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Environmental Science and Research Foundation

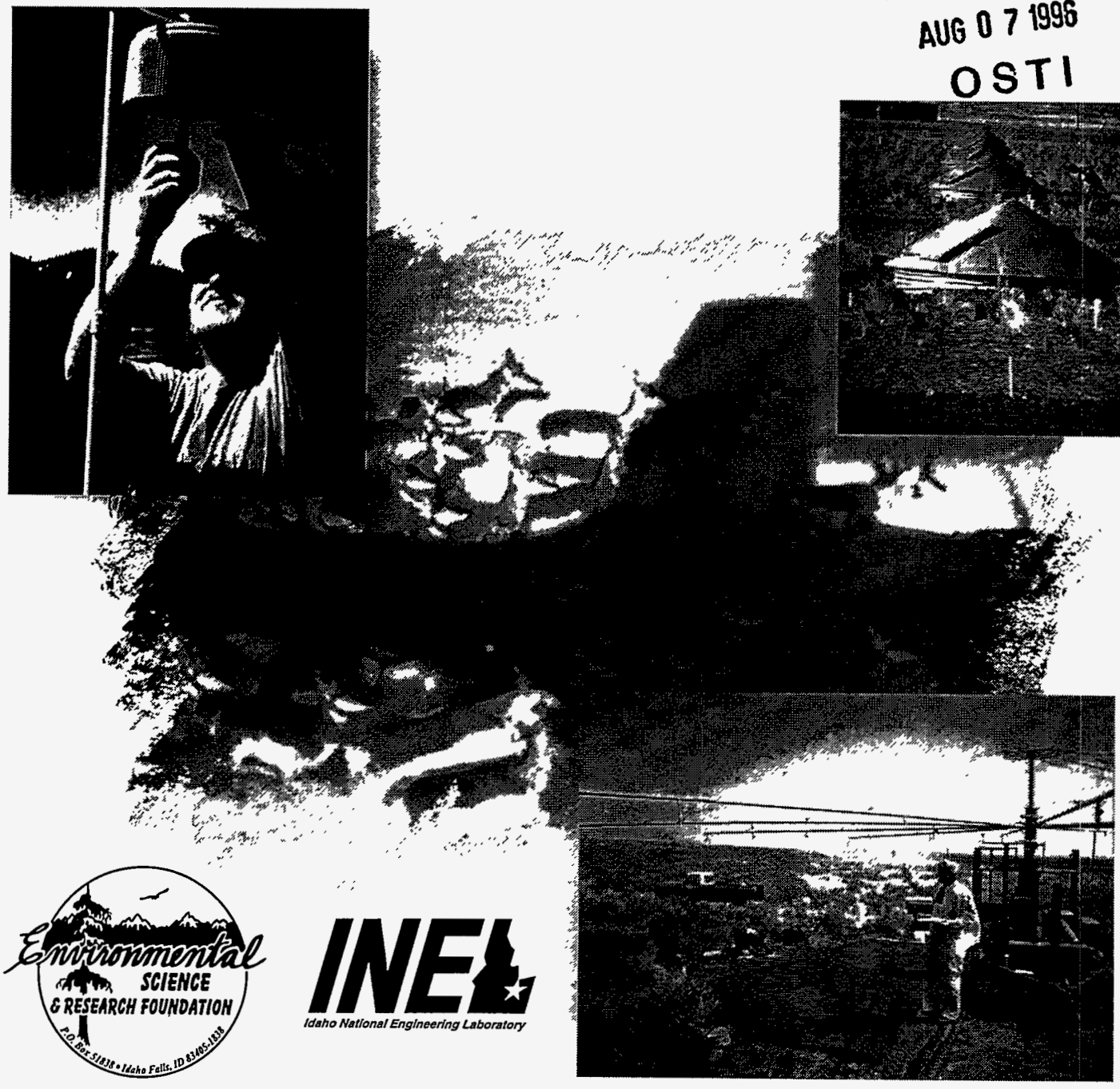
Annual Technical Report to DOE-ID

Calendar Year 1995

Edited by
Timothy D. Reynolds and Randall C. Morris

June 1996

O. Doyle Markham, Executive Director



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INEL
Idaho National Engineering Laboratory

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ENVIRONMENTAL SCIENCE AND RESEARCH FOUNDATION REPORT SERIES, NUMBER 012

ENVIRONMENTAL SCIENCE AND RESEARCH FOUNDATION ANNUAL TECHNICAL REPORT: CALENDAR YEAR 1995

Edited by

Timothy D. Reynolds and Randall C. Morris

June 1996

O. Doyle Markham, Executive Director

Idaho National Engineering Laboratory

EXECUTIVE SUMMARY

THIS ANNUAL TECHNICAL REPORT describes work conducted for the Department of Energy, Idaho Operations Office (DOE-ID), by the Environmental Science and Research Foundation (Foundation) under contract DE-AC07-94ID13268. The Foundation's mission to DOE-ID provides support in several key areas. We conduct an environmental monitoring and surveillance program over an area covering much of the upper Snake River Plain, and provide environmental education and support services related to INEL natural resource issues. Also, the Foundation, with its University Affiliates, conducts ecological and radioecological research on the Idaho National Environmental Research Park. This research benefits major DOE-ID programs including Waste Management, Environmental Restoration, Spent Nuclear Fuels, and Land Management Issues. The major accomplishments of the Foundation and its University Affiliates during the calendar year 1995 can be divided into five major categories.

ENVIRONMENTAL SURVEILLANCE PROGRAM

In this category, the Foundation and its University Affiliates:

- Routinely sampled air, water, soils, environmental dosimeters and various foodstuffs throughout the upper Snake River Plain for contaminants originating from the INEL. During 1995, we collected 2,124 samples as part of the surveillance program, and performed 3,259 analyses on these samples.

- Completed planning for a Community Monitoring Station. An agreement was signed and construction activity began on a community monitoring station at the Madison Middle School in Rexburg, ID.

- Prepared the *INEL Site Environmental Report for Calendar Year 1994*. Also, we prepared and distributed a report that highlighted the significant data and conclusions from the annual site environmental report. This report was written for a more general audience than the full report and was titled, *In Summary: Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1994*.

- Developed standard operating procedures for sample collection and preparation, safety, and quality assurance, and incorporated them into the controlled Environmental Science and Research Foundation Manual. The manual contains 40 plans and procedures. Newly implemented procedures require using field logbooks and chain of custody forms for sample collection. The Foundation initiated a quality assurance program designed to verify the contract laboratories ability to perform given analyses accurately.

- Obtained analytical services from independent laboratories, which, among other activities, replaces services previously provided by the DOE Radiological and Environmental Sciences Laboratory. They include laboratories at Idaho State University, University of California at Davis, University of Toronto, and a commercial laboratory.

- Wrote a contract with a commercial software development company to supply the Foundation with a sample/data management system.

ENVIRONMENTAL EDUCATION

In this category, the Foundation and its University Affiliates:

- Published six issues of *Foundation Focus*. Circulation of the newsletter grew greatly.

- Gave 57 presentations. The audiences included professional societies, INEL tour groups, classrooms (from elementary through university graduate level), and others. We estimated that more than 4,000 people attended Foundation presentations.

- Prepared and issued 24 news releases to approximately 110 media outlets. Each month, Foundation activities related to INEL were mentioned by news media across Idaho.

- Installed a Travelers' Information Radio Station for the INEL. This station provides information on INEL environmental topics to passengers in vehicles traveling through the INEL. We began a radio scriptwriting contest for high school students that will run through April 1, 1996. Eighteen high schools are involved in the contest.

- Assembled a focus group of 20 persons, representing varied public interests, to foster public involvement in the INEL offsite environmental surveillance program. The group reviewed the environmental surveillance program and provided constructive criticism.

- Submitted a proposal to design, build, and maintain a one-mile-long nature trail in the vicinity of Experimental Breeder Reactor I, a National Historic Site. Unfortunately, Congressional and DOE-HQ budget cuts suspended plans for the trail. However, the idea remains viable, and it may be pursued using alternative funding.

ENVIRONMENTAL SERVICES AND SUPPORT

In this category, the Foundation and its University Affiliates:

- Responded to more than 215 requests for information from the public, DOE, DOE contractor personnel, scientists, and stakeholders regarding the Foundation's programs or the environmental contamination, radioecology, ecology, surveillance activities and natural resources at the INEL.

- Provided 41 timely field evaluations and recommendations in support of National Environmental Policy Act requirements.

- Conducted two big-game surveys and one site-wide raptor count. We sent the results to appropriate agencies, including DOE, the Idaho Department of Fish and Game, and the U.S. National Biological Service.

- Established working relations with State and Federal resource management agencies on behalf of the INEL. The Foundation continued as the INEL interface with the U.S. Department of Agriculture Animal Damage Control programs and the U.S. Fish and Wildlife Service Threatened and Endangered Species program.

- Facilitated use of the Idaho National Environmental Research Park by 149 University scientists, staff, and graduate students. We provided technical review

of INEL research plans and management documents.

Ecological Risk Assessment

The Foundation has served as a co-leader in the ecological risk assessment guidance development effort since its inception at the INEL. This effort resulted in a guidance document for conducting screening-level ecological risk assessments on the INEL. In 1995, the Foundation:

- Participated in the national Ecological Risk Task Group of the Risk Based Standards Working Group to begin outlining methods for incorporating the Data Quality Objectives process into Ecological Risk Assessment.

- Co-authored two papers at the Second World Congress of the Society of Environmental Toxicology and Chemistry. This is the leading society for ecological risk assessment.

- Co-authored two invited papers for a special issue of the *International Journal of Environment and Pollution*. This issue will address innovative approaches in ecological risk assessment. One paper presents an overview of methodology and the other discusses methodology for grouping ecological components.

- Developed a human health risk assessment of external dose from radionuclides brought to the surface by vegetation, small mammals, and ants at BORAX-I and SL-1. DOE cited the work as instrumental in obtaining a signed Record-of-Decision for these sites.

Research Benefitting the DOE-ID Mission

In this category, the Foundation and its University Affiliates:

- Conducted 23 research projects. A total of 149 scientists, graduate students, and technicians from 12 universities and colleges participated in Foundation research projects at the INEL. These projects supported DOE-ID programs for Waste Management, Environmental Restoration, Spent Nuclear Fuels, Land Management Issues, and other INEL and DOE programs.

- Provided research data to DOE-ID for use in complying with various mandates and regulations including the National Environmental Policy Act; the Endangered Species Act; the Natural Resource Damage Assessment and Risk Assessment sections of the Comprehensive Environmental Response, Compensation, and Liability Act; and the Federal Noxious Weed Act.

- Prepared 27 technical manuscripts for peer-reviewed journals, six Foundation Technical Reports, and two articles in the popular literature. Three University Affiliates prepared books, or book chapters, partially based on Foundation research at the INEL.

- Presented research results at regional, national, and international scientific society meetings, as well as in university and other classroom environments. Other products of our research program included the design and manufacture of various electronic gauges to measure snowmelt runoff, predictive models and GIS maps of snake hibernacula, various computerized databases of plants and

animals on the INEL, and significant additions of specimens to lichen and invertebrate museum collections.

Overall, the Foundation was productive and efficient while under contract to DOE-ID during 1995. Most of the goals of each individual program were accomplished, and the Foundation's responses to requests from DOE-ID and INEL contractors were timely, complete, and cost effective.

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JANUARY 1 - DECEMBER 31, 1995

INTRODUCTION

THIS ANNUAL TECHNICAL REPORT is submitted to the Department of Energy, Idaho Operations Office (DOE-ID), by the Environmental Science and Research Foundation in accordance with contract DE-AC07-94ID13268. This report summarizes the major activities conducted for DOE-ID by the Environmental Science and Research Foundation during the period January 1 through December 31, 1995. Because universities are involved in almost all Foundation activities, in this report the term "Foundation" collectively refers to Foundation Staff and Foundation University Affiliates.

The Environmental Science and Research Foundation designed this Annual Technical Report to be readable and meaningful to DOE-ID and the general public. We made efforts to reduce the occurrence of scientific terminology and detailed descriptions of specific experimental and statistical design.

The Foundation manages, coordinates, and conducts ecological and environmental research, environmental surveillance, environmental services, and environmental education for DOE-ID at the Idaho National Engineering Laboratory (INEL). The Foundation's staff has more than 80 years combined experience in conducting these activities at the INEL.

By using University Affiliates and university and commercial analytical laboratories, and by operating as a private, non-profit organization, the Foundation obtains facts independent from Management & Operations contractors. This provides independent data analyses and reports which help to satisfy concerns expressed by the State of Idaho and its citizens. Additionally, this approach is consistent with DOE's commitment to public openness.

To meet these obligations to DOE-ID and the public, the Foundation has established several principal goals. These goals form the basis for the five major sections of this report.

SECTION I: INEL OFFSITE ENVIRONMENTAL SURVEILLANCE PROGRAM

This section describes the offsite environmental surveillance program and a summary of the sampling effort. This summary indicates the types, frequency, and location of routine environmental samples, and the constituents for which each sample was analyzed. This section does NOT provide analysis or interpretation of the program data for 1995. Analysis and interpretation will be presented in a separate report (*The Idaho National Engineering Laboratory Annual Site Environmental Report for Calendar Year 1995*), available in August 1996.

SECTION II: ENVIRONMENTAL EDUCATION

This section emphasizes the Foundation's support of DOE-ID's open and frank discussion of environmental issues with various individuals and stakeholder groups. The Foundation's Environmental Education program includes an aggressive agenda of press releases, newsletters, and presentations to both technical and non-technical audiences.

SECTION III: ENVIRONMENTAL SERVICES AND SUPPORT

This section summarizes the Foundation's activities regarding natural resource issues on the INEL. The Foundation provided DOE-ID with information and recommendations for wildlife and other ecological concerns on the INEL. We served as the point of contact for DOE-ID on natural resource issues with

various agencies (e.g., Bureau of Land Management and the Idaho Department of Fish and Game). In addition, the Foundation responded to public and professional inquiries about the ecology of the INEL.

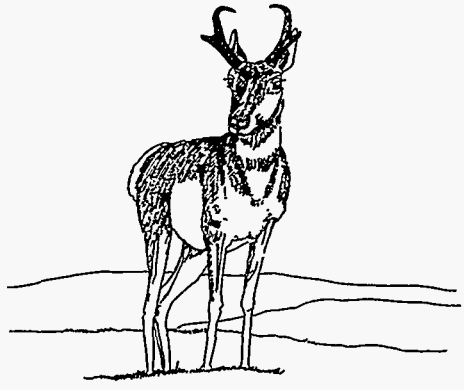
SECTION IV: ECOLOGICAL RISK ASSESSMENT

This section describes the Foundation's involvement in ecological risk assessment issues and efforts, both locally and nationally. This program provides DOE-ID with the basic tools to comply with various federal and state regulations, mandates, and agreements.

SECTION V: ECOLOGY AND RADIOECOLOGY RESEARCH

This section summarizes the various radioecology and ecology research projects conducted by Foundation staff and University Affiliates on the INEL. This research provided sound, scientifically-defensible answers to basic and applied ecological questions related to DOE-ID projects in the shrub-steppe ecosystem. The knowledge gained from this research is the basis for the environmental education, services and support supplied to DOE-ID by the Foundation.

This Annual Technical Report was a collective effort of Foundation staff and University Affiliates. Foundation contributors included O. D. Markham, R. G. Mitchell, R. C. Morris, D. S. Peterson, T. D. Reynolds, D. E. Roush, R. D. Blew, and R. W. Warren. The University Affiliates contributing to this report included Principal Investigators J. J. Bromenshenk (University of Montana); L. D. Flake (South Dakota State University); J. E. Anderson, J. W. Laundré, B. D. Eshelman, and C. R. Peterson (Idaho State University); W. H. Clark (Albertson College of Idaho); J. B. Johnson and J. M. Peek (University of Idaho); S. A. Ibrahim (Colorado State University); L. C. Pearson (Ricks College, retired); and J. P. Dobrowolski (Utah State University); Research Assistant Professor W. E. Limbach (Idaho State University); Research Associate G. C. Smith (University of Montana); Senior Research Assistants T. D. Ratzlaff (Idaho State University) and P. E. Blom (University of Idaho and Albertson College of Idaho); and Graduate Students T. J. Christian (University of Montana); J. L. Carney, S. L. Cooper, K. I. Gabler, L. T. Heady, K. E. Rasmuson, C. S. Sonnemann, (Idaho State University); D. E. Beaver (University of Idaho); and E. K. Duffin (Utah State University).



SECTION I

INEL OFFSITE ENVIRONMENTAL SURVEILLANCE PROGRAM

OPERATIONS AT THE IDAHO NATIONAL ENGINEERING LABORATORY (INEL) have the potential to release both radioactive and nonradioactive contaminants into the air and water. To assess the effects of these contaminants, the Environmental Science and Research Foundation conducted the INEL Offsite Environmental Surveillance Program for the Department of Energy, Idaho Operations Office (DOE-ID). The program's primary purposes were to sample media representing pathways of contaminants from the INEL to the general public, to obtain radiological analyses for these samples, and to report and interpret the results of these analyses for the general public. The Foundation conducted surveillance to satisfy the environmental protection program requirements of DOE Order 5400.1 which assure compliance with environmental laws and regulations, executive orders, and DOE policies. We compared the data to derived concentration guides established for protection of members of the public and the environment in DOE Order 5400.5.

PROGRAM GOALS AND OBJECTIVES

The Foundation's major goals for the INEL Offsite Environmental Surveillance Program were to:

- Sample and analyze media from all relevant contaminant (primarily radionuclides) pathways to the offsite environment.
- Evaluate results of offsite environmental surveillance data and coordinate with other agencies performing environmental monitoring both on and offsite, including INEL contractors and Federal and State organizations.
- Collect the necessary data to verify that INEL operations are in compliance with applicable environmental standards and assess the offsite impact, if any, of INEL operations on humans and the environment.
- Report and interpret environmental surveillance results obtained by the Foundation, Lockheed Idaho Technologies Company (LITCO), the National Oceanic and Atmospheric Administration, the United States Geological Survey, and other agencies to DOE-ID and the public.
- Promote public awareness of the surveillance program and its results, and provide opportunities for public comment on environmental surveillance issues at the INEL.

In order to achieve these goals, we established the following objectives for 1995:

- Conduct a routine surveillance program to sample media representing potential exposure pathways for contaminants from the INEL.
- Prepare technical reports that present and interpret environmental surveillance data for the DOE and the public, including the *Annual Idaho National Engineering Laboratory Site Environmental Report* and quarterly environmental surveillance reports.
- Initiate independent university or commercial analytical services that, through 1994, were provided by the Radiological and Environmental Sciences Laboratory (DOE-ID).
- Continue to develop a quality assurance program to ensure that the Environmental Surveillance Program

produces quality results and is operated in a manner consistent with the requirements of DOE Orders such as 5400.1 and 5400.5.

- Develop a community monitoring program.
- Evaluate the Offsite Environmental Surveillance Program through public input as well as through internal review.
- Provide environmental surveillance program data, and interpretation of these data, to the public through periodic reports, news releases, the *Foundation Focus* newsletter, and public presentations.
- Install a computerized sample/data management system that allows samples to be tracked from collection through disposal.

PROGRAM DESCRIPTION AND ACCOMPLISHMENTS

The Foundation conducted the INEL Offsite Environmental Surveillance Program for DOE-ID during 1995. The objectives described above were satisfied by major accomplishments in all aspects of the surveillance program.

ROUTINE SAMPLING PROGRAM

A total of 2,124 samples of air, water, foodstuffs, and environmental dosimeters were collected during 1995, and 3,259 analyses were performed on these samples (Table 1). Of this total, quality control samples (replicates, duplicates, and spiked samples) accounted for 232 samples and 361 analyses.

A network of 14 low-volume air samplers (Figure 1), including 11 at offsite locations and three on the INEL, operated continuously. We compared data from onsite samplers with data collected offsite, and with data obtained from co-located air samplers operated by LITCO, the INEL contractor responsible for the onsite surveillance program. Each week, we changed filters at each location, and performed screening analyses (^{131}I for charcoal cartridges, gross alpha and gross beta for particulate filters). Quarterly composites of the weekly filters were analyzed for gamma-emitting radionuclides, and selected locations were also analyzed for ^{90}Sr and transuranic radionuclides (Pu and Am).

Atmospheric moisture was collected at two offsite locations and precipitation at three locations (two onsite and one offsite) to assess levels of tritium.

The Foundation funded the Interagency Monitoring of Protected Visual Environments (IMPROVE) samplers located at Craters of the Moon National Monument and the INEL, which are operated under a Memorandum of Understanding between the DOE and the National Park Service. The Foundation also operated the IMPROVE sampler located at the INEL, and sent semiweekly samples to the University of California, Davis for analysis. The IMPROVE program is used nationwide at National Parks and wilderness areas to measure parameters that can reduce visibility.

The Foundation obtained semiannual water samples from 12 drinking-water locations and two surface-water locations. In addition, quarterly samples were collected at two drinking-water and three surface-water sites in the Magic Valley. At special request, a sample was collected from an additional spring in the Magic Valley during the first half of the year. All samples were analyzed for gross alpha, gross beta, and tritium.

We collected milk from one dairy weekly and from eight other dairies monthly. Each milk sample was analyzed for ^{131}I, with one sample from each location also analyzed for tritium and ^{90}Sr during the year. Annual samples of foodstuffs were collected from private gardens (lettuce), local grain elevators (wheat), and warehouses (potatoes). These were analyzed for gamma-emitting radionuclides and ^{90}Sr.

