**Pacific Northwest Laboratory
Annual Report for 1976
to the
ERDA Assistant Administrator for
Environment and Safety**

**Part 5 Control Technology, Overview,
Safety, and Policy Analysis**

June 1977

Prepared for the Energy Research
and Development Administration
under Contract EY-76-C-06-1830

Battelle

Pacific Northwest Laboratories

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**Part 5 Control Technology, Overview,
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**by
W. J. Bair and Staff Members
of Pacific Northwest Laboratory**

June 1977

**Battelle
Pacific Northwest Laboratories
Richland, Washington 99352**

PREFACE

Pacific Northwest Laboratory's 1976 Annual Report to the ERDA Assistant Administrator for Environment and Safety is organized by major program categories into five Volumes, or Parts. Parts 1-4 are oriented to particular segments of the program supported by the Division of Biomedical and Environmental Research. Part 5 includes reports on projects supported by the Division of Safety, Standards and Compliance; Division of Technology Overview; Division of Environmental Control Technology; and the Office of Environmental Policy Analysis. Each Part consists of project reports authored by scientists from several PNL research departments, reflecting the interdisciplinary nature of the research effort. The Parts of the 1976 Annual Report are:

Part 1	Biomedical Sciences Program Manager - W. R. Wiley	R. C. Thompson, Report Coordinator D. L. Felton, Editor
Part 2	Ecological Sciences Program Manager - B. E. Vaughan	B. E. Vaughan, Report Coordinator J. L. Helbling, Editor
Part 3	Atmospheric Sciences Program Manager - C. L. Simpson	J. M. Hales, Report Coordinator E. L. Owzarski, Editor
Part 4	Physical and Technological Programs Program Manager - J. M. Nielsen	J. M. Nielsen, Report Coordinator G. M. Garnant, Editor
Part 5	Control Technology, Overview, Safety, and Policy Analysis Program Managers - N. E. Carter D. B. Cearlock J. C. Fox D. L. Hessel H. V. Larson	W. J. Bair, Report Coordinator L. C. Counts/R. W. Baalman, Editors

Activities of the Environmental and Safety Research Program at PNL are broader in scope than the articles in this report indicate. PNL staff members participate throughout the year in many projects not funded through specific 189s. These efforts include overall program planning, response to requests for information from the ERDA Assistant Administrator for Environment and Safety and other officials, participation on national and international standard-setting committees, and public education. During 1976, staff of PNL's Environmental and Safety Research Program:

- prepared two volumes (Fission and Fusion) of ERDA's Balanced Program Plan for Biomedical and Environmental Research;
- contributed to a number of environmental assessments and impact statements, including the Generic Environmental Statement for Mixed Oxide Fuels and the Clinch River Breeder Reactor Statement, and participated in hearings on nuclear issues;
- sat on National Academy of Sciences/National Research Council Committees, the National Council on Radiation Protection and Measurements, and the International Commission on Radiological Protection;
- compiled and prepared the final reports for two of these committee efforts; and
- provided, in response to requests from the Assistant Administrator for Environment and Safety, interpretations of research results to clarify information given to the public on a number of issues. These included the Hanford Mortality Study findings, faulty published interpretations of data on mortality in plutonium workers, and several other issues concerned with nuclear power.

W. J. Bair, Manager
S. Marks, Associate Manager
Environmental and Safety Research Program

Previous Reports in this Series:

Annual Report for

1951	HW-25021, HW-25709
1952	HW-27814, HW-28636
1953	HW-30437, HW-30464
1954	HW-30306, HW-33128, HW-35905, HW-35917
1955	HW-39558, HW-41315, HW-41500
1956	HW-47500
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1959	HW-63824, HW-65500
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1961	HW-72500, HW-73337
1962	HW-76000, HW-77609
1963	HW-80500, HW-81746
1964	BNWL-122
1965	BNWL-280, BNWL-235, Vol. 1-4
1966	BNWL-480, Vol. 1, BNWL-481, Vol. 2, Pt. 1-4
1967	BNWL-714, Vol. 1, BNWL-715, Vol. 2, Pt. 1-4
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1969	BNWL-1306, Vol. 1, Pt. 1-2, BNWL-1307, Vol. 2, Pt. 1-3
1970	BNWL-1550, Vol. 1, Pt. 1-2, BNWL-1551, Vol. 2, Pt. 1-2
1971	BNWL-1650, Vol. 1, Pt. 1-2, BNWL-1651, Vol. 2, Pt. 1-2
1972	BNWL-1750, Vol. 1, Pt. 1-2, BNWL-1751, Vol. 2, Pt. 1-2
1973	BNWL-1850, Pt. 1-4
1974	BNWL-1950, Pt. 1-4
1975	BNWL-2000, Pt. 1-4

FOREWORD

Part 5 of the 1976 Annual Report to the ERDA Assistant Administrator for Environment and Safety presents Pacific Northwest Laboratory's first yearly progress report on work performed for the ERDA Divisions of Environmental Control Technology; Safety, Standards, and Compliance; and Technology Overview. It also reports, for the first year, our program for the Office of Environmental Policy Analysis.

Part 5 is organized into four sections, corresponding to the program elements. The sections are introduced by blue summary pages. In each section, articles relate progress made during 1976 on individual projects, as identified by Schedule 189 titles. Authors of these articles represent a broad spectrum of capabilities from across the laboratory, reflecting the interdisciplinary nature of the work.

For PNL's Environmental and Safety Research Program, 1976 was a year of pronounced growth and change, particularly in the program elements reported in this Part. For example, we are able to report the first results from many new nonnuclear projects, reflecting the shift in emphasis from nuclear to nonnuclear-related technologies. Creation of the Office of Environmental Policy Analysis has brought closer involvement in multidisciplinary, interlaboratory analysis and overview functions. In addition, we began to formulate plans for embarking on a large project management effort, the Environmental Control Technology program for utilization of liquefied natural gas. The next few years are expected to bring other significant changes as we respond to ERDA's needs for the developing energy technologies.

For additional information on any of the projects reported in this Part, contact the author(s) of the articles.

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ENVIRONMENTAL CONTROL TECHNOLOGY

The objective of the overall Environmental Control Technology Program is to assure that the environmental control capability for each ERDA energy technology is complete, practical, cost effective, and available in a timely manner as the energy source is developed. Program activities are oriented to identifying control technology status and needs for emerging energy systems, then developing methods and equipment for meeting these needs.

PNL's effort in this program is growing rapidly. During 1976 we conducted studies in support of both nonnuclear and nuclear technologies, with programs in oil shale, coal, energy materials transport and nuclear fuel cycle analysis. In the following pages we report on progress achieved during 1976 on these projects:

- Environmental Control Technology Treatment of Oil Shale
- Assessment of Environmental Control Technologies for Commercial Coal Gasification
- Transportation Safety Studies
- Transportation Problems . 1976-2000
- A Safety and Economic Study of Special Trains
- Development of High-Level Waste Shipping Cask Models
- Analysis of Nuclear Fuel Cycles
- Toxic Materials in the Nuclear Fuel Cycle
- Decontamination and Decommissioning of Retired Contaminated ERDA Facilities at Hanford

- Bullets indicate 189 titles.

• ENVIRONMENTAL CONTROL TECHNOLOGY TREATMENT OF OIL SHALE

Large-scale production of pipeline quality shale oil may involve the management of substantial quantities of water and wastewater. Little or no wastewater discharges are anticipated from ex situ retorting facilities since the process waters will be used for moisturizing spent shale. With in situ retorting, wastewater is generated by the pyrolysis process in volumes approximately equal to the amount of oil produced. The retort water contains substantial quantities of both inorganic and organic substances and poses a particularly difficult treatment problem. The objectives of this program are to review each of the major shale oil recovery processes, identify the associated wastewater characteristics and volumes, and evaluate the treatment and disposal alternatives for these waters.

Analysis, Screening, and Evaluation of Control Technology for Wastewater Generated in Shale Oil Development B. W. Mercer

Pollution of the limited water resources of the Colorado Basin by inadequately treated oil shale process water discharges is one of the primary problems facing the oil shale industry. This problem may not be significant in the early stages of commercialization if ex situ retorting is used, since process wastewater from this approach is generally consumed in moisturization of the spent shale. However, in situ retorting methods are being developed rapidly because they have the following advantages: mining operations are simpler, there is no need for large-scale production facilities, and the spent shale presents fewer disposal problems. One of the primary environmental disadvantages of in situ retorting is that it produces considerable quantities of process wastewater, which is not needed for moisturizing and compacting spent shale. This wastewater must be treated and disposed in an environmentally sound manner.

At the present time there is no systematic body of information on the characteristics of shale oil process wastewaters or the technology for treatment and disposal. Significant efforts in this field are beginning, but it will be some time before specialized techniques will be available for treatment and disposal of this waste. Very little has been reported on the application of conventional or advanced waste treatment technology to retort wastewater. For example, steam stripping, biological treatment, chemical coagulation, air flotation, sedimentation, filtration, and carbon adsorption--processes used for treatment of oil refinery wastewaters--have not been evaluated on an integrated pilot plant scale for oil shale process waters.

A review of the literature on shale oil recovery processes and associated wastewater treatment and disposal alternatives concluded the following:

- The lack of information on the treatment of oil shale processing wastewaters is probably due to the expectation that

discharges of wastewater from above ground or ex situ retorting and upgrading facilities will be extremely minimal or nonexistent. The Tosco II process wastewater, for example, will be used to moisturize spent shale to facilitate compacting and sealing of the spent shale dumps.

- In situ retorting facilities are expected to generate retort wastewater that cannot be fully utilized at the facility; this wastewater represents a difficult disposal problem. In situ retort wastewater is generated in volume approximately equivalent to the amount of oil produced. Therefore, a 50,000 bbl/day facility will generate about 2 MGD of retort wastewater.
- Oil shale retort wastewater contains considerable organic matter, ammonia, bicarbonate/carbonate alkalinity, and dissolved mineral salts. Discharge to unpolluted receiving waters without extensive treatment would not be permitted. Analysis of wastewaters from a 10 ton NTU-type simulated in situ retort revealed that the predominant chemical species in these wastewaters were ammonium and bicarbonate ions, which ranged from 6200 to 18,200 mg/l and 10,000 to 42,000 mg/l, respectively. Other dissolved matter, such as mineral salts, was on the order of several thousand mg/l. Organic carbon concentrations ranged from 2800 to 10,000 mg/l.
- Waste treatment technology developed for petroleum refinery wastewater would appear to be applicable in many instances to the treatment of oil shale retort wastewater. For example, American Petroleum Institute gravity separators could be used for removal of suspended oil and solids that either float or sink in the separator. Air flotation could potentially be employed for removing suspended matter that neither floats nor sinks in reasonable time periods.
- Other processes developed for oil refinery waste include biological treatment, filtration, and activated carbon sorption. Biological treatment is widely used in the petroleum refinery industry and filtration and activated carbon treatment are coming into wider use for upgrading the quality of the wastewater discharges.
- The high and varied organic content of the retort wastewater may cause problems in biological treatment. There is some evidence that toxic materials exist in this waste that may cause interference

with biological processes. Pretreatment and acclimation of the biota may be needed before biological treatment can be used.

- Chemical treatment for coagulation of suspended matter and precipitation of specific pollutants may be a powerful tool in an integrated treatment scheme. Lime treatment, for example, could both coagulate suspended matter and precipitate organic substances such as long-chain fatty acids. Calcining the lime sludge (largely calcium carbonate) would eliminate much of the sludge disposal problem and recover the lime for reuse. Excess combustible retort gases could keep the cost of calcining the sludge at a low level. Energy costs of calcining would also be minimized if substantial organic wastes were carried down with the sludge.
- Reverse osmosis would be the recommended desalination method after the organic and ammonium carbonate removal steps. Brine disposal from reverse osmosis treatment may be a problem unless solar evaporation or deep well injection can be used.
- Limited treatment to remove suspended matter and perhaps some specific organic substances to render the wastewater suitable for deep well injection into a saline aquifer is an alternate approach.
- Treatment of the wastewater for removal of ammonia represents a potential approach to recovering some of the cost of treatment, since the ammonia is a valuable commodity in the fertilizer market. Steam stripping is the recommended process for removal of ammonia and much of the bicarbonate and carbonates.

Although a number of studies on specific areas of retort wastewater treatment are being conducted by other contractors, no evaluation of a complete treatment system is presently under way. Such an evaluation is needed to properly assess the demonstrated wastewater treatment technology and to fully appraise the impact of the shale oil industry, especially in situ extraction, on the region involved.

• **ASSESSMENT OF ENVIRONMENTAL CONTROL TECHNOLOGIES
FOR COMMERCIAL COAL GASIFICATION, EXCLUDING LURGI**

Status of environmental control technologies used in commercial coal gasification systems employing Winkler and Koppers-Totzek (KT) gasifiers is being determined. Manufacturers of these gasifiers have been contacted to request data on commercial systems. A literature search to obtain published data was completed and areas where insufficient information is available have been determined.

