FISCAL YEAR 1987 PROGRAM REPORT
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for

U. S. Department of the Interior
Geological Survey

by

Water Resources Center
University of Rhode Island
Kingston, R. I. 02881

Calvin P. C. Poon, Director
July, 1988

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The contents of this publication do not necessarily reflect the views and policies of the Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the United States Government.
ABSTRACT

The 1987 program objective was to conduct studies and research of value to the New England region as well as to assist in the solution of problems in the State of Rhode Island. Current and anticipated state and regional water problems are contamination of surface and groundwater by natural radioactivity such as radon, by chemicals from industrial and agricultural activities, septic tank and leach field, improperly managed landfills and the lack of public awareness and public participation in water quality protection and management. It was found in the 1987 program that an epithermal neutron activation analysis was best suitable for measuring uranium and thorium of which radon is the decayed product. Lower U and Th were found in calc-alkalic and mafic volcanic rocks while higher concentrations were found in the alkalic and peraluminous rocks. A computer model using finite element method to simulate fluid flows through fractured porous media was developed for predicting the extent of groundwater contamination in the State. Techniques were developed to use metal resistant bacteria Arthrobacter HC823 for metal removal from plating wastes. Nitrogen and phosphorus contaminants were found short distances from the drainage field of septic tank systems. Educational programs in water resources issues included conference, fact sheet publication, citizen watershed watch. Handbook and short courses were either conducted or being initiated. Mixed ash from a mass-burn incinerator containing sufficient cadmium to be classified as toxic substance using TCLP procedure but sufficient lead to be classified as toxic using either EPTC or TCLP procedure. This Center works closely with the R.I. dept. of environmental Management; USGS subdistrict office, R.I. Solid Waste Management Corp., and other New England Water Resources Centers for program planning and research coordination.
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WATER PROBLEMS & ISSUES OF RHODE ISLAND

In Rhode Island and New England region as a whole, groundwater constitutes the major water resources for domestic, commercial, and agricultural activities. Most of the groundwater in Rhode Island is confined to shallow aquifers which are overlain by sandy soils suitable for agriculture and suburban development. The rapid housing and commercial development in Rhode Island in recent years presents a potential threat of groundwater contamination which threatens the quality of groundwater in the state. An industrial waste pretreatment is not yet fully implemented in the state. This, coupled with the inadequate treatment of municipal wastewaters, leads to the contamination of the surface water in many parts of the state.

Known petrologic and geochemical characteristics of geologic materials in Rhode Island suggest anomalously high concentrations of radioactive parent nuclides of radon and radium. Radon is an enert gas which is relatively soluble in water. These properties allow it to readily diffuse into the atmosphere including the confined household space or into groundwater aquifers. Characterization of radon in groundwater and radioactive parents in host aquifers will permit the state to focus on specific geographic areas where health hazards are likely to exist.

One of the threats to both the surface water and groundwater quality is the occurrence of spills and leaks of organic chemicals such as petroleum products which occur during their transport, storage, and disposal. The infiltration and migration of petroleum products in the subsurface is a complex process. There is a number of groundwater contamination case histories in Rhode Island where the subsurface medium in fractured rocks. Therefore, there is a need for the development and verification of a computer model for
analyzing the areal flow under transient conditions of an immiscible contaminant fluid in fracture rocks.

Many metal platers and finishers in Rhode Island are not in compliance with the pretreatment regulations that limit the discharge of toxic metals and cyanide into public sewers. The existing technology of chemical treatment is beyond the capability of small platers who do not have the capital resources for this type of investment. A less expensive and simpler means of pollution control is needed to assist this large number of small companies in meeting their effluent standards.

On the southern shore of Rhode Island, the coastal pond region is experiencing groundwater pollution and surface water eutrophication resulting from a three-fold increase in housing since 1950 which threatens to diminish the recreational, commercial, and ecological values of the coastline. A large number of seasonally used homes use individual sewage disposal systems. Studying of the migration and attenuation of contaminants from these seasonally used individual sewage disposal systems will be useful in improving the future septic system design and establishing the minimum setback/separation distances from septic systems to wells and groundwater table for coastal regions.

The state of Rhode Island, as in other states in the nation, find it very difficult to find new sites for landfills. Municipal waste incinerators will be built as part of an integrated scheme of solid waste management in the state. Incinerator ash is a potentially hazardous material. Information on ash characterization and the possibility of toxic chemicals leaching out from a landfill for ash disposal is needed for future landfill design.
PROGRAM'S GOALS AND PRIORITIES

The research needs on water resources in the New England region as identified by the New England Council of Water Center Directors have been:

Groundwater Quality Control
   Sources of toxic materials
   Fate and transport of chemicals

Management of groundwater Supplies
   Location and extent
   Rural and small town water supply systems
   Recharge characterization

Surface Water Quality Control
   Acid precipitation
   Eutrophication
   Watershed management

Management of Surface Water Supplies
   Land use/hydrology interactions
   Water reuse and conservation

Institute Frameworks
   Water use planning and management
   Water allocation and reallocation
   Conflict resolution among competing users

Ecological and Health Relationships
   Wetland ecology
   Effect of chemicals in water on human health

Using these research needs as a guide, the Rhode Island Water Resources Center developed its program goal to meet some of these research needs as well as to transfer the information of water resources research/management to the public. Both the State Advisory Committee and the University Water Resources Coordinating Committee for the Center finalized the specific research needs for the FY-1987 program with heavy emphasis on groundwater protection. Project proposals were reviewed and selected on the criteria of (1) satisfying the state and regional research needs, (2) technical competency, and (3) reasonable budget.
Three projects addressed the groundwater quality problems and met the research needs identified by the Center. Project 02 on Uranium-Thorium Concentrations in Bedrock and Surficial Materials: Primary Sources of Radon in Rhode Island Aquifers developed a new, modified technique of neutron activation analysis. Using this epithermal neutron activation procedure, background levels of uranium and thorium were established for a broad group of volcanic and plutonic rocks in Rhode Island. These background levels are used against which anomalous concentrations can be compared. The second phase of this research (in the FY-1988 program) will collect and analyze more samples with the final data integrated into a Geographical Information System in order to generate a dynamic working map identifying areas of potentially low, intermediate, and high levels of radon. The information is intended to be available to help guide future radon programs undertaken by the R. I. State Department of Health as well as state and local planners.

Project 03 on Numerical Model Study of Contaminant Flow in Fractured Rock responded to the research need in Rhode Island where a number of groundwater contamination case histories has been found where the subsurface medium is fractured rock. The computer model is available to state agencies or other interest groups for predicting the extent of groundwater contamination in fractured rock for existing and future problems. The same model can also be used to estimate the most efficient pumping rates in a clean-up process.