TABLE 1 SUMMARY OF THE FOUNDATION ENVIRONMENTAL SURVEILLANCE PROGRAM (1995)

Sample Type / Analysis	Collection Frequency	Number of 1995 Analyses	Locations		
			Distant	Boundary	INEL
Air					
Gross Alpha Gross Beta ^{131}I	weekly	832 832 832	Blackfoot, Craters of the Moon, Idaho Falls, Rexburg	Arco, Atomic City, FAA Tower, Howe, Monteview, Mud Lake, Reno Ranch	Main Gate, EFS, Van Buren
Gamma Spec Particulate Mass	quarterly	65 64	Blackfoot, Craters of the Moon, Idaho Falls, Rexburg	Arco, Atomic City, FAA Tower, Howe, Monteview, Mud Lake, Reno Ranch	Main Gate, EFS, Van Buren
^{90}Sr Transuranics	quarterly	27 23	Rotating schedule	Rotating schedule	Rot. schedule
Moisture (Air)					
Tritium	6 to 13 weeks	10	Idaho Falls	Atomic City	None
Precipitation					
Tritium	monthly	23	Idaho Falls	None	CFA
Tritium	weekly	19	None	None	EFS
Surface H_2O					
Gross Alpha Gross Beta Tritium	semiannual	20 20 20	Bliss, Buhl, Hagerman, Idaho Falls, Twin Falls	None	None
Drinking H_2O					
Gross Alpha Gross Beta Tritium	semiannual	34 34 34	Aberdeen, Blackfoot, Carey, Fort Hall, Idaho Falls, Minidoka, Roberts, Shoshone	Arco, Atomic City, Howe, Monteview, Mud Lake	None
Milk					
^{131}I	weekly	52	Idaho Falls	None	None
^{131}I	monthly	97	Blackfoot , Carey, Dietrich, Minidoka, Roberts	Howe, Terreton, Arco	None
Tritium ^{90}Sr	annually	9 7	Blackfoot , Carey, Dietrich, Idaho Falls, Minidoka, Roberts	Howe, Terreton, Arco	None
Potatoes					
Gamma Spec ^{90}Sr	annually	6 6	Blackfoot, Idaho Falls, Rupert	Arco, Mud Lake	None
Wheat					
Gamma Spec ^{90}Sr	annually	11 11	American Falls, Blackfoot, Dietrich, Idaho Falls, Minidoka, Carey	Arco, Monteview, Mud Lake, Tabor, Terreton	None
Lettuce					
Gamma Spec ^{90}Sr	annually	9 9	Blackfoot, Carey, Idaho Falls, Pocatello	Arco, Atomic City, Monteview, Mud Lake	None
Fish					
Gamma Spec	annually	1	None	None	Big Lost River
Sheep					
Gamma Spec	annually	18	Blackfoot	None	INEL grazing areas
Waterfowl					
Gamma Spec ^{90}Sr Transuranics	annually	48 15 15	Fort Hall	None	waste disposal ponds
Game					
Gamma Spec	Varies	20	None	None	INEL roads
Soil					
Gamma Spec ^{90}Sr Transuranics	biennially	4 4 4	Carey, Crystal Ice Caves, Blackfoot, St. Anthony	Butte City, Monteview, Atomic City, FAA Tower, Howe, Mud Lake (2), Reno Ranch	None
TLDs					
Gamma Radiation	semiannual	26	Aberdeen, Blackfoot, Craters of the Moon, Idaho Falls, Minidoka, Rexburg, Roberts	Arco, Atomic City, Howe, Monteview, Mud Lake, Reno Ranch	None

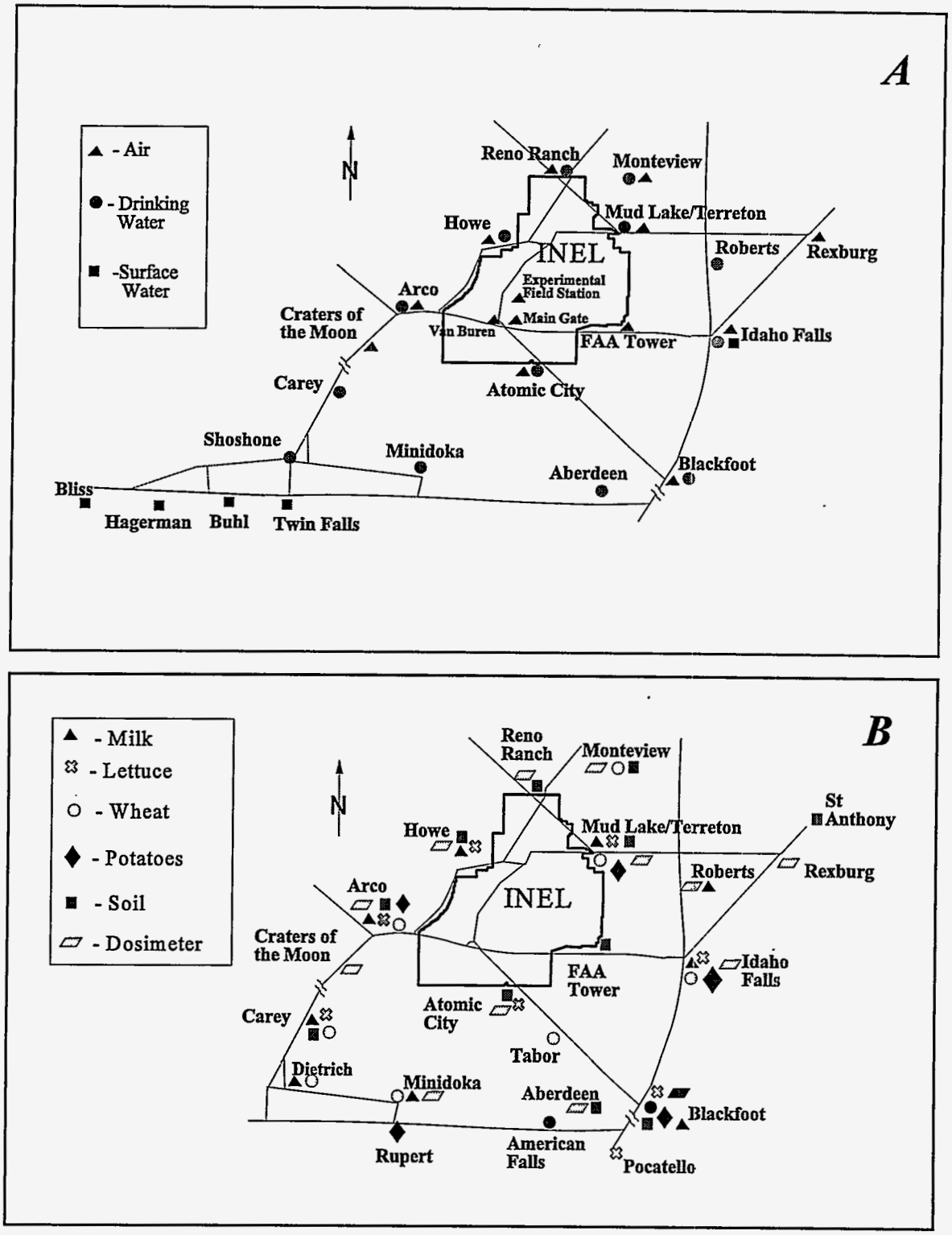


Figure 1. Locations for Air and Water (A) and All Other Media (B) Sampled as Part of the Foundation's Routine Environmental Surveillance Program

The Foundation took muscle, liver, and thyroid samples from sheep that grazed onsite and at a control location, and from game animals killed on INEL roads.

Environmental dosimeters were collected from 13 sites during May and November to assess radiation exposure at distant and boundary sites.

Environmental Reports

The Foundation prepared the *INEL Site Environmental Report for Calendar Year 1994* as required by DOE Orders. The report contained environmental monitoring data collected by the Foundation, INEL contractors, the U.S. Geological Survey, and the National Oceanic and Atmospheric Administration. In addition, the report summarized the INEL's compliance status with respect to major environmental laws and regulations, and provided a summary of significant environmental restoration and waste management issues. The report also included an evaluation of the hypothetical dose to a member of the public resulting from operations at the INEL. Following DOE-ID and INEL contractor review, the report was printed and distributed to more than 400 individuals. The Foundation will also prepare the *INEL Site Environmental Report for 1995.*

We completed and distributed a document entitled, *In Summary: Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1994.* This report highlighted the significant data and conclusions from the annual site environmental report, and was written so that the public could easily understand the results and interpretations of environmental programs at the INEL.

The Foundation prepared quarterly environmental surveillance reports for the second through fourth quarters of 1994. Following review by DOE-ID, each of these reports was printed and distributed. Draft reports were prepared for the first and second quarters of 1995.

Quality Assurance Program

The Foundation developed standard operating procedures for sample collection and preparation, safety, and quality assurance and incorporated them into the controlled Environmental Science and Research Foundation Manual. At the end of 1995, the manual contained 40 plans and procedures. A Quality Assurance Project Plan, consistent with the guidelines of QAMS 005/80, was prepared for the environmental surveillance program.

We continued improving documentation and tracking for environmental surveillance program activities. New procedures were implemented requiring field logbooks and chain of custody forms for sample collection. We also implemented a new sample identification scheme, that allows samples to be submitted for analysis without location identifiers. Routine assessments were initiated on sample collection and preparation activities. These assessments range from informal "walkdowns" of selected field activities by the program manager to formal surveillances. A formal surveillance consists of a thorough review of compliance with procedural requirements and is performed with the use of a checklist. New training and qualification requirements were implemented for staff members.

A program to obtain and submit spiked samples (to which a known amount of radioactive material is added) to laboratories performing radiological analyses was also started. This program, combined with routine analysis of sample blanks, replicate samples, and split samples assists in providing verification of the ability of our contracted laboratories to accurately perform given analyses.

Analytical Laboratories

The Foundation obtained analytical services from two independent laboratories, replacing services formerly provided by the DOE Radiological and Environmental Sciences Laboratory. The Environmental Monitoring Laboratory at Idaho State University began conducting most routine analyses in January 1995, including gross alpha, gross beta, tritium, and most gamma spectrometry. Strontium-90, transuranic analyses, and some gamma spectrometry analyses were obtained from Quanterra, Inc. in Richland, Washington.

Crocker Nuclear Laboratory at the University of California, Davis, continued to provide analytical support for the IMPROVE program. We also developed a sampling plan for routine analyses of ^{129}I in milk and tissue. IsoTrace Laboratory at the University of Toronto is to perform this analysis by accelerator mass spectrometry beginning in 1996.

Community Monitoring Program

We developed a community monitoring program to inform stakeholders about, and involve them in, environmental surveillance at the INEL. We sent letters to several schools throughout southeastern Idaho soliciting interest in the project, and five schools responded with full proposals. Madison Middle School in Rexburg was chosen because they presented the best combination of location, personnel, and support of the project by faculty and staff. An agreement was signed between the Foundation and the school. We worked with the Shoshone-Bannock Tribes to establish a station at Fort Hall. A construction contractor was selected by competitive bid.

A community monitoring station, consisting of air and radiation monitors and meteorological equipment, is operated by members of the community in which the stations are located. Data obtained from the station are displayed near the station, allowing the public to view the results of the environmental surveillance program. Most importantly, the station serves as an educational tool for the school where it is located. Data generated by the station will be accessed through the school's local area network, allowing the school to incorporate the data into science classes dealing with topics such as meteorology and radioactivity.

Public Input/Program Review

The Foundation solicited public input into the environmental surveillance program through a variety of methods. At each of the presentations and displays listed in the following section, the public was asked to provide comments or concerns regarding the program. In addition, a toll-free number and an electronic mail address were made available to the public.

An in-depth focus group was convened in Idaho Falls in July to discuss various aspects of the surveillance program, including evaluation of the economics of the program. More than 20 individuals and representatives of organizations covering a diverse range of viewpoints attended the focus group. Nearly all provided favorable comments on the quality of the discussion; some suggested that this was the best discussion group related to the INEL that they had ever attended. The focus group recommended that similar discussion groups be held in other parts of the state. However, we did not conduct these due to budget concerns from DOE-ID. A detailed report on the focus group is being prepared.

In addition to gaining public input into the surveillance program, the Foundation also conducted a thorough internal program review. Corrective action for items identified during the review are currently being implemented.

PUBLIC INFORMATION

One of the Foundation's major goals is to inform and educate the public about environmental surveillance at the INEL. We used a variety of approaches to provide information on the environmental surveillance program to the general public including presentations, an educational display, and media releases. Detailed information is provided in Section II.

SAMPLE/DATA MANAGEMENT SYSTEM

The Foundation used the *Commerce Business Daily* to solicit vendors to provide a sample/data management system for the environmental surveillance program. A Selection Board rated and identified the top candidate. An onsite assessment of the selected vendor was conducted in November and a contract was drafted following the visit.

SUMMARY

The Foundation conducted the INEL Offsite Environmental Surveillance Program for DOE-ID during 1995. Results from 2,124 samples collected during the year and 3,259 analyses (performed by two offsite analytical laboratories) indicated that radioactivity from the INEL could not be distinguished from natural radioactivity and worldwide fallout in the vicinity of the INEL. We prepared the *INEL Site Environmental Report for Calendar Year 1994* and quarterly reports of environmental surveillance program data. A number of presentations and displays were provided throughout Idaho, and a variety of approaches were used to solicit the public's concerns regarding environmental surveillance at the INEL. We continued to develop a high-quality surveillance program by initiating new procedures for sample documentation and tracking, sample identification, and analysis of a variety of quality control samples to verify our contracted laboratories' precision. To further improve sample tracking and results, we solicited vendors to provide a computerized sample and data management system, and developed a contract to procure this system. At the close of the year, we began constructing the first of two proposed community monitoring stations that will serve as an educational tool for environmental surveillance at the INEL.

SECTION II

ENVIRONMENTAL EDUCATION

SUCCESSFUL MANAGEMENT of natural resources takes place in a social framework of open communication. Fazio and Gilbert (1986) called for natural resource organizations to plan, honestly and actively, all interactions with the groups of people affected by agency actions. They are only slightly overstating the case when they claim, "Natural resource management is 90 percent managing people and 10 percent managing resources" (Fazio & Gilbert 1986).

Because of revelations of the Cold War's environmental legacy, the Department of Energy (DOE) now operates in an atmosphere of tight scrutiny. Nonetheless, DOE has stated, "These challenges cannot be solved by science alone" (U. S. DOE 1995).

DOE's role as the nation's nuclear weapons maker overshadows the department's important environmental roles. Nonetheless, DOE is a manager of large land holdings and generator of vital ecological knowledge. The seven sanctuaries of DOE's National Environmental Research Parks serve as storehouses of biodiversity and platforms for better understanding of ecosystems, contributing significantly to DOE's goal of improving environmental quality (U. S. DOE 1994).

Gaining public consent for current and future DOE activities depends on communications that first raise awareness and then foster understanding. In Idaho, the need for efficacious communications about DOE's environmental activities at the Idaho National Engineering Laboratory (INEL) is also flavored by the people of Idaho's heavy reliance on the natural world for both livelihood and recreation. Idahoans have a keen interest in how the federal government manages its lands.

The perceptions and expressed opinions of elected officials, activists, adjacent landowners, tribal leaders, INEL employees, other Idaho residents, and visitors to the upper Snake River Valley impact DOE's management of the INEL environment. Satisfactory public opinion should be viewed as a critical element in the INEL's future. The Foundation, through its environmental education mission, aims to improve public understanding of the INEL. This goal requires regular, planned, two-way exchange of information about ecological research, environmental monitoring, and environmental issues.

PROGRAM OBJECTIVES

The Foundation's Environmental Education Program objectives are:

- Develop and distribute educational materials about the environment of the INEL.
- Disseminate results from the INEL Offsite Environmental Surveillance Program and provide opportunities for public involvement.
- Provide environmental education activities to schools.
- Distribute information about INEL ecological research findings, to publics beyond traditional scientific audiences.

These objectives contribute directly to better public understanding of the INEL.

COMMUNICATION STRATEGIES

The Foundation designed and employed eight communication strategies in 1995. These strategies were to:

- Periodically release information about INEL ecological research and environmental surveillance to mass

media outlets in Idaho and other Rocky Mountain states.

- Make presentations to a wide variety of audiences, including elementary and secondary schoolchildren, civic groups, university students and faculty, INEL tour groups, and professional peers.
- Place portable and permanent interpretive signs, posters, and displays at various locations.
- Publish brochures, reports, flyers, papers, and other documents, many of which were designed and written for non-technical audiences.
- Construct a travelers' information radio station, airing messages about the natural and cultural history of the INEL.
- Work with the INEL Offsite Environmental Surveillance Program to design and construct two community monitoring stations and foster public involvement in the management decisions for the surveillance program.
- Develop and maintain an interpretive nature trail at Experimental Breeder Reactor I (EBR-I) on the INEL.
- Publish a bimonthly newsletter, *Foundation Focus*.

PROGRAM ACCOMPLISHMENTS

NEWS RELEASES

The Foundation issued 24 news releases. An additional release was prepared by the Foundation for issuance by the DOE, Idaho Operations Office (DOE-ID). We distributed most of these releases to approximately 110 media outlets, including Idaho newspapers, periodicals, and broadcast stations, as well as some major outlets in neighboring states.

As a result, news media attention to environmental surveillance and ecological research at the INEL was steady and regular. In every month of 1995, these activities were mentioned by news media across Idaho. We know of 60 instances of editorial coverage. (Many more probably occurred given the difficulty of tracking all news media.) Nearly all instances can be traced to planned releases of information. Response was consistent across media, with 24 newspaper stories; 14 articles in newsletters, magazines, and other popular periodicals; 14 radio pieces; and eight television interviews. This media coverage demonstrated that broad audiences can be reached, while enjoying scientific success at the INEL. By contributing to knowledge, the Foundation also made news.

PRESENTATIONS

A skilled personal presentation to an attentive audience is accepted as one of the best ways to explain scientific findings. For this reason, Foundation scientists often give presentations at scientific meetings. Multimedia presentations are also used to provide information to other types of audiences. During 1995, the Foundation staff and University Affiliates gave 57 presentations to professional peers, students, civic leaders, and other audiences (Table 1). More than 4,000 persons attended Foundation presentations during the year.

TABLE 1. FOUNDATION PRESENTATIONS DURING 1995

Title	Audience
The Environmental Transport of Plutonium and Related Cleanup Issues	University of Colorado Public Interest Science Conference (Boulder, CO)
Annual Soil Water Recharge and Extraction in a Cold Desert Steppe in Southeastern Idaho	Ecological Society of America (Snowbird, UT)

TABLE 1 (CONTINUED). FOUNDATION PRESENTATIONS DURING 1995

The Historic and Present Distribution of *Bromus tectorum* on the Idaho National Engineering Laboratory	Northwest Scientific Association (Idaho Falls, ID)
Potential Dose to Humans from Game Animals	Radiation Environmental Monitoring and Surveillance course at Idaho State University
A Case Study for Evaluating Ecological Risks	1995 Conference on Hazardous Wastes and Materials (Pocatello, ID)
INEL Offsite Environmental Surveillance Program	Greater Pocatello Chamber of Commerce
Protective Cap/Biobarrier Experiment	State of Idaho INEL Oversight Program staff
Snake Safety at the INEL	INEL employees
INEL Offsite Environmental Surveillance Program	Blackfoot Chamber of Commerce
Protective Cap/Biobarrier Experiment	Engineering students from Wyoming
INEL Offsite Environmental Surveillance Program	Pocatello Rotary Club
Ecological Risk Assessment on the INEL	Personnel from EPA, DOE, and State of Idaho
Writing Messages for the INEL Travelers' Information Radio	12th grade English classes, Ririe (ID) High School
Protective Cap/Biobarrier Experiment	Texas Low-Level Radioactive Waste Task Force
Using Local Plant Materials for Vegetating a Severely Disturbed Site in Southeastern Idaho	Society for Ecological Restoration (Seattle, WA)
Meeting the Challenges: Ecological Solutions	Northwest Scientific Association (Idaho Falls, ID)
Challenges to Waste Repositories: Animal Intrusion	Northwest Scientific Association (Idaho Falls, ID)
INEL Offsite Environmental Surveillance Program	Arco City Council Meeting
Ecological Aspects of Waste Management	Northwest Scientific Association Annual Meeting Symposium
Research at the Experimental Field Station	Personnel from DOE-ID, State of Idaho INEL Oversight Program, and LITCO WAG 5 Management
Protective Cap/Biobarrier Experiment	Three environmental science classes at Madison Jr. High School, Rexburg, ID
Protective Cap/Biobarrier Experiment	Chuck Burt, Roy F. Weston Inc./UMTRA
The Foundation's Mission at the INEL	LITCO staff of Kathleen Falconer
Environmental Surveillance	Salmon Corps (Ft. Hall, ID)
Careers in the Environment at the INEL	Career class students, Gooding High School
Foundation Orientation	Foundation Summer Interns
Research on the Butte City Burn	Science Action Team participants, teachers, and parents
Caves, Snakes, and Ordnance on the INEL	Foundation, LITCO, DOE staff
Foundation Overview of INEL Offsite Environmental Surveillance, TRA Pond Study, Protective Cap/Biobarrier Experiment	Colorado State University health physics graduate student field trip
Career Opportunities in Environmental Fields	Salmon Corps (Ft. Hall, ID)
Environmental Research and Surveillance	Vale, OR, science students

TABLE 1 (CONTINUED). FOUNDATION PRESENTATIONS DURING 1995

Mule Deer on the INEL	Boy Scouts
Protective Cap/Biobarrier Experiment	Madison Junior High School science class (Rexburg, ID)
INEL Travelers' Information Radio Scriptwriting Contest	Faculty, West Jefferson High School (Mud Lake, ID)
INEL Travelers' Information Radio Scriptwriting Contest	English Faculty, Idaho Falls High School
INEL Travelers' Information Radio Scriptwriting Contest	Faculty, Skyline High School (Idaho Falls, ID)
Animals of the INEL	5th grade classes, Madison Middle School (Rexburg, ID)
Writing Messages for the INEL Travelers' Information Radio	11th grade English classes, Firth (ID) High School
TRA Pond Study	INEL tour
INEL Travelers' Information Radio Scriptwriting Contest	English Faculty, Hillcrest High School (Ammon, ID)
Writing Messages for the INEL Travelers' Information Radio	9th grade honors English class, Hillcrest High School (Ammon, ID)
Using Natural Ecosystem Processes for Keeping Water from Reaching Interred Hazardous Wastes	Ecological Society of America (Snowbird, UT)
A Comparison of the Distribution and Abundance of the Herpetofauna of the INEL: 1975 and 1994	Idaho Herpetological Society (Boise, ID)
A Comparison of the Distribution and Abundance of the Herpetofauna of the Idaho National Engineering Laboratory: 1975 and 1994	Northwest Scientific Association (Idaho Falls, ID)
Snowmelt erosion research at the Idaho National Engineering Laboratory	Utah State University Rangeland Resources Graduate Seminar (Logan, UT)
Evaluating Snowmelt Erosion from Simulated Waste Burial Trench Caps	Northwest Scientific Association (Idaho Falls, ID)
Raptor Studies on the INEL	Orinthology course, South Dakota State University (Brookings)
The Effect of Seed Priming on the Growth of Thickspike Wheatgrass in Competition with Cheatgrass	Northwest Scientific Association (Idaho Falls, ID)
The Effect of Seed Priming on the Growth of Thickspike Wheatgrass in Competition with Cheatgrass	Society for Range Management (Phoenix, AZ)
The Effects of Seed-Priming on the Growth of *Elymus lanceolatus* in Competition with *Bromus tectorum*	Ecological Society of America (Snowbird, UT)
Growth and Physiological Responses of *Bromus tectorum* to Increasing Levels of Salinity	Ecological Society of America (Snowbird, UT)
Growth and Physiological Responses of *Bromus tectorum* to Increasing Levels of Salinity	Northwest Scientific Association (Idaho Falls, ID)
Soil Dynamics in Sagebrush Steppe Habitats	Idaho Academy of Science (Pocatello, ID)
Rationale and Experimental Details of the PC/BE	State of Idaho INEL Oversight Committee
Honey Bees as Monitors of Ecosystem Conditions and Human Health	International Conference on Tropical Bees and the Environment (Pedu Lake, Kedah, Malaysia)
Bird Studies on the INEL	Orinthology Course, South Dakota State University (Brookings)
The Design of the Protective Cap/Biobarrier Experiment	Colorado State University graduate students

INTERPRETIVE SIGNS, POSTERS, AND DISPLAYS

In order to reveal the purposes and findings of INEL ecological research and environmental monitoring, the Foundation creates and places illustrative media—signs, displays, and posters (Table 2).

An interpretive sign, at the Protective Cap/Biobarrier Experiment site on the Experimental Field Station, explains the experiment to visitors in a concise and attractive manner.

The Foundation designed and produced a portable display describing the INEL Offsite Environmental Surveillance Program. It appeared at 12 locations. The display shows the extent of the INEL's offsite surveillance program, interprets recent results, and explains basic radiation science. Information handouts and surveillance program reports were available at the display. The display premiered at Grand Teton Mall in Idaho Falls. Using the display, we conducted a tour of malls in Pocatello, Twin Falls, Coeur d'Alene, Moscow, Lewiston, and Boise, and the post office in Hailey during July and August. Foundation staff members were on hand during these appearances to answer questions. Beginning in September, the display was placed in schools and libraries for month-long appearances. Eastern Idaho Technical College was the first location, followed by the Idaho Falls Public Library in October, the Idaho Falls Center for Higher Education in November, and the Blackfoot Public Library in December.

Foundation scientists created six posters for presentation at scientific meetings. Of particular note, the Foundation was invited to present a poster ("Research Parks and NEPA: Two Decades of Symbiosis") in Washington, DC, at a conference celebrating the 25th anniversary of the National Environmental Policy Act.