Status of Environmental Control Technologies
Used in Commercial Coal Gasification Systems
L. K. Mudge and G. F. Schiefelbein

Data on material and energy flows in commercial plants that use either Winkler or Koppers-Totzek gasifiers to generate synthesis gas were sought by contacting manufacturers of these gasifiers and by searching the literature. The objectives of the study were: 1) to determine if environment control technologies in commercial use are adequate relative to existing and proposed standards, 2) to identify areas where improved control technologies are needed, and 3) to rank research and development programs in terms of their potential benefit.

Letters explaining our program and requesting data on their systems were sent to representatives of Koppers Company, Inc. and Davy Power Gas, Inc., suppliers of KT and Winkler gasifiers, respectively. No data on Winkler gasification systems are available, according to representatives of Davy Power Gas.

Discussions were held with Koppers, Inc. and Krupp-Koppers GmbH, the German manufacturer of KT gasifiers, in Pittsburgh on July 22, 1976. Availability of the requested data and methods of obtaining the data were explored during the visit. Koppers agreed to request operating data

from plants in Europe, Africa, and Asia and forward any information obtained to PNL. Koppers suggested that additional information might be obtained by analyzing process streams from operating plants, if the plants gave permission to do so. Such on-site testing is beyond the scope of this investigation, however.

A literature review revealed that studies by Exxon^(1,2) on evaluation of pollution control in fossil fuel conversion processes are the main sources of published information. Designs for Winkler and KT gasifiers presented in the Exxon studies were used to prepare material and energy balances for production of synthesis gas. Further information is desirable in the areas of coal storage and preparation, acid gas removal (sulfur control), process water treatment, and fate of trace elements. These problems are common to many fossil fuel conversion processes.

To date, the review has not revealed any serious obstacle to use of these environmental control technologies in coal gasification plants. More precise information needed to assess the adequacy of these technologies could be developed in demonstration programs. Many operating plants in foreign countries are not faced with restrictions on environmental releases, as U.S. operations would be. They do not, therefore, employ the control technologies

that are available. Considerable additional data could be obtained from sampling streams at operating plants.

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2. C. E. Jahning, "Evaluation of Pollution Control in Fossil Fuel Conversion Processes, Gasification: Section 8: Winkler Process." EPA-650/2-74-009j, PB-249 846, National Technical Information Service, Springfield, VA 22151, September 1975.

• TRANSPORTATION SAFETY STUDIES

To plan and regulate the transport of potentially hazardous energy materials in the best public interest, the safety aspects of this activity must be understood. Research programs are one method for improving this understanding. Since 1972, PNL has conducted a Transportation Safety Studies Project for the Transportation Branch, ERDA Division of Environmental Control Technology. The initial objective of this program was to develop and use a model to assess the risk associated with shipment of radioactive materials. During FY-1976, the scope of the program was expanded to include transport of nonnuclear energy-related materials.

Risk analysis was chosen for assessing the safety of transporting these materials. In this technique, the severity and frequency of events related to postulated releases of energy materials are examined to put the consequences of the releases into perspective. During FY-1976, three energy material transportation systems were studied and associated risks were assessed. These systems were: (1) shipment of plutonium oxide and liquid plutonium nitrate by train; (2) shipment of plutonium oxide by cargo aircraft; and (3) tank truck shipment of gasoline. Studies of chlorine shipments, uranium hexafluoride shipments, and the loss of spent fuel and plutonium shipping packages at sea were initiated. In addition, a number of papers were presented at technical conferences.

Safety Aspects of Transporting Potentially Hazardous Energy Materials

R. J. Hall, R. E. Rhoads, J. F. Johnson,
T. I. McSweeney, S. W. Heaberlin

Work was conducted on six transportation safety studies during FY-1976 and the transition quarter: 1) the risk of shipping plutonium oxide powder and liquid plutonium nitrate by train; 2) the risk of shipping plutonium oxide by cargo aircraft; 3) the risk of shipping gasoline by truck; 4) the risk of shipping chlorine by train; 5) the risk of shipping uranium hexafluoride by truck and train; and 6) the consequences

of the loss of spent fuel and plutonium packages at sea.

For the studies of shipping plutonium by rail, plutonium by aircraft and gasoline by truck, risks were estimated on the basis of quantities of these materials projected for transportation in the 1980s. Reference shipping systems were described, fault trees were developed to identify release sequences, release consequences models were initiated, accident environments were described and package failure thresholds were estimated. A brief summary of each analysis follows.

An Assessment of the Risk of Transporting
Plutonium Oxide and Liquid Plutonium
Nitrate by Train
R. J. Hall

This analysis followed directly from a previous study of the risks involved in shipping the two forms of plutonium by truck.⁽¹⁾ To provide a direct comparison between the train and truck transportation modes for plutonium, the methodology, analysis techniques and assumed shipping requirements used in the truck risk analysis were also used in the train risk assessment.

The preliminary results of the study showed that the risk of shipping plutonium in the liquid nitrate form is about the same for both transport modes. However, the risk involved in shipping plutonium oxide by train was found to be lower than the risk of truck shipment. Figure 1 shows risk spectra for both studies.

FIGURE 1. Risk Spectra for Transportation Safety Studies Carried Out During FY-1976 (Plutonium by Train, Plutonium by Cargo Aircraft, Gasoline by Truck) Based on 1980 Projected Shipping Levels

An Assessment of the Risk of Shipping
Plutonium Oxide by Cargo Aircraft
T. I. McSweeney and J. F. Johnson

This study used the risk analysis methodology and analysis techniques established for the initial truck shipment risk assessment. The same shipping requirements, amounts, containers, etc., were used to provide a direct comparison of the results of these three studies. Only plutonium in the oxide form was analyzed in the aircraft study, however.

The results showed that the risk involved in shipping plutonium in the oxide form on cargo aircraft is higher than for either of the two previously studied transport modes. This risk spectrum is also shown in Figure 1.

An Assessment of the Risk of Transporting
Gasoline by Truck
R. E. Rhoads

This was the first study involving a nonnuclear energy source. Shipping requirements were based on projected needs in the 1980s. The general risk assessment methodology used in the plutonium transportation studies was also used in this analysis, but a new consequence model was developed for use in determining the risk. The study was conducted to allow comparisons to be made with the earlier studies described above. The results are presented in Figure 1.

Consequences of the Loss of Spent Fuel
and Plutonium Shipping Packages at Sea
S. W. Heaberlin

An initial study of the consequences of the loss of LWR spent fuel and plutonium shipping packages at sea was initiated during this fiscal year. The ocean environment and its potential effects on the packages were studied, loss scenarios were postulated and radiological effects of releases in the ocean environment were considered.

Radioisotope Customer List
J. L. Simmons

The purpose of this program is to prepare and distribute the annual document entitled List of Radioisotope Customers with Summary of Radioisotope Shipments. This document lists the FY-1975 commercial radioisotope production and distribution activities of ERDA facilities at Argonne National Laboratory, Pacific Northwest Laboratory, Brookhaven National Laboratory, Idaho Operations Office, Los Alamos Scientific Laboratory, Mound Laboratory, Oak Ridge National Laboratory, Savannah River Plant and United Nuclear Industries, Inc.

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• TRANSPORTATION PROBLEMS, 1976-2000

This study is being carried out to provide the basic information required to assure a more orderly approach to solving problems in nuclear fuel cycle material transportation. To accomplish this, the program is examining future (1976-2000) transportation systems and trends and identifying potential problems associated with transportation of fuel cycle materials.

Transportation Problems, 1976-2000 R. J. Hall and W. V. Loscutoff

During FY-1976 and the transition quarter work was done on three major phases of the Transportation Problems program:

- Characterization of the current transportation system for nuclear fuel cycle materials and projection of transportation requirements through the year 2000.
- Identification of trends, events or changes outside the nuclear industry that could affect the transportation of fuel cycle materials.
- Identification of events, trends or changes internal to the nuclear industry that could significantly affect the transportation of nuclear fuel cycle materials.

Accomplishments in each of these areas are summarized below.

A description of the current transportation system for radioactive nuclear fuel cycle materials was prepared. The following information is included in the description: maps showing locations of current and planned reactors and fuel cycle facilities; an overview of federal regulations pertaining to transportation of radioactive materials; the form and general characteristics

of the materials shipped; a description of the packaging and other special equipment used to transport the material; and a base-case projection of the amount of material shipped, number of shipments and total shipping miles for the years 1976, 1990 and 2000. Information on the costs of shipping fuel cycle materials was also collected.

A workshop entitled "Nuclear Material Transportation, 1976-2000" was held to identify events, trends and changes outside the nuclear industry that could affect transportation of fuel cycle materials. Participants in the workshop included representatives of the trucking and railroad industries, staff from the Senate Commerce Committee, a security consultant, a transportation planning consultant, and staff from Battelle-Columbus and Pacific Northwest Laboratories. Potential problems in five broad categories were identified and the workshop participants were asked to rank the potential problems in each category by likelihood and significance. The five categories of problems included: (1) institutional, societal and political; (2) economic; (3) technological; (4) management and operational; and (5) legal and regulatory. The issues raised at the workshop are currently being studied to determine their relative importance, evaluate interdependencies and identify and analyze items with multicategory effects.

Possible events, trends and changes internal to the nuclear industry which could affect nuclear fuel cycle material transportation have been described in a series of scenarios. These include industry growth rate, fuel cycle alternatives, siting, safeguards, government regulations and alternative transportation modes. The impact of implementing each alternative scenario was measured by a sensitivity analysis in terms of the required number of shipments, necessary material volumes, and required new technologies.

• A SAFETY AND ECONOMIC STUDY OF SPECIAL TRAINS

The objective of the study was to analyze the relative safety and economics of shipping spent fuel by conventional freight trains and spent fuel special trains. A railroad network that would transport approximately 2250 metric tons of spent fuel in 1986 was identified as the transportation model for the shipment of spent fuel. The safety record of freight train service was analyzed to determine the potential effect on accident frequency and severity if special trains are used. Finally, the primary cost factors in these shipments--tariffs, special train charges, and cask use charges--were used to establish comparative costs of regular and special train service. Results indicate that special trains have a limited potential to improve safety during spent fuel shipments but at substantial additional cost to the shipper.

Safety and Economic Analyses of Rail Systems for Shipping Spent Fuel Assemblies

W. V. Loscutoff, R. J. Hall, E. S. Murphy, L. L. Clark

The railroad industry has expressed concern that additional measures are necessary to assure safe transport of spent fuel assemblies from reactor sites. The Board of Directors of the Association of American Railroads has recommended a set of operating practices intended to provide a greater degree of control of the transportation environment for the shipment of spent fuel. The operating practices would require use of special trains for spent fuel shipments with the additional restrictions that 1) no other freight be carried in a spent fuel special train, 2) the special train speed be limited to 35 mph, and 3) when the special train meets or passes another train, one must be stopped.

The objective of this study was to examine the reduction in frequency and severity of accidents resulting from the proposed restrictions and to compare the

economics of transporting spent fuel in special trains and in conventional freight trains. Program activity was divided into three major work areas:

- characterization of rail transportation system and shipments
- safety analysis of special trains and conventional freight trains
- economic analysis of special trains and conventional freight trains.

Characterization of the rail system and shipments was completed early in FY-1976. The safety and economic analyses were initiated during FY-1976 and completed during the transition quarter. A draft of the final report is scheduled for completion in January 1977.

To minimize uncertainties in the analyses, a railroad network was established for the study and nuclear power plants, reprocessing plants, and railroad systems that could be involved in the shipment of spent fuel

between these sites in 1986 were identified. Sixty three origin-destination pairs were identified and it was estimated that 2250 metric tons of spent fuel would be shipped by rail in 1986.

Freight train accident data for Class I line-haul railroads were analyzed to determine the potential effect of proposed special train restrictions on frequency and severity of train accidents. Accident data obtained from the Federal Railroad Administration for the period 1972-1974 included 17,153 accidents and 1,389,000,000 train miles.

To determine the effect of the 35 mph speed restriction, accident data were examined to determine the relationship between accident frequency and the speed at which the accidents occurred. The data showed that about 81% of all regular freight train accidents occur at speeds below 35 mph. To examine the effect of the 35 mph speed limit on accident severity, accidents with railroad equipment damage exceeding \$75,000 were studied. About 3% of regular freight train accidents that occur at speeds below 35 mph result in damages exceeding \$75,000, while about 4% of the accidents that occur above 35 mph produce damage in excess of \$75,000. Although the \$75,000 damage limit is a somewhat arbitrary measure of accident severity, the 35 mph speed restriction for spent fuel special trains appears to produce a small improvement in safety.

The expected effect of the passing restriction was investigated by examining collision accidents for Class I line-haul railroads. Data indicated that about 93% of all collision accidents occur at speeds below 35 mph. It was estimated that about 4% of collision accidents occurring at speeds below 35 mph will produce more than \$75,000 damage, while about 2% of collisions above 35 mph will produce more than \$75,000 damage. The no-passing restriction appears to have a small potential for improving train safety.

To evaluate the effect of the no-other-freight requirement, accident data on rail transport of hazardous materials were examined. Fire is the primary means by which a spent fuel shipment could be affected by other hazardous materials on the same train. Data indicate that the frequency of occurrence of fire in the vicinity of a spent fuel cask is approximately one event per 400 to 2000 yr. However, this includes fires which do not affect a spent fuel cask. Other factors exist which tend to lessen the effect of the no-other-freight

restriction. Thus, the overall effect of the restriction appears to be limited.