Project 05 on Microbial and Phosphorus Migration in Groundwater from Seasonally-Used Septic Systems monitored the occurrence of nitrate nitrogen and phosphorus at various distances from the septic drainage fields of seasonally used vacation homes. Effect of sand filters on the removal of phosphorus was monitored. With more data to be collected in the summer of 1988, important
questions can be answered on the attenuation of contaminants in the drainage field as well as the pollutant removal efficiency of the seasonal systems compared to a continuously used recirculating sand filter system.

Project 04 on A Microbial Method for Removal of Metals, Cutting Oils and Cyanide from Polluted Water - Phase I, used a serial enrichment-adaptation procedure to expand the resistance spectrum of *Arthrobacter* HC823 to a combined mixture of heavy metals commonly found in plating wastes. Studies of the required cell mass, energy supply and kinetic were carried out. Experiments will be continued into the FY-1988 program to include biodegradation of cyanide and cutting oil. Either single reactor or multiple-reactor system will be tested in order to obtain data useful for future system design. The system would be inexpensive and simple to operate so that small plating companies would be able to apply the technology for meeting the wastewater pretreatment requirements.

Project S1 on Study of Flyash and Bottom Ash and Their Leachate Characteristics in a Simulated Landfill condition, a privately funded project started on December 1987, performed extensive chemical analyses on incinerator ash and ash extracts. Multiple columns were set up to simulate landfill conditions for separate or co-disposal of ash and municipal waste. Acid rainfall condition typical of the Rhode Island situation was applied while the simulated landfill leachate was collected for analysis. Pollutants in the leachate were monitored and chemical interactions within the simulated landfill were being identified. The objective of the project is to investigate the fate of the pollutants and the amounts leaching out in the acid rain condition. The project will be completed in May 1989 with data available to engineers designing the landfill for ash disposal in Rhode Island.
Sources and level of funding for the various projects including the information transfer activities are listed below.

<table>
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<th>Project</th>
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<tr>
<td>02 Uranium-Thorium Concentrations in Bedrock &amp; Surficial Materials: Primary Sources of Radon in R. I. Aquifers</td>
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<tr>
<td>03 Numerical Model Study of Contaminant Flow in Fractured Rock</td>
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<td>04 A Microbial Method for Removal of Metals Cutting Oils &amp; Cyanide from Polluted Water</td>
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<td>1,955</td>
<td>University of R. I.</td>
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Information Transfer Activities (See information transfer project description later in this report. Quarterly newsletters were published with the Center administrativ e fund).

| $15,000 | USGS    |
| 39,171  | University of R. I.  |

Center Administration (publication of newsletters included)

| $30,372 | USGS    |
| 44,906  | University of R. I.  |

*Ending May 31, 1988
SYNOPSIS

PROJECT NUMBER: 02

DURATION: June 1, 1987 to May 31, 1988

TITLE: URANIUM-THORIUM CONCENTRATIONS IN BEDROCK AND SURFICIAL MATERIALS: PRIMARY SOURCES OF RADON IN RHODE ISLAND AQUIFERS

PRINCIPAL INVESTIGATOR:

O. DON HERMES
GEOLOGY DEPARTMENT
UNIVERSITY OF RHODE ISLAND
KINGSTON, RHODE ISLAND

COWRR CATEGORY: O2-K

CONGRESSIONAL DISTRICT: SECOND

DESCRIPTORS: URANIUM, RADIOACTIVITY, GRANITES, AQUIFERS, URANIUM RADIOISOTOPES, WATER QUALITY

PROBLEM AND RESEARCH OBJECTIVES:

Radon, a naturally occurring gas which has been recognized as a significant and widespread environmental health problem, forms by radioactive decay of primary $^{238}\text{U}$:

$$^{238}\text{U} \rightarrow ^{234}\text{Th} \rightarrow ^{234}\text{Pa} \rightarrow ^{234}\text{U} \rightarrow ^{230}\text{Th} \rightarrow ^{226}\text{Ra} \rightarrow ^{222}\text{Rn}$$

$^{222}\text{Rn}$ decays with a half life of 3.8 days, undergoing several rapid disintegrations leading to $^{210}\text{Pb}$, which has a half life of 22 years. The $^{210}\text{Pb}$ ultimately decays to $^{206}\text{Pb}$, which is stable.

The primary geologic sources of uranium, and hence radon, are igneous rocks, especially alkali enriched granitic rocks, and sedimentary and metamorphic materials subsequently derived from these igneous protoliths. Radon is an inert gas which is relatively soluble in water. These properties allow it to readily diffuse into the atmosphere and into groundwater aquifers that are in contact with rocks of high uranium content. Previous
studies (King and others, 1982) have shown that high radon levels in groundwater show a positive correlation with high radium levels, and that both radon and radium may correlate with high U and Th in the geologic materials that comprise the aquifers.

Known petrologic and geochemical characteristics of geologic materials in Rhode Island suggest anomalously high concentrations of radioactive parent nuclides of radon and radium. The primary object of this project has been to quantitatively determine uranium and thorium contents in crystalline bedrock, metasedimentary rocks of the Narragansett Basin, and surficial glacial deposits, in an attempt to identify and map groundwater aquifers that are potential geochemical sinks for daughter products radon and radium.

Characterization of radon in groundwater and radioactive parents in host aquifers will permit the state to focus on specific geographic areas where health hazards are likely to exist. At present, reports of anomalous radon findings are sporadic, that is their significance is uncertain because we do not know much about the magnitude and distribution of such occurrences. Although radon distribution must relate in some way to geologic control, specifics are far from conclusive. Hence it is unclear whether radon is, or is not, a potential health problem in Rhode Island.

Uranium and thorium are present in nearly all geological materials, but their concentrations are usually so low that trace level techniques are necessary. The determination of U and Th contents requires the establishment of new analytical techniques not previously available to the URI community. The proposed method is a modified technique of neutron activation analysis called epithermal neutron activation analysis, and as a result of this work will be performed for the first time at the Rhode Island Reactor Facility. The setup of this method entails the development of a suitable procedure based on trial irradiations, experimentation and on recent related literature. The establishment of this technique will constitute a major early effort of this project and is intended to be a valuable by-product of our work.
METHODOLOGY

EPITHERMAL NEUTRON ACTIVATION ANALYSIS

The basic principle of activation analysis is that a stable isotope, when irradiated by neutrons (or charged particles), can undergo a nuclear transformation to produce a radioactive nuclide (Lyon, 1964). The emanations from this formed radionuclide are measured using radiation detection instruments, such as a scintillation counter, thus allowing quantitative determination of the elemental composition of the sample before irradiation. A special method of neutron irradiation, epithermal irradiation, is necessary when determining concentrations of heavy elements such as U and Th in geologic materials as the ratio of these trace elements to the light matrix elements is extremely small.