TABLE 2. FOUNDATION SIGNS, POSTERS, AND DISPLAYS DURING 1995

Title	Audience
Research Parks and NEPA: Two Decades of Symbiosis	NEPA25 Conference (Washington, DC)
An Experimental Comparison of Protective Caps for Burial of Hazardous Waste Poster	DOE Technology Information Exchange Workshop (Cincinnati, OH)
Cover Demonstration Project Poster	DOE Technical Information Exchange Workshop (Cincinnati, OH)
INEL Offsite Environmental Surveillance Program Display	Grand Teton Mall shoppers (Idaho Falls, ID)
INEL Offsite Environmental Surveillance Program Display	Pine Ridge Mall shoppers (Pocatello, ID)
INEL Offsite Environmental Surveillance Program Display	Hailey (ID) Post Office customers
INEL Offsite Environmental Surveillance Program Display	Magic Valley Mall shoppers (Twin Falls, ID)
INEL Offsite Environmental Surveillance Program Display	Silver Lake Mall shoppers (Coeur d'Alene, ID)
INEL Offsite Environmental Surveillance Program Display	Palouse Empire Mall shoppers (Moscow, ID)
INEL Offsite Environmental Surveillance Program Display	Lewiston (ID) Center Mall shoppers
INEL Offsite Environmental Surveillance Program Display	Boise (ID) Towne Square Mall
INEL Offsite Environmental Surveillance Program Display	Eastern Idaho Technical College (Idaho Falls, ID)
INEL Offsite Environmental Surveillance Program Display	Idaho Falls (ID) Public Library

TABLE 2 (CONTINUED). FOUNDATION SIGNS, POSTERS, AND DISPLAYS DURING 1995

INEL Offsite Environmental Surveillance Program Display	Idaho Falls (ID) Center for Higher Education
INEL Offsite Environmental Surveillance Program Display	Blackfoot Public Library
Incorporating Ecological Principles into Ecological Risk Assessment	Second World Congress of the Society of Environmental Toxicology and Chemistry
Protective Cap/Biobarrier Experiment Interpretive Sign	Visitors to the Experimental Field Stations
Observations of several insect species exploiting soils associated with the harvester ant	Orma J. Smith Museum of Natural History, Albertson College of Idaho (Caldwell)
Screening Radionuclides for Ecological Risk Assessment at the INEL	Second World Congress of the Society of Environmental Toxicology and Chemistry (Vancouver, British Columbia, Canada)

PUBLICATIONS

Research findings become accepted by the scientific community after they are scrutinized through peer review and published as a technical report or in a scholarly journal. During 1995, six reports were published by the Foundation (Table 3). In addition, two reports, with late 1994 publication *dates, Radioecology and Ecology Publications of the Idaho National Engineering Laboratory: 1974-1994*, and *INEL Offsite Environmental Surveillance Program Report for the Second Quarter of 1994*, were distributed early in the year. Audiences for Foundation reports range in size from a few dozen to several hundred individuals.

TABLE 3. FOUNDATION REPORTS PUBLISHED DURING 1995

Report Number	Report Name	Author(s)
ESRF-004 (3QT94)	INEL Offsite Environmental Surveillance Program Report for the Third Quarter of 1994	Russell Mitchell, Don Peterson, Amy E. Adams
ESRF-004 (4QT94)	INEL Offsite Environmental Surveillance Program Report for the Fourth Quarter of 1994	Don Peterson, Russell Mitchell, Amy Adams
ESRF-006	A Survey of 14 Caves on the Idaho National Engineering Laboratory	Scott Earl, Randall C. Morris
ESRF-007	Environmental Science and Research Foundation Annual Technical Report: April 11-December 31, 1994	Timothy D. Reynolds, Randall C. Morris, O. Doyle Markham (eds.)
ESRF-009 [also DOE/ID-12082(94)]	Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1994	Russell G. Mitchell, Don Peterson, Diana L. Hoff
ESRF-010	In Summary: Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1994	Amy E. Adams, Russell G. Mitchell, Don Peterson

In addition to Foundation published reports, Foundation researchers had 27 technical, peer-reviewed articles and reports published, in-press, or submitted during 1995 (Appendix B).

TRAVELERS' INFORMATION RADIO

A Foundation-operated travelers' information radio station began broadcasting messages about the INEL environment on December 6. Located at the intersection of U.S. Highways 20 and 26, the low-powered transmitter broadcasts on a frequency of 530 AM and is available to persons in the 800,000 vehicles driving on these highways each year. The three-minute repeating messages discuss the environment, natural history, and cultural history of the INEL and the southeastern Idaho desert. Messages are changed every three weeks. Signs three miles from the junction alert travelers to tune in. The station's signal has been picked up from 12 miles away. In response to the station, other DOE laboratories have requested the Foundation's advice on implementing their own travelers' information radio stations.

COMMUNITY MONITORING STATIONS AND PUBLIC INVOLVEMENT IN THE INEL OFFSITE ENVIRONMENTAL SURVEILLANCE PROGRAM

The INEL Offsite Environmental Surveillance Program, operated by the Foundation, extensively monitors the southeastern Idaho environment for INEL contamination. In 1995, it collected more than 2,100 samples on which more than 3,200 analyses were performed. The program provides ample assurances of INEL operational safety. Public awareness of the program's results is integral to allaying fears, correcting misconceptions, and promoting support for the INEL. However, making the INEL environmental surveillance data available to anyone who asks for them is not enough. The Foundation packages the data, along with easy-to-follow interpretations and explanations of their underlying concepts, into reports, report summaries, fact sheets, multimedia presentations, and a portable display.

The Foundation added two components in 1995. First, a 20-person focus group was held in Idaho Falls. The group reviewed the environmental surveillance program and to suggested ways to improve it. A wide variety of interests were represented including environmental activism, higher education, city government, agriculture, fishing, and hunting. A professional external facilitator led the discussions. Group comments focused on public relations and economics. They suggested disseminating results more often, through more channels, to reach more people. They also recommended reducing duplication of efforts between agencies, such as DOE and the State of Idaho INEL Oversight Program.

The second new educational tactic, under development, is a pair of community monitoring stations, to be built at Rexburg and one other southeastern Idaho location. These stations monitor radioactivity and particulates in the air, environmental radiation levels, and weather conditions, providing some real-time measurements and collecting samples for laboratory analysis. The stations will provide community involvement and educational opportunities, as well as actual environmental surveillance data. The Foundation created and designed interpretive signs for the stations and is producing educational materials for the schools where the stations will be located. For example, at Rexburg, data will be transmitted via a local area network to computers in each classroom. These data will then be available for incorporation into the curriculum.

EBR-I NATURE TRAIL

Each summer, about 10,000 visitors stop to visit the Experimental Breeder Reactor-I National Historic Site. If provided an opportunity, many of these visitors might be encouraged to learn more about the sagebrush-steppe landscape around them. For that reason, the Foundation proposed to design, build and maintain a one-mile-long nature trail around EBR-I. The trail would be supported by interpretive signs and a

brochure, with the theme of "The Diversity of the Desert: From Sky to Stone." This proposal was favorably reviewed by DOE-ID, with hopes of Spring 1996 construction. Unfortunately, Congressional and DOE-HQ budget cuts suspended plans for the trail as of January 1996 (D. B. Harelson, DOE-ID, personal communication). However, the idea remains viable and may be pursued using alternative funding sources.

FOUNDATION FOCUS

The bimonthly *Foundation Focus* is the flagship of the Environmental Education Program. Its first full six-issue volume was published for 1995. Newsletter circulation consists of selected individuals and requestors. The number of persons receiving the *Foundation Focus* grew by more than 40 percent, to 572 at the end of 1995. Each issue opens with "From the Desk of the Director." The piece provides an opportunity to recap surveillance and research accomplishments and express plans for future activities. The balance of each newsletter presents a cross section of research findings, monitoring results, and educational opportunities. The newsletter's value as a direct voice of an independent non-profit organization is significant in highlighting important environmental work at the INEL.

CONCLUSIONS

The Foundation's Environmental Education Program seeks to meld two DOE core values: advocating teamwork and respecting the environment (U.S. DOE, no date). The Foundation communicates knowledge openly and candidly, so that decisions affecting environmental quality are made with the best available information. The program's ultimate goal is to elevate perceptions of the INEL in audiences reached by Foundation communications.

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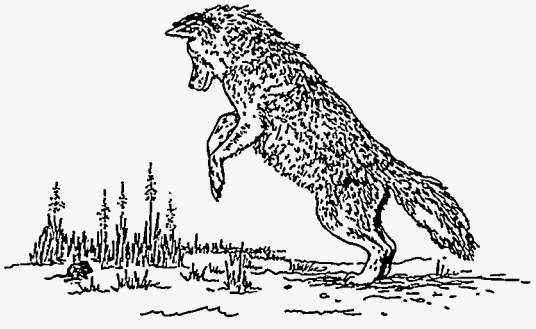


SECTION III

ENVIRONMENTAL SERVICES AND SUPPORT

A MAJOR COMPONENT of the mission of the Environmental Science and Research Foundation is to provide the Department of Energy, Idaho Operations Office (DOE-ID) with a variety of environmental services and support. In 1995, the Foundation performed National Environmental Policy Act (NEPA) field evaluations and conducted environmental surveys to provide information for NEPA documentation, Risk Assessments, and other activities. The Foundation assisted DOE-ID in interactions with the Idaho Department of Fish and Game (IDF&G), the U.S. Fish and Wildlife Service (USF&WS), and other natural resource management agencies. For example, we performed wildlife surveys and provided data on elk and pronghorn populations to DOE-ID and IDF&G. Information on Threatened and Endangered Species was obtained from the USF&WS and interpreted for the Idaho National Engineering Laboratory (INEL) as part of this function. In addition, the Foundation was a valuable source of ecological expertise for the INEL in 1995. Foundation staff members served on committees dealing with a variety of ecological, radioecological, ecological risk, and natural resource issues. Also, the Foundation responded to more than 215 inquiries about environmental or surveillance related issues from INEL personnel, the scientific community, and the general public.

Ecological and natural resource related information is vital to the completion of environmental compliance documentation such as Environmental Assessment efforts and day-to-day management at the INEL. Foundation staff members have more than 80 years collective experience interpreting the environment at the INEL. This knowledge resource is a valuable part of the INEL community. The Foundation makes this knowledge resource available to DOE-ID, Lockheed Idaho Technologies Company (LITCO) and INEL stakeholders. Responding to requests for information and expertise is a growing segment of the Foundation's activities.

Valuable as it is, past experience is insufficient to assure competent decision making. Past experience with the ecological resources of the site must be supplemented with current knowledge about the constantly changing plant and animal populations on the INEL. For this reason, plant and wildlife surveys must be completed on a regular basis. Generally speaking, such surveys must then be interpreted by competent ecologists to be of value to decision makers. The Foundation conducts and interprets those surveys.

The Foundation's role in performing and interpreting plant and animal surveys complements its role in transferring information to the public, state and federal agencies, and legislators. The quality of the environment on and near the INEL is important to most local residents because it is one of the last large, undisturbed areas of sagebrush steppe remaining in the western United States, and is an important habitat for game animals. Our knowledge of the current condition of the populations of plants and animals enables us to respond quickly and accurately to public concerns about environmental issues involving the INEL. For example, past wildlife depredation on the agricultural areas surrounding the INEL prompted criticism of DOE by IDF&G and local legislators. Knowledge of the current status and trends in the populations of elk and pronghorn helps the Foundation anticipate depredation problems, and guard against, or respond to such criticism.

PROGRAM OBJECTIVES

The Foundation's specific environmental services and support objectives are to:

- Respond to requests from DOE-ID, other DOE sites, other State and Federal agencies, and members of the public for assistance, advice, and information on a wide range of ecological issues, including wildlife and environmental surveillance.

INEL managers as well as resource managers at other DOE facilities, or with other State and Federal Agencies, require information about the INEL environment to effectively manage the resources in their care. The Foundation is the primary repository of such information. In addition, responding promptly and accurately to these requests is an important part of the INEL initiative to be open and honest about environmental issues. Because the environmental picture at the INEL is generally positive, this also provides positive public relations for DOE.

- Conduct field investigations and offer ecological recommendations for the NEPA process.

Most Environmental Checklists require biological evaluations and many require field investigations. The Foundation performs these evaluations and investigations. The Foundation also provides current information about the plant and animal species that inhabit the INEL, including threatened, endangered, or otherwise listed species, for use in Environmental Assessments and Environmental Impact Statements.

- Coordinate and participate in studies to determine the status of Threatened and Endangered, or otherwise important species on the INEL.

The INEL is habitat for one Threatened Species (Bald Eagle), eight candidate (C2) species, and nine other listed species of concern. Monitoring these species on the INEL is necessary to ensure that DOE-ID is able to meet its legal obligations with regard to the Endangered Species Act. Monitoring these species and their habitats assists in conducting NEPA field evaluations for activities at the INEL. In addition, depredating species (pronghorn and elk) and other game species (sage grouse and mule deer) are of interest to the local public and other State and Federal agencies. Monitoring these species helps establish and improve DOE-ID's credibility with these groups.

Breeding Bird Surveys have proven to be an effective method of monitoring ecological and environmental change. For this reason, the Foundation continues to conduct annual Breeding Bird Surveys. For more information on this effort, see the research report titled "Breeding Bird Surveys on the INEL" in Section V of this report.

- Serve as a point of contact for environmental expertise and information exchange with the USDA Forest Service, USDA Animal and Plant Health Inspection Service (Animal Damage Control [ADC]), USDA Dubois Sheep Experiment Station, USDI National Biological Service (NBS), USDI Bureau of Land Management (BLM), USDI National Park Service, and IDF&G in matters involving natural resource management.

Sharing information with these agencies is important for enhancing and maintaining DOE's credibility with them. The Foundation has specific responsibilities with respect to some of these agencies. For example, as part of the DOE Memorandum of Understanding with BLM that established the grazing zones on the INEL, DOE agreed to fund predator control by ADC in the grazing areas. The Foundation funded and administered that program for DOE.

During some years the INEL is winter range for one third of all the pronghorn in Idaho and up to 250 elk. Besides being game species, these animals have a history of depredation on the agricultural fields

surrounding the site. The IDF&G is responsible for managing this depredation problem. Because these animals spend time on the INEL, an area closed to hunting, IDF&G looks to the DOE for assistance. The Foundation contributes to the dialogue between DOE and IDF&G on this and other issues. For example, the Foundation provides current information about animal population trends to IDF&G and has assisted in the coordination of elk removal operations.

Raptor populations are important indicators of ecological and environmental change. Three raptors that potentially inhabit the INEL are either listed as Threatened or candidates for listing (C2) under the Endangered Species Act. For this reason, the Foundation participates in the annual midwinter eagle count sponsored by the NBS. On the INEL, the Foundation expands this count to include all raptors. This count enables us to track population trends and to compare trends on the INEL with those in other, similar locations. These data help the biological evaluation of construction and other activities on the INEL to prevent further decreases in sensitive species.

- Correspond with USF&WS to satisfy the requirements of Section 7 of the Endangered Species Act and exercise local authority to determine whether proposed developments on the INEL require formal Biological Assessment consultation with that agency.

- Coordinate and encourage use of the Idaho National Environmental Research Park by ecologists, environmental scientists, and other natural resource scientists.

The boundaries of the INEL enclose a large expanse of nearly undisturbed sagebrush steppe habitat. This unique environment provides an excellent opportunity for environmental scientists and ecologists to study natural processes and, in particular, the impact of human energy development on such systems. For this reason, DOE designated the INEL as a National Environmental Research Park in 1975. As coordinator of the Research Park, the Foundation encourages scientists to perform research on the INEL, coordinates their work, and assists them with logistics. DOE-ID obtains valuable data about the INEL environment from the studies performed by these scientists. In addition, by supporting this research DOE demonstrates its concern for the environment to the public. Finally, because much of the research is conducted by students seeking graduate degrees, DOE demonstrates its support for science education.

- Review and contribute to documents describing the ecology and radioecology of the INEL whether generated at the INEL, by other DOE sites, or by outside agencies.

PROGRAM ACCOMPLISHMENTS

The following list provides a brief synopsis of the variety and scope of the environmental services and support provided by the Foundation staff. During the contract year of 1995, the Foundation:

- Responded to more than 215 requests for information about our environmental surveillance and research programs, or the environmental contamination, radioecology, and ecology of the INEL.

These requests came from DOE-ID, its contractors, interest groups, the scientific community, and the general public. Responses to these requests included short, informal telephone conversations, formal presentations (Appendix A), and preparation of written documents (Appendix B).

- Conducted 41 field evaluations in support of NEPA at the INEL (Table 1). The Foundation has taken a leading role in monitoring compliance with requirements of Environmental Checklists during the progress of projects at the INEL.

TABLE 1. NEPA FIELD INVESTIGATIONS CONDUCTED BY THE ENVIRONMENTAL SCIENCE & RESEARCH FOUNDATION DURING 1995.

Contractor	Project Title
LITCO	- Monitoring wells near PBF, MWSF, and CFA Waste Water Land Application Project - Expansion of two drainage basins at PBF-WERF - CFA Administrative Support Facility - Demolition of WMO-601/601A, AEF-603, & ancillary components - Revision of location of monitoring well near PBF - Electrical Upgrade at CFA and ICPP - Drilling of monitoring wells at ICPP - New transmission line from CFA to RWMC - Power and telephone lines to CFA Landfill - Upgrade Van Buren Blvd. from Hwy 20/26 to EBR-1 - New ICPP Radiochemical Counting Facility - Release of test water from TRA treatment ponds - Drill additional monitoring well near TAN - Construction of cattle guard near Spreading Area B - Demolition of Fire Station #2 - Trenching by railroad bed near CFA-640 - Increase power line voltage to Pit 9 - Add additional parking and a batch plant adjacent to Pit 9 - Change scope of well drilling near ICPP - Soil sampling at CFA-674 and Fire Station #2 - Drill test holes for TRA sewer upgrade - Environmental restoration and removal of contaminated soil - Remove basalt rubble to access PBF septic system - Install culvert to upgrade road to NODA - Improvements and routine maintenance at Security Firing Range Complex - Revise location of parking lot and batch plant near Pit 9 - Reinternment of human remains to Prickly Cave - Drilling aquifer monitoring well near RWMC - Move microwave tower from TAN to CFA - Geotechnical soil sampling - Removal of Bunkhouse CFA-613 - Fence installation at RWMC-West Storage Area - Expansion of RWMC sewage lagoon - Revegetation survey for ARVFS NaK - Construction of additional lay down area near RWMC - Candidate sites for Gas Tracer Test LDRD Project
ESRF	- INEL Traveler's Information Radio - Permanent corral posts for elk capture facility - Removal of rhizotrons at the Experimental Field Station
MSE	- Phytoremediation of radionuclide-contaminated soil
USGS	- Monitoring wells at mouth of Birch Creek

- Corresponded with the USF&WS to satisfy the requirements of Section 7 of the Endangered Species Act. Information concerning listed species was disseminated to the DOE-ID NEPA Compliance Officer, the LITCO NEPA Permitting Group, and various INEL contractors.

- Was the district coordinator for the annual mid-winter eagle count sponsored by the USDI National Biological Service.

The district covered the INEL and surrounding counties. Several staff members participated in this count. For the INEL, this was an expanded effort to count not only eagles, but all raptors.

Eight eagles were counted on the INEL during the 1995 survey. One was a bald eagle. This compares to a 13-year average of almost 11 golden eagles and two bald eagles observed per survey. The most common raptor observed on the site during the survey was the rough-legged hawk. One-hundred two rough-legged hawks were recorded, compared to an 11-year average of nearly 64. Due to natural year-to-year variability, changes in numbers of raptors observed were not considered significant when compared to the long-term averages.

- Conducted two big game surveys (midwinter and midsummer) and supplied the resulting data to DOE-ID and the IDF&G.

The midwinter survey took place January 3 and 4, 1995. A total of 1,093 pronghorn, 115 elk, and 31 mule deer were observed. The midsummer survey was conducted from July 31 through August 2, 1995. Fifty-three elk were observed during this survey and the pronghorn population was estimated at 474. There is little question that the pronghorn population is lower now than prior to the harsh winter of 1992-1993. However, numbers seem to be increasing, because only about 265 pronghorn were observed during the midsummer survey of 1994. It is difficult to determine the trend in the elk population on the INEL. Based on both the surveys and depredation problems, numbers are likely increasing.

- Played a lead role in rehabilitating waterfowl affected by construction activities on the TRA sewage lagoons on the INEL. The Foundation collected and maintained water and bird-tissue samples for the investigation of the incident by the USF&WS.

- Provided funding to ADC to conduct predator control on the INEL. During 1995, four sheep and eight lambs were killed by predators on the INEL. In response to complaints by livestock operators, nearly 50 coyotes were taken by ADC personnel.

- The Foundation facilitated use of the Idaho National Environmental Research Park by 33 scientists from 12 universities. These research efforts supported eight research assistants, 36 technicians, seven administrative staff members, 40 temporary employees, and science education for 25 graduate students. A total of 149 university personnel participated in Foundation programs on the INEL. The activities of these research scientists, their students, and their staff are described in Section V of this document.

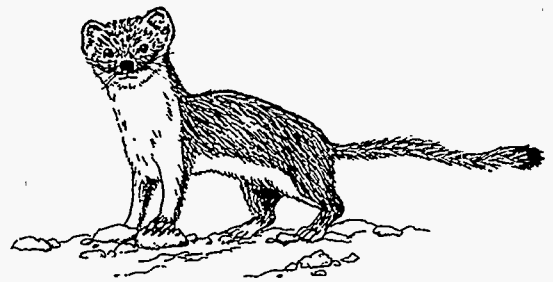
- The Foundation provided technical review of research and management plans for the INEL. For example, Foundation personnel reviewed the following documents and research projects:

Remedy Screening Test Plan: Phytoremediation of Radionuclide-Contaminated Soils at Test Area North's

TSF-07 Percolation Pond, Idaho National Engineering Laboratory (TAN-09-002) Foundation staff members offered a critical review of this proposal.

Comprehensive Facility and Land Use Plan (DOE/ID-10514 • DRAFT) Foundation staff members reviewed this draft plan and submitted more than six pages of comment to the authors.

Idaho National Engineering Laboratory Management Plan for Cultural Resources • FINAL DRAFT (DOE/ID-10361, Rev. 1). At the end of 1995, this document was undergoing review by Foundation staff members.



SECTION IV

RISK ASSESSMENT

FOUNDATION STAFF MEMBERS have participated in the ecological risk assessment guidance development effort at the Idaho National Engineering Laboratory (INEL) from the beginning. During 1995, one Foundation ecologist was a member of the three-person team that led the completion and publication of a methodology for conducting screening-level ecological risk assessments at the INEL. Three papers describing the methodology were presented at two scientific meetings. The team responded to reviewer comments on three articles submitted by invitation last year for publication in a special issue of the *International Journal of Environment and Pollution* on innovative approaches to ecological risk assessment. Two Foundation staff members drafted a human health risk assessment of external dose from radionuclides hypothetically brought to the surface of the BORAX-I and SL-1 burial grounds by vegetation, ants, and small mammals. One Foundation staff member was invited to participate in a working group of prominent radioecologists sponsored by the Department of Energy (DOE) headquarters (HQ). The function of the group was to determine whether current recommendations of the International Atomic Energy Agency (IAEA) for radiation dose limits to non-human organisms are relevant and appropriate for DOE facilities. Foundation staff also participated in activities of the Ecological Risk Task Group of the DOE-HQ-based Risk-Based Standards Working Group.

JUSTIFICATION

The Environmental Protection Agency (EPA), under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires that all Superfund sites perform both human health and ecological risk assessments. In addition, the Action Plan for Implementing the Federal Facility Agreement and Consent Order (FFA/CO) for the INEL requires developing risk assessment guidance for the entire INEL site.

Human health risk assessment is a well-developed discipline and these assessments are conducted using existing guidance from the EPA. However, ecological risk assessment is not well-developed, particularly for primarily terrestrial ecosystems like the INEL. In this case, guidance is not available and must be developed specifically for the site. The tremendous variety of contaminants, pathways, and species of potential concern across the INEL makes this a particularly difficult and time-consuming task. It requires knowledge of the contaminant distribution on the site, its ecology and radioecology, and expertise in risk assessment methodology.

The Foundation has participated in the development of guidance for ecological risk assessment from the beginning of this effort at the INEL. As coordinators of the National Environmental Research Park and the primary organization for the study of the ecology and radioecology of the INEL, we have unique expertise that is critical to the success of the guidance development effort.

Successful ecological risk assessment cannot occur in a vacuum. It is important to coordinate our efforts at the INEL with those of other sites to benefit from one another's experience. Thus, participation in the Ecological Risk Task Group of the Risk-Based Standards Working Group is part of the Foundation's mission. This group is developing guidance for ecological risk assessment that is applicable across the DOE complex. In addition to this forum, Foundation staff members presented papers at scientific meetings and in scientific journals in order to share our methodology with, and receive input from, other organizations

involved in ecological risk assessment around the world.

The evolving nature of the Environmental Restoration effort requires quick, accurate, human health and ecological risk analyses of particular projects. The Foundation's expertise in modeling radionuclide transport and calculating doses was a valuable resource to DOE in this area.

OBJECTIVES

Program objectives for 1995 were to:

- Participate, with the INEL Ecological Risk Assessment Group, in developing guidance for conducting ecological risk assessments for the Waste Area Groups at the INEL.

- Participate, with the INEL Ecological Risk Assessment Group, in completing a guidance document for conducting screening-level ecological risk assessments at the INEL.

