been centered on the use of a general adaptive solution technique which automatically optimizes the information of local element equations. Some comparisons have been made of five different equation formulations. The pressure-pressure form, with mass storage terms as saturation-time derivatives, provides the best performance. Efforts continue to implement the interfacial mass transfer in the procedure to analyze gas flow and transport, and to develop a three dimensional flow code. Construction of a prototype two dimensional flow and transport experimental cell is completed and the first 2-D experiments are underway.

Multiphase Chemical Transport in Porous Media

Institute:	Princeton University (James Weaver, P.O.)
Task No:	2022
Project Period:	10/88 - 02/92
Principal Investigator:	George Pinder (802) 656-8802 Mike Celia (609) 452-4602 Peter Jaffee (609) 987-6744

Abstract: The purpose of this investigation is to develop and test in the laboratory, a numerical model of two-dimensional multiphase, multicomponent flow that is capable of easily incorporating sharp fronts. Two methods will be investigated, including the Optimal Test Function (OTF)/Alternating Direction Collocation (ADC) and Least Squares Collocation (LESCO). After preliminary development, one of the methods will be selected for further development as the final simulator. Measurements of the organic/water and organic/air partitioning coefficients will determine if equilibrium is achieved, as is commonly assumed in simulation. Results of these experiments will be used in guiding the simulator development.

Status: Work continues in developing collocation-based solutions for both miscible and immiscible problems. The results have been used to test linearization and iteration techniques, the incorporation of boundary conditions and source/sink terms, the incorporation of spatial variation, and grid orientation effects. Work has also continued on the Eulerian-Lagrangian Localized Adjoint Method for reactive transport. The single phase unsaturated flow code is currently being extended to the two-phase case. This work has resulted in two journal articles and one conference presentation. The determination of primary drainage and imbibition curves for water and air in sandy soil has been completed. Currently the water/TCE curve is being measured, but several difficulties are being encountered. The design of the one and two dimensional flow experiments are beginning. An analysis of the first experiment suggests that the effect of dispersion can be neglected. Changing the size of the REV was not able to reduce the variance of the mass transfer coefficients for saturations above 5 percent. The column has been redesigned and a new experiment is underway.

Solute Transport in Structured Porous Media

Institute:	RSKERL	
Task No:	2026	
Project Period:	10/88 - 03/91	
Principal Investigator:	Stephen Schmelling (FTS 743-2315)	Thomas Short (FTS 743-2292)

Abstract: This investigation is directed at enhancing the quantitative and qualitative understanding of the processes involved in solute transport through fractured porous systems. More specific objectives of the proposed work are to: (1) examine, both mathematically and experimentally, the extent to which the modified one-dimensional advective-dispersion equation describes a solute transport in a one-dimensional dual porosity system; (2) develop information and understanding of the roles of the processes of diffusion, ion-exchange, and sorption in the transport of solutes through a fractured porous system. The transport processes will be studied in the laboratory using systems that closely approximate the ideal systems used to form the conceptual basis of recently published mathematical models. This project should provide a direct test of the assumptions in these models and provide data on the basic processes such as diffusion, sorption, and ion-exchange, that control solute transport in macroporous systems. Specific activities for the research are: (1) measure breakthrough curves for ^{3}HOH, $^{45}Ca_2$, ^{36}Cl and diuron in columns filled with porous ceramic (alumina) spheres, and compare measured breakthrough curves with theoretical predictions; (2) independently measure diffusion and partition coefficients that enter into the two-region advective-dispersion transport equation; (3) determine the effect of matrix geometry including size, porosity, and surface area on transport processes; (4) adjust the organic carbon content of the matrix and determine its effect on transport properties; and (5) compare the measured breakthrough curves with model predictions.

Status: Data were collected for several additional breakthrough curves for ^{36}Cl and ^{3}H. Independent measurements of partition coefficients were also made as a function of pH. Data are being fitted to test the spherical diffusion model.

Solute Transport under Time-Variant Mobile Phase Composition

Institute:	RSKERL
Task No:	2029
Project Period:	10/88 - 03/90
Principal Investigator:	Lynn Wood FTS 743-2420

Abstract: The objective of this project is to evaluate the impact of time variant solvent composition on the transport of hydrophobic organic solutes and to develop mathematical descriptions of the phenomena. The transport of selected organics through soil columns under both isocratic and gradient elution systems is being examined. Isocratic elutions will be run at various cosolvent fractions in order to determine the relationship between the fraction cosolvent and sorption coefficient and to provide input parameters for predicting retention times under gradient elution. For gradient conditions, the influence of the following parameters will be determined: (1) initial cosolvent factors; (2) slope of the solvent gradient; (3) the slope of the cosolvent gradient; (4) the type of cosolvent; (5) nature of the solute; and (6) organic carbon content.

Status: A series of experiments were conducted which evaluated the validity of gradient elution techniques for several organics in chromatographic sorbents. These experiments confirmed the appropriateness of the techniques and the experimental design being used in the study.

Transport of Metal Contaminants in the Subsurface--Sorption/Desorption on Inorganic Colloids and Organic Acid Effects

Institute:	RSKERL
Task No:	2035
Project Period:	09/89 - 09/90
Principal Investigator:	Robert Puls FTS 743-2262

Abstract: This research is being conducted to determine the effect organic acids have on metals transport in subsurface systems. Complexometric titrations and batch equilibrium competition techniques will be used in the laboratory to quantify metal-mineral, organic-mineral, metal-organic, and organometallic-mineral reactions.

Status: Laboratory work has been completed on organic-metal complexation using lead and cadmium with four organic acids, lead and cadmium sorption on kaolinite, and organic-acid sorption on kaolinite and ferrihydrite. Competitive sorption studies with lead, cadmium, and the organic acids were completed using ferrihydrite as the sorbent phase. Sorption of p-chloroaniline, an additional organic contaminant selected for the study, on selected clay mineral was initiated, as were competitive sorption studies between p-chloroaniline, lead, and cadmium on various clay minerals.