The neutron energy distribution in the nuclear reactor core is divided into three neutron flux components. The fast neutron component are those neutrons above about 0.1 MeV; the epithermal component are those with energies between 0.2 ev to 0.1 MeV; and the thermal component consists of neutrons below 0.2 ev. In most cases irradiation with the whole reactor neutron spectrum is performed, with most nuclides capturing the thermal neutrons with a relatively high probability (cross sections) and epithermal neutrons with very low probability (the resonance integral).

Epithermal neutron activation allows the activation rate of some nuclides relative to others to be enhanced by shielding the rock sample from the thermal flux component. If a sample is irradiated in a cadmium cover, which has a very high absorption cross-section in the thermal neutron region, the thermal neutrons are excluded, and only the neutrons with energies greater than 0.4 ev will contribute to the activation process (Steinnes and Brune, 1969). For heavy elements such as U and Th, the fractions of activations by epithermal neutrons exceeds the fraction of activations via thermal neutron capture. Therefore, for
complex matrices such as geological samples, the activity level of abundant light matrix radionuclides such as \(^{24}\text{Na} (T_{1/2}=15h)\) and \(^{56}\text{Mn} (T_{1/2}=2.58h)\) will be suppressed to a much greater extent than the activities of Th and U (Meyer, 1971; Parry, 1982). As a result the radioactivity level of the U and Th is enhanced, thus permitting detection to approximately 0.1 ppm levels.

**PROCEDURE**

A broad spectrum of volcanic and plutonic rocks, representative of the major igneous rock groups in Rhode Island, have been analyzed for U and Th content. After field collection, the rock samples for geochemistry were ground and prepared for analysis using equipment in the Geology Department. Routine major and trace chemistry analysis was done, as needed, on a Kevex ED-XRF system that is fully operational in the Geology Department.

Splits of each powdered sample were analyzed for U and Th by epithermal neutron activation techniques at the Rhode Island Nuclear Science Center. To prepare each sample approximately 300 mg of powdered rock sample was weighed into 2/5 dram polyethylene capsules and heat sealed to avoid post-irradiation spillage of the radioactive sample. Iron wires, about 5 cm in length, served as flux monitors for each sample. Each cleaned and weighed iron wire was wrapped and taped around a sealed sample capsule, essentially recording the neutron flux on each individual sample, as this flux is not uniform among all samples.

The samples and respective flux wires were then placed in one of two cadmium vials which have been designed to hold nine sample capsules each. Each Cd vial measures 7.75 cm in height with a diameter of 2.92 cm. These two Cd vials were in turn placed in a rabbit and irradiated at a flux of \(4 \times 10^{12} \text{ n/cm}^2\text{-sec}\) for two hours. Irradiations were done in the late afternoon on any given day to ensure that the rabbit would remain in the reactor following shutdown and overnight. This necessary precaution allowed the cadmium
isotopes produced sufficient decay time before being released to the rabbit station the following day.

After removal from the rabbit the samples were separated from the encapsulating cadmium, thus immediately lowering exposure levels, and stored in the appropriate facility in the reactor. The samples and standards were measured for their gamma-ray spectra on a lithium drifted germanium detector (Ge(Li)) with an energy resolution of 0.5 KeV/channel and an efficiency of 39%. Counting of each 18 samples was done 7 to 9 days after irradiation in order to obtain the gamma-ray spectra indicative of $^{238}$U. The samples were counted a second time 25 to 30 days following irradiation for the spectra resulting from the $^{235}$Th in the sample. In both cases the 18 samples were placed in an automatic sample changer and counted for 2 hours each. Each of the spectra were recorded and stored on a magnetic tape.

The gamma-ray spectra were then evaluated using the total peak area method. A peak height analysis program was run, which identifies and labels the energy (KeV) of each peak and the corresponding intensity (counts/second) for each of the spectra. The data from the peak analysis program were then entered into a Lotus program on an IBM PC in the Geology Department, resulting in final concentrations (ppm) of U and Th. Thus, there was approximately one month between the time of irradiation and final compilation of results for each irradiation.

**PRINCIPAL FINDINGS AND SIGNIFICANCE**

A major early effort of our study has been to develop and perfect the above analytical techniques to quantitatively determine U and Th concentrations in geological material. Compared to several alternative analytical techniques for U and Th analyses, the chosen method requires a simpler setup, less preparation per sample and has been proven
quantitatively accurate and statistically reproducible. This method is now of potential use to other researchers and constitutes a valuable by-product of our work.

Preliminary results from a broad group of volcanic and plutonic rocks in Rhode Island indicate a considerable range in U and Th values (Table 1). The lower concentrations are consistently found in the calc-alkaline and mafic units, as expected. These units include the Esmond granodiorite, Dedham granite and Lynn volcanics (Figure 1). Such data are necessary to establish background levels against which anomalous concentrations can be compared. The higher values are found in the alkaline and peraluminous rocks which are known to be of appropriate mineralogy and geochemistry to be suspected of containing anomalously high U and Th concentrations.

Approximately 70% of the state is underlain by granitic rock, and the remaining 30% consists of sedimentary strata derived from this granitic substrata. Of importance is the widespread occurrence of alkaline rich igneous rocks in Rhode Island (Hermes and others, 1981; Hermes and Zartman, 1985), rock types which are amongst the most enriched in primary U and Th. Commonly, granitic rocks enriched in U and Th also show high concentrations of other high field strength elements such as Zr, Nb, Ta, Y, and Zn (Harris and Marriner, 1980). In Rhode Island, the Scituate granite and Quincy Granite (Figure 1) are K-Feldspar, potash rich granites that contain anomalously high values of Zr, Nb, Y, and Zn. Thus, it is no suprise that these units are among the most U and Th rich of the rocks analyzed in this study to date (Table 1).

This project is part of an ongoing study, to be completed in June, 1989. The analyses of the igneous and metasedimentary rocks are to date incomplete as an additional twenty five samples have been irradiated and will be measured for their gamma-ray spectra in the next twenty days.
The final data will be integrated into the Geographical Information System (GIS), run by the Environmental Data Center at URI, as part of a multiple natural resource analysis. The GIS will generate a dynamic working map identifying areas of potentially low, intermediate, and high levels of radon. Digitization of radon-related geographic information has already been started with the GIS. This geographic information is intended to be available to help guide future radon programs undertaken by the Department of Health as well as state and local planners. The results of this project also will serve to complement the latest studies dealing with groundwater in fractured bedrock, and the nature of its flow through such aquifers.
REFERENCES CITED


Figure 1: Generalized bedrock geologic map of southeastern New England, showing occurrences of alkaline rock units characterized by anomalous concentrations of high-field strength trace elements, such as Nb, Zr, Y, Ta, Zn (Hemes and Zartman, 1985). Elsewhere granitic rocks high in these elements also contain anomalous concentrations of U and Th (Harris and Marriner, 1980).
### VOLCANIC ROCKS

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<th>TH (ppm)</th>
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Table 1: Results from a range of RI lithologies.  
(NPG=Narragansett Pier Granite)
SYNOPSIS

Project number: 03
Start 6/01/87
End 5/31/88

Title: Numerical Model Study of Contaminant Flow in Fractured Rock

Investigator: Cheng-Jung Chang
Dept. of Civil and Envir. Engineering
University of Rhode Island
Kingston, R.I.