- Contribute to the development of DOE complex-wide ecological risk assessment strategies and guidance by participation on the Ecological Risk Task Group of the DOE-HQ-based Risk Based Standards Working Group.

- Share the INEL's ecological risk assessment expertise with the ecological risk assessment community through oral presentations at scientific meetings and writing papers for publication in scientific journals.

- Provide human health and ecological risk assessments and assessment advice to DOE as needed.

ACCOMPLISHMENTS

The Foundation had accomplishments related to all objectives during 1995. Specifically, we:

- Continued developing guidance for conducting ecological risk assessments.

One Foundation staff member and two Lockheed Idaho Technologies Company (LITCO) employees headed this development effort. Other team members included LITCO employees and personnel from two consulting firms. The team interacted regularly with one another and with personnel from the EPA, the State of Idaho, and DOE-ID. We continued to refine guidance for screening potential contaminants of concern, grouping ecological components, developing conceptual models, developing ecologically-based screening levels, and interpreting the results of screening-level ecological risk assessments. These efforts led into developing methods for conducting interim scale, and site-wide scale, assessments.

- Collaborated with the other team leaders to complete a draft guidance document for conducting screening-level ecological risk assessments on the INEL.

- Provided environmental data and article reprints describing research conducted by Foundation affiliates. These data were used to develop conceptual models, select contaminants of concern, group ecological components, and complete other activities necessary for ecological risk assessment.

- Participated in a meeting of the Ecological Risk Task Group of the Risk-Based Standards Working Group to begin outlining methods for incorporating the Data Quality Objectives process into Ecological Risk Assessment.

- Interacted regularly by telephone and E-mail with other members of the Ecological Risk Task Group to discuss ideas and share solutions to ecological risk problems which are of interest across the DOE complex.

- Attended and presented papers at the Second World Congress of the Society of Environmental Toxicology and Chemistry in Vancouver, British Columbia, Canada.

This society is the leading society for ecological risk assessment. Attendance provided an opportunity for several fruitful discussions with colleagues from Los Alamos, Savannah River, Oak Ridge, and throughout the world. It also provided opportunity to hear papers which addressed problems of interest at the INEL. A Foundation staff member coauthored two presentations at the meeting.

- Helped the INEL Ecological Risk Assessment Team respond to reviewer comments on three papers.

A Foundation staff member was coauthor of two of the three papers. One paper presents an overview of our methodology and the other discusses our methodology for grouping ecological components. We submitted the papers, by invitation, for publication in a special issue of the *International Journal of Environment and Pollution*. This issue will address innovative approaches in ecological risk assessment.

- Developed a human health risk assessment of external dose from radionuclides brought to the surface by vegetation, small mammals, and ants at BORAX-I and SL-1.

This assessment was conducted on very short notice and involved recalculating several scenarios by a variety of methods. The work was heavily reviewed by other scientists outside the Foundation. The work was cited by DOE-ID as instrumental in obtaining a signed Record-of-Decision for these sites.

- Participated, by invitation, in a working group of prominent radioecologists sponsored by DOE-HQ. The function of the group was to determine whether current recommendations of the IAEA for radiation dose limits to non-human organisms are relevant and appropriate for DOE facilities.

The group's recommendations for dose limits and dose assessment methodologies will be incorporated into the proposed rule 10 CFR 834, Subpart F, scheduled for comment release in early 1996.

PRODUCTS

Tangible products resulting from this work in 1995 included:

- *Guidance manual for conducting screening level ecological risk assessments on the INEL* (VanHorn et al. 1995).

A Foundation staff member collaborated with two LITCO employees to complete this draft. It includes the justification and methodology for conducting the screening-level assessments as well as appendices describing the ecological resources on the INEL, the functional grouping methodology, background data for various contaminants of concern, and the case study. It was used, with input from the team, to perform the screening-level ecological risk assessment for several Waste Area Groups at the INEL.

- Two presentations at the Second World Congress of the Society of Environmental Toxicology and Chemistry in Vancouver, British Columbia, Canada.

A Foundation staff member coauthored these presentations. They included an overview of the INEL guidance for screening radionuclides (VanHorn et al. 1995) and a discussion of the importance of incorporating ecological principles into ecological risk assessments (Morris and McClellan 1995).

- A draft risk assessment of external dose from radionuclides brought to the surface by vegetation, small mammals, and ants at BORAX-I and SL-1 (Morris and Warren 1995).

LITERATURE CITED

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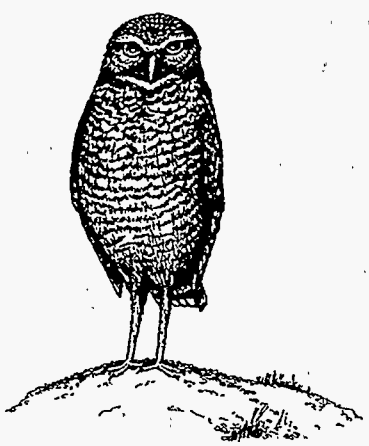

SECTION V

RESEARCH BENEFITTING THE DOE-ID MISSION

PROGRAM DESCRIPTION AND SUMMARY

AT THE IDAHO NATIONAL ENGINEERING LABORATORY (INEL), the Foundation develops scientific goals and conducts environmental research consistent with the needs of the Department of Energy, Idaho Operations Office (DOE-ID). Because the INEL is a National Environmental Research Park, the Foundation also coordinates ecological research on the INEL that is not directly supported by funds from DOE-ID. Research projects benefit DOE-ID by providing credible and defensible environmental data. These data support decision making and regulatory compliance for Waste Management, Environmental Restoration, Spent Nuclear Fuels, and DOE-ID Infrastructure Programs. DOE-ID uses these data for complying with various mandates and regulations including, but not limited to, the National Environmental Policy Act, the Endangered Species Act, Natural Resource Damage Assessment and Risk Assessment sections of the Comprehensive Environmental Response, Compensation, and Liability Act, and the Federal Noxious Weed Act. Moreover, projects are generally consistent with the DOE Secretary's statements on land stewardship responsibilities and they promote the mission statement for National Environmental Research Parks.

Some Foundation research projects and ecological surveys are INEL-wide in scope. These are not tied specifically to any particular DOE-ID program, but generally benefit all programs. For example, the pygmy rabbit is classified by the U.S. Fish and Wildlife Service as a C2 candidate for listing as a Threatened or Endangered species. Surveys conducted for this species indirectly benefit all site activities and programs by providing data regarding its population and distribution on the INEL. These data are needed to satisfy the mandate of the National Environmental Policy Act. Big game surveys (pronghorn, deer, and elk) are also not tied to a particular INEL program, but provide information that allows DOE-ID to work effectively with stakeholders (e.g. adjacent land owners, sportsmen, legislators, and the Idaho Department of Fish and Game) on issues related to crop depredation and hunting.

Some projects are more program specific, for example, research into the effect of plastic liners on radionuclide cycling and transport in evaporation ponds. Although an individual project generally has a single funding source, the research often benefits more than one major INEL program. Table 1 summarizes which major INEL programs benefit most from particular research projects.

In 1995, the Foundation conducted research, data analysis, and interpretation on 23 projects. We developed technical publications from three projects for which field work was previously completed. Many individual research projects were related, providing a more comprehensive approach to a particular goal. Projects could be organized into three general categories: (1) contaminant transport, detection, and effects; (2) stewardship of natural resources; and (3) ecology of waste covers. Results from some projects, such as the suite of experiments associated with the Protective Cap/Biobarrier Experiment, can potentially make significant contributions to municipal and industrial landfill practices, including low-level radioactive waste management. These contributions can result in a considerable future cost savings to DOE.

TABLE 1. DOE-ID PROGRAM BENEFICIARIES OF SPECIFIC ENVIRONMENTAL SCIENCE AND RESEARCH FOUNDATION RESEARCH PROJECTS

Research Project	DOE Program[1]			
	Infra.	WM	ER	SF
Wildlife Use of Man-Made Ponds on the INEL		■	■	■
Breeding and Wintering Populations of Raptors on the INEL	■	■	■	■
PC/BE I: Comparison of Four Protective Cap Designs		■	■	
PC/BE II: A Comparison of Water Use by Annuals and Perennials		■	■	
PC/BE III: The Effect of Vegetation Height		■	■	
Mitigating Long-Term Impacts of Small Mammal Burrowing		■	■	
Effectiveness of Biobarriers in Preventing Harvester Ant Excavation		■	■	
Soil Subsidence and Snowmelt Erosion on Waste Disposal Sites	■	■	■	
Distribution and Abundance of the Pygmy Rabbit, a C2 Species	■	■	■	■
Concentrations of Heavy Metals in Populations of Small Mammals		■	■	
Distribution and Abundance of Cheatgrass	■	■	■	
Long-Term Vegetation Dynamics	■	■	■	
Habitat Use and Movement Patterns of Mule Deer	■			
Plutonium Distribution Among Soil Phases at the INEL		■	■	
Lichens as Biomonitors of Air Pollution		■	■	
Breeding Bird Surveys and Long-term Data Analyses	■	■	■	■
Distribution and Status of Reptiles and Amphibians on the INEL	■	■	■	■
Monitoring Environmental Contaminants with Honey Bees		■	■	■
Diversity of the Ant Fauna over the INEL	■	■	■	■
Radioactivity Cycling in Plastic Lined Evaporation Ponds		■		
^{129}I in Effluents from the ICPP: Concentrations in Plants & Animals		■	■	■
Surface Water Penetration at the Subsurface Disposal Area		■	■	
Trace Elements & Organics in SDA Soils	■	■	■	■

[1] DOE Program abbreviations: Infra. = Infrastructure, WM = Waste Management, ER = Environmental Restoration, SF = Spent Fuels.

It is fundamental to the Foundation's research program to include regional, and other, universities in the research process. This association is mutually beneficial. Universities provide specialized expertise at a reasonable cost to complement the skills of Foundation staff. University faculty and students benefit from educational and research opportunities offered by the Foundation. Four Foundation staff members and 12 University Affiliates had lead roles in research projects. University personnel included 66 university researchers, graduate students, and research assistants. Other Foundation staff members and university personnel supported different phases of the research. A total of 149 university personnel participated in Foundation research during 1995.

Products from Foundation research are mostly information, in the form of reports and publications. These provide factual and citable sources for various INEL documents (e.g., the *DOE Programmatic Spent Nuclear Fuel Management and INEL Environmental Restoration and Waste Management Environmental Impact Statement*). These products provide a credible, defensible scientific basis for making informed decisions regarding INEL operations, land and natural resource stewardship, and many other topics. Because a research project is not complete until the information is published in the scientific literature, Foundation researchers are required to publish in peer reviewed journals. They are also strongly encouraged to recast the information in non-technical outlets. In 1995, the Foundation produced, submitted,

or published 23 technical articles for publication in appropriate scientific journals, six Foundation Technical Reports, and two articles in the popular literature. Three Principal Investigators are preparing books, or book chapters, based on Foundation research.

Other tangible products of our research program include designs (e.g., low-level waste covers), scientific equipment development, new research techniques, novel data analysis procedures, and creative application of existing technologies in new areas.

A product in common among all the projects, and deserving special recognition, is new scientists with advanced degrees. Generally, one or more graduate students work under the direction of a Principal Investigator on each of the research projects. These students receive training in research principles, field experience, and report writing while conducting research for the Foundation. The research provides substance for a Master's thesis or Ph.D. dissertation and satisfies the research requirements for an advanced degree. Twenty-four Master of Science students and one Ph.D. student were supported by their participation in Foundation research.

The following summaries of individual research projects detail the scope of each project, tell why it was important to conduct each investigation, list major accomplishments, describe important results, and identify products produced during 1995. Some projects are in their infancy, and accomplishments such as locating a suitable study area or installing equipment, are more common than product completion. For more mature projects, field work may be complete, and products, such as technical publications and presentations, will dominate.

WILDLIFE USE OF MAN-MADE PONDS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Lester D. Flake[1]

ABSTRACT—Data from the previously completed field research regarding wildlife use of ponds were further analyzed and several technical publications were developed. Efforts were concentrated on pond use by deer, pronghorn, waterfowl, night hawks, swallows, and birds overall. One manuscript was published, two others were completed and reviewed by the Foundation, and two abstracts were prepared and submitted for the Annual Conference on Wetlands Restoration and Creation.

KEYWORDS: *Man-made ponds, wastewater ponds, wildlife.*

JUSTIFICATION

In a cold desert ecosystem such as the Idaho National Engineering Laboratory (INEL), water may be highly limiting to many wildlife species. There is a broad array of vertebrate species associated with wastewater ponds on the INEL. Species such as the Sora (*Porzana carolina*) and Eared Grebe (*Podiceps nigricollis*) appear during the reproductive season on man-made ponds such as the north cell of the Naval Reactor Facility (NRF) and the west pond at Argonne National Laboratory West (ANL-W). Both species are dependent on wetlands with at least some emergent vegetation, which the NRF and ANL ponds have available. These two ponds demonstrate the value of ponds in increasing species richness in the desert ecosystem. Because natural ponds containing water throughout the year or during the entire summer are almost nonexistent on or near the INEL, man-made ponds have a major role in increasing and maintaining biodiversity on the INEL.

Empirical and quantitative data indicate wastewater ponds on the INEL are an important and, for some species, necessary resource for wildlife (Howe and Flake 1988, 1989). However, statistically significant, low-level, radionuclide contamination was observed in several bird species and mammals associated with radionuclide leaching ponds (Halford and Markham 1978). Although studies of animal movements (Browers 1983, Browers and Flake 1985, Connelly et al. 1988, Howe and Flake 1988, Hoskinson and Tester 1980, Laundré and Keller 1981, Reynolds 1984, Woodruff and Keller 1982) provide important information on the potential for contaminant movement to off site areas, little is known about wildlife use of ponds and subsequent potential exposure to contaminants.

This information will be useful for Department of Energy's Environmental Risk Assessments. It will also support environmental documentation and policy such as the National Environmental Policy Act and Natural Resource Damage Assessment. Information on pond characteristics in relation to wildlife use can be used to design future ponds on the INEL to increase or decrease wildlife use.

Between 1991 and 1993, Cieminski (1993) examined and reported wildlife use of ponds on the INEL. The objectives of that study were to:

- Determine daily and seasonal patterns of pond use by birds, and intermediate to large mammals.
- Estimate visitation rates and, where possible, actual numbers of birds and

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mammals using ponds and identify the functional value of ponds for these species.

- Determine pond characteristics that are associated with use of a pond by a particular bird or mammal species.

- Provide information for predicting the wildlife potential of new ponds constructed at the INEL based on pond characteristics.

That study indicated that INEL ponds had greater numbers of individual invertebrates, but fewer taxa (groupings of taxonomically similar organisms such as all rotifers or all daphnia), than did natural ponds in other studies. High numbers of invertebrates may have been linked to the lack of fish predators and the high levels of nitrogen and phosphorus, particularly in ponds receiving sewage effluent. The abundance of invertebrates likely influenced bird use. INEL ponds were used by a minimum of 144 bird species. Peak numbers of species occurred from April through September. Wastewater ponds provided important feeding and resting areas for migrant birds. They also provided watering, feeding, and reproductive sites for many bird species that reproduce on the INEL. The greatest numbers of bird species were found at large, nutrient rich ponds surrounded by dense grass or shrub cover. Numbers of individuals within a species or species grouping were often influenced by other pond characteristics. For example, shorebirds were attracted to ponds with increased amounts of bare shoreline.

Wastewater ponds also attracted big game species. Mule deer were observed at waste water ponds from June through December . Peak use was during September and October. Pronghorn were most commonly seen at the ponds in July and August although use occurred from May through November. Ponds with more succulent forage on the periphery received the heaviest use by ungulates.

We concluded that many ponds on the INEL are important to a great variety of bird species and several large mammals. They add to the diversity of wildlife on the INEL. Compared with natural wetlands, INEL ponds had fewer taxa but more individuals of most taxa.

OBJECTIVES

The objectives of this effort in 1995 were to:

- Develop and submit manuscripts for publication to appropriate journals, symposia proceedings, or as INEL publications from data previously collected on wildlife use of wastewater ponds on the INEL.

- Respond to journal reviews with appropriate editing and analysis on accepted papers through final publication stage.

PROJECT ACCOMPLISHMENTS

Based on the results of the field work, five technical manuscripts were developed and are in various stages of the publication and review process.

PRODUCTS

One manuscript was published. An overview of the research was given as a classroom presentation. Two abstracts for a national conference were prepared and submitted.

MANUSCRIPTS

- Cieminski, K. L. and L. D. Flake. 1995. Invertebrate fauna of wastewater ponds in southeastern Idaho. Great Basin Naturalist 55:105-116.

- Cieminski, K. L. and L. D. Flake. In revision. Avian communities of wastewater ponds in southeastern Idaho. Proceedings: Annual Conference on Wetlands Restoration and Creation.

- Cieminski, K. L. and L. D. Flake. In revision. Common nighthawk diel activity patterns at desert ponds. Journal of Field Ornithology.

- Cieminski, K. L. and L. D. Flake. In revision. Swallow activity patterns on desert ponds. Journal of Field Ornithology.

- Cieminski, K. L. and L. D. Flake. In revision. Mule deer and pronghorn use of wastewater ponds in a cold desert. Great Basin Naturalist.

ABSTRACTS

- Cieminski, K. L. and L. E. Flake. 1995. Submitted. Bird communities at wastewater ponds in southeastern Idaho. Annual Conference on Wetlands Restoration and Creation.

- Flake, L. D. and K. L. Cieminski. 1995. Submitted. Waterfowl use of wastewater ponds on the Idaho National Engineering Laboratory. Annual Conference on Wetlands Restoration and Creation.

PRESENTATIONS

- Flake, L. D. 1994. Bird studies on the INEL. Classroom Presentation in Ornithology at South Dakota State University, Brookings, SD.

LITERATURE CITED

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Browers, H. W. and L. D. Flake. 1985. Breakup and sibling dispersal of two sage grouse broods. Prairie Naturalist 20:29-37.

Cieminski, K. L. 1993. Wildlife use of wastewater ponds at the Idaho National Engineering Laboratory. Unpublished master's thesis. South Dakota State University, Brookings. 233 pp.

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Halford, D. K. and O. D. Markham. 1978. Radiation dosimetry of small mammals inhabiting a liquid radioactive waste disposal area. Ecology 59:1047-1054.

Hoskinson, R. L. and J. R. Tester. 1980. Migration behavior of pronghorn antelope in southeastern Idaho. Journal of Wildlife Management 44:132-144.

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Howe, F. P. and L. D. Flake. 1989. Mourning dove use of man-made ponds in a cold-desert ecosystem in Idaho. Great Basin Naturalist 49:627-631.

Laundré, J. W. and B. L. Keller. 1981. Home-range use by coyotes in Idaho. Animal Behavior 29:449-461.

Reynolds, T. D. 1984. Daily summer movements, activity patterns, and home range of pronghorn. Northwest Science 58:300-311.

Woodruff, R. A. and B. L. Keller. 1982. Dispersal, daily activity, and home range of coyotes in southeastern Idaho. Northwest Science 56:199-207.

BREEDING AND WINTERING POPULATIONS OF RAPTORS ON THE IDAHO NATIONAL ENGINEERING LABORATORY

Lester D. Flake[1]

ABSTRACT—Previously collected field data were analyzed, technical manuscripts were developed and submitted for peer review, and revisions were made as needed. Work occurred on six separate manuscripts. Two articles were subsequently published in technical journals. One technical manuscript will be submitted early in 1996. Two popular articles were recently completed, and will be submitted for publication when suitable photographs are available. All manuscripts have been reviewed by DOE and the Foundation.

KEYWORDS: *Candidate (C2) species, publications, raptors.*

JUSTIFICATION

The Idaho National Engineering Laboratory (INEL) is designated as a National Environmental Research Park. This provides an excellent field laboratory for monitoring long-term changes in natural populations of wildlife, including birds of prey, and separating natural population variability from impacts of energy related development. Several species of owls, hawks, and eagles occupy the INEL seasonally. The Bald Eagle (*Haliaeetus leucocephalus*) is a winter visitor that is classified as a threatened species. The Ferruginous Hawk (*Buteo regalis*) and Burrowing Owl (*Athene cunicularia*) nest on the INEL and are classified as Candidates (C2) for the Threatened and Endangered Species List.

Birds of prey are considered indicator species, providing a warning to society of unacceptable levels of contaminants in the environment. Their position in the food chain dictates that persistent toxins that accumulate in smaller prey organisms will likely show up in raptors. Thus, raptors can be important as early indicators of contamination problems. Although there is no information indicating a decline in raptor populations on the INEL, previous studies (Craig and Craig 1984) documented that populations of nesting and wintering raptor fluctuate greatly.

Monitoring these species is important for the Department of Energy (DOE). This complies with the spirit and intent of the Endangered Species Act and the National Environmental Policy Act, and demonstrates DOE's commitment to land stewardship (U. S. DOE 1994). Further, the evidence of a stable raptor population suggests a healthy ecosystem and provides a strong message to the public of the adequacy of environmental safeguards on the INEL.

OBJECTIVES

We completed field research on raptors of the INEL in 1994 (Hansen 1994). The research included a comprehensive assessment of past and present raptor population numbers, and identified the distribution of nest sites, nest site characteristics, nesting and fledging success, and priority nesting areas. We also modernized and updated the existing database. Based on those results, our objectives for 1995 were to:

- Evaluate the status of raptors on the INEL listed by state or federal agencies as endangered, threatened, or candidate species, or species of special concern.
- Develop and submit manuscripts to appropriate technical journals.

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- Respond to journal reviews with appropriate editing and analyses or reanalyses to ensure ultimate publication in the scientific literature.

PROJECT ACCOMPLISHMENTS

Six manuscripts were revised in 1995. Two required extensive changes and were subsequently published in scientific journals. Three other manuscripts will be submitted in 1996; a fourth will be resubmitted once additional supporting data are obtained. Arrangements have been made to obtain suitable photographs for three of these.

PRODUCTS

The products include four technical and two popular articles in various stages of the publication and review process, and one classroom presentation.

MANUSCRIPTS

- Hansen, R. W. and L. D. Flake. 1995. Nest structure cohabitation by raptors in southeastern Idaho. Journal of Raptor Research 29:32-34.

- Hansen, R. W. and L. D. Flake. 1995. Ecological relationships between nesting Swainson's and Red-tailed hawks in southeastern Idaho. Journal of Raptor Research 29:166-171.

- Hansen, R. W. and L. D. Flake. Revised. Wintering and prebreeding raptor populations on the Snake River Plain of southeastern Idaho. Journal of Raptor Research.

- Hansen, R. W. and L. D. Flake. Revised. Owl occurrence in the sage-steppe desert of southeastern Idaho. Great Basin Naturalist.

- Hansen, R. W. Revised. Hawks of Idaho's high desert. Idaho Wildlife.

- Hansen, R. W. and L. D. Flake. Revised. Prairie biologists in the desert. South Dakota Conservation Digest.

PRESENTATIONS

- Flake, L. D. 1995. Raptor studies on the INEL. Classroom Presentation in Ornithology at South Dakota State University, Brookings, SD.

LITERATURE CITED

Craig, T. H. and E. H. Craig. 1984. Recent changes in *Buteo* abundance in southeastern Idaho. Murrelet 65:91-93.

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PROTECTIVE CAP/BIOBARRIER EXPERIMENT I: COMPARISON OF FOUR PROTECTIVE CAP DESIGNS FOR BURIAL OF HAZARDOUS WASTE AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Jay E. Anderson[1], Teresa D. Ratzlaff[1], and W. Eric Limbach[1]

ABSTRACT—The Protective Cap/Biobarrier Experiment (PC/BE) was designed to rigorously test the performance of four protective cap configurations for precluding moisture from reaching buried wastes. The objective of the study is to recommend a low-cost cap that uses natural ecosystem processes to protect interred hazardous waste from moisture and minimizes long-term maintenance costs. The cap designs include a simple cap of 2 m of soil, two caps with gravel-cobble biobarriers at 0.5 m or 1 m beneath the soil surface and a total of 2 m of soil, and a cap incorporating a plastic membrane covering a compacted clay layer. The experiment includes three irrigation treatments and two vegetation types. Monitored variables include soil moisture, plant growth and composition, and plant phenology and physiology. Construction of the experimental plots was completed in November 1993; installation of the irrigation system and an herbivore exclosure fence was completed in 1995. Total plant cover doubled on the plots during the 1995 growing season. Despite record high precipitation during 1995, no drainage was observed from any of the soil-only or biobarrier plots under ambient precipitation. The maximum depth of the wetting front was 1.2 m on the soil-only plots. With 550 mm of supplemental irrigation on the high-irrigation subplots, drainage was observed from only two of 18 soil-only or biobarrier subplots, but the wetting front did reach the bottom on subplots of each cap configuration. A slight increase occurred in water storage capacity above the biobarriers, induced by the capillary break at the soil-gravel interface. In contrast to the soil-only and biobarrier plots, water drained from the plastic membrane liner in one of the three EPA plots under natural precipitation. This indicates that 1 m of soil above a flexible membrane liner is insufficient to store the precipitation that is received during a high precipitation year.