To analyze the economic impact of the special train requirement, the cost of shipping spent fuel by special trains was compared to the cost by conventional freight train service. Variables included in the analysis were (1) rail freight tariffs, (2) special train charges, (3) cask use charges, (4) roundtrip travel time, (5) terminal time for each at reactor and reprocessing plant, (6) frequency of cask car pickup and delivery, (7) cask utilization, and (8) cask capacity. Results of the analysis show that the special train requirement will probably increase spent fuel shipping costs by an average of about 50%. Sensitivity analysis of the above factors shows a range of variability in costs from a decrease of 20% to an increase of 300%. The most likely average shipping costs have been estimated at \$23.50/kg of uranium for special train shipments and \$15.50/kg of uranium for conventional freight train shipments.

• DEVELOPMENT OF HIGH-LEVEL WASTE SHIPPING CASK MODELS

The objective of this program was to conceptually design a high-level waste shipping cask and to fabricate scale models with supplemental graphical information for display. A conceptual cask design for rail shipment was developed based on a reference high-level waste canister and reference high-level waste physical characteristics. The conceptual design is similar in weight and configuration to large rail casks currently licensed to transport spent fuel. Two 1/10th scale models were completed and two HO-gauge (1:87) models of the cask/rail car system were fabricated. Graphic displays to accompany the models were also developed.

Conceptual Design and Fabrication of a Scale Model High-Level Waste Shipping Cask P. L. Peterson

The advent of commercial facilities to reprocess nuclear fuel will necessitate an associated capability to transport solidified high-level waste safely and economically between reprocessing plants and storage facilities. Casks do not presently exist that are licensed or specifically designed for transporting solidified high-level waste. The objective of this program was to design a high-level waste shipping cask and fabricate scale models with supplemental graphical information to use when displaying the models.

The conceptual cask design shown in Figures 1 and 2 was derived by first selecting a reference high-level waste canister and reference high-level waste physical characteristics. Probable design constraints were established based on these characteristics. Design constraints of particular importance included provision for handling at origin and destination, shielding and heat dissipation requirements and degree of protection required from the accident environment. Requirements or regulations for transporting radioactive

materials were then matched to the design constraints initially identified. The inherently large shielding requirements favored transportation by railroad because the ratio of shielding weight to payload decreases significantly with cask size. The conceptual high-level waste cask design developed is similar in weight and configuration to the largest casks presently licensed to transport irradiated fuel.

During FY-1976 and the transition quarter, two 1/10th scale models of the conceptual cask were completed (Figure 3). Two HO-gauge (1:87 scale) models of the cask/rail car system were also fabricated. Placards and supplemental handout information were prepared to accompany and explain the models while on exhibit (Figure 4).

FIGURE 1. Conceptual Design of High-Level Waste Shipping Cask

FIGURE 2. Model of High-Level Waste Cask on Rail Car

FIGURE 3. Cutaway of Model High-Level Waste Cask

HIGH-LEVEL SOLID RADIOACTIVE WASTE SHIPPING CASK AND RAIL CAR*

This 1/10th scale model is representative of shipping casks that will transport high-level solid waste from nuclear fuel reprocessing plants to waste storage facilities. The high-level waste contains radioactive fission products removed during reprocessing of irradiated reactor fuel. The quantity of high-level waste carried by the cask will be about that resulting from one year's operation of a typical modern power reactor. It is also roughly equivalent to the high-level waste resulting from one year's electrical generation by nuclear power for about a half million people.

SHIPPING CASK PARAMETERS:

• LENGTH OF CASK (NOT INCLUDING FINS)	4 METERS (13.2 FEET)	• CASK WEIGHT	100 METRIC TONS (220,000 POUNDS)
• OUTSIDE DIAMETER OF CASK (NOT INCLUDING FINS)	2 METERS (6.8 FEET)	• MAXIMUM INTERNAL HEAT LOAD	48 KILOWATTS (ABOUT THE HEAT OUTPUT OF A LARGE HOME FURNACE)
• DIAMETER OF INNER CAVITY	1.5 METERS (5 FEET)	• CAPACITY	9 CANISTERS, EACH 3 METERS (10 FEET) LONG AND 30 cm (1 FOOT) DIAMETER
		• TOTAL WEIGHT OF CANISTERS	7.5 METRIC TONS (17,000 POUNDS)

*CONCEPTUAL DESIGN PREPARED BY BATTELLE, PACIFIC NORTHWEST LABORATORIES FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION.

FIGURE 4. Placard Prepared to Accompany Models on Exhibit

• ANALYSIS OF NUCLEAR FUEL CYCLES

The operation of nuclear fuel cycle facilities will introduce noxious materials, both radiological and chemical, into the environment through routine discharges of both liquid and airborne effluents. The environmental control implications of continuing to develop existing nuclear fuel cycles and implementing new fuel cycles must be systematically determined so technologies that control or eliminate the discharge of noxious materials can be developed and demonstrated in a timely manner.

The objective of this program is to identify areas in developing nuclear fuel cycles where inadequate consideration is being given to environmental controls, where inconsistencies and conflicts exist in environmental policy, and where environmental control improvements can be justified on a cost/risk/benefit basis.

Analysis of LWR and LMFBF Fuel Cycles

T. J. Kabele, C. M. Heeb, K. J. Schneider,
E. C. Watson, J. R. Young

The objective of this program is to provide the Environmental Control Technology Division of ERDA with technical and economic bases for planning and analyzing research and development programs on the treatment and control of radiologically and chemically toxic effluents and wastes generated in nuclear fuel cycles. The information developed will provide the perspective required to determine whether environmental control technologies are adequate relative to existing and proposed standards; to assess the potential benefits of various research and development programs; and to establish adequate backup options for high-risk development programs.

The program was initiated in January 1976. It was organized into four major task areas:

1. Fuel Cycle Computer Model - A computer code is being developed to model the

entire light water reactor (LWR) fuel cycle, from mine to reprocessing plant. The code handles fuel logistics and heat and mass balances for each nuclear facility, and includes capital and operating cost information.

2. Facility Description - Each nuclear fuel cycle facility is described, including heat and mass balances, process flow diagrams, identification of major equipment, and details of all effluent control and waste processing technology.
3. Environmental Analysis - A generic site description is being prepared for use in analyzing the environmental impacts of nuclear fuel cycle effluents. The impacts of both radioactive and nonradioactive effluents on the environment are being evaluated in this task.

4. Cost Analysis - Operating and capital costs for each nuclear fuel cycle facility are provided by this task. Cost information will be used to evaluate the cost/benefits of effluent control technology options.

Progress on these tasks through the FY-1976 transition quarter has been substantial. The computer code development is on schedule and is expected to be completed early in FY-1977. Reference facilities for the LWR fuel cycle (Figure 1) were chosen, and detailed facility descriptions were well on their way to completion at the end of the transition quarter. In addition to the facilities shown in Figure 1, several liquid metal fast breeder reactor (LMFBR) fuel cycle facility descriptions were also initiated during the transition period. These included a reactor and fuel fabrication and reprocessing plants for oxide, nitride, and carbide LMFBR fuels.

The environmental and cost analysis tasks naturally follow the computer and facility description tasks. However, some parallel work was possible and progress on these tasks included the generic site description, a document describing methodology for evaluating impacts of radioactive effluents (BNWL-2075), and work preliminary to placement of a contract with

Bechtel Corporation for estimating facility capital costs.

The completion of the LWR and LMFBR fuel cycle analyses will provide Division of Environmental Control Technology with a basis for:

- formulating a cost-effective environmental control technology improvement program well suited to the realities of the nuclear power generation economy
- characterizing the burden on the environmental control technology of the various nuclear fuel cycle options now known to confront the nuclear industry
- defining, on a continuing basis, the current condition of the nuclear industry with regard to environmental factors
- projecting current conditions into the immediate future on a rapid turnaround basis to gauge the effect of presently unforeseen changes in the nuclear economy.

Future work will extend the tools developed for the LWR and LMFBR analyses to the thorium fuel cycles (LWR breeder, gas cooled reactors) and to fusion systems. Applications to analyses of nonnuclear fuel cycles will also be considered.

FIGURE 1. Steps in the Nuclear Fuel Cycle

• TOXIC MATERIALS IN THE NUCLEAR FUEL CYCLE

The long-term objective of this program is to characterize toxic materials present in the nuclear fuel cycle and to provide quantitative projections of the controlled accumulation and routine release of these materials. Detailed characterization of the amounts and the chemical, physical and radiological properties of toxic effluents is required to give guidance to biomedical and environmental research and development programs. Quantities and characteristics of pollutants associated with existing and future nuclear energy systems will form a basis for guiding these research programs and help to assure that source terms used are consistent with ERDA's expectations of the growth of nuclear power.

This program was initiated in FY-1975. The principal effort has been directed to characterizing toxic effluents from the light water reactor (LWR) UO_2 fuel cycle.

Toxic Effluents from the UO_2 Fuel Cycle

W. A. Muckerheide, R. M. Fleischman,
R. C. Liikala

The implementation of nuclear energy systems poses potentially serious questions about the ecological and health effects of possible accumulations of toxic materials from routine effluent and other releases. To measure the effects of pollutants released to the environment, data must be collected over long time periods. Therefore potential sources of toxic materials in the growing nuclear industry should be identified as early as possible to guide these experimental programs.

This program was terminated at the end of FY-1976. As a result, the scope of the task was restricted to the most viable short-term nuclear option, i.e., the light water reactor UO_2 fuel cycle. Within that restriction, the characterization of toxic effluents and their release rates was emphasized.

The effort to characterize toxic effluents involved multidisciplinary expertise from several PNL departments. For each fuel cycle component (i.e., mining through reprocessing) toxic effluents were identified and characterized by radiological, chemical and physical properties. The rate of effluent release for each fuel cycle component was determined on the basis of available information.

As a result of this effort, six reports are being written:

- Toxic Effluents from Uranium Mining
- Toxic Effluents from Uranium Milling
- Toxic Effluents from Uranium Fuel Fabrication
- Toxic Effluents from UO_2 -Fueled Light Water Reactors

- Toxic Effluents from Light Water Reactor UO₂ Fuel Reprocessing
- Toxic Effluents from the Light Water Reactor UO₂ Fuel Cycle - A Summary Report.

The results in all of these reports have a common basis, that the LWR fuel requirement is the driving function for the fuel cycle. For each of the effluents, the dilution index for air and water was calculated based on maximum permissible concentration values, the units being liters (l) of water per MTU and cubic meters (m³) of air per MTU. This consistent methodology permits direct comparison of results among the five reports. A general comparison is given in the summary report. Time and funds permitted only a cursory analysis of the fuel cycle components for U₃O₈ to UF₆ conversion and uranium enrichment so these are included in the summary report only.

The information and technical approach developed in this effort is being used in a comprehensive program for the Division of Environmental Control Technology that emphasizes the cost-benefit picture related to improved effluent control in the nuclear fuel cycle.

• DECONTAMINATION AND DECOMMISSIONING OF RETIRED CONTAMINATED ERDA FACILITIES AT HANFORD

On the Hanford Reservation are many manufacturing and laboratory facilities (e.g., plutonium production reactors, chemical processing plants) that have become contaminated with radionuclides during their operation. The Reservation also has many waste disposal facilities (burial grounds, cribs, etc.) in which large quantities of transuranics and fission products have been deposited. With the evolution of production requirements and manufacturing technology and practices, many of these sites and facilities have been retired from use and must be decommissioned.

Since 1974, PNL has been engaged in 1) developing an overall plan, including procedures, costs, safety analysis and priorities, for decommissioning retired facilities at Hanford; 2) providing the detailed planning for a demonstration project; and 3) performing supporting research and development. Effort to date has included identification of alternative decommissioning modes and procedures, preparation of cost estimates, development of methodology for establishing priorities, definition of residual contamination criteria, and performance of a variety of related research and development (R&D) projects.

Fission Product Migration Beneath 200 Area Cribs

B. W. Mercer and S. W. Ahlstrom

An important consideration in evaluating the potential offsite hazard from the presence of fission products and transuranics in subsurface soils of the Hanford Reservation's 200 Area plateau is the extent to which these materials might migrate if the surrounding media were inundated by groundwater. During FY-1976 a modeling study was initiated to estimate the extent of such an effect on migration of strontium-90 and plutonium sorbed on the soil beneath cribs in 200 West Area, an event that could potentially occur if a dam were installed at mile point 348 on the

Columbia River and the water table in the crib area rose 2 m.

Assuming the rising water table would inundate 1800 m³ of contaminated soil with an average ⁹⁰Sr concentration of 2000 pCi/g and assuming a steady-state flow of ground water at a velocity of 0.3 m/day, the initial calculations show that the 10 pCi/g isopleth for ⁹⁰Sr would travel no farther than about 100 m from the crib site. After 140 yr, the combined effects of radioactive decay and dispersion would be such that none of the water-saturated soil beneath and downstream of these cribs would contain a concentration of ⁹⁰Sr greater than 10 pCi/g.