COWRR: 05 Water Quality Management and Protection
C Effect of Pollution

Congressional District: 2nd

Descriptors: Gasoline, Groundwater Contamination, Model Studies, Multiple Flow, Oil, Petroleum Products

Problem and Research Objectives:

Contamination of groundwater by industrial products has become a problem of growing concern for years. They pose a potential threat to large volumes of groundwater if they are somehow introduced into the subsurface. One of such threats to groundwater resources is the widespread occurrence of contamination due to spills and leaks of organic materials such as petroleum products which occur during their transport, storage and disposal. These organic materials
contain compounds that are immiscible or slightly soluble in water and can be a long term source of contaminants. They can migrate with water through the soils or fractured rocks and within a certain period of time can spread over a considerable area.

The infiltration and migration of petroleum products in the subsurface is a complex process. Most numerical models either consider the flow domain to be a porous medium or deal with the qualitative analysis of the contamination problems. Difficulty, however, arises when such assumptions are utilized for quantifying flow through fractured rock. This is because fractured rock has two distinctly different porosities - one due to interconnected fracture network and the other due to the inherent porosity of the rock mass itself. In general, the interconnected fractures form a system of channels in such a manner that the entire porous domain is made up of a large number of porous blocks, each completely surrounded by the void space of the channel and the fracture system. Thus, accurate prediction of immiscible organic contaminants as a separate phase in fractures and pores is a prerequisite to the development of models describing the flow of immiscible contaminants in fractured rock.

The objective of this study is the development and verification of a numerical model for the analysis of areal flow under transient conditions of an immiscible contaminant fluid in fractured rock. The procedure towards this
objective consists of the following:

1) Development of the numerical model from the basic partial differential equations describing the immiscible fluids in two overlapping continua using necessary physical and mathematical assumptions.

2) Development of a computer software which can be used for predicting horizontal spread of various hydrocarbon spills.

Methodology:

Two sets of governing equations are required to describe the flow in fractured porous media, one for each type of porosity. These sets of equations are coupled by the interaction of fluid in the primary pores with the fluid in the fractures. The continuity equations for the flow of two immiscible fluids, water and oil, are given by:

for oil in fractured medium,

\[
\frac{\partial}{\partial t} \left[ \eta_f \rho_f (P_f) S_{of} + \eta_f \rho_w (P_f) s(P_f) S_{wf} \right] \\
+ \nabla [ \rho_f (P_f) q_{0f} ] = m_o^* - - - - - - - (1)
\]

for oil in porous blocks,

\[
\frac{\partial}{\partial t} \left[ \eta_p \rho_o (P_p) S_{op} + \eta_p \rho_w (P_p) s(P_p) S_{wp} \right] \\
+ \nabla [ \rho_o (P_p) q_{0p} ] = - m_o^* - - - - - - - (2)
\]
for water in fractured medium,

\[
\frac{\partial}{\partial t}\left[ \eta_f \rho_w (P_f) S_{wf} \right] + \nabla \left[ \rho_w (P_f) q_{wf} \right] = m_w^* \quad (3)
\]

for water in porous blocks,

\[
\frac{\partial}{\partial t}\left[ \eta_p \rho_w (P_p) S_{wp} \right] + \nabla \left[ \rho_w (P_p) q_{wp} \right] = -m_w^* \quad (4)
\]

where subscripts 'f', 'p', 'o' and 'w' have been used for fractured medium, porous medium, oil phase and water phase respectively, \( n \) is the porosity of the medium, \( \rho \) is the density of the fluid, \( S \) is the degree of saturation, \( s \) is the solubility of oil in water, \( q \) is the specific discharge vector given by Darcy's Law and \( m^* \) is the transfer of fluid from porous blocks to fissures per unit bulk volume of the flow domain and per unit time.

The above set of partial differential equations can be simplified with the assumptions that densities are independent of pressure and oil is insoluble. The mass flow rates, \( m_o^* \) and \( m_w^* \), per unit time per unit volume of medium are the average interactions of the fluids in the primary blocks with the fluids in the fractures. These terms are, therefore functions of time and space and can be formulated in terms of fluid pressures in fractured and porous mediums.

Equations (1), (2), (3) and (4) form a system of coupled nonlinear partial differential equations, closed form solution of which is intractable. Therefore, these equations are solved numerically using finite element technique. Since variational formulation of this problem is
rather complicated, Galerkin finite element procedure has been used in this research. Time integration of the heads and the interface elevation is done using fully implicit backward finite difference scheme.

Principal Findings and Significance:

The solution scheme that has been used in the present study is based on some of the existing models for simulating fluid flow in porous medium. They have been associated and modified to take into account flow through fractured medium. A computer software has been developed based on the mathematical formulation. This computer model can be used to simulate flow of any two immiscible fluids through fractured rock consisting of both fractures and pores or through only fractured or porous medium. The medium can have different porosities in x and y directions. The injection of contaminant can be through a nodal source or an elemental source. The rate of recharging can be varied through different time increments. Another important feature which the computer model is capable of simulating is that for a given existing plume, it can predict the plume profile after certain amount of time. Therefore, during the clean-up process with a particular rate of discharge the model gives a very good idea about when the pumping should be stopped and started again to have maximum efficiency.
Fully implicit finite difference scheme has been used for time integration so that the user need not concern about the stability problems. The element library of the model consists of three different types of element. They are three noded linear triangular element, six noded quadratic triangular element and four noded isoparametric quadrilateral element. However, it has been observed that the benefit obtained from the use of higher order functions is very minimal.