Sorption/Desorption Kinetics

Institute:	RSKERL
Task No:	3017
Project Period:	11/88 - 09/90
Principal Investigator:	Susan Mravik (FTS 743-2434) Carl Enfield (FTS 743-2410)

Abstract: The objective of the project is to develop and demonstrate methods for measuring sorption and desorption kinetics of neutral hydrophobic contaminants in soils containing a water-immiscible, residually saturated fluid phase. In unconsolidated soils, tests will compare static and dynamic sorption and desorption of contaminants to determine if physical agitation modifies the equilibrium concentration. Flow velocities for the dynamic system will be as close to existing field velocities as reasonably possible. The results will be compared to those obtained through empirical approximation. In consolidated porous cores, both sorption and desorption will be measured as a function of the flow velocity.

Status: A proceedings manuscript entitled, "Measurement Techniques for Sorption of Organics to Residual Amounts of Fuel Hydrocarbons," was submitted to NWWA. Batch column studies have been conducted with pristine but disturbed Traverse City material. Column studies and post-column batch studies with atrazine have been conducted with a pristine and a contaminated "intact" core from Traverse City. Additional partitioning studies using tetradecane and dried residual gasoline were conducted for diuron, atrazine, naphthalene, and benzene.

Development of Qualitative and Quantitative Information Pertaining to Fate/Transport of Residual Matrix Constituents in Contaminated Soils at Closed Sites

Institute:	University of Texas at Austin (Scott Huling, P.O.)
Task No:	255
Project Period:	10/87 - 04/90
Principal Investigator:	Raymond Loehr (512) 471-4624

Abstract: As part of the land disposal restrictions being developed by EPA in response to the Hazardous and Solid Waste Amendments of 1984, land treatment of hazardous wastes will be limited to those wastes that either can be treated to performance standards based on the best demonstrated achievable technology, or those that have undergone a successful petition process demonstrating that there will be no migration of hazardous constituents from the soil treatment zone for as long as the waste remains hazardous. The results will show: (1) whether soils at a hazardous waste land treatment site (HWLT) should be considered a hazardous waste at closure, (2) the extent to which the organics remaining at closure will continue to degrade, (3) migration potential of the organics and metals present in the soil-residual matrix when a HWLT site is closed, and (4) whether the proposed scenarios for closure of HWLT sites are appropriate. The principal site selected for study is an oil refinery HWLT site in Washington State. Other sites at which samples will be collected include: (1) wood preservative contaminated soil site in Montana, (2) an oil refinery HWLT site in Alabama, and (3) a coal gasification waste contaminated soil site in New York. The collected soils will be used to conduct extensive laboratory and bench scale studies designed to: (1) characterize the residual matrix, (1) determine transport and transformation kinetics for residual organic and inorganic constituents, and (3) provide information needed to model and predict the long-term transport and fate characteristics of such constituents. In addition, the sites will be monitored over time to evaluate the validity of predictions based on laboratory studies.

Status: Field sampling has been completed at all sites and additional background information is being collected for each field site. The soils have been characterized for; oil and gas, organic matter, microtox, TCLP, specific metals and organic analyses. In addition, mobility and degradation studies are underway. Modeling has been completed which evaluates the persistence and mobility of organics and metals under different closure options. Recent activities have centered on monitoring the degradation of freon extractables and polynuclear aromatic hydrocarbons in soil. Additionally, leaching experiments using the Toxicity Characterization Leaching Procedure were completed. The final report is nearing completion.

Identification of Sources of Ground-Water Salinity

Institute:	University of Texas (Bert Bledsoe, P.O.)
Task No:	1037
Project Period:	06/89 - 09/91
Principal Investigator:	Charles Kreitler (512) 471-7721

Abstract: This ongoing investigation is an a attempt to develop methods for identifying the sources of salinity involved in ground-water contamination. The literature will be reviewed for existing methods of identifying sources of salinity in ground water such as fingerprinting techniques. These techniques will be tested using existing data, and the advantages and disadvantages of each will be outlined. Both the ideal, or state-of-the-art, and the most practical techniques will be developed.

Status: A detailed literature search and review has been initiated and several hundred references have been identified. Approximately 9,000 chemical analyses of saline water with TDS greater than 3,000 mg/l are available from these publications. Before compilation of these data, saline ground-water information from the USGS (WATSTORE) will be acquired.

Performance Testing of Ground-Water Models

Institute:	Oregon State University (Thomas Short, P.O.)
Task No:	2003
Project Period:	10/87 - 02/91
Principal Investigator:	Larry Boersma (503) 754-2441

Abstract: A major difficulty in developing strategies to protect ground water is the lack of efficient methods to synthesize scientific information and predict the major physical, chemical, and biological factors affecting the transport and fate of contaminants in the subsurface. Current models which describe contaminant transport are largely empirical. Although many of these can be useful in certain applications, there is a need for more fundamental scientific modeling. The object of this project is to provide a technology to evaluate a model's performance by comparison to a physical model of the same system. This will be accomplished with the use of two large physical aquifer models which have been constructed at RSKERL to simulate ground-water flow. These models are instrumented to track the transport and fate of contaminants introduced to the systems and evaluate remediation activities. All model inputs will be developed exclusive of the physical model so that only data normally available in the field can be used for model input.

Status: A report on the modeling of the fate and transport when concerned with denitrification in non-homogenous aquifers has been completed. The bromide tracer study has been completed and the data is being analyzed to determine the expected dispersivity for the large physical model aquifers. The two-dimensional computer model has been revised to incorporate the transport and fate of the four parameters involved in the denitrification process including substrate, nutrient, oxygen, and nitrate.