Radiological Studies

D. A. Waite and W. D. McCormack

A technique⁽¹⁾ for deriving radiological criteria governing the release and use of decommissioned nuclear facilities was applied to a number of retired contaminated Hanford facilities: a reactor retention basin system; the Redox Plant plutonium concentration building; and reference liquid waste disposal sites (cribs and ponds) in the 200 Areas. The results of the study have provided proposed maximum radionuclide concentration levels for the following four use restriction categories:

- Restricted use - the facility or site is to be limited to nuclear use only, with access allowed only under conditions normal to nuclear sites.
- Controlled use with surveillance - use of the site is to be limited, according to the nature of the facility; continuing surveillance is required.
- Controlled use without surveillance - use of the site is to be limited, by laws or regulations, to appropriate activities.
- Unrestricted use - the site may be unconditionally released for access and use by the public.

For each site, including reference sites on the Hanford Reservation, the use restriction depends principally on the mix of radionuclides present and on amounts being released. Tentative criteria for releasing the study sites for unrestricted use are shown in Table 1.

One of the steps in developing the radiological criteria is the calculation of "worst case" radiological dose evaluations, based on atmospheric release of the entire inventory over a one-year period, and (where appropriate) aquatic release over a period of 24 hr or one year as determined by the largest resulting dose. These dose calculations yield a one-year dose and a 50-yr dose commitment for a hypothetical individual assumed to reside continuously at the closest maximum exposure location offsite.

Typical results of such calculations are shown in Tables 2-4.

Decommissioning Alternatives

H. T. Fullam, K. M. Harmon, J. C. King, B. W. Mercer

In work done during FY-1976 on this subtask of the Hanford D&D Studies, four alternatives for decommissioning contaminated facilities at Hanford were defined:

- Layaway - The facility or site is preserved essentially in its current state as a temporary measure.
- Protective Storage - The facility is prepared to be left in place safely for an extended period (which might range from decades to centuries).
- Entombment - The facility is prepared to be left in place safely, with a long-lasting barrier surrounding all contaminated materials and with no intent to allow for their subsequent retrieval.

TABLE 1. Inventory of Selected Nuclides, Curies (12/73)

No.	Facility Type	Inventory of Selected Nuclides, Curies (12/73)					R.E.	Criteria for Unrestricted Use
		TRU	⁹⁰ Sr	¹³⁷ Cs	⁶⁰ Co	U, kg		
216-S-17	Pond for low-level effluents	1.3	24	19	---	140		$1.6\alpha + \beta\gamma = 16 \text{ p Ci/g}$
216-Z-12	Crib for Pu Wastes	1.8×10^4	0.08	0.08	0.03	---		$15\alpha + \beta\gamma = 146 \text{ p Ci/g}$
216-S-1,2	Crib for Pu & FP wastes	334	1930	1290	280	---		$\alpha + \beta\gamma = 10 \text{ p Ci/g}$
216-B-30	Crib for FP wastes	1.5	400	2300	0.2	88		$\alpha + \beta\gamma = 11.4 \text{ p Ci/g}$
216-A-1	Crib for low level wastes	0.05	0.06	0.07	0.01	150		$2\alpha + \beta\gamma = 19 \text{ p Ci/g}$
107-DR	Reactor Retention Basin	.132	.75	7.5	11	---	50	$4\alpha + \beta\gamma = 45 \text{ p Ci/g}$
233-S	Plutonium Concentration Building	only TRU assumed						70 p Ci/g

* α = alpha emitters, p Ci/g

$\beta\gamma$ = beta/gamma emitters, p Ci/g

TABLE 2. Radionuclide Inventories (Estimated) Used as Basis for "Worst Case" Radiological Dose Calculations

Estimated Radionuclide Inventory Ci	107-DR (Retention Basin - 100 D Area)	216-S1 & 2 (Crib - 200 W Area)
^{60}Co	11.4	276
^{90}Sr	0.747	1932
^{90}Y	--	1932
^{125}Sb	--	46
^{137}Cs	7.51	1288
^{152}Eu	38.8	--
^{154}Eu	10.5	--
^{155}Eu	0.532	--
^{238}Pu	0.00489	--
^{239}Pu	0.127	70
^{240}Pu	--	14
^{241}Pu	--	250
^{241}Am	--	0.24

TABLE 3. 107-DR Retention Basin "Worst Case" Doses

	Liquid Release		
	1-Year Dose	50-Year Dose Commitment	Critical Organ
<u>24-Hr Release</u>			
Maximum Individual	4×10^{-1} mrem	8×10^{-1} mrem	Bone
<u>1-Year Release</u>			
Maximum Individual	6×10^{-2} mrem	10^{-1} mrem	Bone
Population	4×10^{-1} person-rem	2 person-rem	Bone
	Airborne Release		
	1-Year Release		
Maximum Individual	34 mrem	380 mrem	Lung, Bone
Population	0.7 person-rem		Bone
8-Hr Exposure	160 mrem		

TABLE 4. Crib 216-S1 & 2 "Worst Case" Dose, Airborne Release

	1-Year Dose	50-Year Dose Commitment	Critical Organ
<u>24-Hr Release</u>			
Maximum Individual	1.7×10^2 mrem	3.9×10^3 mrem	Bone
	6.6×10^1 mrem	8.4×10^2 mrem	Total Body
	1.0×10^2 mrem		GI-LLI
Population		5.2×10^1	Lung
	0.01 person-rem	0.51 person-rem	Total Body
<u>1-Year Release</u>			
Maximum Individual	1.6×10^1 mrem	1.0×10^3 mrem	Bone
	5.3 mrem	9.6×10^1 mrem	Total Body
	8.4 mrem		GI-LLI
Population		9.6×10^1 mrem	Liver
	2.5×10^1 mrem		Lung
8-Hr Exposure		7.2×10^1 mrem	Kidney
	160 mrem		

- Decontamination or Dismantling - As a minimum, all radioactive components and materials which exceed the criteria for unrestricted release are removed from the site.

Conceptual procedures were also outlined for each alternative.

Systems Studies

J. C. King, J. W. Litchfield, C. L. McDonald, S. E. Schulte

A computer model has been developed for setting priorities for decommissioning the various retired facilities at Hanford. The output of the model provides priority listings that indicate the relative urgency for undertaking some type of D&D action with each facility. A facility's relative position on the list depends on a partially subjective evaluation of the ranking of that facility, in its present condition, by four independent factors:

- potential for causing an offsite radiological hazard
- potential for becoming a hazard to persons onsite
- cost of maintenance and surveillance in its present condition
- compatibility of the facility, in its present status, with projected use of the environs.

Relative importance weights for the four criteria were established by representatives of ERDA and the major contractors at Hanford using a DELPHI approach. The importance weights are to be coupled with an appropriate index for each facility to establish relative decommissioning priorities. Importance weights, as derived in two separate trials, are shown in Table 5. Preliminary application of the model gives high priority to the retired Hanford production reactors and to certain waste disposal sites along the Columbia River.

TABLE 5. Importance Weights for D&D Criteria

Criterion	Trial 1	Trial 2
Potential Offsite Hazard	40	39
Potential Onsite Hazard	32	33
Cost of Continued Maintenance of the Facility in the As-Is Condition	14	15
Compatibility of the Facility, As-Is, with Potential Future Use of the Site	14	13

Preparation of Plans to Dismantle
233-S Building

C. H. Allen, D. E. Blahnik, J. R. Carrell,
P. L. Koehmstedt, R. E. Smith^(a)

The Redox Plutonium Concentration Building in the 200 West Area of the Hanford Reservation was selected for a D&D demonstration program. During FY-1976 activity specifications were prepared by PNL and approved by PNL and Atlantic Richfield Hanford Company, and preparation of detailed plans was started by ARHCO.

Concrete Decontamination Studies

C. H. Allen, S. Mandel, R. G. Sullivan

The development of improved techniques to remove contaminated surface layers from concrete walls and floors has been identified as a D&D need. Two techniques are under investigation at PNL:

- the use of a "water cannon" which fires a small, high velocity jet of glycerine and causes spallation of a shallow, roughly conical section from the surface; and
- a concrete scarfer based on a rock splitter concept.

The water cannon device uses a standard rifle mechanism and barrel, modified to produce a small-diameter jet. The rifle is loaded with a blank cartridge and a glycerine suppository-type pellet and is fired with the end of the muzzle close to the target surface. Factory tests showed the concept to be feasible and a prototype based on a .458 magnum was purchased and tested. In factory tests, the glycerine jet from the prototype produced a spalled area of about 5 in. X 4 in. X 0.9 in. deep at the apex. In tests of the prototype at PNL, problems developed with the firing mechanism, which will have to be reworked before testing can continue.

Investigation of the commercially available rock splitter revealed that it is not usable for the removal of surface layers of concrete. A new experimental tool based on the rock-splitter principle, termed a "concrete scarfer," was therefore designed and tested.

In this method, a pattern of holes is drilled into the concrete and the scarfing tool is inserted into each hole in turn. Operation of the tool causes the concrete to fracture from the surface in a roughly circular pattern around the drilled hole.

^(a)Atlantic Richfield Hanford Company

The scarfer was tested on aged concrete which had originally served as a foundation for a building. The holes were laid out in two types of patterns: 1) square patterns with center-to-center hole distances of 4 in., 5 in., 6 in., 7 in., and 8 in. and 2) equilateral triangle patterns with hole spacings of 5 in. and 6 in. In these tests:

- the average spall area had approximately a 6 in. diameter;
- with a square pattern and a 4-in. hole spacing, all of the concrete surface was cleaned away; with the holes on 5-in. centers, some of the concrete surface was left undisturbed;
- with a triangular pattern and the holes on 5-in. centers, approximately 95% of the surface concrete was removed.

Figure 1 shows the results obtained with a square pattern and the holes on 4-in. centers. Figure 2 shows the results obtained with a triangular hole spacing pattern and the holes on 5-in. centers.

Bio-Barrier for Contaminated Soils

J. F. Cline, E. L. Klepper, W. H. Rickard

This program was established to test and demonstrate techniques for preventing penetration of contaminated subsurface zones, such as cribs and burial grounds, by plant roots and animals.

A 7-ft deep test trench was dug and contaminated on the bottom surface with a lithium salt. The floor of the trench was covered with a test "bio-barrier," successive layers of boulders, gravel, sand and topsoil. Then the trench surface was planted with cheat grass. The cheat grass was blown out by high winds, so in February 1976 the site was replanted to Russian thistle. The site was also fenced.

On September 2, 1976, 100 mCi of ¹³¹I was placed in the soil below the cobble. The ¹³¹I was added as 10% of aqueous iodine solution through plastic drip-irrigation tubes installed during construction of the trench.

Some plant analyses were performed in October. Results showed that one large Russian thistle bush contained small amounts of ¹³¹I (0.8 nCi ¹³¹I/g tissue), indicating that the plant's roots had penetrated the cobble-and-soil barrier. Russian thistle and bursage plants were also collected at the end of August for lithium analysis, but this analysis had not been completed at the end of the transition quarter.

FIGURE 1. Test Wall for Rock Splitter, Showing Results Obtained with Square Pattern

FIGURE 2. Test Wall for Rock Splitter, Showing Results Obtained with Triangular Hole Spacing Pattern

TECHNOLOGY OVERVIEW

The Integrated Assessment Program, funded by the ERDA Division of Technology Overview, is the mechanism by which health, environmental, social, economic and institutional factors are combined into a form useful for energy planning and decision making. This program selectively combines information about effects of alternative energy technologies (such as waste releases, land and water use, and social effects) to produce broad-based assessments of the advantages and disadvantages of energy and conservation options. As a corollary, needs for further research, development, and technology transfer are identified.

The program is focused on four interrelated activities: 1) supporting systems analysis, to develop and improve methods for use in assessing and comparing impacts of energy and conservation options; 2) integrated technological impact assessment, applying these methods to help ERDA select technologies for development that are safe, clean, and environmentally acceptable; 3) regional comparative assessments, applying the results of the technological impact assessments to identification of regional energy strategies; and 4) a regional outreach effort to assist regional and state agencies in their energy planning programs.

Pacific Northwest Laboratory carries out these activities for the Pacific Northwest Region. As lead laboratory for oil, gas and oil shale technologies, PNL is responsible for the primary analyses of these energy resources and for directing other national laboratories in analyzing specific regional problems. In the following pages we report on progress made in 1976 in these areas:

- Pacific Northwest Energy-Related Regional Studies
- Development of Methodology for the Assessment of Social Values
- Social Impact Methods
- Statistical and Environmental Considerations and Methodologies
- Population Radiation Exposure
- Evaluation of Radionuclides in Man

• PACIFIC NORTHWEST ENERGY-RELATED REGIONAL STUDIES

The objective of the Regional Assessment Program is to assess the impacts of various energy development scenarios on the Pacific Northwest. The theoretical model to assess socioeconomic impacts has been developed. Although more simple and site-specific than anticipated, tools are now available to assess impacts of energy developments on land and water use. A logic has been developed to estimate average annual consumptive water demands of coal-related facilities and their support communities. A regional scale transport, transformation, and removal model for air quality impacts was applied to a coal-related energy development scenario. A dynamic simulation model has been developed to forecast the electrical supply system and demographic characteristics of the Pacific Northwest. Work has also begun on a model for localized impacts and nonelectric energy forecasts.