KEYWORDS: *Biobarrier, protective cap, hazardous waste, evapotranspiration.*

JUSTIFICATION

Shallow land burial is a common method for isolating industrial, municipal, and low-level radioactive waste. Water intrusion into buried wastes presents the greatest challenge in managing such disposal sites, so exclusion of water must be a priority in their design. The presence of water in the waste zone may promote growth of plant roots to that depth and the subsequent transport of hazardous materials to above-ground foliage. Furthermore, percolation of water through the waste zone may contaminate ground water (Fisher 1986).

Various designs and recommendations for protective caps have been proposed and implemented (Nyhan et al. 1990, Wing and Gee 1990, Anderson et al. 1991), but there have been few attempts to statistically compare their effectiveness and long-term stability. Highly engineered protective caps are very costly to construct, and their designs often fail to account for, or exploit, local climatic characteristics and natural processes. The longevity of some caps depends upon the continued integrity of manufactured materials that are a critical component of the design.

In semiarid areas potential evapotranspiration greatly exceeds precipitation. Thus, it is theoretically possible to prevent water from reaching interred wastes with 1) a simple soil cap that is thick enough to store precipitation received while plants are dormant and 2) a stable plant cover that depletes soil moisture reserves during the

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growing season, thereby emptying the soil's water storage reservoir. Plants are a critical component of a protective soil cap because they extract water from the soil at depths not affected by evaporation. We have demonstrated the feasibility of this soil-plant cover system at the Idaho National Engineering Laboratory (INEL), where 2 m of local soil supporting a healthy stand of perennial vegetation prevented deep drainage of water even under twice the average annual precipitation (Anderson et al. 1991, 1993). However, it is possible that burrowing by small mammals or ants may decrease the water storage capacity of a soil cap and provide paths for preferential water flow through the cap. Biological intrusion barriers (biobarriers) of gravel and cobble restrict burrowing (J. Laundre, unpublished data), but the impacts of such barriers on soil moisture storage and plant rooting depth are unknown.

The Protective Cap/Biobarrier Experiment (PC/BE) was designed to test the efficacy of four protective cap designs at the INEL. The cap designs include a simple 2-m cap of soil, two caps with biobarriers at 0.5 m or 1 m beneath the soil surface and a total of 2 m of soil, and a cap recommended by the Environmental Protection Agency (EPA) that uses a non-permeable plastic membrane covering a compacted clay layer. The biobarriers consists of a 0.3-m cobble layer sandwiched between 0.1-m gravel layers.

The experimental design is a three-way factorial split-strip plot. Irrigation (three levels) is the strip plot factor, cap (four configurations) is the split plot factor, and vegetation (two types) is the subplot factor. Each 16 x 24-m plot is subdivided into 8 x 8-m subplots. The design is replicated three times for a total of 12 plots and 72 subplots (Anderson et al. 1995). Each subplot is planted with either a monoculture of crested wheatgrass (*Agropyron desertorum*) or a native species mixture containing five shrub species, five grass species, and two forb species (Limbach et al. 1994). The experimental plots were constructed at the INEL Experimental Field Station during the fall of 1993.

OBJECTIVES

The ultimate PC/BE objective is to recommend an effective, low-cost protective soil cap for buried wastes at the INEL and other climatically similar repositories. During the first three years we will establish vegetation and collect baseline data (plant establishment, rooting depths, patterns of soil water storage and depletion, and interactions among cap design, vegetation type, and levels of irrigation). We will introduce burrowing ants and rodents in year four. In the fifth year we will apply excess irrigation until cap failure occurs (drainage through the entire cap). Results from these experiments will enable us to predict 1) the amount of precipitation that could fall on the site before a particular cap configuration would fail, and 2) whether burrowing organisms will significantly affect cap performance during high levels of precipitation.

The specific objectives of the PC/BE are to:

- Compare the ability of four protective cap designs to prevent water infiltration into a buried waste zone.
- Estimate plant establishment and survival, canopy development, rooting depths, and water use for each vegetation type.
- Evaluate the impact of placing biological intrusion barriers at different depths on moisture storage capacity of the soil cap.
- Examine the interaction between barrier design and vegetation type regarding plant establishment and survival, changes in plant community composition, plant rooting depths, and patterns of soil water extraction.

- Evaluate the ability of biobarriers to restrict burrowing into protective soil caps and examine the interaction of biobarrier depth and soil water movement in profiles containing burrows.

- Compare costs of constructing the different protective caps.

- Refine recommendations for the design, construction, and maintenance of protective caps at the INEL.

Our first three objectives were addressed during 1995.

PROJECT ACCOMPLISHMENTS

- We compared soil water infiltration, drainage, and depletion among four protective cap designs during a record precipitation year under ambient precipitation and supplemental irrigation.

Total precipitation for the 1995 water year (Oct. through Sept.) was 360 mm. This surpassed the previous 45-yr record of 335 mm in 1963. Mean precipitation for this period is 222 mm. June 1995 was the wettest month on record at the INEL with 118 mm of rainfall, exceeding the previous record of 112 mm in May 1957. Precipitation from March through June was a record 247 mm; the mean precipitation for this period is 97 mm. Under ambient precipitation, soil water recharge reached 1.2 m in the soil-only caps (Figure 1). Soil moisture content increased below the 0.5-m biobarriers on 5 of 18 subplots. On those, the wetting front reached depths of 1.2 to 1.8 m in the 2.5-m cap. On the 1-m biobarrier plots, moisture content increased below the biobarrier on only 1 of 18 subplots; In this case, the wetting front reached a depth of 2.2 m in the 2.5-m cap. Despite a record high precipitation, no drainage was observed from the nonirrigated soil-only and biobarrier plots. Changes in mean water content over the growing season for the four cap configurations under ambient precipitation are shown in Figure 1.

Before irrigation treatments were initiated, water was collected in the caissons from the soil of one EPA plot (about 1,000 L from plot 12). This water drained from the soil above the impermeable liners, demonstrating that 1 m of soil was not sufficient to store the precipitation received. Drainage was not observed from the other two EPA plots.

- We assessed the impact of biobarriers on water storage capacity of the soil above them by applying about 550 mm of water to the high-irrigation subplots between August 1 and 14. We applied this amount of water to ensure infiltration through the biobarriers and a substantial increase in the moisture content of the underlying soil. This will help future evaluation of root growth and water extraction from the soil below the biobarriers.

The wetting front reached the bottom of most of the irrigated subplots following the irrigation treatments. However, water drained from only 2 of 18 subplots. Approximately 30 L each was collected from a soil-only cap and a 1-m biobarrier plot.

Preliminary analyses indicate a slight increase in the water storage capacity of soils above the capillary break imposed by the gravel/cobble biobarrier.

- We compared evapotranspiration (ET) among caps, vegetation types, and irrigation treatments.

Under ambient precipitation, ET estimates were similar for the soil-only plots, the 1-m biobarrier plots, and EPA caps (Table 1). ET estimates for the 0.5-biobarrier caps were lower than those for the other caps. This reflects a large difference in the amount of water readily available to plants at the

beginning of the growing season. Readily available water is that above biobarriers or the impermeable liner on the EPA plots, or in the top meter of soil on the soil-only plots. For example, in March the mean depth of water stored above the 0.5-m biobarriers was 113 mm; 231 mm was stored above the 1-m biobarriers.

Our estimates show that, on average, more than 300 mm of water was removed via evapotranspiration from the irrigated plots after irrigation was applied in early August (Table 1). This suggests that actual ET was near the potential ET for this period and indicates the capacity of these perennial species to pump water into the atmosphere.

TABLE 1. EVAPOTRANSPIRATION ESTIMATES (MM) FOR THE 1995 GROWING SEASON FOR FOUR CAP DESIGNS, TWO VEGETATION TYPES, AND TWO IRRIGATION TREATMENTS ON THE PROTECTIVE CAP/BIOBARRIER EXPERIMENT PLOTS AT THE INEL. ET WAS ESTIMATED BY SUBTRACTING VOLUMETRIC SOIL WATER CONTENT ON SEPTEMBER 20 (MAXIMUM DEPLETION) FROM THAT ON MARCH 31 (SPRING RECHARGE) AND ADDING PRECIPITATION RECEIVED AND IRRIGATION APPLIED DURING THAT PERIOD.

	Ambient Precipitation		Irrigation Applied	
CAP	Crested Wheatgrass	Native Species	Crested Wheatgrass	Native Species
SOIL-ONLY	433	384	761	765
0.5-m BIOBARRIER	371	370	720	689
1.0-m BIOBARRIER	421	401	696	761
EPA DESIGN	415	394	886	848

- We compared plant cover among caps, irrigation treatments, species, and growth form.

Plant cover on the native species subplots doubled during the 1995 growing season. Cover of crested wheatgrass was double that of the native species (Table 2; cover of crested wheatgrass was not estimated in the spring). On the native species subplots, shrub cover increased by a factor of three, whereas grass cover decreased slightly. The decrease in native grass cover may be the result of competition with shrubs, or with the exotic annual, Russian thistle (*Salsola kali*), which was abundant on the native species plots. Because samples were taken very late in the season, it is also possible that the low cover of perennial grasses reflected fall senescence of these species.

- To estimate depth of root growth, we collected samples of leaves and stems in the spring and fall from plants located on plots treated with tracer chemicals (LiCl and CoCl) and on control plots.

Very small quantities of lithium and cobalt were present in the samples collected in early spring. Differences between treated and untreated plots were not significant, so the quantities detected likely reflect background amounts in the soil. These results indicate that plant roots had not yet reached the depths of the tracer layers in the spring. Analyses of the fall samples are in progress.

- We measured predawn and midday water potentials in the two sagebrush (*Artemisia tridentata*) subspecies on native species plots throughout the growing season. We also monitored phenological parameters (new leaf production, ephemeral leaf drop, inflorescence number and development) for both subspecies.

TABLE 2. PERCENT COVER OF SPECIES ON NATIVE PLOTS (SPRING AND FALL) AND CRESTED WHEATGRASS (FALL ONLY) PLOTS AT THE PROTECTIVE CAP/BIOBARRIER EXPERIMENT, 1995.

	SPRING	FALL	
	Native species	Native species	Crested Wheatgrass
CAP DESIGN			
Soil Only	10	20	46
Biobarrier @ 0.5 m	10	21	36
Biobarrier @ 1.0 m	13	23	42
EPA Design	12	25	48
IRRIGATION			
Ambient	11	21	42
Supplemental	11	25	45
GROWTH FORM (Native plots only)			
Shrubs	6.2	19	
Grasses	5.0	3.6	

IMPORTANT RESULTS

Under ambient rainfall during a record precipitation year, drainage was not observed from any of the soil-only or soil-biobarrier plots. Evapotranspiration ranged from 690 to more than 800 mm (or 3 to >3.5 times the mean annual precipitation for the INEL) from plots that received an additional 550 mm of irrigation. These results indicate that the soil-plant cover system we are testing is effective under extreme climatic conditions.

PRODUCTS

This project produced one publication in the technical literature, and one completed manuscript in 1995.

- Anderson, J. E., R. S. Nowak, K. E. Rasmuson, and N. L. Toft. 1995. Gas exchange and resource-use efficiency of *Leymus cinereus* (Poaceae): Diurnal and seasonal responses to naturally declining soil moisture. American Journal of Botany 82:699-708.

- Anderson, J. E. 1995. Meeting the Challenges: Ecological Solutions - A Soil-Plant Cover System. Manuscript submitted for publication in: Proceedings, Symposium on Ecological Aspects of Waste Management.

Eight presentations were produced as part of this project in 1995.

- Anderson, J. E. 1995. Using natural ecosystem processes for keeping water from reaching interred hazardous wastes. Symposium: Ecological Engineering: a New Paradigm for Ecology. 80th Annual Meeting of the Ecological Society of America. Snowbird, Utah.

- Limbach, W. E. 1995. Using local plant materials for vegetating a severely disturbed site in southeastern Idaho. Annual Meeting, Society for Ecological Restoration. Seattle, Washington.

- Limbach, W. E. and S. P Hardegree. 1995. The effects of seed-priming on the growth of *Elymus lanceolatus* in competition with *Bromus tectorum*. 80th Annual Meeting of the Ecological Society of America. Snowbird, Utah.

- Limbach, W. E. 1995. The effect of seed priming on the growth of thickspike wheatgrass in competition with cheatgrass. Annual Meeting of the Society for Range Management. Phoenix, Arizona.

- Anderson, J. E. 1995. Meeting the challenges: ecological solutions. Symposium: Ecological Aspects of Waste Management. 1995 Meeting, Northwest Scientific Association. Idaho Falls, Idaho.

- Limbach, W. E. 1995. The effect of seed priming on the growth of thickspike wheatgrass in competition with cheatgrass. Presentation, annual meeting Northwest Scientific Association. Idaho Falls, Idaho.

- Anderson, J. E. 1995. Rationale and experimental details of the PC/BE. Presentation to the State of Idaho INEL Oversight Committee.

- Limbach, W. E. 1995. The design of the Protective Cap/Biobarrier experiment. Field seminar presentation to Colorado State University graduate students at the study site on the INEL.

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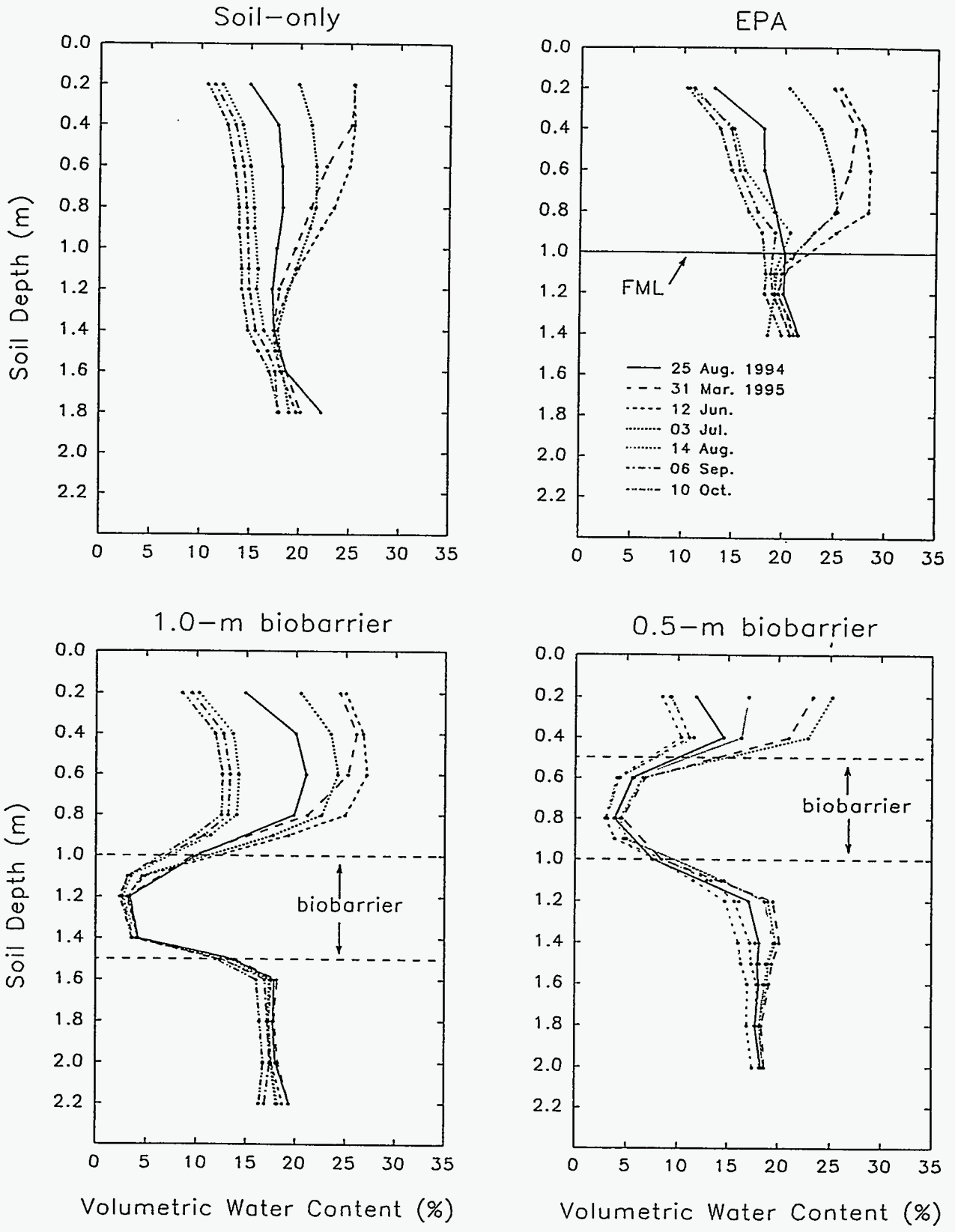

FIGURE 1. MEAN VOLUMETRIC WATER CONTENT AT 0.2-M DEPTH INTERVALS IN THE SOIL FOR THE FOUR PC/BE CAP CONFIGURATIONS AT THE END OF THE 1994 GROWING SEASON AND FOR VARIOUS DATES DURING THE 1995 GROWING SEASON.

PROTECTIVE CAP/BIOBARRIER EXPERIMENT II: A COMPARISON OF WATER USE BY ANNUAL AND PERENNIAL SPECIES ON SIMULATED WASTE BURIAL PLOTS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Jay E. Anderson[1] and Teresa D. Ratzlaff[1]

ABSTRACT—Plants in arid regions typically use all the available soil water during a growing season because potential evapotranspiration far exceeds precipitation. Thus, a cover of perennial vegetation can be used to preclude drainage through soil caps covering buried wastes. However, cheatgrass (*Bromus tectorum*) and other exotic annuals have replaced native perennial species in sagebrush steppe in the Intermountain West. The presence of invasive annual species at the Idaho National Engineering Laboratory poses a risk to the integrity of protective soil caps because annuals may not extract all of the plant-available soil moisture during a growing season. A comparison of water use by annual and perennial species on simulated waste burial plots in 1993 and 1994 indicated that annual species may not use water as completely from the entire soil profile as perennials. These data indicated that replacing perennial species with annuals on a protective soil cap would likely reduce the effective water storage capacity of that soil. Data from 1995, a record precipitation year, indicated again that annual species may not use all of the water available to perennials. However, the mixed stand of annual species did use most of the plant-available soil water. Data on water extraction characteristics of the individual species in monoculture are needed to assess potential implications of year-to-year variability in species composition.

KEYWORDS: Agropyron, Artemisia, Bromus tectorum, *cheatgrass, evapotranspiration,* Leymus, *waste management.*

JUSTIFICATION

In arid regions, the potential for water loss by evapotranspiration (ET, the sum of evaporation from leaf and other surfaces) is far greater than the amount of water that falls as precipitation. Plants in these areas typically use all of the available water in the soil. Available soil water is the difference between the actual volumetric water content and the lower limit of extraction (LLE), the limit to which plants can extract water from a soil (Ritchie 1981). The effective water storage capacity of a soil is the difference between the drained upper limit (field capacity) and the LLE. If a soil cap protecting buried wastes is sufficiently deep to store precipitation received while vegetation is dormant and is vegetated with plants that use all of the stored moisture each growing season, then no water will drain through the soil and into the wastes. Our studies at the Idaho National Engineering Laboratory (INEL) show that a cover of perennial plants will use all available soil moisture in a 2 m protective soil cap during a growing season, preventing drainage into the waste zone (Anderson et al. 1993).

The integrity of native perennial communities in the Intermountain West is threatened by invasion of exotic annual species, especially cheatgrass, *Bromus tectorum* (Klemmedson and Smith 1964, Mack 1981, Young and Evans 1973). Cheatgrass is a short lived, facultative winter annual that has converted much of the sagebrush steppe into annual grasslands. It is present in many areas of the INEL, including areas near the Radioactive Waste Management Complex. Research by Cline et al. (1977) indicated that cheatgrass may not use all the available soil water from depths greater that 0.8 m. Thus, establishment of cheatgrass on protective soil caps could reduce the effective water storage capacity of the soil, resulting in eventual moisture intrusion into the waste zone.

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In the fall of 1992, we broadcast cheatgrass seed onto two simulated waste burial plots to examine soil moisture dynamics in a stand of cheatgrass and to compare its water use with that of Wyoming sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), crested wheatgrass (*Agropyron desertorum*) and Great Basin wildrye (*Leymus cinereus*). These perennial species will use all of the plant-available water in a 2-m soil profile, even during a very wet growing season (Anderson et al. 1993). Although precipitation during the winter and spring was ample, emergence of cheatgrass on the experimental plots in the spring of 1993 was poor. The plots became occupied by dense stands of various annual species, dominated by Jim Hill mustard (*Sisymbrium altissimum*), another aggressive alien. Soil moisture data from the 1993 growing season indicated that the LLE for these annuals may be higher than for the perennial species. This has serious implications for waste management. If the LLE is higher, the effective water storage capacity of a protective soil cap vegetated with annuals would be lower than one supporting perennials. However, in 1994 (a much drier year) the plots were dominated by Russian thistle (*Salsola kali*) and cheatgrass. Soil moisture was extracted to about 10% by volume in the top 1 m of soil, similar to the LLE of perennial species. Below 1 m, the annual species did not use water as completely as the perennial species. We monitored soil moisture in these plots during the 1995 growing season when the plots were again dominated by Jim Hill mustard and cheatgrass. Observing vegetation and soil-water dynamics in these plots for several years will provide valuable information on the long-term effects of annual species occupying of a buried waste site.

OBJECTIVE

- To determine whether annual plant species occupying protective soil caps has a significant impact on soil water storage and depletion.

PROJECT ACCOMPLISHMENTS

- We compared soil water recharge and depletion in three monocultures of perennial species with that of a mixed stand of annual species during the 1995 growing season.

Precipitation during the 1995 water year (October 1994 through September 1995) was greater than any other year on record at the INEL. Moisture recharge over the winter was higher on the annual species plot than on the crested wheatgrass plot (Table 1). The wetting front reached about 1 m on the annual species plot compared with 0.8 m on the crested wheatgrass plot (Fig. 1).

- We estimated water available to plants for three dates during the 1995 growing season (Table 1).

The perennial species all depleted soil moisture to the LLE by the end of the 1995 season. (We defined LLE as the soil moisture content in October of 1994.) On the annual species plot, about 10 mm of water that would have been available to perennial species remained in the top meter of soil. Nevertheless, the annual species used most of the available water by the end of the growing season (Fig. 1), and evapotranspiration estimates for perennial and annual species plots were similar (Table 1).

TABLE 1. MEAN PLANT-AVAILABLE SOIL MOISTURE (MM) AND VOLUMETRIC SOIL WATER CONTENT (%) IN THE UPPER METER OF SOIL FOR STANDS OF THREE PERENNIAL SPECIES AND A MIXED STAND OF ANNUALS FOR THREE DATES DURING THE 1995 GROWING SEASON. ET IS TOTAL EVAPOTRANSPIRATION FOR 27 MARCH THROUGH 19 SEPTEMBER 1995.