Approximate Multiphase Flow Modeling by Characteristic Methods

Institute:	RSKERL
Task No:	2027
Project Period:	10/88 - 03/91
Principal Investigator:	James Weaver FTS: 743-2420

Abstract: This investigation is intended to develop an approximate method for modeling pressure-dominated, one-dimensional, three-phase flow of oily liquids (NAPLs), dissolved chemicals, water and air. When the imposed pressure gradients are important, the system of governing equations is still hyperbolic, but more highly coupled than in the kinematic model: in fact the kinematic model is a special case of the proposed model. By using the method of characteristics for the proposed model, the new work could be incorporated directly into the existing code for the kinematic model, resulting in a code able to simulate both types of situations. Although the method of characteristics will be used extensively in the new model, there is an opportunity to use some improved techniques. Under the influence of strong pressure gradients, some parts of the solution may display "coherent" behavior. Usage of this method would simplify the calculations considerably. Part of the project, therefore, is to investigate the application of this method to appropriate parts of the problem. Other specific areas which will be investigated include: (1) effect of NAPL on the soil infiltration capacity; (2) selection of appropriate hysteretic relative permeability and capillary pressure models; (3) investigate the incorporation of quasi-analytic or analytic models for diffusion of the sharp fronts, both liquid and chemical; (4) comparison of results with an available full dynamic multiphase flow code and data available for either the VPI (Task No. 2021) or Princeton (Task No. 2022) projects.

Status: A presentation entitled, "Simplified Multiphase Flow Modeling via Method of Characteristics Solutions," was presented at the fall meeting of the American Geophysical Union.Work has focused on constructing profiles from the coherent path grid for various injection conditions. The most important of these is the injection of water only into a system containing a known amount of oil (NAPL). A solution of this problem showed that there exists two different flow regimes. The first is characterized by incomplete displacement of oil into an oil bank which moves ahead of the infiltrating water. This is the type of solution that has previously been developed and does not appear to present any added difficulty. The second regime is characterized by complete by-passing of the oil phase without the presence of the oil bank. This discovery is a major step forward in the project. Further work remains on refining the solution methodology. In developing this solution, the two alternative formulations of the grid path equations were created. All three give identical paths across the saturation space, further confirming the correctness of the path grid solution.Although previously reporting that the coherent solution is relatively unimportant, later work makes it appear that the method of coherence solution may be all that is needed to extend the kinematic wave theory of the KROPT model. Work is now underway to determine the need, if any, of the more general method of characteristics solution.

Improved Methods for Estimating the Hydraulic Properties of Unsaturated Soils

Institute:	USDA/ARS (Joe Williams, P.O.)
Task No:	2033
Project Period:	10/89 - 05/91
Principal Investigator:	Martin van Genuchten (714) 369-4847

Abstract: This work is underway to establish a large computerized data base of the unsaturated hydraulic properties of a broad spectrum of disturbed field cores. The data base will be used to calibrate and test statistical pore-size distribution models which predict the unsaturated hydraulic conductivity from more easily measured soil water retention data. A user friendly computer program will be developed for this purpose and made available to action and planning agencies as well as research organizations. The project will also critically review past and current methods of predicting the soil hydraulic properties from cumulative particle-size distributions and other more readily available soil survey data. As a initial step of the project, a soil data base will be constructed to include the broadest possible range of hydraulic property information as possible. Testing and evaluation of the data base will be conducted in-house and through outside specialists not directly involved with its development. A critical review of all available models, which predict hydraulic conductivity from soil water retention data, will be conducted to identify the most promising predictive equations. This work will be incorporated into a user friendly program for calculating hydraulic conductivity. A review of particle-size distribution theories will be performed to develop computerized methods for estimating soil water retention curves and hence, indirectly, the unsaturated hydraulic conductivity.

Status: An "International Workshop on Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils" was held in Riverside, California, during October, 1989. It was attended by over 80 participants from 14 countries. The workshop was divided into sessions covering: (1) pore-size distribution models; (2) particle-size distributions and other approaches; (3) physico-empirical approaches and applications; (4) fractical-mathematical and other approaches; and (5) soil data bases. The proceedings for this workshop are available in the form of a hard-cover book.

Evaluation of Denitrification for Biorestoration of JP-4 Contaminated Aquifer

Institute:	RSKERL			
Task No:	3013			
Project Period:	05/88 - 12/90			
Principal Investigator:	Stephen Hutchins	FTS: 743-2327	Guy Sewell	FTS: 743-2232
	Robert Smith	FTS: 743-2204	Garmon Smith	FTS: 743-2306
	Wayne Downs	FTS: 743-2272	John Wilson	FTS: 743-2259

Abstract: The object of the project is to conduct laboratory studies of biorestoration supported by denitrification for the remediation of aquifers contaminated by fuel spills. A series of experiments will be conducted to evaluate whether denitrification, using either nitrate or nitrous oxide, can be used to remove residual BTX from an aquifer at Traverse City contaminated with JP-4 jet fuel. The process will be assessed for the optimum conditions and parameters required for effective biorestoration. In addition, concomitant microbiological and biochemical analyses of the microcosms will be made in order to understand the specific role of the microorganisms and determine whether that role can be enhanced.

Status: Core material has been acquired from the Traverse City site and used to construct batch and column microcosms to test the removal of BTX under denitrifying conditions. An initial test was made to determine base line removal of BTX from contaminated Traverse City core material. A lag time of 30 days was noted for each of the compounds with the exception of toluene. Benzene was not degraded under these test conditions. Toluene, m-xylene, p-xylene, and 1,2,4-trimethylbenzenes were removed (0.025 mg/l detection limit) within the following 26 days. Alkanes and cycloalkanes were not affected. Results thus far have been presented to the SETAC Conference in Toronto in October and the NWWA Conference in Houston in November. A journal article, "Biodegradation of Petroleum Hydrocarbons by Aquifer Microorganisms Under Denitrifying Conditions," has been submitted to ES&T.