In the past, virtually no numerical work has been done in the area of flow of contaminant through fractured rock. As a result, development of numerical procedures to analyse the flow of contaminant through fractured rock, like the present one, is very important. The Rhode Island Department of Environmental Management has a number of groundwater contamination case histories in the state where the medium is a fractured one. With laboratory tested contaminants and explored geological data available, this model is able to predict the potential and extent of groundwater contamination in fractured rock for existing as well as future such problems in Rhode Island. Moreover, the model can be used to find efficient ways of cleaning the groundwater for the above cases. It can also be used by other potential users like researchers, consulting engineers and environmental regulating agencies in the United States.
SYNOPSIS

Project Number: 04
Start 6/1/87
End 5/31/88

Title: A Microbial Method For Removal Of Metals, Cutting Oils And Cyanide From Polluted Water - Phase II

Investigators: Dr. R. W. Traxler, Univ. of Rhode Island
Dr. Tung-Ching Lee, Univ. of Rhode Island
Dr. D. R. Nelson, Univ. of Rhode Island

COWRR: 05D Waste Treatment Process

Descriptors: Bacteria, Biodegradation, Heavy Metals, Waste Disposal, Pollution Control

Problem & Research Objectives:

Rhode Island regulations limiting the discharge of toxic metals and cyanide into public sewers have been in effect for five years but the majority of affected platers and finishers are not in compliance with these regulations. Many of the larger firms meet discharge standards or are expected to do so in the near future but the smaller companies have not had the resources to effectively meet these standards.

The magnitude of the problem is seen by the amount of heavy metal entering the Narragansett Bay Commission sewer system in recent years. The peak was in 1981 with 956,099 pounds release with a drop in 1985 to 409,657 pounds. The interim goal is to reduce this volume to about 200,000 pounds within a year. The existing technology for solution of this problem by chemical means is expensive. One of the larger companies was forced to spend $500,000 for a pretreatment system. This type of a solution to the problem is beyond the capability of the smaller operator who does not have the capital resources for even a 5th of this type of investment. The ultimate result is that without a less expensive system these small companies will be forced out of business. This project is aimed at the small operation to provide to these companies a relatively simple, inexpensive but effective means of pollution control. The project while of extreme potential value to Rhode Island can also be applied to the same problem in other states.

A. The FY 1987 Objectives Phase I Metal Removal:

1. Expand resistance spectrum in one isolate, if possible, to include resistance to Cu, Pb, Ag, Cr, Zn, Cd, Ni and Hg.

2. Determine the kinetics of metal removal.

3. Determine the saturation level of cell mass.
4. Determine the effect of nutrients on metal removal.

5. Perform bioreactor studies with simulated and real waste for metal removal.

6. Determine the presence or absence of plasmid DNA which is linked to the objectives of Phase II.

Methodology:

a. Enrichment Isolations: The basic procedure is to use a chemically defined mineral salts medium minus one essential nutrient (in this series either carbon or nitrogen). For isolation of hydrocarbon degraders, oil (or pure hydrocarbon) is added to this medium at a final concentrations of 1% (V/V). The medium contains a nitrogen source which is usually ammonium nitrate. An inoculum source (from an oil polluted area) is added at about 1% volume and the flask incubated with shaking at 25-30 C until visible growth occurs. At visible turbidity, 1.0 ml of this primary enrichment is transferred to a second flask of the same medium. When growth occurs the growth is streaked for isolation on a general purpose medium and the isolation medium solidified with 1.5% washed agar-agar. One of each colony type that grows on the isolation medium is streaked for purity then reinoculated into sterile mineral-salts substrate broth. Growth in this flask indicates a successful enrichment isolation. In the same way a non-repressive substrate is used as a carbon source in a nitrogen free medium for the isolation of cyanide utilizers with cyanide as the nitrogen source. The non-repressive substrate can be sucrose (not glucose) or any of a variety of substances such as glycerol, acetate which do not contain nitrogen. Also, simple complex media are used in diluted form, i.e. nutrient broth 1/10 formulation with cyanide added at varied concentrations (0.02 to 0.5%). This work is performed in a fume hood at an air flow rate of 100 cu.ft/sec. to ensure safety of personnel. Disposable gloves are used in all handling of materials and placed in a closed container in the hood after use. It is not necessary to sterilize the cyanide salts which are prepared as stock solutions and aseptically added to sterile medium. KCN is the salt normally used in this type of experiment

b. Bioreactor testing: One organisms has been selected for this system and the nutrient supplement needs established. The experiments will be conducted in a two liter fermenter structured for continuous flow at a working volume of 1350 ml. This reactor is part of the New Brunswick Scientific Co. C-30 Bioflow unit equipped with pH, agitation, temperature and aeration control. A variable speed peristaltic pump is used to flow an effluent waste to the reactor at variable dilution rates which determines the residence time in the system. The effluent from the reactor flows by gravity to an effluent collection reservoir. The effluent stream is sampled at time intervals and analyzed for pollutant residues. The parameters to be studied are
biomass loading, uptake and degradation kinetics, determination of optimum pollutant feed rate and time for biomass saturation from metal uptake.

The final phase of the study is conducted in the same fermenter system but using a non-continuous flow reactor vessel. In these experiments the reactor content is pumped via a high speed pump to a tangential flow filter which separates cells and aqueous phase. The retentate flow (containing cells) is returned directly to the bioreactor while the permeate (aqueous phase) stream is split with partial flow to waste and the remainder of the flow back to the bioreactor. The volume of permeate to waste is set to equal the rate of waste feed into the bioreactor. The system is adjusted to a steady state for optimum pollutant removal. Concentrated waste would be diluted with makeup water to desired feed concentration and fed on a continuous basis to the bioreactor. Supplemental nutrients are fed to the reactor by addition to the waste stream. In this second phase of the project we will use actual waste from metal working operations.

Principal Findings & Significance:

Objective 1.

Using a serial enrichment-adaptation procedure we have been able to expand the resistance spectrum of Arthrobacter HC823 to a combined mixture of eight metals, each at a concentration of 50 ppm. The eight metals are: Cu, Pb, Ag, Cr, Zn, Cd, Ni, and Hg. This is a combined total metal ion load of 400 ppm of metal ion in the test system. We are delighted to be able to achieve this resistance pattern in one isolate.

Objective 2.

Kinetic studies were initiated in November using Cu as the first metal in non-nutrient supplemented experiments. The first experiments indicate a much more rapid removal of the metal from a microbial suspension in distilled water than anticipated. We expect on the basis of the data that the bulk of the copper is removed within the first few minutes of the experiment. Copper is apparently distinct from the other metals in that it may be chelated by a low molecular weight protein or peptide and effectively co-precipitated with the cells. Similar experiments have been performed with other metals and a mixture of metals. In these experiments we have encountered reduced levels of metal binding, which at this time have not been explained. Experiments in May have used more concentrated cell mass in small scale experiments. It was expected that the amount of metal removed from aqueous solution would be directly related to the dry weight mass of cells used in the reactor. This is true up to approximately 20 mg/ml then there is an actual decline in metal removal. Our normal procedure is to shake the bioreactor during the experiment which provides aerobic conditions. An experiment under anaerobic conditions demonstrated a significant reduction in metal removal, indicating an aerobic process. It would appear that when increased cell mass is used we are unable to provide a sufficient dissolved oxygen for metal removal. Experiments are
being prepared to used enhance aeration system to resolve this question.