Overview

J. B. Burnham

The objective of the Pacific Northwest Laboratory (PNL) Regional Assessment Program is to assess the impacts of various energy development scenarios on the Pacific Northwest. Similar work is under way at five other ERDA laboratories. With these analyses regional and national planners can construct comprehensive plans for long-term energy development. When performed in this manner, the national plans will represent an aggregate of regional plans. As such, they will have a high degree of credibility.

Our efforts on this program were concentrated in four major work areas:

- Coal Utilization Assessment
- Oil and Gas Utilization Assessment
- Regional Liaison
- Subcontracts in the Region.

The assessment of the environmental and socioeconomic impacts of various coal utilization technologies has accounted for the major portion of the PNL budget. Many of the analytical tools developed for this assessment will be directly applicable to other assessments. Although Argonne National Laboratory has been charged with overall management responsibilities for this program, we have attended planning and working group sessions and been active in the Program Managers, Socioeconomic, Air Quality, and Health Effects committees.

At the request of the Division of Technology Overview, PNL is scoping plans for an Oil and Gas and Oil Shale Utilization Assessment program paralleling the National Coal Utilization Assessment effort. The program plan is being prepared recognizing the relative maturity of the industry and its technologies and the extent of ERDA's involvement.

A large number of contacts were made with state and local offices, federal

offices, and utilities in the Region. For example, agencies contacted in the State of Alaska include:

Alaska Public Utilities Commission

Division of Minerals and Energy Management

Department of Revenue

Department of Commerce and Economic Development

Department of Environmental Conservation

Alaska Pipeline Commission

Alaska State Department of Natural Resources

El Paso Alaska Company

Northwest Pipeline Corp.

Arctic Environmental Information and Data Center

Alaskan Arctic Gas Pipeline Co.

University of Alaska

Division of Energy and Power Development.

We have kept ERDA's Richland Operations Office apprised of our efforts to ensure that all contacts in the Region are coordinated.

A subcontract with Dr. Robert Wensink at Oregon State University, Corvallis, is entitled "Impact of Technology, Cropping Patterns and Capital Investment on Irrigation Energy Requirements in the Pacific Northwest." The objectives of this research are to assess current and future regional energy, water, and labor requirements in agricultural production and to determine the relative tradeoffs between these inputs.

We have made available to the City of Richland a version of the planning model which has been developed for the Regional Assessment Program. They will use this model on a portable minicomputer to analyze their options for developing a new section of the City.

As a consequence of the energy system knowledge developed under the Regional Assessment Program, PNL has been asked by the State of Alaska to assess the economic development opportunities arising from the utilization of natural gas and natural gas liquids within the state.

A more detailed description of the program efforts for the various sectors is given below.

Socioeconomic Sector

M. E. Olsen and M. G. Curry

The objectives of the work relative to the socioeconomic sector of the Regional Assessment Program are to:

- Develop a methodology for conducting social impact assessments using quality of social life indicators.
- Complete the study of citizen involvement in energy decision making begun in FY-1975.
- Identify and describe the major federal statutes affecting energy development that are addressed to planners and officials.
- Develop a program plan for assessing the social impacts and impact management techniques associated with coal development in the Powder River region of Wyoming and Montana.
- Identify issues around which public acceptance in energy decision making has centered and the methods used to voice public acceptance in this area.

The impact assessment methodology was approximately three-quarters completed during these 15 months, including development of the underlying theoretical model, a list of relevant indicators, data sources for these indicators, and an instrument for obtaining weightings of preferred values for the indicators. A preliminary description of the methodology has been distributed.⁽¹⁾

With this data, we performed statistical analyses on techniques of citizen involvement in nuclear decision making gathered through a survey of Washington State residents in May 1975.

Literature pertaining to energy development was surveyed with specific emphasis on federal legislation relevant to non-legal planners and public officials involved in energy policy formation. The findings were reported in The Influence of Selected Federal Statutes on Energy Development,⁽²⁾ which discusses major areas of federal policy that influence energy development decisions and also includes an annotated bibliography of relevant statutes.

Previous social impact and other studies of the Powder River region were utilized to develop a detailed program plan for performing social impact assessments in that region.⁽³⁾

Literature concerning the role of public acceptance in energy policy making was surveyed briefly, including both case studies and attitude surveys. The analysis focused on the nature and extent of public acceptance in energy decision making and the relationship between public actions and these issues.

Land Use Sector

M. L. Warner and S. J. Shupe

The primary objective of the Land and Water Sector during FY-1976 was to develop a "first generation" of tools for assessing the impacts of energy developments on land and water use. These tools were to be operational in simplified form by the end of the fiscal year and to provide a solid basis for tool refinement in subsequent years. This objective was partially met during the fiscal year; assessment tools were developed but in some cases these were more simple and site-specific than we had hoped, and only enough data were collected to apply them to one subregion of the Northwest. A six-county area of potential extensive coal development in eastern Montana and Wyoming was selected as the geographical focus of the year's activities.

A generalized logic for estimating acreage shifts in land usage was developed incorporating both direct land requirements of new energy facilities and secondary land requirements of new or expanded support communities. This logic permits us to estimate the number of acres converted to energy production or urban use from other broad land use categories such as agriculture or grazing.

Two other potentially useful tools for land use analysis were briefly examined: CORAS, a computer program potentially useful to identify facility sites using mapable land characteristics and subjective site preferences, and LANDSAT imagery, useful as a means of producing generalized land use maps and acreage estimates. Though both tools showed promise, neither was examined in depth as part of the Regional Assessment Program because their development was being supported by other research programs with other objectives.

Water Use Sector

M. L. Warner and S. J. Shupe

A logic, similar to that developed for land use, was developed to estimate average annual consumptive water demands of coal-related facilities and their support communities. The HYD-2 model, developed by the Bureau of Reclamation, was obtained for estimating the availability of surface waters for energy development. The model uses readily available hydrologic data and data on present diversions to assess the availability of water to meet hypothesized energy needs under each of several alternative reservoir system configurations. Testing of the model's uses and limitations was begun during FY-1976. As a result of further testing during the current fiscal year, we have concluded that the model's outputs under complex multireservoir systems were invalid in some respects. A simpler configuration was used, however, to test the impact of various instream flow requirements on the availability of water for new energy developments. Results of this work will be published during FY-1977.

Air Quality Sector

D. S. Renne and D. L. Elliott

The objective of the air quality sector is to assess the impact on air quality and the deposition of pollutants on the terrestrial environment caused by alternative energy development scenarios in the Pacific Northwest. During FY-1976 we applied a regional scale transport, transformation and removal model to a near-term probable coal-related energy development scenario. In this model application, we assumed that generating facilities will emit pollutants at a rate equivalent to the New Source Performance Standards for coal-fired power plants. This effort resulted in a report which showed regional ground level air concentrations and surface deposition patterns for this scenario.⁽⁴⁾ An example of this output is shown for SO₂ concentrations in Figure 1.

This type of effort will continue during FY-1977 with further application of the regional model to different coal-related scenarios in the West, as a component of the National Coal Utilization Assessment, and to energy development scenarios in the Northwest as part of PNL's regional assessment of coal usage. In addition, we will be applying different types of air quality diffusion models to various

FIGURE 1. Annual Average Ground-Level Air Concentrations of SO_2 from Existing and Proposed Coal-Fired Power Plants in the Northwest Using New Source Performance Standards and a Regional Scale Transport, Transformation and Removal Model

development scenarios to assess the "close-in" impacts of alternative developments. These modeling efforts will continue to provide information on the potential effects of regulatory constraints on energy development. They will also provide information to other sectors of the Regional Assessment Program, such as the ecosystems effort, for an integrated assessment of alternative energy development scenarios.

During the spring of 1976, PNL hosted a workshop on air quality and meteorological assessment. This workshop permitted inter-laboratory dialogue on the kinds of models that can be applied to assessments such as these and on the way laboratories can combine resources to improve the quality and efficiency of the environmental assessment process. This meeting paved the way for additional interaction by the workshop participants in subsequent meetings of the Air Quality Working Group of the Coal Utilization Assessment. Such interactions will continue at an increasing level of technicality during FY-1977. A report on the workshop was issued.⁽⁵⁾

Terrestrial Ecology Sector R. H. Sauer and W. H. Rickard

The objectives of Terrestrial Ecology's efforts in the Regional Assessment Program were:

1. Estimate agricultural production (crops) from regional weather data
2. Determine importance of SO_2 on crop production
3. Determine the effect of coal utilization on wildlife in the Powder River Basin.

Progress toward the first objective was hampered by inadequate data, but rough estimates have been prepared. Progress toward the second objective has been good, and it appears that in arid regions atmospheric SO_2 concentrations will be high enough to decrease production only in the immediate vicinity of coal combustion facilities. Progress toward the third objective has been stalled by slow response to our request for data from Montana on hunter harvest.

Economic Modeling Sector D. W. Fraley, T. P. Harrington, J. J. Jacobsen

The economic modeling sector is to provide the Regional Assessment Program the information necessary to assess performance. Contributions during FY-1976 were (1) model development for the generic characterization of the Region, and (2) the provision of tools and methodologies to address localized assessment. Activities have included:

- Conceptualization of a structure for the conduct of regional assessments
- Model development for the analysis of electricity supply and demographic evolution in the Northwest
- Model development for the analysis of local environmental and social impacts of coal development in the West
- Data collection and characterization of the environmental pollutants and economic costs associated with energy development
- Coordination of information and communications with other participants in the conduct of the program.

At the onset of FY-1976, a formal structure was conceptualized for an analytical assessment program to evaluate changes that may result from various energy development or conservation scenarios. Incorporating dynamic simulation techniques, we structured the project in a framework comprised of a number of sectors, including energy, economics, and demography. These sectors are linked conceptually in the provision of information for assessments within other sectors. As indicated in the 1975 Annual Report, the role of modeling activity has been to provide information in the form of forecasts relative to given scenarios.⁽⁶⁾

In support of the objectives, the earliest activity has been development of the dynamic simulation model ELSA (Electric Power Supply Analysis Model) to forecast the characteristics of the electrical supply system of the Pacific Northwest over the long term.⁽⁷⁾ The system's behavior is based upon given estimates of future demands (scenario inputs) and contains exogenous policy and energy cost assumptions specific to the Region. ELSA simulates the behavior of electric power development, capturing the effects of demands, basic energy prices, and public policy in the Region. ELSA is an adaptation of a series of nationally aggregated models developed by Andrew Ford at Dartmouth College⁽⁸⁾ but has been modified for regional application to accommodate the specific characteristics of the Northwest.

ELSA is currently being used to provide forecasts of electrical generation capacity and mixes of generation types. In addition, the model provides estimates of environmental residuals which result from power generation. Current development includes linking of regional electrical power demand models in a closed loop

fashion so that load growth rates (demands) will not need exogenous specification.

The Region's population characteristics are forecast via a dynamic simulation incorporating the interactions among population, birth rate, death rate, net migration rate, and jobs available in the region from 1960 to 2020. The population is disaggregated so that age-specific birth and death rates, propensity to migrate, and labor force participation rates may be evaluated independently. The output of the demographic model provides consistent population histories and forecasts and includes births, deaths, migration for various age groups and labor force participants, as well as households and unemployment. The model is utilized in conjunction with various scenario characterizations in support assessments.⁽⁹⁾

A local impact model which is a dynamic regional coal development model of the Eastern Powder River Basin of Wyoming has also been developed.⁽¹⁰⁾ The Powder River Model can be utilized to test alternative development schedules for the Region's coal production. Included among the alternatives are different mixes of export capacity, different mixes of coal conversion techniques within the Region, as well as various levels of coal production. The model has been utilized to simulate several alternative development schedules from a recent environmental impact statement submitted to the Department of the Interior.

In support of model development and simulation, large amounts of data and a number of data bases were collected and reviewed. In the process, regional and national contacts were established. The ELSA model was presented to the Pacific Northwest River Basin Commission, and the staff of the Bonneville Power Administration has provided technical assistance.

Two national energy data bases have been acquired by PNL in support of these activities. The Brookhaven National Laboratory Energy Model Data Base is being used to provide environmental pollutants related to energy development.⁽¹¹⁾ A portion of the data has been incorporated in the ELSA simulation to provide forecasts of environmental effects. The Bechtel Energy Supply Planning Model has been used to implement the PNL system, which was then employed to provide construction and manpower estimates for the program.⁽¹²⁾

PNL has contacted other researchers in the Regional Assessment Program to exchange information and to participate in working group assignments. Preliminary characterization of coal utilization scenarios has motivated the preparation of supporting information for the regional assessments.

Activity during the transition period included, in addition to the demand model linkage to ELSA, preliminary work on a model for localized impacts and nonelectrical energy forecasts for the Pacific Northwest. The Local Impact Management and Assessment (LIMA) model will provide an integrating framework for local impact research at PNL, and will incorporate modeling of social impact indicators developed by this program.⁽¹⁾ Regional nonelectric energy forecasts are expected to be based upon a regional adaptation of a national model developed by Kent P. Anderson at the Rand Corporation.⁽¹³⁾ Preliminary results based on regional data are currently being evaluated.