Modeling Organic Contaminant Transport

Institute:	NSI (Susan Mravik/Roger Cosby, P.O.)
Task No:	3023
Project Period:	05/89 - 09/90
Principal Investigator:	Ko-Hui Liu FTS 743-2322 Fred Busche FTS 743-2235

Abstract: The project was established to develop and demonstrate methods for modeling sorption and desorption kinetics of neutral hydrophobic contaminants in soils containing a water-immiscible, residually saturated fluid phase. The work will involve a number of phases, including:

1. Conduct numerical modeling for organic contaminant transport with an equilibrium model;
2. Employ numerical modeling for organic contaminant transport with a combined equilibrium and first order kinetic reaction;
3. Develop a numerical model to better describeorganic contaminant transport in field situations; and
4. Validate the numerical models by comparison of the simulated results with experimental data obtained from column studies.

Status: A numerical method of solutions for organic contaminant transport with a linear (equilibrium) sorption term and one with a non-linear (Freundlich) sorption term has been coded. Both constant and flux type boundaries were provided with these models. Simulations were made using data from breakthrough curves for naphthalene for Lincoln and Eustis soils. Work has begun on the development of the mathematical formulations and coding for a two-site, two-region model which includes both an equilibrium and a first order kinetic term. A literature review concerning residual saturation in porous media was conducted, resulting in the addition of a residual oil phase to the model. An article describing this work is completed.

Development and Calibration of Computer Models Describing Bioventing of Hydrocarbons from Unsaturated Subsurface Materials

Institute:	University of Massachusetts at Amherst (Jong Cho, P.O.)
Task No:	3025
Project Period:	09/90 - 09/92
Principal Investigator:	David Ostendorf (413) 545-0685

Abstract: Soil venting has proved to be an effective technique for remediation of oily contaminants in the unsaturated zone. As practiced, the fumes in the vent gas are: (1) released to the atmosphere, (2) destroyed in an internal combustion engine, (3) captured on activated carbon, or (4) destroyed by catalytic combustion. These treatment processes can add significantly to the cost of remediation. This project is aimed at investigating the feasibility of in-situ treatability of these volatiles in order to reduce remediation costs. The planning and installation of a field demonstration requires a design model to guide in the positioning and installation of wells, to determine the capacity of the air handling system, and to determine the size of the injection zone required for an efficient system. Cores will be obtained from a fuel contaminated site at the Traverse City Coast Guard Air Station. Laboratory studies will be performed to assess mass-transfer coefficients for alkylbenzenes from water and oil to air. This information will be used to determine the rate of restoration and the volume of air required to sweep a given volume of a contaminated aquifer. Column and batch microcosm studies will determine the kinetics of fume degradation in the unsaturated zone. This information will be incorporated into a comprehensive mathematical model that will define well spacing, air flow velocities, and size of the plume injection zone required to treat a predetermined volume of subsurface material.

Status: The project is scheduled to begin in September.

Anaerobic Processes in the Subsurface Environment

Institute:	RSKERL			
Task No:	1041			
Project Period:	03/89 - 10/91			
Principal Investigator:	Guy Sewell	FTS 743-2232	Susan Gibson	FTS 743-2309
	Garmon Smith	FTS 743-2316	Stephen Hutchins	FTS 743-2327
	Robert Smith	FTS 743-2352	John Wilson	FTS 743-2259

Abstract: Anaerobic conditions predominate in contaminated aquifers and are common in uncontaminated areas. Comparatively little is known about degradative processes and nutrient cycling under anaerobic conditions. However, it is apparent that these processes are fundamentally different and more complex than aerobic processes. The objective of this research is to define and study anaerobic microbial metabolic processes which occur in the subsurface environment to further understand the fate of contaminants in that environment. Three areas will be investigated using microbiological, biochemical, and molecular biological techniques, with emphasis in three major areas:

1. Metabolism of aromatic compounds under sulfate reducing conditions. In this study the breakdown and metabolism of fuel aromatics (primarily benzene,toluene, and xylenes) by sulfate-reducing isolates and consortia will be examined.
2. Metabolic processes at the aerobic/anaerobic interface. The role of mixed aerobic/anaerobic conditions on the metabolism of organic compounds is unclear. An attempt will be made to identify and spatially locate the processes and microbes which exist at and near the interface.
3. Effects of altered oxidation/reduction balance on anaerobic metabolism. Anaerobic chemoheterotrophs generate useable metabolic energy (ATP or electro-chemical gradients) from oxidizable substrates via fermentation or anaerobic respiration. Alterations in the O/R balance of these organisms may broaden the range of electron donors and acceptors.

Status: Work continues with the toluene degrading consortia. Laboratory and field studies have linked reductive dechlorination of PCE and TCE with toluene degradation. This is the first conclusive evidence showing alkylbenzenes can serve as a source of reducing power for reductive dechlorination. It is not clear at this time which pathway of toluene degradation is being utilized by the consortia, but phenol and cresol have been detected in field samples, with acetate the only intermediate definitely shown in the microcosm tests. In the microcosm system, the initiation of reductive dechlorination (16 weeks) appears linked to the appearance of measurable levels of acetate (16 weeks), rather than the onset of toluene degradation (8 weeks).

Optimization of In-Situ Biorestoration of Contaminated Subsurface and Aquifer Materials

Institute:	NCGWR (Dick Scalf/William Dunlap, P.O.)
Task No:	1047
Project Period:	09/89 - 12/90
Principal Investigator:	Herb Ward (713) 527-4086

Abstract: This research addresses four major areas, including: (1) investigate microbial transport through subsurface materials with different hydraulic conductivities and organic matter contents, (2) determine the effects of hydrogen peroxide on microbial populations in the subsurface and on the mechanisms by which they adapt to high concentrations of the oxidant, (3) participate in a quantitative demonstration of in situ biorestoration of subsurface materials contaminated with aviation fuel, (4) and determine the significance of bioemulsifiers and surfactants reduced by subsurface microorganisms during the biodegradation of contaminants in the subsurface. The primary goal of this research is to evaluate the use of microcosms to predict the rate and extent of TCE dechlorination in subsurface material. A secondary goal is to evaluate the influence of various electron donors, including natural materials such as peat and co-occurring contaminants such as alkylbenzenes, phenols, and benzoic acids. The microcosms will be constructed from material acquired from a plume of TCE contamination at the US Army Arsenal at Picatinny, NJ.