Objective 3.

We now know that saturation of the cell mass with metal occurs at a metal:cell dry weight in the range of 1:1.4 to 1:2.8 mg metal:mg cell dry weight. From this data we now have a guide to the amount of cell mass needed to clear a waste water. This baseline information will be used as we structure the bioreactor studies.

Objective 4.

We know that glucose used as a energy source (1%) enhances metal removal from a water solution but is not as effective as small quantities of yeast extract (0.01%). Using a mixture of glucose and yeast extract offers no advantage over yeast extract alone.

Phosphate would appear to enhance Cu and Pb cell association but lowers the association of Cr and cells. Phosphate also has a chemical reaction with Ag (apparently the formation of silver orthophosphate which is insoluble) which removes the silver from solution.

Yeast extract is a complex mixture of compounds which are to a large extent amino acids, peptides and vitamins. It is a very promising supplement for this project in that low concentration is required for enhanced activity and it is a relatively cheap product.

Objective 6.

A variety of procedures have been used in the digestion of Gram positive bacteria for the release and recovery of plasmid DNA. In early experiments only nuclear DNA was recovered. Different digestion methods have been used, along with known plasmid bearing organisms as a control on the method. This work is complicated by the fact that molecular studies are not well known for members of the genus Arthrobacter. We have just recently demonstrated what appears to be two regions of non-chromosomal DNA on gels and are in the process of restricting these regions from the gels. The next step will be to transfer this DNA to a non-resistant organism such as E coli to determine if metal resistance is carried on these DNA segments.

Publications & Professional Presentations

None to date, a preliminary publication is in preparation.

M.S. Theses:

Ph.D. Dissertations:
M-C. Lai, underway.
SYNOPSIS

Project Number: 05
Start: 6/1/87
End: 11/1/88 Anticipated

TITLE: Microbial and Phosphorus Migration in Groundwater from Seasonally Used Septic Systems

Co-Principal Investigators:

Arthur J. Gold, Associate professor, Natural Resources Science, URI

Charles G. McKiel, Associate Professor, Natural Resources Science, URI

George W. Loomis, Research Associate III, Natural Resources Science, URI

COWRR: 05A, 05B, 05D, 05G

Descriptors: Groundwater pollution, septic wastewater, soil disposal fields, nitrogen, phosphorus, sewage bacteria, monitoring.
STATEMENT OF PROBLEM:

The population of the United States in recent years has migrated towards the nation's coastlines. It is estimated that by the end of this decade that 75% of the populace will reside within 50 miles of tidal waters and the Great Lakes (Carter, 1980). Development pressures are particularly heavy along the shoreline as the result of rapidly expanding seasonal coastal communities. The southern shore of Rhode Island exemplifies this trend. The coastal pond region is now experiencing ground water pollution and surface water eutrophication resulting from a three-fold increase in housing since 1950 (RIPE, 1981; Olsen and Lee, 1985). The commercial, recreational, residential, and ecological values associated with the Rhode Island coastline warrants staunch protection of these water resources. Recently, seasonally used individual sewage disposal systems (ISDS) have come under increased scrutiny as a major source of water quality deterioration for several reasons:

i) their inherent proximity to coastal waters

ii) their installation in highly permeable coarse grained soils

iii) the high density of homes associated with seasonal communities
iv) their lack of continuous operation time to produce an adequate clogging layer.

The objective of this thesis research is to determine the migration and attenuation of selected contaminants from seasonally used ISDS. Sand filter components of existing alternative septic system (i.e. recirculating sand filter system and RUCK) will also be compared to the seasonally used ISDS in an attempt to assess sand filter efficiency for selected contaminant removals. The result of this study will aid in establishing recommendations on future septic system design and minimum setback/separation distances from septic systems to wells and groundwater table for coastal regions.

Methodology:

Three seasonally used ISDS were selected for detailed study. Potential study sites were first delineated based upon the following geologic criteria:

i) coarse outwash or beach soils

ii) unconfined water table within 2 meters of the surface.

The state of Rhode Island possesses approximately 5500 hectares which satisfy these requirements (Rector, 1981). Final site selection was determined by requiring that all ISDSs meet modern
(post 1969) RI-DEM specifications, and be used seasonally. Suitable sites were found on the barrier spit complex of Charlestown and permission was obtained to investigate 3 suitable homes.

The first stage of instrumentation involved determining the exact location of the septic systems for each of the 3 homes on the barrier. This was accomplished by probing and excavating to expose the various system components. Once the perimeter of the drain field had been staked, samples of the groundwater were obtained at discrete distances around the field and tested for electrical conductivity and relative chloride content to estimate leachate plume migration direction.

A groundwater well instrumentation plan was then devised to intersect the plume and allow for tidal and seasonal flow variations. Wells were constructed of 10 foot lengths of 2 inch PVC pipe, equipped with plastic well points and slotted along the lower half. Seventeen to twenty wells were installed at 1, 3, and 5 meter distances away from the drain field for each home. Bentonite seals were installed around the well to prevent surface waters from channeling down the well casing. In addition an upgradient well was installed to determine background concentrations. To discourage tampering, the wells were secured at ground level with standard PVC female threaded adapters and punctured inverted male caps. The wells were then covered with ventilated well covers to prevent dust contamination.

Experimental sand filters are presently instrumented and in operation at Peckham Farm on the University of Rhode Island campus. Influent and effluent from these systems will be tested
for nitrate-N, phosphorus and bacterial pollutant removal and compared to the results obtained from the Charlestown sites.

Sampling was conducted monthly during the period between March 1 and May 15, 1988. Sampling frequency will then be increased to bi-weekly until September 1. Thereafter monthly sampling will occur for the duration of the study.

Sampling procedures will include evacuation of three well volumes of water prior to sample extraction to remove any contamination build up that may have occurred. Samples are then collected into acid washed polyethylene plastic bottles to be analyzed within 12 hours for anionic pollutants (nitrate-N and phosphate) using a Water's Ion Chromatograph. Wells within the leachate plume, wells, along with several background wells, are then be resampled and subjected to microbial analysis. Five hundred milliliter samples are then taken using separate sterilized poly tubing and glass bottles for each well. Samples are stored at 4°C for no more than 6 hours to insure the integrity of the results and prevent any cross contamination. Samples are analyzed within this 6 hour period for fecal coliforms. All laboratory procedures will be completed in accordance with the standard methods outlined in APHA (1985).