	Mean Soil Water Content						
	March		June		Sept.		ET
	mm	%	mm	%	mm	%	mm
Great Basin wildrye	75.3	19.5	60.7	18.1	0	11.8	304
Crested wheatgrass	44.3	16.4	32.5	15.2	0	11.0	277
Wyoming sagebrush	60.8	18.1	57.4	17.7	0	11.3	291
Annual species	74.0	19.4	61.4	18.1	10.2	13.0	284

IMPORTANT RESULTS

Data from 1993 and 1995 indicate the LLE for a mixed annual community may be higher than for native perennial species. This is likely a consequence of annuals having a shorter life cycle and earlier senescence than perennial species. However, the mixed annual community used most of the water available even during a year in which record amounts of rain fell during the growing season. These results suggest that, from a water management viewpoint, a mixed annual community may be an effective vegetative cover on a waste management area. Whether such annual communities can provide effective long-term erosion control is unknown. Moreover, because species composition of annual communities may vary greatly from year to year, further research is needed to determine the LLE for individual annual species growing in monoculture. A stand dominated by cheatgrass could have a very different pattern of seasonal water use than one dominated by Russian thistle or Jim Hill mustard. Also, additional data are needed to decide whether stands of annuals can extract water from deep in a soil. Future experiments will address these questions.

PRODUCTS

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- Ratzlaff, T. D. 1995. Soil water dynamics in sagebrush steppe habitats. Poster, Idaho Academy of Sciences meeting, Idaho State University, April 14-16.

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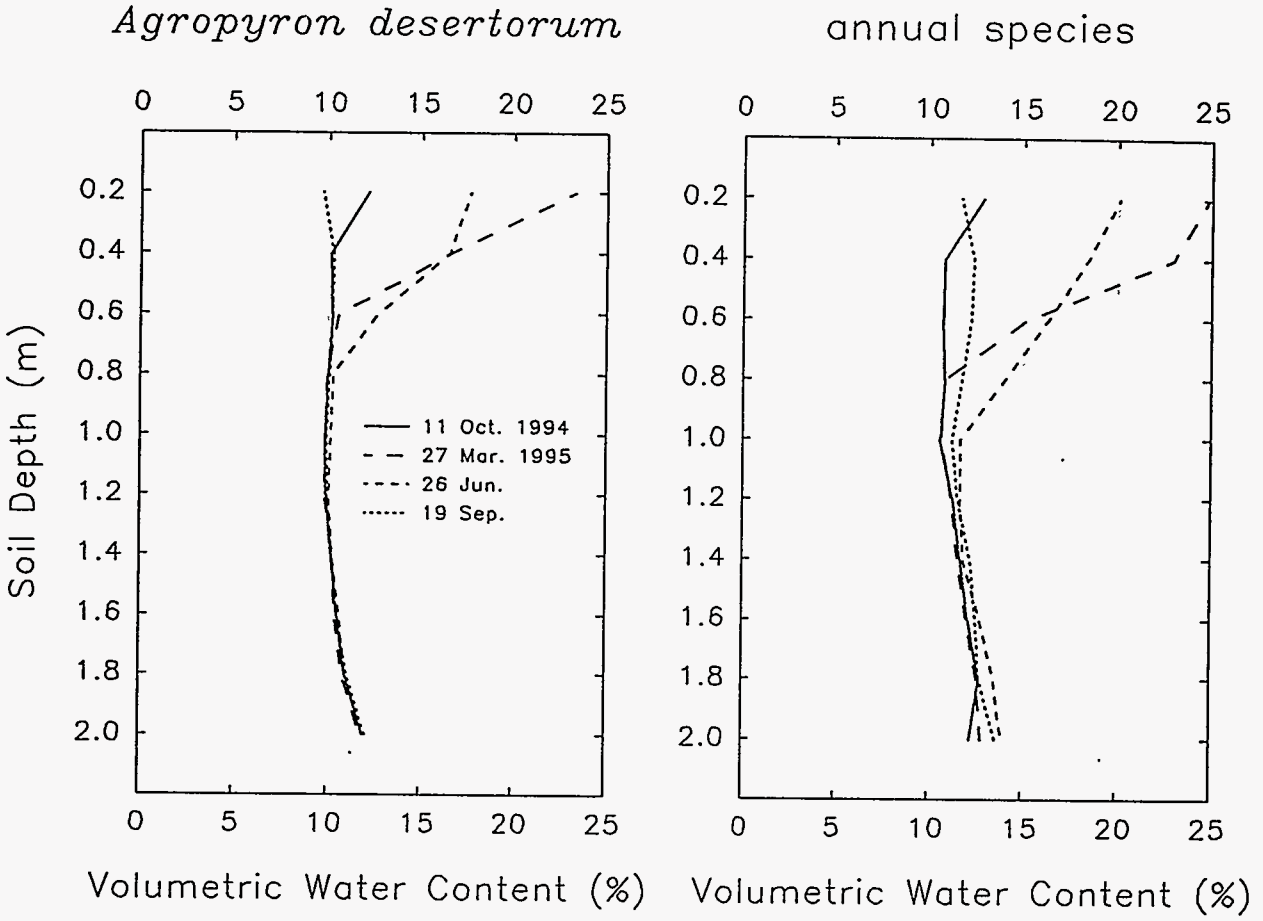

FIGURE 1. VOLUMETRIC WATER CONTENT IN A 2-M SOIL PROFILE FOR *AGROPYRON DESERTORUM* (CRESTED WHEATGRASS) AND FOR A MIXED STAND OF ANNUAL SPECIES ON SIMULATED WASTE BURIAL PLOTS AT THE IDAHO NATIONAL ENGINEERING LABORATORY DURING THE 1995 GROWING SEASON.

PROTECTIVE CAP/BIOBARRIER EXPERIMENT III: THE EFFECT OF VEGETATION HEIGHT ON SNOW ACCUMULATION AND SOIL WATER RECHARGE IN A CRESTED WHEATGRASS STAND AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Teresa D. Ratzlaff[1] and Jay E. Anderson[1]

ABSTRACT—Vegetation management on buried waste sites at the Idaho National Engineering Laboratory includes mowing grasses to prevent deep accumulations of snow. However, in semiarid and arid climates, it may be necessary to leave plants nonmowed so that some snow accumulates. This will provide sufficient water to maintain a healthy vegetal cover. We measured snow depth during winter and soil moisture during the growing season in mowed and nonmowed crested wheatgrass (*Agropyron desertorum)* stands from 1990 through 1995. The nonmowed plot consistently accumulated more snow and had more soil moisture in the spring. Plant cover was similar between treatments, but, in 1994, biomass in the nonmowed plot was greater than in the mowed plot. Snow depth and spring soil moisture were significantly higher in the nonmowed plot in 1995. Soil moisture was similar on both treatments at the end of the season.

KEYWORDS: Agropyron desertorum, *crested wheatgrass, snow accumulation, soil moisture recharge.*

JUSTIFICATION

Interred waste sites are routinely mowed to discourage deep accumulations of snow because drifted snow may result in water infiltration that exceeds the water holding capacity of the soil cap. However, in semiarid climates, it may be important to encourage snow accumulation on the soil cap to provide sufficient water to maintain a healthy stand of plants. In areas where grasses are mowed, snow is lost by wind and there may be insufficient recharge of soil moisture to maintain plant vigor (e.g., see Sharp et al. 1992). Our studies (Anderson et al. 1993 and this volume) show that crested wheatgrass (*Agropyron desertorum*) uses all of the available water in 2 m of soil during the growing season, even when precipitation is augmented to much more than record amounts. Thus, if the soil cap is deep enough to store the moisture it receives (see Anderson et al. 1993) then snow accumulation to the height of the mature vegetation should not result in deep drainage. However, it will help to maintain a vigorous stand of plants.

To explore the relationship between vegetation height and snow accumulation, we established two adjacent 50 x 100-m plots in an extensive crested wheatgrass stand at the Idaho National Engineering Laboratory (INEL). One plot was mowed each November from 1990 through 1994. Snow depth and stored soil moisture were estimated for each plot (n=15 per treatment).

OBJECTIVES

- Examine relationships between snow depth and vegetation height, snow water content, and soil water content.
- Examine the combined effects of annual mowing and soil water recharge on plant cover and biomass.

PROJECT ACCOMPLISHMENTS

- We compared snow depth between mowed and nonmowed crested wheatgrass plots during the winter of 1994-95.

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Maximum snow depth was recorded in December and was significantly greater for the nonmowed treatment. These results are consistent with results from all previous years.

- We compared soil moisture in mowed and nonmowed crested wheatgrass plots.

Soil moisture was significantly higher at 20 and 40 cm in the nonmowed treatment on 10 April 1995. On 7 July, soil moisture was greater in the nonmowed plot at 20 cm, but was similar in both treatments at 40 cm. At the end of the growing season, soil water content was similar for both treatments.

Important Results

Snow accumulation and consequent spring soil water content were significantly decreased in a crested wheatgrass stand by fall mowing. Annual mowing also decreased above-ground plant biomass. During drought periods, this could result in a loss of vigor or plant mortality (e.g., Sharp et al. 1992). On the INEL, we recommend that plants not be mowed where soil caps are sufficiently deep (1.6 - 2 m) to store precipitation received. This will eliminate the expense of mowing and help maintain the integrity of the vegetal cover.

Products

This project is in the data acquisition phase. Thus, we did not complete any products from this research during 1995.

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Anderson, J. E., R. S. Nowak, T. D. Ratzlaff, and O. D. Markham. 1993. Managing soil moisture on waste burial sites in arid regions. Journal of Environmental Quality. 22:62-69.

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MITIGATING LONG-TERM IMPACTS OF SMALL MAMMAL BURROWING ON HAZARDOUS WASTE AREA CLOSURE

John W. Laundré[1]

ABSTRACT—The intrusion of burrowing mammals into hazardous waste areas (biointrusion) and subsequent waste transport away from the disposal site is a problem on older waste areas and continues to be a concern for future closures. This study's objective is to determine the effectiveness of three types of material (biobarriers) in preventing small mammal burrowing into waste areas. The three materials are 1) 5 to 10-cm cobble, 2) chipped gravel, and 3) a mixture of gravel and cobble. Townsend's ground squirrels (*Spermophilus townsendii*) and Ord's kangaroo rats (*Dipodomys ordii*) were introduced into enclosures containing 50-cm thick layers of these materials overlaid by native soil. An additional objective was to determine if creating such biobarriers in the presence of burrowing mammals might alter soil moisture patterns and compromise the waste cap integrity. After two years, there is no evidence that test animals have burrowed through the biobarrier layers. Ambient precipitation during the last two years has not provided a critical test of the impact on soil moisture patterns of small mammal burrows above a biobarrier.

KEYWORDS: *Burrowing mammals, biobarrier, Protective Cap/Biobarrier Experiment, soil moisture.*

JUSTIFICATION

Burrowing mammal intrusion into hazardous waste areas (biointrusion) and subsequent transport of waste away from the disposal site is a problem on older areas and continues to be a concern for future closures. Studies of burrow depths on the INEL show that small mammals can potentially burrow deep enough to reach waste material within many waste areas (Reynolds and Wakkinen 1987, Laundré and Reynolds 1993). Work published by other INEL workers also shows that small mammal burrowing has contributed to the upward transport of hazardous waste to waste area surfaces (Arthur and Markham 1983). Consequently, considerable effort is being expended on mitigating waste transport by burrowing mammals and developing accurate, long-term impact assessments of small mammals on hazardous waste areas.

In 1993, the Environmental Science and Research Foundation began a Protective Cap/Biobarrier Experiment on the Idaho National Engineering Laboratory (INEL). The goal is to test the effectiveness of several possible hazardous waste disposal site covers. Incorporated into the designs being tested are biobarriers of either gravel or cobble. These biobarriers, made of readily available material, are designed to prevent burrowing mammals from penetrating the trench cap. They also act as a capillary break to limit water movement into the waste zone. Data are not available on whether the proposed material will act as an effective biobarrier to burrowing mammals.

In 1992, we initiated an effort to test the effectiveness of the proposed biobarrier material. The experimental design consists of 24 circular enclosures. Six enclosures function as controls; the remaining 18 contain various treatments of two barrier materials, as described in the methods section. Townsend's ground squirrels (*Spermophilus townsendii*) and Ord's kangaroo rats (*Dipodomys ordii*) were released into the 24 enclosures in the summer of 1992. From 1993 through 1995 the enclosures were monitored to determine if the animals had dug through the biobarrier material. We will continue to monitor the enclosures during 1996.

The effectiveness of abrupt soil texture changes (capillary breaks) in stopping downward water movement is well

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documented. However, we do not know what impact burrowing mammals may have on capillary break effectiveness. From 1984 through 1992, we studied the effects of small mammal burrows on soil water dynamics on the INEL. Our results indicated that burrows increased the amount of water that entered the soil and the depth to which it penetrated, especially during spring recharge (Laundré 1993). If burrows extend to, or through, a capillary break, then increased water penetration may compromise its effectiveness. A continuing objective is to predict the impact of burrows on the effective water storage of a soil profile above a capillary break.

We developed regression equations from previously collected data that predict the extent of water infiltration from burrows. These equations can be used to predict burrow impacts on water holding capacity above a capillary break. However, winter precipitation (November through February) during the study years (1984-1992) was at or below average (<5.5 cm water). As of 1992, data were still lacking showing the effects of burrows on water infiltration during spring recharge from above normal winter precipitation. Failure of a capillary break is most likely to occur at these higher precipitation amounts, especially if followed by a rapid spring snowmelt. Data are needed from this worst case scenario of above normal precipitation and rapid snowmelt to validate the regression equations we developed.

The enclosures used to test the different biobarriers will provide an additional test of burrow impacts on soil water storage capacity. They will also provide data to help validate the regression equations we developed. Each enclosure consists of 50 cm of the biobarrier material overlain by 50 cm of soil (lakebed material used for waste disposal). The ground squirrels and kangaroo rats constructed several burrows per enclosure. We designed the enclosures to catch enough snow so that, when it melts, the moisture fills the 50 cm layer of soil above the capillary break to the drained upper limit. We will compare the ability of the burrowed soil profiles to hold the prescribed amount of moisture with six control enclosures that lack small mammals.

The results of this work will help determine the potential for using biobarriers to prevent small mammals from burrowing into waste areas. If the tested biobarriers prove effective, they will be valuable to the Department of Energy in its hazardous waste management efforts.

OBJECTIVES

The overall objective of this project is to test the feasibility of using biobarriers to prevent small mammals from burrowing into hazardous waste areas. This objective will be accomplished by:

- Testing the effectiveness of three potential biobarrier layers: 1) 5 to 10-cm cobble, 2) chipped roofing gravel, and 3) a mixture of gravel and cobble. Two small mammal species are used in the experiment: Ord's kangaroo rat (*Dipodomys ordii*) and Townsend's ground squirrel (*Spermophilus townsendii*). These two species are the deepest burrowing small mammals on the INEL (Reynolds and Wakkinen 1987, Laundré and Reynolds 1993). For each species, the hypothesis tested is that each biobarrier layer is equally effective in preventing animals from burrowing beyond the barrier layers.

- Testing the impact of small mammal burrowing on the effectiveness of these biobarrier layers as capillary breaks for water moving into the soil. Our test hypothesis is that moisture movement beyond the capillary break during spring recharge is similar for enclosures containing small mammals and the controls.

PROJECT ACCOMPLISHMENTS

During calendar year 1995 we:

- Monitored burrowing activity of the animals in the enclosures.

In January 1995 a badger entered many enclosures and killed the ground squirrels and kangaroo rats. We spent time trapping new animals for these enclosures.

- Sampled soil moisture above and below the biobarriers during the spring recharge.

IMPORTANT RESULTS

- As of Fall 1995, we found no evidence that either ground squirrels or kangaroo rats penetrated the biobarrier material.

- During this calendar year, there was insufficient snow pack for snowmelt to penetrate to the biobarrier level.

PRODUCTS

We prepared two manuscripts in 1995 for submission to technical journals in 1996:

- Laundré, J. W. Draft. Effect of ground squirrel burrows on plant productivity in a cool desert environment. Oecologia.

- Laundré, J. W. Draft. The relationship between carbon isotope ratios and sagebrush productivity. Ecoscience.

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STUDIES ON THE EFFECTIVENESS OF BIOBARRIERS AGAINST HARVESTER ANT EXCAVATION OF BURIED WASTE

James B. Johnson[1] and Paul E. Blom[1]

ABSTRACT—Harvester ants in the genus *Pogonomyrmex* are known to excavate subterranean nests deeper than 2 m. As such, they pose a threat to the integrity of shallow, subsurface waste closures. In the laboratory, two soil particle sizes were screened for their utility in blocking vertical penetration during ant nest construction. Ants did not breach a 25-cm thick gravel layer incorporated 25 cm below the surface of laboratory nesting soil profiles. However, they did pass through similar layers of cobble and a cobble-gravel mix. Presently various gravel layer thicknesses are being tested. Treatments of 3-, 6- and 9-cm thickness failed to stop *Pogonomyrmex salinus* excavation. Screening of 12-, 15- and 18-cm thicknesses is underway.

KEYWORDS: *Biobarriers, harvester ants, waste disposal covers.*

JUSTIFICATION

Buried contaminants at the Idaho National Engineering Laboratory (INEL) could be excavated by animal activity. Ants are among the organisms that can move buried waste. They are numerous and taxonomically diverse in this area (Allred and Cole 1971; Blom and Clark, unpublished data), and harvester ants, *Pogonomyrmex salinus* Olsen, are widespread over the INEL (Blom et al. 1991a).

Pogonomyrmex salinus galleries can be extensive. Nearly vertical tunnels, about 5 mm in diameter, have been found as deep as 1.8 m on the INEL. Plate-like chambers radiate from the vertical tunnels (Lavigne 1969, Blom 1990). Ants could bring radioactive waste to the surface by excavating these tunnels and chambers. Previous research shows that they concentrate radioactive materials in their mounds if the colonies are located on or near a site with contaminated soil (Blom 1990, Blom et al. 1991b, Blom et al. In preparation). Ant mounds and galleries are likely to influence water infiltration (Blom et al. 1994, Blom and Johnson unpublished data), which could affect redistribution of buried radioactive materials. Thus, in designing a soil cap for shallow waste disposal, incorporating a layer that is resistant to ant excavation would be very beneficial.

Cline et al. (1980) found that a thick layer of cobble retarded penetration of various organisms into a simulated shallow surface disposal trench. In their study, three colonies of *P. salinus* were successfully transferred to the simulated trench by moving a queen and many associated workers. The colonies prospered for two years before they were excavated to determine the depth of penetration. Only one channel of a single nest could be found reaching into the cobble material, from which it was concluded that the material was an adequate biobarrier. Two confounding factors prohibit this conclusion. Barrier placement may have been too deep (1.2 m) to be confident the ants had challenged it. This is especially true given the modest size of the test colonies (1,000-3,000 workers) and the short duration (2 years) of the experimental period. It is likely that depth to the barrier and the time of its exposure to ants was tested and not the material itself. The ants could have easily traversed the

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spaces formed by the cobble given adequate opportunity and biological need.

During this study, in 1992-93, both the cobble and cobble-gravel mix failed to stop ant excavation. However, during the length of the trial (about 6 months), the 25-cm thickness of gravel prevented the ants from digging beyond the 25- to 50-cm section. The thickness of a gravel biobarrier layer needed to stop the ants is unknown.

OBJECTIVES

During 1995, we continued a two-phase (laboratory and field) test of barrier materials under consideration for use at a shallow land burial site. We had the following principal objectives:

- Complete laboratory tests of potential gravel layer thicknesses that were initiated in 1994.
- Initiate laboratory tests of gravel layer thicknesses of 21 cm, and two forms of a 10-30-10-cm layering of gravel-cobble-gravel.
- Refine methods for moving harvester ant field colonies in preparation for moving colonies to the Protective Cap/Biobarrier Experiment (PC/BE) site.

PROJECT ACCOMPLISHMENTS

In 1995 we completed the following accomplishments:

- Completed laboratory tests of potential gravel layer thicknesses initiated in 1994.

We used lake bed sediments collected south of the Radioactive Waste Management Area on the INEL in the ant farm sections. Columns were packed from the base upward. We tested three thicknesses (12, 15, and 18 cm) of subangular rock ranging from 1.8 cm to 2.7 cm diameter in the 25- to 50-cm depth section (Fig. 1). Each treatment was replicated twice along with a control that contained only lakebed soils. A tracer layer of colored aquarium gravel was placed at the bottom of each soil section. Four colors were used (gray, yellow, green and pink) and they were randomly assigned to particular depths within each column.

We collected ants for the laboratory structures during September 1994 from 18 *P. salinus* colonies on the INEL. Only eight of the intended 12 laboratory colonies were supplied with ants. A poor developmental year resulted in field colonies of reduced populations and only eight synthetic colonies could be formed by combining workers from the 18 colonies collected. The colonies were randomly assigned to the three treatments and control.

Observations of the excavation (e.g. tracer layers reached) were recorded periodically throughout the day during the first few weeks of the trial. After that we recorded observations once daily.

We completed the trials for gravel thickness of 12, 15 and 18 cm in spring 1995.

- Initiated laboratory tests of 21-cm thick gravel layer and the configurations used in the field test.

We reconstructed twelve cylindrical laboratory "ant farm"' using 8-inch diameter PVC pipe (schedule 40) and plexiglass (Lexan, 1/4 inch).

Three treatments and a control are being tested in three blocks of colony size. One treatment is the final thickness of gravel (21 cm) in a series running from 3-21 cm in 3-cm increments. We are also screening the treatment layer being used at the PC/BE of 10 cm gravel, 30 cm cobble, and 10 cm gravel. In this case the top of the barrier begins at 25-cm and 50-cm depths. The control is a 1 m soil column lacking any treatment. Colonies collected at the INEL were randomly assigned

to laboratory nest structures within colony size blocks.

We excavated and transferred twelve field colonies to the 12 laboratory nests. The 1995 *Pogonomyrmex* colonies were more populated than those sampled in 1994.

Workers extracted from the near surface soil portions of 12 colonies totaled from 2,486 to 5,807 per nest. After handling and transport mortality, colony counts from 2,111 to 4,591 workers were added to the laboratory nests structures. The six-month trial is currently underway.

Important Results

The pattern of excavation displayed by tracer gravel did not show a treatment effect. One colony from each of the 15-cm and 18-cm gravel thicknesses brought tracer up from below the barrier layer. Later physical examination of soil columns indicated that all eight colonies dug to or below the 50-cm depth, the underside of the treatment barrier.

Products

Three manuscripts are in preparation for publication in the technical literature during calendar 1995:

- Blom, P. E., J. B. Johnson, S. K. Rope, and B. Shafii. Draft. Radionuclide concentrations in soils associated with the harvester ant, *Pogonomyrmex salinus* Olsen (Hymenoptera: Formicidae), nesting in a shallow waste disposal area. Science of the Total Environment.

- Clark, W. H., P. E. Blom, and P. J. Johnson. Draft. *Gonasida elata* LeConte associated with *Pogonomyrmex salinus* Olsen nest soils in southeastern Idaho (Coleoptera, Tenebrionidae, Asidinae; Hymenoptera, Formicidae, Myrmicinae). Proceedings of the Entomological Society of Washington.

- Blom, P. E., D. A. Schoep, and W. H. Clark. Draft. Observations of Cicada Nymphs, *Okanagana annulata* Davis (Homoptera: Cicadidae) and the Harvester Ant *Pogonomyrmex salinus* Olsen (Hymenoptera: Formicidae) in Southeastern Idaho. Great Basin Naturalist.

We gave one presentation at a technical symposium describing the INEL research:

- Blom, P. E. and J. W. Laundré. Challenges to waste repositories: animal intrusion. Symposium on the Ecological Aspects of Waste Management, Annual Meeting of the Northwest Scientific Association, Idaho Falls, Idaho, 9-11 March 1995.