Status: Samples for the construction of the microcosms have been obtained and the microcosms are nearing completion.

Forced Air-Ventilization for Remediation of Unsaturated Zone Contaminated by VOC

Institute:	RSKERL
Task No:	2028
Project Period:	10/88 - 12/90
Principal Investigator:	Jong Soo Cho FTS: 743-2292

Abstract: The objective of this project is to investigate the movement of the air-ventilation process. Several mechanisms control gas movement through unsaturated soils including diffusive and convective transport. The physical properties of soil such as; porosity, pore size distribution, and water content, are the primary physical limits to the movement of VOCs in gas phase. Therefore, the ultimate goal of this project is to investigate the relationships among these properties as they impact gas phase movement of contaminants, and to develop a computer code for the design of remediation processes. The project consists of two parts. The first is the development of a numerical model of gas phase movement in soil; and the second is the experimental verification of the model with emphasis on an understanding of the physical and chemical properties which effect vapor phase contaminant transport.

Status: Nine soil columns, built in a constant temperature room, have been used for preliminary experiments. The apparatus and equipment for continuation of the project is in place. The development of a three-dimensional model has been initiated. A finite difference algorithm will be used to solve the three dimensional gas flow and transport equation. New computer hardware, suitable for the development of large computational programs, has been received and is being used. A ground-water flow model, with slight modification, has been used and the results compared with a simple, approximated, analytical model. The comparison showed compatibility when a small vacuum was applied. A journal article is nearing completion which will discuss the comparison results.

In Situ Biorestoration of a Gasoline Spill (Nitrate)

Institute:	U.S. Coast Guard/RSKERL (John Wilson, P.O.)
Task No:	3012
Project Period:	08/88 - 09/90
Principal Investigator:	Linda Lefkovitz FTS: 942-3934

Abstract: An existing model, BIOPLUME II, can easily be modified to describe nitrate supported degradation of BTX. Work at RSKERL will develop the site-specific process information needed to run the model on a spill of JP-4 jet fuel at the U.S. Coast Guard Air Station at Traverse City. The model will be used to make projections for use in the design of an in situ perfusion cell that bathes the contaminated region of the aquifer with nitrate-amended water. Recovery wells will reclaim any nitrate that is not consumed by the bacteria to prevent regional contamination of the aquifer. The progress of biorestoration will be followed with monitoring wells, and at the end of the demonstration, the contaminated area will be cored and analyzed for the concentration of remaining BTX. The objectives of the project are: (1) to modify BIOPLUME II to describe the degradation of BTX by nitrate-respiring bacteria in aquifers contaminated with oily materials; (2) use the model to design a biosystem field demonstration for in situ restoration of oily wastes; (3) carry out the demonstration; and (4) evaluate the model by comparing the actual progress of the restoration to that projected by the model.

Status: Within six months the concentrations of benzene and toluene in ground water were reduced to below 0.1 μg/l. Other alkylbenzenes were brought below 5 μg/l. Approximately 120 core extracts are being analyzed by GC/MS to confirm the removal of BTX in the aquifer matrix material. An internal report, "Field Evaluation of Biorestoration of a Fuel Contaminated Aquifer Using Nitrate," has been forwarded to the appropriate Program Office.

In Situ Biodegradation of Carbon Tetrachloride under Denitrifying Conditions

Institute:	Stanford University (Wayne Downs, P.O.)
Task No:	3020
Project Period:	08/89 - 09/90
Principal Investigator:	Paul Roberts (415) 723-1073

Abstract: The project is designed to quantitatively assess the biodegradation of carbon tetrachloride in a field demonstration under denitrifying conditions. Acetate, as a carbon source and electron acceptor, will be used to simulate the growth of indigenous microorganisms which are expected to transform carbon tetrachloride.

Status: Field studies were initiated with the addition of carbon tetrachloride (CT) to the test zone, prior to biostimulation, to study its transport and observe whether transformation losses occurred in the absence of active biostimulation. The test zone was biostimulated with the addition of acetate and the resulting biotransformation of CT and the production of intermediate products was monitored. Laboratory studies have focused on batch soil column studies.

Field Evaluation of Bioventing of Hydrocarbons from Unsaturated Subsurface Material

Institute:	U.S. Coast Guard (Don Kampbell, P.O.)
Task No:	3024
Project Period:	09/90 - 09/92
Principal Investigator:	Linda Lefkovitz (216) 522-3934

Abstract: Soil venting is a widely popular technique for remediation of oily contaminants in the saturated zone. As practiced, biological activity in the unsaturated zone often results in the depletion of oxygen and enrichment in carbon dioxide, and contributes to the removal of contaminants. This natural activity could be incorporated into the design of a project aimed at the in-situ biological treatment of vent gases. Cores will be obtained from a fuel-contaminated area at the U.S. Coast Guard Air Station at Traverse City, Michigan, to determine the three-dimensional distribution of the contaminant. The model described in project Task Number 3025 will be used to design the demonstration. After the demonstration, the site will be cored again to determine the actual performance of the degradation process.

Status: Planning of the project is underway with the various participating research groups.

Supplement to In Situ Biorestoration of a Jet-Fuel Spill

Institute:	U.S. Coast Guard (John Wilson, P.O.)
Task No:	3026
Project Period:	09/89 - 09/91
Principal Investigator:	Linda Lefkovitz (216) 522-3934

Abstract: As of September, 1989, benzene and toluene have disappeared in water beneath the infiltration gallery, at the Traverse City site, and the concentration of the xylenes is below 20 µg/liter. Contrary to expectations, benzene and toluene disappeared before any nitrate was added. Further work is needed to confirm the mechanisms of biodegradation of benzene and toluene under these circumstances. The section of the gallery should be able to bring the section of aquifer in the demonstration area to closure, but this is to some extent fortuitous. During the design of the demonstration the effect of denitrification on the pH of the recirculated water was not considered. During the course of the demonstration, the pH of the recirculated water increased from 6.5 to 8.0, resulting in a slow carbonate plugging of the infiltration gallery. A nutrient mix should be formulated that will protect infiltration galleries from plugging. A second infiltration gallery will be installed at the Biosystems Demonstration Project at Traverse City. Equipment will be installed in the existing manifold and monitoring building to restore the pH of the recirculated water to the original pH of 6.5. The gallery will be installed, as soon as funds are available, and operated for a 6 to 9 month period.