Results and Discussion:

This study focuses on seasonally used individual sewage disposal systems, thus the period of continuous use extends only from Memorial Day weekend (May 27) to Labor Day weekend (September 5). During the summer of 1987, 280 seasonal residents
of Charlestown and South Kingston were contacted by mail to assist in this project. Approximately 10% of those contacted responded to this request and by October 1, three homes had met the above mentioned criteria and had been instrumented. This implementational setback rendered the summer of 1987 useless for the collection of data; consequently, this synopsis and the July 15 report are only interim reports. A final report will be submitted in the fall of 1988 when complete results have been obtained. This project also represents the M.S. thesis research of Frank B. Postma and will be completed in the winter of 1988. Data collection began on March 15, 1988 and will continue according to the above mentioned schedule at no additional cost to the Water Resource Center.

Preliminary results have been obtained for the months of March, April, and May from the Charlestown sites. Several results have also been obtained from the recirculating sand filter and RUCK systems, however, an accidental introduction of a toxic substance into this system has stalled attempts to obtain microbial data. This problem has recently been corrected and sampling of these systems is scheduled to resume by June 6, 1988.

The Charlestown sites (individually identified as: sites M, S, and K) during the months of March, April, and May 1988 demonstrated minute quantities of nitrogen and sporadic presence of phosphorus from the monitoring wells and while all upgradient wells remained free of these contaminants. From sites M and K only 17.1% of the wells tested positive for nitrate-N with a mean concentration of 1.89 mg/l and a range of 0.45 - 11.3 mg/l. Site S demonstrated a greater number of wells contaminated
with nitrate-N (38.2%). Site S has experienced far greater usage during these months than the other two sites. Phosphorus has been confirmed in only one well at the Charlestown sites. In well 5, site S a phosphorus concentration of 7.5 mg/l at a distance of 3 meters was detected from the septic field. No fecal coliform movement has yet been measured from any of these Charlestown sites.

Samples from the recirculating sand filter were also tested specifically for phosphorus concentrations. An ortho-phosphorus concentration mean of 1.02 mg/l and range of 0.16 - 2.68 mg/l were obtained for the effluent leaving the sand filter. These results should in no way be compared those obtained from the Charlestown sites due to the limited uses of the homes due preliminary sampling periods.

Drawing conclusions from this limited data set is not yet feasible; however, several interesting questions have surfaced from this initial research:

i) what is the loading rate of pollutants to the environment?

ii) what quantity of pollutants is attenuated by the soil and clogging mat?

iii) does a clogging mat develop in seasonally-used homes?

iv) how much attenuation and dilution of various
contaminants occurs with distance from drainfield?

v) how does the pollutant removal efficiency of these seasonal systems compare to a continuously used recirculating sand filter system?

With the completion of this study, these questions will be further addressed.
References Cited


SYNOPSIS

Project Number: S1  
Start: 12/87  
End: 05/89

Title: Study of Flyash & Bottom Ash & Their Leachate Characteristics in a Simulated Landfill Condition

Investigators: Poon, Calvin P. C., University of Rhode Island

COWRR: 05A 05B, Congressional District: Second

Descriptors: Acid Rain, Drainage, Heavy Metals, Infiltration, Leaching, Incinerator Ash, Sanitary Landfill

Problem & Research Objectives:

The state of Rhode Island is going to build three solid waste incinerators in the near future. Incinerator operations in other states show that the ash is a potentially hazardous waste material. In light of the unique design using high-alkaline flu gas scrubber and the new USEPA extraction protocol (TCLP) in defining hazardous waste, it is necessary to study the characteristics of the ash using both the existing EPTC protocol and the proposed TCLP protocol. Special attention will be given to heavy metals cadmium (Cd) and lead (Pb) as they are most commonly found in incinerator ash. With the acid rainfall in the northeast region, it is a major concern if the leachate from a landfill for ash disposal would contain Cd and Pb. Therefore, simulated landfill studies using columns in laboratory will be useful to characterize the leachate quantity as well as quality. The result will be useful for future design of landfill used for ash disposal.

Methodology:

Columns containing a sand layer in the bottom with drains, and ash or ash/municipal solid waste layers, were used to simulate landfills. Artificial acid rains were introduced to the columns based on a typical Rhode Island rainfall condition. Leachate and gas samples were collected for chemical
analysis. Interactions of Cd and Pb with other substances in the columns were examined. Mass balance of fluid infiltration, leachate collected, Cd, Pb, and other chemicals that control the fate of Cd and Pb in the columns will be carried out.

Principal Findings and Significance:

Using the existing EPTC extraction procedure, the incinerator ash used in this study shows that it is not a hazardous substance in reference to Cd, however, the ash is a hazardous substance in reference to Cd when the newly proposed TCLP procedure by USEPA is used. Either procedure shows that the ash is a hazardous substance in reference to Pb. Deionized water extraction (pH=4.95) shows that the ash is nonhazardous for both Cd and Pb.

Column study up to the present time shows that the leachate from acid rains contains both 2 to 3 ppm of Pb and 0.3 ppb of Cd. The study will be continued for another 10 months to show the fate of both Pc and Cd in the simulated landfill and acid rain conditions.

Thesis:

A Ph.D. Dissertation is underway.
INFORMATION TRANSFER ACTIVITIES:

The information transfer activities can be divided in two parts: (a) Newsletter, and (b) coordinated efforts in environmental education (Project 22, FY-1987).

(a) Newsletter, published on September 1, and December 1, 1987, and on March 1, and June 1, 1988 by this Center were distributed to the public as well as water agencies and the research community in Rhode Island, and all other 54 water Resources Research Institutes. Items covered in the newsletter included research project accomplishments, on-going research works, the planning activities of this Center, announcements of the activities of part (b), as well as discussions on water related environmental issues relevant to the State of Rhode Island such as groundwater legislation, real estate transactions, outlook of water pollution and hazardous waste control.

(b) Project 22, coordinated efforts in Environmental Education Water Protection, Management and Conservation, aimed at key groups and disseminated information on planning strategies for effective land use and water protection with official as well as private citizens' participation.

The following activities were carried out in FY-1987:

(a) Questionnaires regarding topics for two conferences (Waste Water Management Districts and Groundwater Issues) were sent to Town Councils, Planning/Zoning Boards, Conservation Commissions, and other planning officials in the 39 Rhode Island municipalities.

(b) Dialogue with various state, local, and private agencies was established to ensure coordination of water quality programs. Meetings were held with Rhode Island Audubon Society, the Department of Environmental Management, Save
the Bay, Chariho Water Resources Group, Wood-Pawcatuck Watershed Association, Sierra Club, South County Planners, and the Coastal Resources Management Council.

(c) A series of factsheets was developed for use by municipal planning officials and the general public. Topics reflect specific environmental concerns and solutions incorporating University of Rhode Island and national research.