Data Base Compilation Sector G. L. Wilfert

The objective of data base compilation is to put into perspective for purposes of regional assessment and model validation the energy supply, transmission/transportation, and consumption patterns in the Region over recent history, and to identify energy resources, energy facilities, and commercial plans for the future.

Over two hundred pages of energy data were compiled to provide collected regional energy data to various team members of the Regional Assessment Program.⁽¹⁴⁾ We expect to update this compilation as new data become available.

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• DEVELOPMENT OF METHODOLOGY FOR THE ASSESSMENT OF SOCIAL VALUES

A methodology is being developed to facilitate selection of favorable thermal power plant site and design alternatives from the community perspective. A two-stage multiattributed decision technique is being employed to combine technical assessment of plant effects with corresponding community values, using eight judgment criteria. Judgment criteria include aesthetics, economics, water quality, land use, air quality, ecological effects, cultural and recreational opportunities, and human health and safety. The first stage involves use of multiple-attribute submodels to assess plant effects on each of the judgment criteria. In the second stage, each of the eight assessments of the impact are weighted by the corresponding community values, then summed to obtain an index of overall plant effect.

Assessment of Social Values in Thermal Power Plant Siting

J. B. Burnham, J. C. King, J. A. Hébert

The objective of this research is to develop and test a methodology for incorporating social values of the affected community early in the power plant siting and design process. A multiattributed decision technique is used which combines technical estimates of plant effects in eight areas of potential impact (judgment criteria) with measures of public values in these same areas. Auxiliary methodologies are provided for obtaining community values from representative citizens. Submodels are provided for assessment of plant effects on each of the judgment criteria.

Work completed at the beginning of FY-1976 included conceptual development of the general methodology; identification of a method of combination; development and initial testing of the survey instrument for identification of community values; and development of a submodel for quantitative assessment of aesthetic effects of plant

construction and operation. A method of quantifying land use effects had also been initially investigated.

Effort in FY-1976 focussed on the development of submodels for quantifying assessment of plant impact for three of the remaining six judgment criteria. Criteria selected for quantification included air quality, water quality, and plant and animal life.

Impact Assessment Submodels. The general form of each of the impact assessment submodels is a multiattributed decision technique, similar to the overall assessment model. For each submodel, environmental qualities potentially affected by power plant construction or operation are selected as judgment criteria. Systems of scaling, weighting and combination are devised to provide an index of environmental quality relative to the scope of the submodel (i.e., water quality, air quality, or plant and animal life), when measured or predicted levels of the judgment criteria are entered. The ratio of

change, S_j , in environmental quality attributable to a site or design alternative is based on the expression:

$$S_j = \frac{EQ_j - EQ_i}{EQ_i}$$

EQ_i represents the pre-plant (initial) level of environmental quality, as determined from measured baseline values of the judgment criteria. EQ_j represents the level of environmental quality, with site or design alternative "j," as determined from predicted values of the judgment criteria under conditions of plant operation. The ratio of environmental change attributable to different site and design options can be compared for individual submodels (water quality, air quality, etc.) or can be incorporated into the overall assessment model to obtain a composite index of impact.

- Parameters of water pollution selected to assess the effect of power plant alternatives on water quality include chlorine, copper, total dissolved solids, and total suspended solids. Nonlinear scaling functions are used to transform measured levels of each of these four pollutants into scales of value. Scaling functions are based on the biological effects of the pollutants over the anticipated range of concentration in receiving water. Relative weights are applied to the four pollutant-specific scales of value to convert the four into a common metric of environmental value. The scaled and weighted pollutant concentrations are summed to obtain an index of water quality (EQ_w). Measured preplant levels of water quality and predicted with-plant levels of water quality can be combined as described above to obtain a ratio of change on water quality attributable to plant construction.

A final report on the assessment of water quality effects will include a discussion of potential power plant effects on water quality, a description of the assessment methodology, and procedures for implementing the assessment system.

- The system for assessment of air quality effects of power plant construction and operation will utilize two subindices which are weighted and combined to give an overall index of air quality effects. The Maximum Air Quality Sub-Index (MAI) is a measure of the change in maximum ground level pollution, and the Regional

Air Quality Sub-Index (RAI) is a measure of change in regional atmospheric quality. Judgment criteria used for both indices include SO_x , NO_x , suspended particulates, photochemical oxidants and SO_x -Particulate synergism.

Methods are being identified for predicting effects of power plant construction and operation on each of these pollutants. Measured levels (for the pre-plant condition) and predicted levels (for the with-plant condition) will be scaled, weighted and combined using multiattributed decision techniques to give the MAI and RAI. The MAI and RAI will be weighted and combined to provide a single ratio of change in air quality.

Final reports on the MAI and RAI will contain a discussion of thermal power plant effects on air quality, a description of the assessment methodology and procedures for implementing the assessment methodology.

- The system for quantified assessment of thermal power plant effects on plant and animal life includes separate subindices for aquatic and terrestrial ecosystems. Judgment criteria include community successional value, community commonness, diversity, effect on important ecological relationships, and significance of affected species. Methods are being identified for assessing power plant effects on each of these criteria for both terrestrial and aquatic ecosystems. Assessed effects will be weighted, scaled and combined using a multiattributed decision technique. Resulting subindices for aquatic and for terrestrial ecosystems will then be combined to produce an overall index of power plant impact on plant and animal life.

The final report on the system for assessing power plant effects on plant and animal life will include a discussion of power plant effects on plant and animal life, a description of the assessment methodology, and recommended procedures for implementation of the methodology.

Assessment of Social Values. Less emphasis was placed on the social values assessment tasks in FY-1976. Items completed this past fiscal year include:

- The results of the preliminary testing of the social values survey instrument were evaluated. Methods of identifying representative citizens tested at San Clemente included an organizational

approach and a reputational approach.

The organizational approach involves the identification of organizations or groups of citizens with interests relative to energy production. Members of these organizations are asked to nominate leaders on energy and environmental issues in the community. The reputational approach involves random sampling of citizens for identification of community leaders in environmental and energy affairs. Of the two approaches, the organizational approach appears to be a superior method for identifying community representatives who are knowledgeable in energy and environmental affairs.

- The survey instrument has been revised, enhancing its suitability for fossil fuel applications, in accordance with the broadened scope of this project. Modest pretesting of the modified survey instrument is anticipated in the second quarter of CY-1977.

We also maintained contact with the Electric Power Research Institute (EPRI) via telephone discussions and meetings. Active EPRI support is sought for testing the completed methodology in conjunction with an actual power plant siting proposal.

Funds from this project were used by Battelle to jointly sponsor a conference entitled, Assessing Impacts of Local Land Use Development in Oregon, on June 5, 1976. Cosponsors were Oregon Chapter of the American Society of Landscape Architects and University of Oregon Department of Geography.

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• SOCIAL IMPACT METHODS

A two-unit nuclear power plant site in Skagit County is being used to evaluate social impact assessment methodology. Baseline information about the host community and surrounding environs has been collected, and a model of the health care delivery capability has been developed.

Social Impact Assessment Methodology: Pacific Northwest Plants C. R. Schuller

There are three principal questions to be answered by this project: 1) How is it possible to project, assess and evaluate the impact of the development of large-scale energy facilities on host communities and surrounding regions? 2) What strategies can be evolved to mitigate undesirable social impacts on both the host community and on the surrounding regions? 3) How is it possible to forecast accurately those social impacts from those most likely to occur at a given site?

A comprehensible topology of social and economic impacts has been developed. The major categories are:

- 1) Local economic impacts
- 2) Impacts on public services
- 3) Impacts on health care systems
- 4) Land use changes
- 5) Demographic/sociological effects
- 6) Psychological impacts on local population
- 7) Impacts on aesthetics and recreation.

Work on a site-specific case study began during the late spring of 1976. The site selected for study was in Skagit County, Washington, where a two-unit nuclear power plant site was in the final stages of preconstruction licensing and certification. The principal accomplishments to this point have been the collection of baseline information about the host community and the surrounding environs which can be used as the basis for projecting the impact of large population influx. Additionally, a detailed model of health care delivery capability has been developed. Principal features of this include population, health facilities, and the interrelationships between population and current facilities.

During the study, the research staff gathered baseline information on the host community and surrounding region before any changes occur due to an influx of construction workers. Also, liaison has been effected with the county planning group in charge of coping with any social and economic impacts which may occur during plant construction. Similar liaisons have also been established with the utility. A legal agreement has been made between the county and the utility to provide assistance to prevent undesirable social and economic impacts from disrupting the area during construction of the plant.

At this stage of the research project only preliminary results are available. One final Nuclear Regulatory Commission hearing must be completed before a limited work authorization is issued and construction of the plant begun. Thus no actual impacts have yet been observed. As noted, a contract zoning agreement has been made between the power company and the county which provides for amelioration payments to cover the costs of extra public services. Negotiations for specific payments begin in January 1977. It is expected that members of the research team will take part in these discussions and offer observations as pertinent.

A second major portion of the research project is a retrospective analysis of a number of western energy sites to develop a more systematic set of procedures for assessing social impacts before they occur. This task is well under way. Sites in California, Oregon and Arizona have been examined by members of the research team.

• STATISTICAL AND ENVIRONMENTAL CONSIDERATIONS AND METHODOLOGIES

The general problem of concern is that of assessing health effects of chronic low-level exposures to environmental contaminants. The primary task for this year has been an analysis of the Hanford mortality data, with particular emphasis on occupational exposure to ionizing radiation. A proportional mortality analysis has been completed and a full population-based analysis is well under way. The data base is being expanded to include J. A. Jones construction workers. Statistical and epidemiological literature on relevant topics has been reviewed and the findings summarized in a paper. Finally, our work has included critical evaluation of other studies - in particular, an analysis of the Hanford data carried out by Drs. Mancuso, Stewart and Kneale.

Statistical Health Effect Studies to Assess the Influence of Low-Level Exposures to Environmental Contaminants E. S. Gilbert

The purpose of this program is to develop and evaluate methods for assessing health effects of chronic low-level exposures to environmental contaminants, particularly ionizing radiation. A major part of our effort this year has been analysis of Hanford mortality data. Our work has also included methodological research (in statistics and epidemiology) and critical evaluation of other studies concerning risks from chronic exposures.

Our first task in FY-1976 was preparation of the Hanford data for computer analysis. This included extracting the needed information from the files provided us, some editing, and coding the occupational data. It also included adapting a program developed by Dr. Richard Monson⁽¹⁾ at Harvard. The program utilizes cause-age-time-sex-race-specific U.S. mortality rates to determine the expected number of deaths in a study group.

Early in 1976, proportional mortality of 3333 white male deaths occurring between 1949 and 1971 was analyzed. This analysis included a comparison of the Hanford experience with U.S. vital statistics and utilized dosimetry and occupational data. A draft report describing this analysis has been written. A previous analysis of a subset consisting of 841 local deaths had suggested a correlation of total external radiation dose with the proportion of deaths due to cancer. This correlation appears to have resulted from the restriction of the study to local deaths and is not found in the analysis of the full set of 3333 deaths.

A population-based analysis is in progress. Unlike the proportional analysis described above, a population analysis relates deaths to the population at risk and thus avoids certain problems of interpretation.^(a) The population analysis has

(a) A difficulty with proportional analysis is that a deficiency of deaths from certain causes will increase the proportion of deaths from other causes.

revealed that mortality for Hanford workers is substantially lower than that of the general population for nearly all causes of death. The analysis is currently being expanded to include deaths occurring through March of 1974 and to utilize the available dosimetry data. A paper describing this analysis should be near completion by the end of 1976.

Early in 1976 we decided to expand our data base to include J. A. Jones construction workers. Efforts are under way to obtain the necessary occupational and dosimetry data for these employees. Since mortality data is established for ERDA by the Social Security Administration and states are contacted for death certificates, it will probably be at least a year or two before the J. A. Jones workers can be included in the analysis.

Statistical and epidemiological literature on relevant topics has been reviewed and some procedures adapted for our purposes. In particular, Cox's conditional model for survival analysis with concomitant variables,⁽²⁾ Mantel-Haenszel type procedures⁽³⁾ and classical epidemiological procedures have been explored. These procedures and suggestions for their use with chronic low-level exposures (such as radiation) are described in a paper presented at the ERDA Statistical Symposium.⁽⁴⁾ Some of the methods are being used in the current population analysis. Dr. Norman Breslow, University of Washington, who has had considerable experience with both survival analysis and occupational mortality, is serving as a consultant to aid in developing and utilizing the best statistical methods.

A final task of our program has been to provide critical evaluation of other studies. In October 1976, Drs. Thomas Mancuso, Alice Stewart, and George Kneale presented a paper on the Hanford data at a Health Physics meeting in Saratoga Springs, NY⁽⁵⁾ in which they claimed that a causal relationship exists between radiation and certain cancers. A critique of their analysis was prepared by Dr. Sidney Marks and Ethel Gilbert and was presented at the meeting by Dr. Marks.⁽⁶⁾ These comments will appear in the proceedings for the meeting and have been made available to the independent committee that has been established by ERDA to review the Mancuso et al. paper.