Status: The design and scheduling of the project are underway.

Assessment of Various Class V Injection Well Practices on Groundwater Quality

Institute:	Dynamac Corp (John Matthews/ James McNabb, P.O.)
Task No:	194
Project Period:	05/89 - 02/90
Principal Investigator:	Ron Drake FTS 743-2276

Abstract: This project is being undertaken to determine the impact of various Class V injection wells practices on ground water quality. Through literature searches a determination will be made as to which Class V injection well practices will most significantly impact ground water quality. The search will focus on the types of contaminants identified by the Office of Ground-Water Protection. Information will be gathered on the transport and fate of these contaminants, after being injected directly into aquifers, and recommendations will be developed and suggested for regulating the use of Class V wells.

Status: The final report is nearing completion.

Effectiveness of Drilling Mud as a Plugging Agent in Abandoned Oil and Gas Wells

Institute:	Oklahoma State University (Don Draper, P.O.)
Task No:	1009
Project Period:	10/87 - 04/90
Principal Investigator:	M. D. Smith (405) 624-5711

Abstract: Current methods of plugging dry and abandoned wells in many states call for placing cement plugs through selected zones and drilling mud through the intervening zones. In some states only drilling mud is used as a plugging agent, a method that has been used for many years. In the vicinity of injection wells used for disposal or for secondary recovery of petroleum, numerous plugged and abandoned wells may exist. The environmental concern is the potential for the injected fluids to migrate through these abandoned bore holes and enter fresh water. The objectives of this research project are to: (1) determine if drilling mud is an adequate plugging material when abandoning wells; (2) develop techniques and associated instrumentation for entering previously plugged wells; and (3) to determine the efficiency of the plugging material used. To accomplish these objectives, a 2000-foot well drilled on the property of Oklahoma State University, at the Petroleum Outdoor Laboratory will be used. The well, with extensive surface and subsurface monitoring equipment, has a simulated reservoir at the surface. Simulation of field conditions can be made with respect to depth, fluid pressure, injection fluids, and pressure and plugging agent properties.

Status: The 2000 foot well has been drilled and cased and the site work completed, including; concrete placement, dirt work, access roads, and test equipment. All test facilities have been completed including those for flow as well as temperature and pressure measurements. All testing equipment is operational and tests are well underway.

Methods of Determining Mechanical Integrity of Injection Wells

Institute:	RSKERL/East Central University (Jerry Thornhill, P.O.)
Task No:	1026
Project Period:	10/88 - 02/92
Principal Investigator:	Bobby Benefield (405) 332-8000

Abstract: This project has been designed to investigate, develop, and improve methods for evaluating the mechanical integrity of injection wells to assure that the use of such wells will not endanger underground sources of drinking water, public health. or the environment. Selected procedures and tools will be evaluated in existing test wells to determine their effectiveness for determining the mechanical integrity of injection wells, simulate specific well conditions for reviewing alternative mechanical integrity tests, and perform tests for developing a tool for evaluating water-quality chances in underground sources of drinking water.

Status: Forty-one logs have been run in the two logging wells to determine the capability of evaluating cement behind steel and fiberglass casing. Final agreement has been reached with API for joint testing of noise, temperature, and oxygen activation logs for detecting flow behind the pipe. Meetings were held with the technical review panel on three occasions to develop procedures for selecting candidate wells for testing. As a result, two wells are being evaluated. Schlumberger tested their new "oxygen activation tool" for detecting flow behind pipe. The tool worked well, but the data had to be telemetered to their Houston offices for analysis. The toll will be retested after software has been developed for on site data analysis.

Prioritizing Aquifer Protection

Institute:	Oklahoma State University (Jerry Thornhill, P.O.)
Task No:	1039
Project Period:	04/89 - 09/91
Principal Investigator:	Wayne Pettyjohn (405) 744-6358

Abstract: The project is designed to develop and test methods for prioritizing regions so the most sensitive and productive ground-water areas receive maximum attention with respect to the impact of Class V wells. It will also address the existing and potential impact of Class V wells on the quality of ground water in the U.S. A literature search will be performed for hydrogeologic data from each state which will be evaluated and transferred to base maps after developing a scheme of prioritization. A sensitivity to Class V wells map will be prepared for each state.

Status: The first draft of sensitivity maps have been developed for 17 states. Population density maps have been generated for 10 states and a hydrogeological data base is being collected.

Hydrologic Effects of an Agricultural Drainage Well -- Phase I

Institute:	U.S. Geological Survey - Reston (James McNabb, P.O.)
Task No:	1045
Project Period:	09/89 - 01/91
Principal Investigator:	Stephen Ragone FTS 959-5720

Abstract: The purpose of Phase I of this project is to; (1) develop a scope of work for a Phase II research study designed to characterize the hydrologic setting of an agricultural drainage well and determine the existence and fate of atrazine in the aquifer receiving drainage well discharges, and (2) select an existing agricultural drainage well that will be representative of similar conditions in other areas of north-central Iowa which will serve as the focal point of this study. It is anticipated that Phase II of this study will be a three year cooperative project between the U.S. Geological Survey and EPA. The USGS will be responsible for describing the hydrology of the site and for providing field assistance. EPA will be responsible for the analysis of atrazine degradation products and the interpretation of the results.