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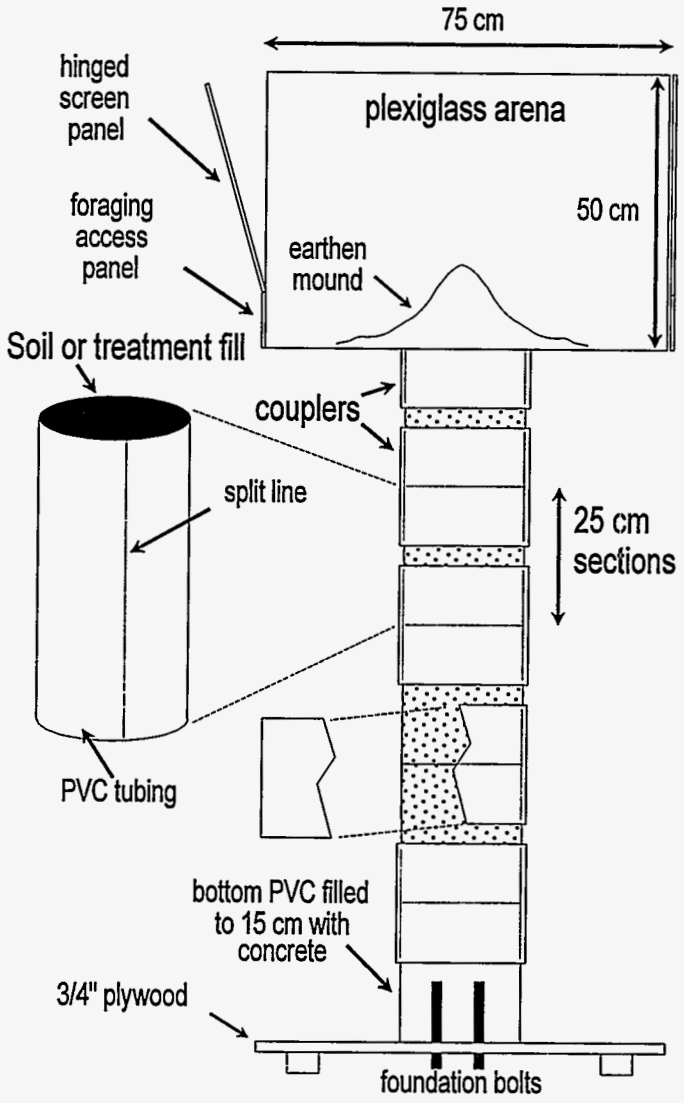

FIGURE 1: SCHEMATIC OF 'ANT FARM' USED IN TESTING OF POTENTIAL BIOBARRIERS FOR THE EXCLUSION OF *POGONOMYRMEX SALINUS* DURING NEST EXCAVATION.

SOIL SUBSIDENCE AND SNOWMELT EROSION ON WASTE DISPOSAL SITES

James P. Dobrowolski[1] and Eric K. Duffin[1]

ABSTRACT—Surface erosion and soil settling (subsidence) over interred low-level nuclear waste are of great concern to waste management personnel. We examined various aspects of these processes during 1995. We developed and tested a statistically valid sampling scheme to accurately measure and compare soil settling on the Protective Cap/Biobarrier Experiment (PC/BE) plots. There were no differences in soil settling among different barrier designs, vegetation covers, or irrigation regimes. We continued to improve the automated data collection system at the simulated trench cap soil erosion plots. We continuously monitored and defined meteorological factors, snowpack, and soil frost conditions that contribute to snowmelt erosion processes. We continued evaluating the effects of rain-on-snow events on soil erosion by collecting control data during several rainfall simulation trials on unfrozen plots during the growing season.

KEYWORDS: *snowmelt erosion, rain-on-snow, soil settling, subsidence, trench caps.*

JUSTIFICATION

Low-level radioactive wastes are buried beneath a shallow soil mantle at the Subsurface Disposal Area at the Idaho National Engineering Laboratory (INEL). These disposal sites must be designed to withstand the normal geomorphological processes that occur in a sagebrush-steppe ecosystem. Some of these processes include soil erosion induced by wind and water, disruption of the soil surface from freeze-thaw and shrink-swell cycles, and soil settling after waste burial (Cooke et al. 1973). The impact of these processes varies from year to year, according to the climatic patterns specific to the area. Our investigations of soil settling and erosion are designed to complement other Foundation research that aims to comprehensively define, and ultimately resolve, the effects of environmental factors that compromise waste management success and environmental restoration efforts.

SOIL SUBSIDENCE ON THE PROTECTIVE CAP/BIOBARRIER EXPERIMENT PLOTS

Of the major environmental exposure hazards in waste disposal areas, soil settling has received less attention than wind and water erosion, infiltration, and percolation. Subsidence can occur in widely scattered situations and might be considered one of the most insidious threats. Subsidence is a common occurrence at some INEL waste disposal areas, and varies greatly in extent and distribution. In this study we are investigating and comparing soil settling among the four cover designs, three irrigation treatments, and two vegetation schemes at the Protective Cap/Biobarrier Experiment (PC/BE).

Natural soils are rarely uniform enough to allow perfectly even settlement after construction (Waltham 1989). Volume reductions are common after the "swell" that accompanies construction, particularly when soils contain much shrink-swell clay material (e.g., montmorillonite). These clays have excessive compressibility and a free-swelling capability that can result in varied surface topography. Different precipitation patterns, as simulated by the PC/BE, may have different effects on the shrink-swell activity. Any resultant soil settling can lead to surface depressions. These depressions can promote water infiltration and deep percolation, and increase the potential for biotic intrusion and movement of contaminants. For this project,

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we defined 1 cm of soil settling as the threshold of ecological importance. Data are needed at the PC/BE to determine the potential effects of various biobarriers, vegetation, and precipitation treatments on subsidence and erosion.

Erosion from Waste Burial Sites

Previous study has shown that lakebed sediments, frequently used to cover wastes at the INEL, have some inherent protection from the erosive forces of summer storms. This is due to the relatively high cohesiveness of clay loam soils (Goff et al. 1994). However, summer thunderstorms are not the greatest erosive threat to trench caps. Because snowfall provides approximately 45% of the annual precipitation on the INEL, the erosive potential of overland flow is greatest in the spring during periods of rain and rapid snowmelt on partially thawed ground. This is especially true for the weakly structured lakebed sediment soils at the INEL (Zuzel et al. 1982, Papendick et al. 1983).

Soil erosion induced by snowmelt runoff is dependent upon two main factors: 1) the rate at which snow melts onto the soil surface (determined by energy fluxes into the snowpack and the physical composition of the snowpack) and 2) the frost condition of the soil surface. In the Idaho sagebrush-steppe, interrill erosion is significantly influenced by freezing and thawing cycles during snowmelt (Blackburn et al. 1990). Freeze-thaw and shrink-swell cycles can disrupt soil surface structures and make them more susceptible to erosion. Repeated freeze-thaw events can saturate the soil surface with water drawn upward from underlying horizons during each cycle. Surface soil aggregates can also break down during this process, increasing their susceptibility to erosion (Blackburn et al. 1990). Hart and Loomis (1982) reported that soil loss on bare mountain plots in northern Utah was more dependent on the rate of snowmelt than the total volume of runoff. Sudden periods of high-intensity snowmelt produced by increased temperature and rain-on-snow events can result in severe erosion (Zuzel et al. 1982).

To accurately predict the snowmelt erosion impact, we need to measure the physical condition of the local snowpack and the energy fluxes incident on it. We also need to monitor the properties of the soil surface and near surface layers during the same period. These measurements can be used to characterize accurately the processes of snowmelt infiltration, runoff, and erosion on simulated waste burial sites at INEL. These data are needed to assess the long-term effectiveness of various cap designs at shallow-land waste disposal sites.

Objectives

Our 1995 objectives in relation to the Protective Cap/Biobarrier Experiment were to:

- Implement a statistically valid sampling scheme to compare soil settling among the various study plots.
- Position stationary markers described by a three-dimensional referencing system to ensure easy relocation if markers are disturbed.
- Characterize the PC/BE surface during spring and fall using tachometry (laser electronic distance measurement) without interfering with other PC/BE research efforts.
- Compare soil settling among biobarrier designs, vegetation covers, and irrigation regimes.

We continue upgrading the automated data collection system and monitoring snowmelt erosion factors at the Simulated Trench Cap Erosion Plots. Our 1995 objectives for that effort were to:

- Continue to document the natural deposition of snow and redistribution mechanisms associated with available snowmelt volumes.

- Continue to measure the controls on snowmelt (radiative versus turbulent exchange) and identify the mechanisms associated with the snow ripening process.

- Monitor the process of melt infiltration, three-dimensional flow paths, and subsequent runoff production.

- Begin estimating the volume of runoff and sediment production from rain-on-snow events.

- Begin modeling the snow deposition, melt, and runoff processes that interact with surface cover treatments, and are meaningful to the INEL experimental site.

PROJECT ACCOMPLISHMENTS

SOIL SETTLING & SUBSIDENCE

In support of the Protective Cap/ Biobarrier Experiment we:

- Familiarized ourselves with tachometry, the survey method of optical distance measurement using a laser-emitting total electronic distance measurement station.

- Evaluated sampling schemes and conducted a pilot study to determine the minimum number of soil surface elevation samples needed to represent the variability across the PC/BE plots and detect differences in soil settling among the treatments.

- Used the pilot study results to established a sampling scheme, took additional elevation measurements, and made statistical comparisons among treatments.

- Established five permanent markers for elevation measurements in each PC/BE subplot. Markers are geo-referenced and tied to the established benchmark.

SNOWMELT EROSION

In support of the snowmelt erosion experiment we:

- Collected data (averaged over 10-minute intervals) on air temperature, relative humidity, wind speed, incoming net radiation, outgoing net radiation, and surface albedo.

- Collected winter data, averaged over 60-minute intervals, for soil temperatures (10-cm increments to 1-m), soil heat flux, snow depth and precipitation.

- Developed specialized data management routines for the large data sets produced on a daily basis by the intensive snowmelt monitoring system at the INEL.

- Used these data to define parameters for a snowmelt and sublimation model (Tarboton 1994).

- Continued to make improvements to reduce down-time of the automated data collection system.

- Developed a new remote sensing design using the existing TDR (Time Domain Reflectometry) network to more accurately measure runoff during the snowmelt period.

- Continued to maintain the plots, improve plot boundaries to restrict overland flow onto the plots, repaired damaged equipment, and upgraded some instruments.

- Completed the final calibration and programming of the TDR system and tested and calibrated ultrasonic snow depth sensors.

- Redesigned the delivery system of the modular drop-forming rainfall simulator and conducted rain on unfrozen soil experiments.

- Calculated mean infiltration rates for unfrozen soils (Fig. 1).

- Placed 96 plot frames for rain-on-snow experiments.

- Redesigned and fabricated the heating mechanism to maintain a reservoir of unfrozen water for the rainfall simulator when air temperatures dropped below 0°C.

- Modified our project vehicle to allow two plexiglass modules to swing out from the truck bed thus delivering simulated rainfall simultaneously to two plots.

- Balanced the electrical current requirements of the forced air, water heater, and flood light systems. They now support rain-on-snow simulations during rigorous winter conditions.

IMPORTANT RESULTS

Results of our pilot study and statistical analysis indicated:

- A single observation per subplot is probably sufficient to detect differences in soil settling.

- Control PC/BE plots, consisting of 2 m of lakebed soil, were significantly lower than the three engineered plot designs. However, the difference is less than 1 cm. Based on our criteria, it is not considered ecologically important.

- Soil settling was not significantly influenced by vegetation cover type or irrigation regime.

- Plot elevations did not change significantly over the growing season (Fig. 2). Elevations are relativized to the elevation of the control points, and range over about 0.60 cm

With several years data, we will be able to analyze the differences in settling rates for biobarrier types using repeated measures analysis of variance.

PRODUCTS

This study is in the data collection phase. Products include two presentations and advances in specialized measurement systems.

The Principal Investigator attended a Regional Research Project in Watershed Science and Management meeting, sponsored by the EPA. Watershed science and management professionals from the USDA Agricultural Research Service, State Agricultural Experimental Stations, USDA Forest Service, USDI Bureau of Land Management, Department of Defense, and several western universities developed a research topic that linked university and agency research. Attendees recognized the unique qualities of the highly instrumented erosion research facility at the INEL and the contribution the large data sets can make to snowmelt erosion models. They expressed an interest in including this in their proposal as a long-term snow-hydrology study area.

PRESENTATIONS

This research was presented in two venues:

- Duffin, E. K. and J. P. Dobrowolski. 1995. Evaluating snowmelt erosion from simulated waste burial trench caps. Annual Meeting of the Northwest Scientific Association. March 1995. Idaho Falls, Idaho.

- Duffin, E. K. 1995. Snowmelt erosion research at the Idaho National Engineering Laboratory. Utah State University Rangeland Resources Graduate Seminar. November 1995.

TANGIBLES

- A new design was developed and implemented using TDR technology for the remote measurement of runoff volumes in tanks at the erosion study plots.

- A heating system was designed to permit the evaluation of worst-case conditions for snowmelt erosion. The system allows rainfall simulation at different water temperatures with warm air blown across the surface of the plot.

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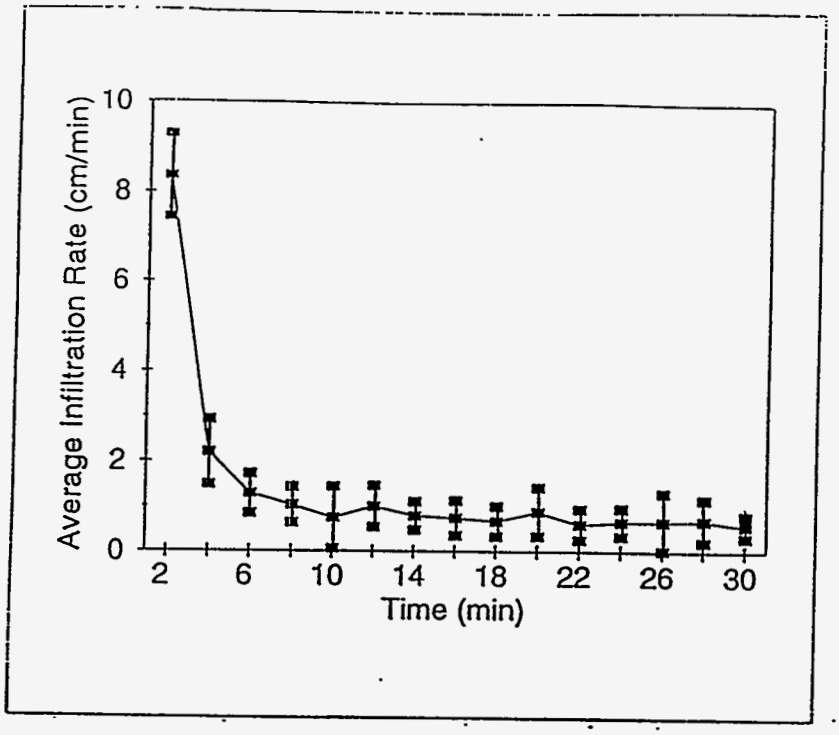

FIGURE 1. MEAN INFILTRATION RATE FOR RAINFALL SIMULATION PLOTS UNDER UNFROZEN SOIL AND GROWING SEASON CONDITIONS (N = 15). BARS SHOW STANDARD DEVIATIONS.

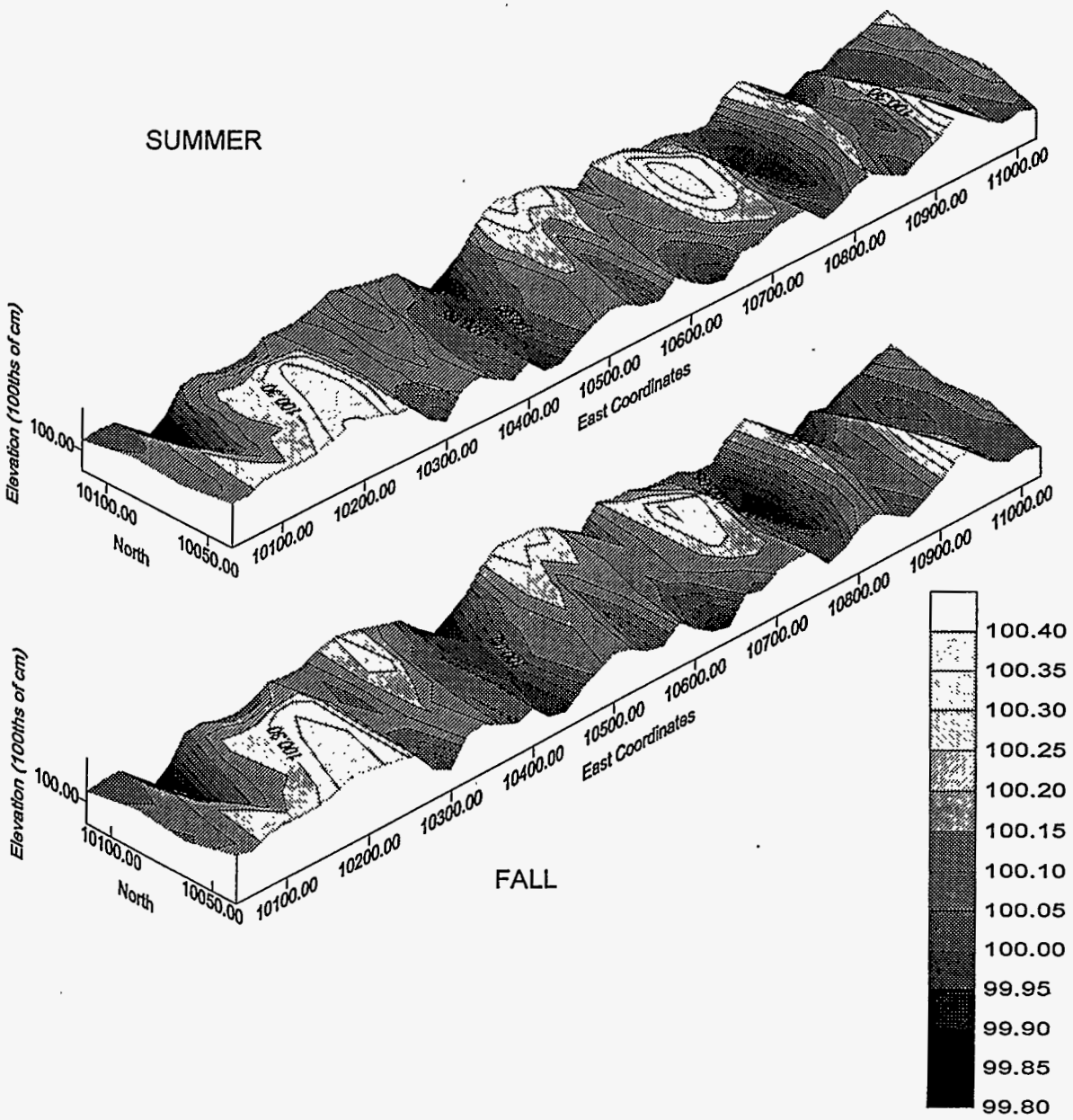

FIGURE 2. SURFACE/CONTOUR MAP OF THE PC/BE TAKEN DURING THE GROWING AND DORMANT SEASONS, 1995 (N = 350). NORTH AND EAST COORDINATE HORIZONTAL DISTANCES ARE IN FEET. NORTH COORDINATE AXIS IS SLIGHTLY EXAGGERATED.

DISTRIBUTION AND ABUNDANCE OF THE PYGMY RABBIT, A C2 SPECIES, ON THE IDAHO NATIONAL ENGINEERING LABORATORY

John W. Laundré[1], Kate I. Gabler[1], and Laura T. Heady[1]

ABSTRACT—The pygmy rabbit (*Brachylagus idahoensis*) is currently a candidate (C2) for listing as threatened or endangered status. If the pygmy rabbit is listed, expensive mitigation actions may be mandated for operations and development on the Idaho National Engineering Laboratory (INEL). Costly mitigation actions can be avoided if INEL managers gain an understanding of the status, distribution, and habitat needs of the pygmy rabbit on the INEL. This study is designed to provide the Department of Energy with information to avoid potential costly actions. Our work will give INEL personnel an assessment of the pygmy rabbit's current status on the INEL. We are also developing a habitat suitability index (HSI) that will be a valid predictor of possible occurrence of pygmy rabbits at proposed development sites. The study is in its second year. Techniques and logistics are being refined. Previously known burrow sites are being relocated and eight new burrow sites were found. Six pygmy rabbits were captured and radio-collared to obtain the location of foraging areas. We conducted 22, 24-hr telemetry monitoring sessions on the six radio-collared rabbits. Vegetation, soil, and topographic features around five burrow systems were measured. An HSI will be calculated based on the measured variables. A global positioning system (GPS) was used to record locations of active burrow sites and we began work with a Geographic Information System (GIS) to predict locations of pygmy rabbit burrow systems.

KEYWORDS: Brachylagus idahoensis, *pygmy rabbit, C2 species, habitat.*

JUSTIFICATION

Historically the pygmy rabbit (*Brachylagus idahoensis*) has had a limited distribution within the sagebrush community in the Intermountain West. The conversion of sagebrush lands to human dominated uses has contributed to reduced pygmy rabbit populations and it is currently a C2 species (a candidate for listing as a threatened or endangered species). One of the last large protected areas where pygmy rabbits are found is the Idaho National Engineering Laboratory (INEL). If the pygmy rabbit is elevated to threatened or endangered listing, there could be significant consequences to DOE-ID operations and development. Compliance with the National Environmental Policy Act (NEPA) and the Endangered Species Act could be costly and time consuming.

Operations or developments that might affect rabbit habitat would need to be curtailed or modified extensively to provide mitigation actions. To comply with such regulations, INEL personnel need information on pygmy rabbit distribution and abundance. Knowing this information on the INEL would help determine if threatened or endangered designation is justified. No recent information is available on the distribution and abundance of the pygmy rabbit on the INEL.

Understanding the rabbit's distribution and habitat needs will help INEL managers formulate plans to avoid costly mitigation. Knowledge of habitat needs could enable a rapid and inexpensive assessment of the potential suitability for pygmy rabbits of areas considered for development. Such an assessment of habitat is lacking at the INEL. Data in these two areas will give the INEL information needed to determine the potential impact the pygmy rabbit might have on future development and help reduce the cost of meeting NEPA regulations regarding this species.

The only prior studies of pygmy rabbits on the INEL are a population dynamics analysis (Wilde 1978) and a study of

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reproduction (Fisher 1979). Wilde's work documented that pygmy rabbits dig their burrows in definable clusters of varied numbers (burrowing sites), presumably in patches of desirable habitat. However, neither study addressed the distribution of rabbits on the INEL nor the habitat characteristics associated with rabbit "burrowing sites." In general, the pygmy rabbit is a relatively unstudied species. The only other recent study of this species was conducted on the U.S. Sheep Experiment Station near Dubois, Idaho (Green 1978). This study documented rabbit diet and assessed vegetation at six burrowing sites (Green and Flinders 1980). Based on the limited sample size, Green and Flinders found pygmy rabbits preferred areas with greater woody cover and shrub height compared to randomly selected areas. However, this information was not used to develop any predictive capability about where pygmy rabbit colonies might be found.

Currently, lack of information on pygmy rabbit abundance and distribution on the INEL could be a major hindrance to compliance with NEPA regulations, specifically Chapter 7 consultation with Fish and Wildlife Service personnel. Data from our study will provide the necessary information for compliance and avoid possible costly delays. If the pygmy rabbit is listed as a threatened or endangered species, it may mandate expensive mitigation costs associated with potential future development. These mitigation costs could be avoided by incorporating the information this study will provide INEL managers. The general decline in pygmy rabbit numbers could also concern Native Americans who traditionally hunted this species. Its preservation could be important to maintaining their traditional values and ways. Consequently, any INEL activities that might affect pygmy rabbit distribution and abundance could come under scrutiny from tribal leaders. The INEL could address any concerns raised if data on abundance and distribution and methods of assessing the impacts of site development were available.

OBJECTIVES

This research is designed to assess pygmy rabbit distribution and abundance on the INEL and develop a habitat suitability index (HSI) as a valid predictor of possible pygmy rabbit occurrence at proposed development sites. Specific objectives of the study are to:

- Locate at least 10 pygmy rabbit burrowing sites.
- Capture and fit 10 rabbits with radio collars.
- Locate foraging areas of the radio-collared animals.

We will determine foraging areas by locating collared animals periodically over 24-hour periods.

- Assess habitat of burrowing and foraging areas.

Measured habitat characteristics will include density and height of tall and short shrubs, topographic characteristics, and soil texture.

- Calculate an HSI.

We will calculate the index as the first principal component of vegetation height, soil composition, and topographic complexity.

- Combine habitat information with Geographical Information System (GIS) vegetation files of the INEL to develop a predictive index of possible pygmy rabbit locations.
- Use the HSI to predict all possible sites of pygmy rabbit locations on the INEL.
- Determine the reliability of the HSI.

We will select 30 sites predicted to have rabbits and determine whether they are actually present at the site.

- Based on the above analyses, produce a map of likely pygmy rabbit locations on the INEL.