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• POPULATION RADIATION EXPOSURE

The objective of this program is to evaluate the potential radiation dose that will accrue to the population as a result of artificial heart use. A comprehensive report on this subject (the Population Radiation Exposure study) was published in 1976. To sharpen the forecasts in that report, a study has since been initiated to define more precisely the potential demand for artificial hearts. A panel of cardiologists and cardiac surgeons will define medical criteria for selecting artificial heart candidates. The criteria will be compared against a population of heart disease death cases to identify potential candidates. The proportion of potential artificial heart users from this group will be applied to the entire U.S. population to estimate the total potential demand for these devices.

Selecting Artificial Heart Candidates R. W. McKee, P. C. Owzarski, S. A. Rao

A major difficulty in evaluating the potential population radiation dose from artificial heart use is projecting the demand for artificial hearts or heart assist devices. Therefore a study was initiated last year to determine this demand more precisely. A retrospective study is being made of a large number of heart disease deaths. Using medical criteria established by a panel of cardiologists and cardiac surgeons, the proportion of potential artificial heart recipients in the study population will be determined from evaluations of their medical records and death certificates. The proportion of potential candidates from this sample will be applied to the annual heart death rate for the entire U.S. to provide the estimate of demand for artificial hearts.

The study plan calls for selection of a population adequate in size to be statistically satisfactory for predicting potential artificial heart use. Using computerized death certificate information, a

narrowed group will be selected and their medical records will be examined for eligibility as potential device recipients.

A set of criteria for selecting heart candidates will be developed by a panel of cardiologists and cardiac surgeons. A team of medical students will match the criteria against information in the records, and the panel will review the final selection of candidates.

Seattle/King County, Washington, has been selected as the population base. Five thousand heart disease deaths occurred in this area in 1975; these comprise the study population. Approval to examine the death certificates was obtained from the Department of Social and Health Services of Washington State. Two medical consultants, a cardiac epidemiologist and a cardiac surgeon, were engaged to help select the panel and guide the establishment of the medical criteria.

Most of the panel members have been selected. The panel includes the two consultants, 12 nationally prominent cardiac

surgeons and cardiologists, and a cardiac physiologist. They represent a wide geographical distribution and their expertise includes heart transplantation, assist devices, and cardiac epidemiology.

A computerized list of pertinent information from the 5000 death certificates was obtained from the Seattle/King County Department of Vital Statistics. From these, 1600 have been identified as a potentially eligible group. Death certificates that do not show obvious contraindications will form the population of hospital medical records to be examined in detail and compared with the panel criteria.

PUBLICATIONS

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• EVALUATION OF RADIONUCLIDES IN MAN

This project is concerned with the development and application of methods for evaluating the radiological impact of the nuclear industry on its workers and on residents in the environs. During the past year the project emphasized post-mortem studies in which the quantities of radionuclides, particularly plutonium, are measured in samples of tissues obtained at autopsy from former workers and residents in the local environs of the Hanford Reservation and from individuals at more distant locations. In addition, this project supported the work of the U.S. Transuranium Registry (USTR) by performing radiochemical analyses of samples obtained by the Registry from exposed workers and unexposed controls throughout the country. The development of an adequately sensitive and accurate technique for assessing the internal deposition of promethium oxide has also been an important part of this project. Recently, a program of wholebody counting measurements on local residents and control groups in the Hanford environs was initiated in order to assess the feasibility of quantifying the environmental impact of fission product waste management programs at Hanford with human data.

Evaluation of Postmortem Tissue Samples

I. C. Nelson, L. J. Kirby, V. W. Thomas, Jr., D. T. Harless, R. M. Bernard, F. N. Eichner

Collection and radiochemical analysis of post-mortem tissue samples (lung, liver, bone, and tracheobronchial lymph nodes) from individuals who had resided in the vicinity of the Hanford Reservation continued during FY-1976 and the transition quarter. During the year commencing November 1, 1975, 102 analyses for ^{238}Pu and $^{239,240}\text{Pu}$ were made on such tissue samples. In addition, 117 analyses were made for gamma emitters on these tissues. At present 18 samples are awaiting processing.

Postmortem tissue samples and blood samples were also analyzed for the U.S. Transuranium Registry. During the year 37 analyses for ^{238}Pu and $^{239,240}\text{Pu}$,

49 analyses for gamma emitters, and 88 analyses for uranium were performed. At present 22 samples are in process and 127 samples are in storage awaiting processing.

Development of capabilities for measuring amounts of ^{241}Am in USTR tissue samples continued. The laboratory now has access to a 500 mm² intrinsic germanium diode which may be used to analyze tissue by direct counting of low energy radiation. Calibration of the detector is in progress. In the absence of significant absorption of the low energy radiation in tissue samples (an effect which will have to be studied), a detection level of a few disintegrations per minute of ^{241}Am per sample for a 10 minute count is expected. Longer counting times would lower this limit. Reasonable counting times, in terms of needed sensitivity, will be explored.

At the request of the USTR, we are studying the feasibility of performing separate analyses for plutonium in human bone and bone marrow. Since first attempts to separate marrow by published techniques were unsuccessful, as demonstrated by tracer analysis, further development work will be required.

The program of interlaboratory calibration cross-check measurements continued. For the current series, 357 samples of bovine lung and liver were prepared, spiked with calibrated plutonium solutions and shipped to participating laboratories. Laboratories at the New York Health and Safety Laboratory, Los Alamos Scientific Laboratory, EPA's Southwestern Regional Laboratory, McClelland Air Force Laboratory, and PNL (2 laboratories) are participating in this series. At PNL, 15 samples each of lung and liver and a vial of standard solution have been analyzed for ^{238}Pu and $^{239,240}\text{Pu}$, and 20 bone samples are in process. These interlaboratory analyses are considered to be an extremely important adjunct to existing in-house quality assurance procedures.

In Vivo Studies

I. C. Nelson and G. W. R. Endres;
F. N. Eichner

The program of whole body counting measurements on local residents and control groups for use in assessing the feasibility of such measurements to quantify the environmental impact of waste management programs was terminated in FY-1977. During the year, 63 children from the Hanford Elementary School were counted on the Hanford Mobile Whole Body Counter. In addition, 84 children were counted at Benton City, Washington, and 57 at Othello, Washington. Neither Benton City nor Othello is on the Columbia River downstream from the Hanford Reservation. Benton City is south of the Reservation and Othello northeast of the Reservation, essentially on opposite sides of the Reservation in terms of prevailing winds. The data have not been analyzed. Based on the findings of a peer review of this program, it was concluded that this effort should not be supported by the Division of Biology and Environmental Research and the program was terminated.

Diagnostic Techniques

I. C. Nelson and D. B. Shipler;
F. N. Eichner and D. L. Haggard

The development of a technique for assessing the internal deposition of promethium oxide was terminated at the end of this year. Although previous experiments involving exposure of dogs to a samarium-promethium oxide aerosol revealed that the two elements were metabolized similarly, the amounts deposited in the lung were insufficient to permit adequate measurements of the radioactive tracer in urine. It was determined that another experiment to fix the level of lung deposition needed to produce measurable quantities in urine was necessary. Such an experiment would have formed the basis for determining the smallest amounts of tracer required to be deposited in lungs of human test subjects to produce measurable quantities in urine for periods up to 14 days. Based on the findings of a peer review of this program, it was concluded that the effort should not be supported by the Division of Biology and Environmental Research under this program and it was terminated.

OPERATIONAL SAFETY

The responsibility of the ERDA Division of Safety, Standards and Compliance is to assure that ERDA-controlled activities are conducted in a manner that will minimize risks to the public and employees and will provide protection for property and the environment. The program supports the various energy technologies by identifying and resolving safety problems; developing and issuing safety policies, standards, and criteria; assuring compliance with ERDA, federal, and state safety regulations; and establishing procedures for reporting and investigating accidents in ERDA operations.

The PNL Safety, Standards and Compliance Program contributes to these objectives through projects in the nuclear and nonnuclear areas. Nonnuclear R&D is assuming growing significance and in the future will comprise a major portion of the program. During 1976 the major emphasis was on developing criteria, instruments and methods to assure that radiation exposure to occupational personnel and to people in the environs of nuclear-related facilities is maintained at the lowest level technically and economically practicable. In the following pages, we report progress made in 1976 on:

- Guidelines for Radiation Exposure - ALAP
- Plutonium Dosimetry Studies
- Environmental Monitoring Handbook
- Emergency Instrumentation Preparedness

• GUIDELINES FOR RADIATION EXPOSURE - ALAP

A three-stage program was planned to help carry out a nuclear industry commitment that individuals shall be exposed to radiation doses that are "as low as practicable" (ALAP) technically and economically. For the first stage of the project, the ALAP efforts at ERDA-owned facilities were reviewed. A game plan to standardize and channel these efforts was suggested.

Technical Guidelines for Maintaining Occupational Exposure As Low As Practicable (ALAP)

J. M. Selby, P. E. Bramson, L. G. Faust,
W. T. Bartlett

The objective of this project is the preparation of a technical document that will provide the basis for assuring that radiation dose to ERDA, ERDA contractor and nuclear industry radiation workers is maintained at levels as low as practicable. ("Radiation dose" means the dose from sources either within or outside the body--also referred to simply as "exposure.") The need for such a document results from an industry commitment that not only shall worker and public exposures not exceed specified limits, but that "operations shall be conducted in a manner to assure that radiation dose to individuals and population groups is limited to the lowest levels technically and economically practicable."

Although interim guidance for meeting this commitment has been provided, an in-depth analysis must be conducted to look at recent radiation exposure trends, present radiation protection practices, production needs and alternatives for reducing exposure at contractor sites throughout the country. Based upon this analysis and other available information including

computer modeling, a document will be prepared with guidelines for assuring ALAP exposures for radiation workers. The document will be for use in on-going programs, and in particular for inclusion in the design stage of future programs.

The project as planned has three phases: 1) identification and characterization of activities at ERDA-owned facilities resulting in "reasonably avoidable" radiation exposure, 2) in-depth analyses of data and identification methods for exposure reduction, and 3) development of minimum ALAP performance criteria. The initial phase has involved reviews of facilities' exposure records, instrumentation, training, facility layout and design, and any relevant studies and discussions with health physics and operating personnel at the facilities.

ALAP interviews have been completed at 16 ERDA contractor sites. Information was collected on:

- management's ALAP philosophy and commitment
- ALAP program administration and documentation
- radiological engineering and design

- operational health physics
- personnel dose assessment.

The interview data has been received and catalogued in a generic outline which may serve as the outline for the ALAP guidelines document.

Several findings have surfaced from the data review thus far. First, documentation of ALAP efforts and results is lacking among ERDA contractors, perhaps because the ALAP programs are still in a developmental stage. Second, ERDA contractors have not seriously explored cost/benefit as an ALAP concept. ERDA guidance on an applicable cost/benefit ratio has been lacking. ERDA contractors are expecting such guidance and without it do not know when they have reached ALAP. Third, a game plan could be useful in providing uniform ALAP efforts. Such a plan might include:

- analysis of the contractors' radiation program and facilities, to identify strengths and weaknesses
- identification of areas requiring improvement
- development of cost data and estimates of the incremental or total exposure reduction involved in each proposed change
- determination of the cost/benefit ratio for the proposed actions, where possible
- decision on program priorities.

This approach, expected to take several years, would be similar to one used by many ERDA contractors in upgrading facilities and changing programs to meet Occupational Safety and Health Administration requirements.

• PLUTONIUM DOSIMETRY STUDIES

Personnel radiation exposure levels associated with the safe handling of plutonium in several forms have been determined by experiments as well as past personnel exposure and work records. Using these data as a basis, extrapolations were made to identify potential areas in the plutonium processing industry where excessive exposures could occur as a result of introducing higher specific activity plutonium. (Neutron exposures were emphasized since they may become the controlling factor.) These data have been incorporated into a guide of good practice for operation of a plutonium facility.

A Guide for Work and Design Practices for Plutonium Processing Facilities L. G. Faust

The increased emphasis on plutonium and its hazards and the general trend of reducing exposures to this radionuclide led to the decision to prepare a guide which details good work and design practices for plutonium processing facilities. The guide is intended to be a compilation of the most current data and knowledge about how to achieve the lowest practicable personnel exposure while maintaining a viable operation. Areas that received special attention were neutron yield measurements, extremity dose rates and shielding effectiveness measurements. These data are presented in numerous tables and graphs that design and planning personnel should find useful.

Necessary experimental work was completed early in FY-1976 and the data were analyzed for inclusion in the guide. A draft of the guide was then prepared and reviewed by selected contractor and ERDA personnel. The draft is being revised to incorporate suggestions made in the review. Additional experimental work remains to be done, since this program was necessarily restricted to

plutonium metal and plutonium oxide. It does not address other forms or compounds which may be encountered in the future, some of which may present formidable problems.

The studies revealed one item of particular importance: most extremity exposures result from hood glove contamination, rather than material processing. It was found that exposure rates could be reduced by as much as a factor of 10 by simply wiping the gloves. This makes it possible to reduce extremity dose rates to 30 rem/year. Another advantage afforded by clean gloves is the reduction of whole-body exposures, especially if operators keep unused gloves outside the glove box.

It was an original goal of this program to identify job classifications that involve the highest personnel exposure. It was found that this could be accomplished only in the broadest sense because of inadequate records, poor dosimetry and inconsistencies in job classifications. However, it was possible to identify one particular group of workers, those in non-destructive testing, as most likely to have significant exposure rates. This probably results from the large volume of work and

variety of radiation forms they encounter in this work.