Status: The IAG was initiated 09/01/89. Activities are underway to complete Phase I and to coordinate the work with the other involved federal agencies.

Development of Methods to Identify Sources of Contamination in a Wellhead Protection Area and Develop Relations Between Land Use and Regional Ground Water Quality

Institute:	U.S. Geological Survey - Reston (James McNabb & Wayne Downs, P.O.)
Task No:	1028
Project Period:	08/88 - 03/90
Principal Investigator:	Stephen Ragone FTS: 959-5720

Abstract: The object of this project is to develop information for identifying sources of contamination in a wellhead protection area. The study will focus on developing, calibrating, and verifying statistical relations between land use utilizing existing ground-water quality data. Statistical evaluations to determine the significance of hydrogeological factors will be made with methods that would have a bearing on the definition of a zone of contribution. Specific activities include:

1. Development and verification of methods to conduct regional ground-water appraisals.
2. Studying the scale dependencies of these methods.
3. Determination of critical data needed to make effective appraisals.
4. Evaluation of methods to determine contributing areas to the quality of water at wells.
5. Evaluation of the mass-balance approach as a means of conducting regional ground-water quality appraisals.

The study will focus on developing, calibrating, and verifying statistical relations between land use with existing ground water quality data. This existing data will be collected within defined study areas to create a data base for the development of models relating sources of contaminants, as defined by land use or other measures of human activities, to observed ground-water quality. Stochastic ground-water quality models have recently been verified that relate population density and land use with the occurrence of volatile organic compounds (VOCs). As part of this study, additional models will be developed to relate ground-water quality with such factors as road network density, vehicular traffic volumes, and power consumption. Furthermore, in association with EPA's Wellhead Protection Plan, statistical evaluations will be made to determine the significance of hydrogeologic factors (depth to ground water, surficial geology, ground-water flow direction) with methods that would have a bearing on the definition of a zone of contribution.

Status: A draft report is being reviewed internally. The Project Officers met with project personnel at the USGS offices in Trenton to discuss the project and long-term deliverables. An on-site review of the project was held in conjunction with the Office of Ground Water Protection.

Evaluation of the Influence of Human Activities on Ground-Water Quality

Institute:	U.S. Geological Survey-Reston (Wayne Downs, P.O.)
Task No:	1044
Project Period:	10/89 - 10/90
Principal Investigator:	Stephen Ragone FTS 959-5720

Abstract: The project, which compliments Task 1028, will evaluate the influence of human activities on ground-water quality in the Atlantic Coastal Plain physiographic province in New York and New Jersey. Methods to statistically quantify the influence of human activities on ground-water quality will be developed, tested, and verified. Sources of contamination will be identified and methods to estimate contributing areas to wells will be compared.

Status: Extensive reviews and revisions of the work plan have been conducted by all participating organizations.

Ground Water Technology Transfer

Institute:	RSKERL/CERI (Dick Scalf, P.O.)
Task No:	121
Project Period:	Continuing

Abstract: Agency and State personnel responsible for carrying out the mandates of RCRA, SDWA, CERCLA, and other environmental legislation directed at ground-water protection and restoration must have an understanding of the subsurface environment and the factors involved in protection and remedial actions. Ground-water protection and restoration is based on a relatively new and rapidly developing science. Although most of the people working in the ground-water area have a technical background. They may not be trained in ground-water science or may find it difficult to keep abreast of developing findings and technologies. The objectives of this project are: to develop a series of technology transfer materials that can be used as self training aids; to provide training to Regional, State, and Headquarters personnel; and to provide technical publications on developing science and technology to the ground-water community.

Status: A series of 20-30 minute narrated-slide presentations are under development and are in various stages of completion. Those which are complete include:

Basic Geology
Monitoring Well Installation
Ground-Water Sampling
Fundamental Hydrogeology
Ground-Water Models

Those nearing completion include: Ground-Water Contamination, Ground-Water Investigations, Ground-Water Tracers, and Ground-Water Restoration. In addition, a companion document entitled Ground Water Handbook (EPA/625/6-87-016) with chapters corresponding to the narrated-slide presentations has been published by the Center for Environmental Research Information in Cincinnati, Ohio, and is in the process of being updated. In the area of training, two-day seminars titled, "Site Characterization for Subsurface Remediations," have been presented in all ten Regions. RSKERL technical publications are distributed to the ground-water community on a continuing basis.

China - U.S. Ground-Water Project

Institute:	Sino-USA International Agreement (Lowell Leach, P.O.)
Task No:	175
Project Period:	03/85 - 10/90
Principal Investigator:	Duan Zhenbo, Beijing Municipal Research Institute of Environmental Protection, China

Abstract: EPA's Office of Research and Development has entered into an agreement under a normal protocol (Item IIB, Annex 3, US-PRC) to conduct cooperative research with the People's Republic of China (PRC) on municipal wastewater land treatment systems. The Chinese selected land treatment technology because of high pollutant removal efficiency, low construction and energy costs, and simplicity in operation and management. Under this agreement the research will be conducted on rapid infiltration systems (RIS) and overland flow systems (OFS). The RIS study will focus on optimizing denitrification techniques as a method to treat municipal sewage. The treated water will then replenish ground water containing high concentrations of nitrate. Concurrently, the scientists will evaluate the removal potential for volatile organic compounds and pathogenic bacteria from the RIS, which complements RSKERL's research program. These studies will provide design information for the evaluation of eight sites selected as key pilot projects as specified in China's 7th 5-year plan. The potential of using an overland flow system to treat wastewaters containing high concentrations of BOD and COD and the resulting impact of this treatment process on ground water will be investigated. Upon completion of these studies, as outlined in the March 1985 workplan, the EPA and Chinese staffs will jointly author a report which will be published in an international peer reviewed journal.