(d) A conference on Waste Water Management Districts, developed jointly with the Rhode Island Audubon Society and co-sponsored by Rhode Island League of Cities and Towns, EPA Small Flows Clearinghouse, URI Water Resources Center, and URI Cooperative Extensions, was held on April 30, 1988. The purpose of the conference was to offer municipalities information needed to take advantage of the new enabling legislation and to plan for septage disposal. Participants were municipal planning officials, septage haulers, consultants, environmental groups, and public works officials. Participants received a Natural Resources Science Facts notebook with URI factsheets and other relevant materials.

(e) WATERSHED WATCH, the citizen monitoring program in the Pawcatuck Basin, was begun in cooperation with the Wood-Pawcatuck Watershed Association. Volunteers participated in several training sessions and received a Natural Resources Science Facts notebook with monitoring protocol and factsheets on water quality issues. Monitoring will be conducted on 15 lakes during the months of May through October, 1988. Collected data will be given to the Department of Environmental Management as a part of their effort to develop a pool of lake quality information.

(f) Technical support was provided to complete the EPA petition for Sole Source Aquifer Designation for the Pawcatuck Basin. A series of slides were
developed to explain the impact of the designation to the involved municipalities (14 towns).

(g) A handbook on strategies for groundwater protection for local officials is in the development stage. It is expected to be in its final draft form August, 1988.

(h) A short course on groundwater protection is being planned for the fall of 1988. The objectives of the course are: 1. to educate local officials and interested citizens about basic groundwater hydrology and groundwater protection, and 2. to provide local communities with the tools to develop and implement community-based management program.

There were many benefits to the programs which were developed. Better informed planning officials, as well as the general public, lead to land use decisions which ensure potable water supplies for the state. Working with environmental groups and state agencies allowed the University to give technical assistance and to strengthen existing water quality programs.

The response to the questionnaires indicated that municipal officials are interested in taking advantage of programs offered throughout the University. Programs developed by the University add an important contribution to the various strategies being developed by state agencies and private organizations. Various state task forces have been established to review current state regulations and to establish guidelines for innovative land use policies. Many municipalities are revising their comprehensive land use plans and are seeking technical assistance.

The conference on Waste Water Management Districts was attended by a wide variety of people and provided the forum for initial distribution of
Natural Resource factsheets. The conference provided a forum for federal, state, and local officials to exchange information on implementing Waste Water Management Districts. Several speakers from other states and several speakers from various departments in the University presented the workshop. The conference dealt with such issues as the community benefits of Waste Water Management Districts, the legal and financial aspects of districts, the importance of planning for sewage disposal, considerations in evaluating large and small septic systems, and the financial resources at state, federal and private levels. In view of the growing concern over water quality issues and the increasing rate of development in Rhode Island, the conference provided an important informational base to towns dealing with these critical issues. Additional factsheets and conferences will provide further technical assistance.

The WATERSHED WATCH program has received enthusiastic support from the volunteers and the State. The program will contribute water quality data to the State's limited information base. It will indicate trouble spots so that the appropriate state agency may be alerted. Additionally, it will become a part of the public education program on water quality issues. The program joins the growing number of national grassroots volunteer monitoring programs. It is the second program in Rhode Island, following the successful Salt Pond Waters, whose 30 member volunteer force has been collecting valuable water quality data on the salt ponds for three years.

The Water Resources Center at the University of Rhode Island can serve an important function improving water resource management within the state. The legislative and regulatory mechanisms necessary to protect water resources can be realized more readily if technical information needed for informed decisions is centralized and accessible.
The following is a list of professional publications published during the grant period resulting from institute-supported research.


2. Leaching of 2, 4-D and Dicamba from Home Lawns, by A. J. Gold et al., 37, 121-129, 1988.


6. Factsheets

   Homeowner's Guide to a Green Lawn and Clean Water
   Site Evaluation for On-Site Sewage Disposal
   Maintaining Your Septic System
   Septic Systems: Pollution Abatement
   Available Resources
   Protecting Water Resources
   Watershed Watch
   Defining Our Watershed
COOPERATIVE ARRANGEMENTS:

The Center has two advisory committees, one that State Advisory Committee and the other the University Water Resources Coordinating Committee, By recommendation from the federal inspection team in FY-1986, both committee memberships have been expanded.

State Advisory Committee

Peter P. Calise, Manager, R. I. Water Resources Board
Rodney Driver, State Legislator
James W. Fester, Assistant Director of Regulation, R. I. Dept. of Environmental Management
Ellen Greiner, R. I. League of Women Voters
Herbert E. Johnston, Subdistrict Chief, U. S. Geological Survey
Vincent Rose, Chairman of Board, Save the Bay
Daniel W. Varin, Chief, Div. of Planning, R. I. Dept. of Administration
In addition, Mr. Alfred L. Hawkes, Director of the Audubon Society of R. I. will be joining the committee starting FY-1988.

University Water Resources Coordinating Committee

Pei Wen Chang, Animal Pathology
Frank Deluise, Mechanical Engineering
Reinhard K. Frohlich, Geology
Scott W. Nixon, Oceanography and Sea Grant Coordinator
James Opaluch, Resources Economics
Calvin P. C. Poon, Environmental Engineering
Leonard Worthen, Pharmacognosy

As in the past years, both committees have contributed significantly to the development and direction of the FY-1987 program.

Project 02 worked closely with the R. I. Dept. of Health and the GIS system of the R. I. Dept. of Environmental Management at the University of Rhode Island for data processing and mapping.

Project 03 received guidance and information from the R. I. Dept. of Environmental Management, Water Resources Division, in developing the project
work. With some explored geological data available, the result of this project could be used to predict the extent of groundwater contamination in fractured rocks in Rhode Island.

Project 05 worked closely with U. S. Dept. of Agriculture, Soil Conservation Service, on site selection and project design.

The project on information transfer worked with Rhode Island Town Councils, R. I. Audubon Society, R. I. Dept. of Environmental Management, Save the Bay, Chariho Water Resources Group, Wood-Pawcatuck Watershed Association, Sierra Club, South County Planners, R. I. Coastal Resources Management Council, League of Cities and Towns, USEPA Small Flow Clearinghouse to develop the program comprising the workshop, Watershed Watch, Technical Support for Sole Source Aquifer Designation Application, and Publication of Factsheets.

In addition, the Center participated, with cooperations from the New England Center, New England Water Resources Research Centers, and other interstate and federal agencies, in the development of the program as well as assisted the conference on "A New Age for Decision Making---Using GIS: A call for regional action and cooperation" which took place at the University of New Hampshire on February 1 and 2, 1988. Most of the issues addressed in the conference were water resources related. The Center also participated in the pilot program of National Network for Water Policy Research and Analysis of the USEPA Office of Water by coordinating the effort of matching topics with student candidates from departments of various disciplines at the University of Rhode Island.
### TRAINING ACCOMPLISHMENT:

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