This guide is oriented to the needs of facilities that process large quantities of plutonium (excluding reactors and reprocessing facilities). It is also directed to those responsible for operating, and perhaps designing, such a facility, although others may also find it useful.

• ENVIRONMENTAL MONITORING HANDBOOK

PNL's work on the Guide for Environmental Radiological Surveillance at ERDA Installations has been completed, and the Guide has now been published as ERDA-77-24. Comments and suggestions were received from ERDA field offices and contractors for inclusion in the Guide. A workshop for contractor representatives on data treatment, including statistical methods, was useful in delineating problem areas and capabilities. The Guide will include recommended general criteria for program design, including minimum levels of interest, as well as more specific recommendations on measurement methods, data treatment, and quality assurance. Inputs for the companion Effluent Monitoring Guide were obtained, but extensive editing remains to be done.

Handbooks of Recommended Practices for Environmental and Effluent Monitoring and Reporting

J. P. Corley, D. H. Denham^(a), D. G. Michels^(b), A. R. Olsen, D. A. Waite, B. V. Andersen, T. W. McClelland, L. C. Schwendiman, M. M. Orgill, G. B. Parker, A. J. Shuckrow^(c), J. A. McNeese

The objectives of this program are to provide:

- recommended standard methods and procedures to bring greater uniformity and comparability to ERDA contractor systems for environmental and effluent radiological monitoring and reporting, and
- guidelines for recommended environmental and effluent radiological monitoring practices for the Division of Safety, Standards and Compliance.

^(a)Lawrence Livermore Laboratory

^(b)Aerojet Nuclear Corporation

^(c)Green International

ERDA field offices and contractors were asked to review the proposed guidelines. The many comments and additional suggestions received in response were incorporated where appropriate. Two major concerns were expressed by several contractors: first, that the recommendations in the Guide might become mandatory; and second, that the annual dose levels above which specific exposure evaluation would be required (1 mrem for individuals, 0.1 mrem average within an 80-km radius) were too low for measurement, especially at those sites with direct off-site radiation from high energy machines. In response to the first of these concerns, the Environmental Protection Branch reiterated its intent that provisions of the Guide should be advisory, not mandatory. As to the second concern, text revisions were made to clarify the intent and to emphasize that the criteria apply only insofar as adequate monitoring equipment and procedures are available. The recommended levels of interest remain controversial, however.

The comments indicated that statistical treatment of environmental data was still a

potential major reason for lack of comparability between sites. A workshop of ERDA contractor representatives with responsibilities for handling and evaluating environmental surveillance data was held in Denver, Colorado in November 1975 to discuss concepts, needs and capabilities. The workshop discussions were fruitful in improving the common understanding of statistical requirements and the Guide's recommendations.

All material was updated to the beginning of CY-1976. In addition to general criteria for designing an environmental surveillance program, specific recommendations were included for measurement methods and performance criteria, quality assurance program content, and data treatment. Key points of the Guide are:

- the guidance for analysis and identification of critical environmental exposure pathways and evaluation of population exposures
- the designation of exposure levels above which specific exposure pathway analysis is warranted
- the definition of adequate quality assurance for environmental monitoring programs
- the documentation of environmental sampling and analytical procedures
- the guidance for data analysis and statistical treatment, including evaluation of analytical results that are below minimum detectable levels.

Substantial editing of the Effluent Monitoring Guide remained to be done at the end of the transition quarter. As with the Environmental Guide, the term "guide" implies the intent to provide advisory recommendations rather than mandatory requirements unless the latter are already extant in legislation, ERDA Manual chapters, or other agency regulations. One major difference between the two guides is that the Effluent Monitoring Guide covers non-radioactive contaminants.

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• EMERGENCY INSTRUMENTATION PREPAREDNESS

To complete a project on technical criteria for emergency instrumentation preparedness, a fuel reprocessing plant was studied to determine sources and magnitudes of potential accidental radionuclide releases. Based on postulated accident conditions, performance criteria were developed for detection and impact analysis instrumentation systems.

A sourcebook of testing and calibration procedures for instrumentation was compiled from methodological literature, interviews, and newly developed procedures.

Technological Considerations in Emergency Instrumentation Preparedness

J. M. Selby, B. V. Andersen, P. E. Bramson, C. M. Unruh

Radiological emergencies, abnormal occurrences and accidents may require the prompt use of both emergency and routine instrumentation. All performance parameters of this instrumentation must be well known so that its applicability and interpretation under emergency conditions can be established. Evaluating current minimum levels of instrumentation requires technical criteria defining performance parameters, calibration and test procedures and evaluation parameters.

Phase I of the project involved determining the current status of emergency instrumentation in the nuclear industry. This phase was completed and reported in 1971.⁽¹⁾ Phase II - developing technically supported and justified criteria for performance, placement, testing and certification of radiological emergency instrumentation, and providing methods for evaluation and calibration - was divided into four subphases: II-A (Reactors)⁽²⁾ and II-B (Mixed Oxide Fuel Fabrication Facilities),⁽³⁾ completed in 1972 and 1973; and II-C (Fuel Reprocessing Facilities) and II-D

(Testing and Calibration Methodology) completed and reported on during 1976.

For Phase II-C, a reference fuel reprocessing plant was used to determine the sources and magnitudes of radionuclide releases to the environment in the event of postulated accidents within the plant. The plant was postulated to process light water reactor fuels with initial enrichments less than 5% ^{235}U or equivalent fissile content, with exposures in the vicinity of 40,000 MWd/MTU and cooling time of approximately 150 days. Based on these estimates of accident-generated conditions, performance criteria were developed for instrumentation systems to: 1) immediately detect the occurrence of a release, 2) determine the magnitude of and direction taken by the release, and 3) permit estimation of the impact of the release on the environs of the plant.

An inspection of the assumed inventory of radionuclides in various areas of the reference plant showed that the areas of maximum potential release are the head-end tanks and the High Activity Waste (HAW) handling systems. In these particular areas the accidents that could produce the largest releases are, respectively, a nuclear criticality event and an explosion

in the HAW concentrator. Other events considered included a fire involving the plutonium product system, a fire involving the solvent extraction system, overheating of the caustic scrubber solutions, and the processing of freshly discharged fuel. These accidents were selected to include release mechanisms for the different types of radionuclides present, i.e., plutonium, mixed fission products and radioiodines.

Since the reference plant structure was assumed to withstand the stresses imposed by most natural phenomena, an accident which would destroy the building was judged highly improbable. Direct measurement of the releases occurring in a major breach of the plant confinement barrier is not currently feasible; hence, calculation of the dispersion of material outside the plant is dependent on meteorological parameter instrumentation and estimates of potential release terms. Under the postulated accident conditions, measurements of releases are apparently best accomplished using monitoring systems on the ventilation stack. Portable survey equipment would verify or refine the predictions made using the environmental dispersion calculations.

Typical emergency instrumentation and instrumentation systems for fuel reprocessing facilities could consist of:

- in-facility criticality detection
- effluent monitoring of stack-released mixed fission products
- fixed environmental stations for collecting particulates
- fixed environmental stations for telemetering direct radiation levels
- portable instrumentation for measuring dose rate.

For Phase II-D, a sourcebook of testing and calibration procedures was compiled from methodology available in the literature and through interviews with government agencies and selected manufacturers. Where applicable methodology was not available from these sources, methods were developed and included in the sourcebook. Because there was little published methodology and the interviews were not particularly productive, the "developed" procedures constitute a major portion of the sourcebook.

The sourcebook consists of three principle sections: performance criteria, with references to appropriate test and calibration procedures; radiological calibration

methodologies; and testing methodologies, including mechanical, electronic and radiological test procedures.

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ENVIRONMENTAL POLICY ANALYSIS

The Environmental Policy Analysis Program was established in FY-1976 to improve the formulation of energy development and environmental policies with due mutual regard for national environmental and energy development needs. As a separate office under the Assistant Administrator for Environment and Safety, the program is implemented by the Director and by Offices of Environmental Policy in the eight ERDA multiprogram laboratories. The program provides the Assistant Administrator with information on alternatives for decision making and early warning of environmental problems and considerations that may affect energy RD&D policy decisions. The program is intended to be a continuing activity, with its scope determined progressively as issues are defined.

The PNL Environmental Policy Analysis Program draws upon the broad scientific and technical capabilities available within the laboratory, from other ERDA multiprogram laboratories, and from qualified outside consultants. Teams representing the particular skills, knowledge, and perspectives relevant to the issues being analyzed are organized as needed. Activities fall into three broad categories: 1) surveillance of current regional, state and local developments; 2) quick response reviews, studies, and analyses; and 3) formulation, exploration, and analysis of broad issues.

• ENVIRONMENTAL POLICY ANALYSIS

The Environmental Policy Analysis program at Pacific Northwest Laboratory is being developed at ERDA's request to provide technical and analytical input to ERDA decision makers in their development of environmental and energy policy options. The program objective is to supply continuous surveillance of relevant regional and national circumstances and events and to perform in-depth analyses of a wide range of technical issues. Issues that received special emphasis during FY-1976 and the transition quarter concerned the management of areas contaminated by plutonium and other transuranics in soils, the control of releases of transuranics into the environment and acceptable levels of risk in the development and use of energy technologies.

Policy Surveillance and Issue Formulation in the Environmental Policy Analysis Program D. L. Hessel

The objective of the Environmental Policy Analysis program is to provide information for use by ERDA in defining its positions on environmental and energy issues and in making energy research, development and demonstration (RD&D) policy decisions. This is accomplished through continuing surveillance of events and circumstances relevant to the development and use of energy technologies, formation of specific issue statements, analysis of these issues and assessment of potential strategies that ERDA might implement. Figure 1 illustrates the procedural sequence PNL follows to identify issues and conduct issue analyses.

Pacific Northwest Laboratory participated extensively in conceptualization and planning of the Environmental Policy Analysis program and has committed its resources to full support of the program. In response to ERDA guidelines, an Office of Environmental Policy (PNL/OEP) was established in July 1976 within PNL's Environmental and

Safety Research Program Office. The PNL/OEP is staffed by a full-time Manager of Environmental Policy Analysis.

The broad surveillance activity is carried on by the manager, with input from scientists, engineers and research managers. Issue formulation, preparation of issue papers, and critical issue analyses are undertaken by ad hoc teams composed of research staff from PNL, other Battelle laboratories, other ERDA multiprogram laboratories and private consultants. This approach allows the use of the best experts available for each issue. During FY-1976 and the transition quarter, the PNL/OEP undertook issue formulation efforts in two technical areas, as described below. Planning began during this period on a number of other issues for which analyses will be completed in FY-1977.

Review of "Federal Guidance for Environmental Limits of Plutonium Contamination in Soils"

In support of ERDA's participation on an interagency committee organized to assist the Environmental Protection Agency (EPA)

in the development of guidelines for managing areas contaminated by plutonium and other transuranics in soils, PNL provided leadership for a detailed review of draft guidelines developed by EPA. The review involved inputs from several ERDA laboratories as well as from PNL staff members and staff from Battelle's Human Affairs Research Centers and Columbus Laboratories. This review effort led to discussions between ERDA and EPA in which a number of constructive recommendations were made. The process of developing the guidelines is continuing.

Potential Effects of Standards for Environmental Releases of Plutonium and Higher Transuranic Elements on the Development and Use of Fission Power

Control of areas in which soil has been contaminated by plutonium and other transuranic materials is part of a larger issue comprising general control of releases of plutonium and transuranic elements to the environment. A draft issue paper on this subject has been prepared by PNL. It involves comparisons of existing and potential new standards, the availability of adequate technology to control and monitor the releases, the costs or time penalties connected with various potential standards, and the broad range of environmental, social and economic impacts that would result from application of new standards.

Evaluation of Levels of Risk to Health and Safety That Are Acceptable in the Development and Use of Energy Technologies

This exceedingly important and complex issue underlies virtually every consideration related to the development and use of energy technologies. Because much public

concern has been directed toward this question and also because thorough evaluations of acceptable risks are vital to correct energy investments, it is imperative that we address this issue thoroughly and without delay. In addition, we are presently in a period of regulatory reform which offers opportunities for guiding future programs with well-founded risk decisions.

Analysis of the issue involves a review of available information on levels of risk presented by various energy technologies, an assessment of alternative approaches for defining and comparing such risks, and a study of policy options available to ERDA for using risk estimates in program decisions and for making such estimates. A preliminary draft issue paper has been developed and submitted to ERDA and plans have been made to expand the paper during FY-1977.

Activity Anticipated in FY-1977

It is anticipated that much of the analysis effort directed by PNL/OEP during FY-1977 will concern the subjects described above. Late in FY-1976 work began on an issue paper on "Potential Effects of Federal Water Pollution Control Activities on the Use and Development of Energy Technologies." This paper will be finalized and issue analysis will take place in FY-1977. In addition, a number of new subjects will be addressed through brief formulation statements and through additional issue papers. The PNL/OEP will also continue to survey regional and national events of potential significance to ERDA and to respond to requests from ERDA for short-term analyses of miscellaneous policy questions.

FIGURE 1. Environmental Policy Analysis Program Activities

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