Status: A journal article entitled, "China-United States EPA's Bilateral Land Treatment Research," was selected for presentation at the WPCF National Symposium in San Francisco; however, the conference was cancelled due to a catastrophic earthquake. The article has been submitted to ORD, the Office of International Activities, and for publication in the Journal of the Water Pollution Control Federation. Phase two of the project (overland flow research of brewery wastewater treatment) in underway near Beijing. Data from the project for the period 7/16/88 through 11/18/89 has been received and indicates that the operation is successful. PRC internal turmoil results in project uncertainty.

Expanding Knowledge Bases and Advancing Utility of Ground Water Models for Management

Institute:	Holcomb Research Institute - Butler University (Joe Williams, P.O.)
Task No:	1017 & 2023
Project Period:	10/88 - 12/90
Principal Investigator:	Paul K.M. van der Heijde (317) 283-9458

Abstract: The goals of this project are to develop an extensive, generally accepted model testing and evaluation methodology, and to improve the access to and utility of quality-assured models. Models will be subjected to careful scrutiny for quality in development and efficiency in their application. The models and the evaluation methodology will then be made available to the user community along with the results of the evaluations and other information developed during the project.

Status: The MARS data base has been reviewed by the advisory committee, comments returned to IGWMC, and implemented into the current version. The inventory of models for flow and transport in fractured rock has been received as well as another document dealing with quality assurance and quality control in ground-water modeling. A inventory of flow models for immiscible liquids has also been completed.

National Center for Ground Water Research

Institute:	NCGWR (Dick Scalf, P.O.)
Project Period:	09/79 - Continuing
Principal Investigator:	Herb Ward (Rice) (713) 527-4086 Norm Durham (OSU) (405) 824-8388 Larry Canter (OU) (405) 325-5202

Abstract: EPA established the National Center for Ground Water Research (NCGWR) in September, 1979, as a consortium of Rice University, the University of Oklahoma, and Oklahoma State University. As part of EPA's Centers of Excellence program, the NCGWR was charged with developing and conducting a long range exploratory research program to help anticipate and solve the nation's emerging ground-water problems. Base funding is provided by EPA's Office of Exploratory Research in Washington, DC. Center Co-Directors and investigators work with the management and technical staff of the R.S. Kerr Environmental Research Laboratory as well as other EPA laboratories to insure that the exploratory research program is cooperatively planned, responsive to national needs, and appropriately linked to the Agency's more applied, mission-oriented research efforts. Technical oversight is provided by an eight-member panel of external scientific peers. The four major areas of responsibility for the Center's research are: (1) development of methodologies for ground-water quality investigations; (2) transport and fate of pollutants in the subsurface; (3) characterization of the subsurface environment with respect to pollutant transport; and (4) information transfer.

Status: Research Projects currently funded by the Center include:

1. Factors Influencing the Slow Release of Hydrocarbons from Aquifer Materials
2. Effects of Various Pumping and Injection Schemes and Variable Source Loading on Biorestoration
3. Optimization of In Situ Biorestoration of Contaminated Subsurface and Aquifer Material
4. Microbial Metabolism of Xenobiotic Chemicals in Anoxic Aquifers
5. A Recombinant Approach to the Isolation and Characterization of a Primary Degrader of Trichloroethylene

Performance Evaluation of Ground-Water Remediations at Superfund Sites

Institute:	NCGWR/Peer Consultants (Randall Ross/Dick Scalf, P.O.)
Task No:	3003
Project Period:	08/87 - 04/90
Principal Investigator:	Joseph Keely (503) 645-7556

Abstract: Ground-water remediation activities at several Superfund sites are currently underway but there are presently no established protocols for evaluating the effectiveness of the various remediation technologies. This project will survey RI/FS and compliance monitoring documents from several sites to determine types of chemical and hydrogeological data typically acquired, the uses to which the data are applied, and the need for additional transport process parameter data. The project will evaluate the state-of-the-art and state-of-the-science of data acquisition in terms of procedures involved, resources required, and benefits obtainable and their relation to the use of mathematical models in remediation performance evaluation.

Status: Phase I of the project, which involves the adequacy of monitoring networks and compliance criteria in use at Superfund sites, is complete. The document, "Protocol for Evaluating Effectiveness of Groundwater Remediation Activities at SF Sites," is nearing completion.

Operation of Subsurface Remediation Information Clearinghouse

Institute:	Dynamac Corporation (John Matthews, P.O.)
Task No:	3009
Project Period:	09/88 - Continuing
Contact:	Ron Drake FTS: 743-2252

Abstract: This program is designed to operate the Subsurface Remediation Information Clearinghouse within RSKERL to provide services to Regional and state Superfund personnel, in terms of scientific information related to the reclamation of contaminated soils and ground water. Both information sources and information transfer activities are provided. This involves maintaining an awareness of current sources of scientific information on the reclamation of contaminated soils and ground water. These activities include locating, assessing, and documenting pertinent information sources on both active and completed remediation activities. The information transfer services involve transferring current information from the research community to the user community. These support activities include the preparation and dissemination of the most current research findings pertaining to the fate, transport, and treatability of contaminants in both the saturated and unsaturated subsurface. Both the Information Sources and Information Transfer services are intended for use by the Technical Support Team, Technical Review Group, RSKERL researchers, and Regional and state remediation decision makers.

Status: The functional responsibilities of the Clearinghouse have been established and services provided as requested. A Manual of Practice describing the Clearinghouse services and the proper mechanisms for making use of those services is nearing completion.

PUBLICATIONS

During RSKERL's tenure of operations, a large number of reports and other types of documents dealing with environmental problems have been published. A list of those publications for the period 1988 to the present is presented in this section. These publications can be obtained as described below:

Publications containing an NTIS number should be obtained from:

National Technical Information Service
U.S. Department of Commerce
Springfield, VA 22161
(703)557-4560

Other publications can be requested from:

Robert S. Kerr Environmental Research Laboratory
P.O. Box 1198
Ada, OK 74820
(405)332-8800

A full list of publications (1967 - 1990) is available upon request.

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G.D. McGinnis, H. Borazjani, L.K. McFarland, D.F. Pope and D.A. Strobel
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