PROJECT ACCOMPLISHMENTS

During the calendar year 1995, we:

- Surveyed 86 miles of INEL road for pygmy rabbit sign.
- Located eight new burrow sites.
- Conducted 302 trap nights and 70 trap days.
- Captured and fitted six pygmy rabbits with radio collars.
- Measured vegetation and topographic features and collected soil samples at five burrow systems.
- Conducted 22, 24-h telemetry monitoring sessions on the six individuals.
- Conducted 220 camera trap days to determine rabbit activity. Over 350 photographic records of pygmy rabbits were collected.
- Constructed a point frame sampling system for use in measuring vegetation at burrow sites.
- Recorded locations of active burrow sites using a global positioning system (GPS).
- Began work with a GIS to use in predicting locations of pygmy rabbit burrow systems.
- Entered data from the above activities into the computer and began preliminary analyses.

PRODUCTS

In calendar year 1995, we prepared an abstract for a presentation in 1996 at the Conservation Biology/Ecological Society of America meetings. The presentation will be "Habitat requirements and activity patterns of an endemic rabbit species on a National Environmental Research Park."

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HEAVY METALS IN SMALL MAMMAL POPULATIONS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT—The objective of this research was to identify contamination levels of small mammal populations exposed to heavy metals in the environment. Inductively coupled plasma mass spectrometry was used to evaluate contamination levels in soil, plant food species, and three species of small mammals: deer mouse (*Peromyscus maniculatus*), Ord's kangaroo rat (*Dipodomys ordii*), and least chipmunk (*Tamias minimus*). Preliminary data showed detectable levels of lead, chromium, and cadmium in small mammals on control and experimental grids. Soils from the experimental grid had significantly higher concentrations of lead and chromium than the control grid.

KEYWORDS: *Cadmium, chromium, heavy metals, heavy metal contamination, lead, small mammals.*

JUSTIFICATION

This research addresses the general mission of the Department of Energy (DOE) Environmental Restoration Program by assessing the extent of harmful substances (heavy metals), identifying contamination levels in various environmental media, and measuring impacts on natural small mammal populations.

Many areas of the United States are currently contaminated with heavy metals. High levels of contamination are often the result of earlier land use practices (Elfving et al. 1979), industrialization (Fleming et al. 1979), or even areas of heavy automobile traffic (Goldsmith et al. 1976; Goldsmith and Scanlon 1977). Contamination levels and areas of contamination may be increasing on a national level. There is a lack of information on the effects of heavy metal exposure on the dynamics of natural populations of animals (McBee and Bickham 1990). This research focuses on the availability and toxicity of chromium and lead to small mammal populations resident on a contaminated area of the Idaho National Engineering Laboratory (INEL). These elements are known to be toxic to small mammals and are found in abnormally high concentrations in some soils at the INEL (Eshelman unpublished data, this study). Small mammals fit the criteria for use as biomonitors suggested by Jenkins (1981): common, geographically widespread, and easily collected. These animals occur naturally on both contaminated and noncontaminated sites and are also large enough to provide multiple tissue samples for analysis. Additionally, each of the three small mammal species examined in this study feed on different portions and species of plants. Because of their different feeding habits, some species may be at more risk than others under the same general level of contamination in the environment.

Heavy metals can become concentrated in plants contaminated sites (Arthur et al. 1992). These plants can then be used as food by local small mammal populations. Using food sources that are contaminated with heavy metals can cause death of individuals (Mason et al. 1986; Fleming et al. 1979) and, as a result, can severely impact local populations and animals higher up the food chain.

We established an experimental grid for long-term monitoring of small mammal populations in an area of known contamination. A control grid is located approximately 700 m away in a natural vegetation community on the INEL.

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Preliminary soil analyses indicated that levels of lead and chromium are significantly higher in the experimental grid than in the control grid. Both grids support populations of deer mice, Ord's kangaroo rats, and least chipmunks. Animals on the experimental grid are exposed to levels of lead in the surface soil ranging from 9.1 to 521.4 parts-per-million (ppm) and levels of chromium ranging from 23.0 to 96.2 ppm.

Currently, there is a great need for information on population-level effects of environmental contamination on naturally occurring populations (McBee and Bickham 1990). Results from this research will begin to fill a gap in our knowledge of natural system responses to environmental contamination, and will provide field data for ecological risk assessments.

OBJECTIVE

This study's objective is to test hypotheses dealing with the effects of *in situ* heavy metal concentrations on resident small mammal populations. The 1995 objective was to determine if there were detectable differences in field levels of heavy metal (lead, chromium, or cadmium) concentrations in:

- Soils of the experimental or control grids.
- Plants that occupy the grids.
- Small mammals that reside on the grids.

The long-term objectives associated with this study address the fitness of individuals exposed to *in situ* levels of heavy metals on the control and experimental grids. It consists of laboratory experiments to compare:

- Growth rate between animals raised on a diet containing heavy metals and animals with a standard diet.
- Reproductive output between animals raised on a diet containing heavy metals and animals with a standard diet.
- Survival of young from animals with and without heavy metals in their diet.

Young mammals often accumulate heavy metals faster than adults (Bacher 1985; Fleming et al., 1979). This observation, combined with the fact that young can obtain metals from mother's milk, may influence life expectancy or reproduction of contaminated individuals and, therefore, influence the dynamics of exposed populations. We will perform experiments addressing these hypotheses in the laboratory.

PROJECT ACCOMPLISHMENTS

During calendar year 1995 we:

- Completed the preliminary analysis of the plant samples collected in 1994.
- Collected an additional 138 plant samples from the experimental and control grids and submitted them for analysis.
- Collected 60 soil samples from the new control grid. We prepared and analyzed these and 36 samples from the experimental grid, plus a small sample set from the drainage ditch that enters the experimental grid.
- Examined the stomach contents of ten deer mice, five kangaroo rats and five chipmunks from each grid to verify food habits. We also submitted various organ tissues from the same animals for heavy metal analyses. We are currently awaiting the results of the tissue analysis.
- Trapped small mammals for a total of 3,700 trap nights during the summer.

This produced 133 captures of only 54 individuals.

- Collected vegetation samples and organized them into a permanent reference series. This will allow us to compare and identify stomach contents from animals collected from each grid.

- We completed the food tray "calibration" (Brown et al. 1994, Valone and Brown 1989) for experiments this spring to determine if animals show a preference for uncontaminated food. We established the density of food necessary for these trials.

Important Results

Soil concentrations of lead, chromium, and cadmium were significantly higher in the experimental area than in the control area. However, they were significantly below values in soils from the drainage ditch coming onto the study site.

Products

This study is still in the data gathering stage. No publications or presentations resulted from this project in calendar year 1995. We anticipate presentation of these results in the summer of 1996 during the American Society of Mammalogists meeting.

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FACTORS THAT AFFECT THE DISTRIBUTION AND ABUNDANCE OF CHEATGRASS, AN INVASIVE ALIEN SPECIES, AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT—Cheatgrass (*Bromus tectorum*), an aggressive alien grass, has invaded many habitats at the Idaho National Engineering Laboratory (INEL). Cheatgrass establishment threatens the biodiversity of the INEL, increases risk of wildfire, and threatens the integrity of protective covers on waste management sites. Thus, it is important to understand factors that may limit or enhance its establishment. Data from our field sites at the INEL indicate that soil salinity, soil surface characteristics, and the availability of nutrients in the soil may limit cheatgrass distribution. We conducted greenhouse studies to assess the effects of soil salinity, surface drying, and nitrogen availability on the physiology and growth of cheatgrass. Soil salinity and soil characteristics that result in rapid drying of surface layers inhibit the establishment and/or growth of cheatgrass plants.

KEYWORDS: *Cheatgrass,* Bromus tectorum, *soil salinity, plant physiology.*

JUSTIFICATION

Alien plant invasion poses one of the greatest threats to the integrity and biodiversity of many ecosystems in the western United States (Soulé 1990). Cheatgrass is the most common alien plant species in the sagebrush steppe of western North America. It poses a serious threat to the integrity of shrub/grassland communities at the Idaho National Engineering Laboratory (INEL).

After its introduction in about 1890, its distribution increased exponentially on overgrazed rangelands (Klemmedson and Smith 1964, Mack 1981). Cheatgrass plants mature early and cured plants are extremely flammable. Thus, dense stands of cheatgrass have greatly increased fire frequency on sagebrush rangelands (Klemmedson and Smith 1964). Furthermore, these annual communities are susceptible to fire much earlier in the season than the native sagebrush steppe. Early fires can be very damaging to native species that are still metabolically active. Recurring fires have virtually eliminated perennial shrubs from some sagebrush-steppe areas, and these conversions to annual species communities appear to be irreversible (Daubenmire 1970, Young and Evans 1973). Its increasing abundance at the INEL may impact critical habitat for many native animals.

Cheatgrass was recorded in the earliest vegetation samples taken at the INEL. It occurred on 13 of the 92 permanent vegetation plots established on the INEL in 1950 and on one additional plot in 1957 and 1965. These plots were on the extreme southern and eastern ends of the transects near the INEL boundary. All were in areas open to livestock grazing. However, in 1975, cheatgrass was recorded on 35 of the permanent plots; its presence for the first time on 24 additional plots suggested a marked increase in distribution. Fourteen of the 24 plots were in an area closed to livestock grazing since at least 1950. Thus, the increase in cheatgrass distribution occurred in the absence of grazing or major disturbances such as fire.

Additional samples and casual observations during the mid to late 1980s indicated that cheatgrass was more widespread and abundant than data from the permanent plots suggested. This encroachment is of concern for three reasons. First, the INEL is an important reservoir of the genetic diversity of the flora and fauna of the sagebrush-steppe

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region; few other protected areas of sagebrush steppe exist. Extensive loss of native steppe habitat at the INEL would threaten the survival of many plant and animal species. The second concern is that increased abundance of cheatgrass increases the potential for devastating fires that could damage buildings or other facilities such as air monitoring equipment. Finally, if cheatgrass displaces perennial species on protective soil covers over buried hazardous wastes, reduced evapotranspiration might result in failure of the cover. Perennial species can remove water from deep in a soil profile (>2 m, at the INEL), maintaining adequate soil water storage to preclude drainage into the waste zone (Anderson et al. 1993). However, research at Pacific Northwest Laboratory in Hanford, WA indicated that cheatgrass may use little water from depths greater than 0.8 m (Cline et al. 1977). Thus, if cheatgrass replaced perennial species on waste burial sites, water might accumulate deep in the profile and eventually percolate into the waste zone.

Our studies show that cheatgrass has invaded some habitats but not others at the INEL. Data from field plots indicated that soil salinity, soil surface characteristics, and the availability of nitrogen and phosphorus in the soil may limit cheatgrass distribution. Understanding how these factors operate would allow us to identify areas at risk of cheatgrass invasion. It would also help us develop management strategies to protect diverse natural communities or prevent establishment of this annual grass on the protective covers of waste burial sites.

This study was supported by a Ph.D. traineeship to K. E. Rasmuson from the Department of Energy's Experimental Program to Stimulate Competitive Research (EPSCoR).

OBJECTIVES

- Identify potential factors that limit the cheatgrass distribution in different habitats at the INEL.
- Develop a mechanistic understanding of how limiting factors affect cheatgrass establishment and persistence.

PROJECT ACCOMPLISHMENTS

During calendar year 1995 we:

- Monitored demographic parameters (e.g., germination and survival rates) for experimental and naturally occurring cheatgrass populations at four field sites.
- Completed analyses of data from a greenhouse experiment that addressed the effects of salinity on growth and physiology of cheatgrass.
- Completed analyses of an experiment that assessed the effects of drying the upper layer of soil while keeping the subsoil moist on growth of cheatgrass plants.
- Tested the hypothesis that cheatgrass plants produce thin leaves with modest photosynthetic rates when nutrients are in limited supply, but increase the amount of photosynthetic machinery packed into its leaves when nutrient supplies are more favorable. The study examined the effects of different concentrations of nitrogen on growth and physiological parameters of cheatgrass from two seed sources. Data analyses of these are in progress.

IMPORTANT RESULTS

- No emergence of cheatgrass was observed at three of the four study sites

in 1994 (a dry year), and populations at those sites were thought to have gone extinct. However, in November 1994, substantial germination was recorded on two of those sites. Survival rates were high and plants set seed in June 1995. These results show that cheatgrass seeds can persist in the soil for at least a year during drought periods.

- Dry weight, area, and length of roots were significantly decreased by salt stress. Salinity reduced biomass allocation to roots relative to shoots. The phenology of whole plant development was retarded by salinity. Alteration of root/shoot ratio, coupled with significant reductions in root growth rates, would impair the competitive ability of cheatgrass in habitats having saline soils.

- Carbon isotope discrimination differed significantly among salinity treatments and was negatively correlated with increasing salinity ($r = -0.85$; $P < 0.01$). Time-averaged intercellular CO_2 concentrations were as much as 60 ppm lower for plants in the high salinity treatment compared with controls. These results indicate that stomatal conductance is reduced, even at low salinity levels. This negatively impacts carbon gain by the plants.

- Drying the surface soil layer in experimental containers reduced root growth, leaf area, and photosynthesis in cheatgrass plants. Leaf water potentials were significantly lower in the surface drying treatment compared with controls ($P = 0.01$). Stomatal conductance and photosynthesis were reduced by 49% and 32% respectively. Specific leaf area and shoot branching pattern were unaffected.

In general, soil salinity and soil characteristics that result in rapid drying of the surface layers inhibit the establishment and/or growth of cheatgrass plants. Soil salinity had negative impacts on all measured physiological and growth parameters. Dry soil surfaces inhibited cheatgrass shoot growth through effects on root growth, plant water status, and gas exchange physiology.

PRODUCTS

Three presentations and one written report resulted from this project in 1995.

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LONG-TERM VEGETATION DYNAMICS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT—The Idaho National Engineering Laboratory (INEL) is the largest of the few protected areas of sagebrush steppe, the most extensive vegetation type in the northern Intermountain West. Extensive, healthy populations of indigenous shrubs, grasses, and forbs found in cold desert communities occur at the INEL. Many of these species were extirpated from other areas by livestock grazing. Thus, the INEL provides a unique opportunity to study vegetation dynamics under relatively natural conditions. Long-term vegetation studies at the INEL were initiated in 1950. Data have been collected at least every 10 years from 92 permanent plots along perpendicular lines that transect the entire INEL. The data show that vegetal structure and composition on the INEL are dynamic and tend to follow climatic patterns. Data were collected from all permanent plots during the summer of 1995, a record high precipitation year. We will use these data to assess current trends in vegetation dynamics. We also examined the distribution and abundance of microbiotic crusts on the permanent plots. Microbiotic crusts, consisting of cyanobacteria, lichens, and mosses, help stabilize soil and may be an important source of fixed nitrogen in these communities. Thirteen species of lichens were identified in the microbiotic crusts at the INEL. Of those, *Collema tenax*, the only known nitrogen fixer in the group, was among the most abundant.

KEYWORDS: *Microbiotic crusts, long-term vegetation transects, sagebrush steppe, vegetation dynamics.*

JUSTIFICATION

The Idaho National Engineering Laboratory (INEL) occupies 2,315 km^2 of the temperate sagebrush-steppe region (West 1983) on the upper Snake River Plain in southeastern Idaho. Because much of the INEL has been protected from livestock grazing and other human caused disturbances since 1950, it provides a unique opportunity for research in a relatively pristine natural cold-desert ecosystem. Extensive, healthy populations of most of the indigenous shrubs and grasses found in cold-desert communities of the region occur at the INEL (Anderson and Holte 1981, Anderson and Inouye 1988). Of particular significance is the diversity of native forbs (Anderson et al. in press) that have been extirpated from many areas by continued livestock grazing. Thus, the INEL is an important reservoir of the biodiversity of sagebrush-steppe ecosystems (Anderson et al. in press).

Vegetation studies were initiated at the INEL in 1950. At that time, 94 permanent sample plots were established at 1.6-km intervals along two perpendicular lines that transect the entire INEL from the southwest to the northeast and from the southeast to the northwest (Anderson et al. 1978). Two plots were destroyed before 1957. Data from the remaining 92 plots were collected in 1957, 1965, 1975, and 1985. Additional data from a 35 plot subsample were collected in 1978, 1983, and 1990. These data have been the basis of numerous publications and reports (Harniss and West 1973a, b, Anderson et al. 1978, Anderson and Holte 1981, Anderson 1986, Anderson and Inouye 1988) and provide a critical baseline for future studies of long-term vegetation dynamics. The data show that the vegetation at the INEL is anything but static, even in the absence of major disturbances such as grazing or fire. For example, two-fold changes in shrub cover and five-fold changes in perennial grass cover

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occurred between 1950 and 1985 (Anderson and Inouye 1988). These rather dramatic fluctuations appear to be correlated with long-term climatic patterns. The average richness of perennial grasses and forbs per plot has increased since the area was first protected. The density of perennial forbs appears to track variation in precipitation more closely than does density of perennial grasses or shrubs. These patterns could not have been detected without this long-term data base. To analyze recent trends in vegetation dynamics, and to maintain this long-term data base, we sampled all of the permanent plots during the summer of 1995.

In most arid and semi-arid regions, a crust consisting of microorganisms, lichens, mosses, and soil particles forms on the surface of undisturbed soils (St. Clair and Johansen 1993). The role of such "microbiotic crusts" in stabilizing soils and reducing erosion has been recognized for decades (Booth 1941, Fletcher and Martin 1948, Loope and Gifford 1972). Recent evidence indicates that these crusts may also improve soil fertility (e.g., West and Skujins 1977, Klubek and Skujins 1980, Jeffries et al. 1992). In particular, microbiotic crusts may be the most important source of fixed nitrogen in some cold-desert communities (Evans and Ehleringer 1993). Crusts can be seriously damaged by domestic livestock grazing (Anderson et al. 1982, Brotherson et al. 1983) and by wildfire (Johansen et al. 1982). The INEL provides an important natural laboratory for studies of the structure and function of microbiotic crusts because much of the area has been free from the impacts of livestock grazing or wildfire for at least the past 45 years.

There have been no studies of microbiotic crusts per se at the INEL. Lichens at the INEL were inventoried by Pearson and Rope (1987), and Rope and Pearson (1990) investigated the use of lichens as air quality indicators. We measured visible microbiotic crusts cover (mosses and lichens) and sampled associated soil surface characteristics in conjunction with collecting vegetation data at all permanent vegetation plots in 1995. We will use these data to assess factors affecting the distribution and abundance of organisms that constitute microbiotic crusts at the INEL.

This long-term vegetation monitoring provides data necessary for implementing, or complying with, the National Environmental Policy Act, Endangered Species Act, Federal Noxious Weed Act, and agreements with the Bureau of Land Management and the Shoshone-Bannock Tribe.

OBJECTIVES

- Collect cover, density, and frequency data for vascular plants on 92 permanent vegetation plots on the north-south and east-west transects at the INEL.

- Collect baseline data on the distribution and abundance of microbiotic crust organisms on the permanent plots.

PROJECT ACCOMPLISHMENTS

In calendar year 1995 we:

- Collected cover, frequency, and density data for vascular plants from all long-term vegetation plots, following the methods described by Anderson et al. (1978) and Anderson and Inouye (1988). Data are being entered into computer files.

- Collected data on microbiotic soil crust cover at all of the permanent plots. Soil lichens were identified with assistance from Roger Rosentrater, a lichenologist in the Idaho State Office, Bureau of Land Management.

- Classified soil surface characteristics at each permanent plot, and collected a soil sample for texture analysis. Analyses are in progress.

IMPORTANT RESULTS

- Thirteen species of lichens were identified in the microbiotic crusts at the INEL.

We have five unknown samples, which will likely yield several additional species. *Collema tenax*, the only known nitrogen-fixing lichen identified, was among the most abundant.

- Microbiotic crusts were more common at plots on central portions of the INEL than at those on the periphery.

This difference appears to be associated with soil surface characteristics. Lichen crusts are found primarily on soils that have a stable surface and plate-like structure.

PRODUCTS

We gave one oral presentation during FY 1995 that was based in part on data from the long-term vegetation transects:

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HABITAT USE AND MOVEMENT PATTERNS OF MULE DEER ON THE INEL

James M. Peek[1] and David E. Beaver[1]

ABSTRACT—We initiated field work to determine the seasonal distribution, habitat use, and density of mule deer (*Odocoileus hemionus*) on the Idaho National Engineering Laboratory (INEL). Our objective was to answer questions concerning depredation on surrounding croplands, availability of winter forage, and possibilities for habitat improvement. We radio-collared 20 does in January 1995 and gathered movement and location data on them throughout the year. We tentatively identified some preferred use areas and characterized those habitats. We collected vegetation for nutrient analyses. Considerable effort was devoted to establishing a network of telemetry receiver stations at precisely known locations. We began discussing depredation issues with nearby landowners and developed a preliminary questionnaire for formal interviews. Collared deer had movement patterns not previously anticipated. Some animals made seasonal moves of nearly 50 km.

KEYWORDS: *Mule deer, habitat use, depredation.*

JUSTIFICATION

Little is known about the ecology and behavior of mule deer in sagebrush-steppe habitats like the Idaho National Engineering Laboratory (INEL). Deer appear to concentrate around INEL facilities during certain times of the year, especially during severe winter conditions. Their high visibility makes their well being a concern to INEL workers and visitors and hence a public relations issue. The most recent example of this situation was during the winter of 1992-1993 when relatively harsh conditions resulted in significant stress on the animals. Many dead or dying deer were seen by employees. Animals that concentrate around facilities can also have an economic effect because they may cause significant damage to landscape shrubbery and ornamental vegetation. For these reasons, the Department of Energy, Idaho Operations Office (DOE-ID) is interested in determining if forage can be modified to accommodate mule deer at INEL facilities. In addition, there is concern about potential depredation on croplands surrounding the INEL. We will initially address this potential problem through a survey of landowners adjacent to INEL property.

The INEL is designated as a National Environmental Research Park. The INEL property is possibly a crucial area of winter habitat for regional populations of mule deer, and presents a rare opportunity to investigate the unique habitat represented by the sagebrush steppe of the upper Snake River Plain. Local game management agencies are under considerable pressure from consumptive and non-consumptive users to protect and provide for wildlife populations under their jurisdiction. Therefore, management of these populations is important not only to the INEL, but also to other stakeholders involved in the regulation, management, and conservation of wildlife. Regulation and conservation activities are possible only if a basic understanding of mule deer requirements are known. Information from this study will allow DOE-ID to knowledgeably discuss wildlife issues with management agencies and stakeholders, such as the Shoshone-Bannock Tribes, the Idaho Department of Fish and Game, and the Bureau of Land Management. DOE-ID will then be in a position to help these groups make informed decisions

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regarding the management of deer on and near the INEL.

OBJECTIVES

This study's primary objectives are to determine movement patterns, habitat use, and densities of mule deer on the INEL. Secondary objectives are addressed below. The experimental design was established to use various sampling regimes and data collection procedures to determine:

- Deer habitat use in relation to domestic livestock grazing, habitat patch size, and habitat type.
- Selective preference in homogeneous habitat between non-treated and land-surface waste-water application areas.
- Mule deer seasonal movements on the INEL.
- Cropland depredation adjacent to the INEL.
- Mule deer densities on the INEL.
- Feasibility of establishing green strips to supplement winter forage and serve as fire breaks.
- Effects of prescribed burns on big game habitat use on the INEL.

PROJECT ACCOMPLISHMENTS

During 1995 most of the field effort was related to capturing and radiotracking free ranging deer on the INEL.

- Twenty female mule deer were captured, radio-collared, and released.

This was accomplished by aerial net-gunning on 14 and 15 January 1995. We were assisted by the INEL security aviation crew, Idaho Helicopter, and several Idaho Department of Fish and Game personnel.

- We established a system of receiver sites to increase the accuracy of radio-telemetry efforts.

These sites were located on strategic points of relatively higher elevation, providing a vantage point that allows radio signal detection for considerable distances. These sites facilitate efficient and accurate telemetry location of collared animals. This method allowed collection of more than 300 animal locations during calendar year 1995. We will assess the accuracy of this technique in this environment following the guidelines proposed by Hupp and Ratti (1983). We will also conduct a comparative analysis of readings taken at existing well-head positions.

- We located and recorded positions of radio-collared deer throughout the year.

Radio-telemetry has the potential for considerable error (White and Garrott 1990). For this reason radio-telemetry locations will be validated and augmented by collecting visual animal locations. We will collect these locations by homing in on animals signals and collecting accurate GPS (Geographical Positioning System) locations at the point of visual contact. By gathering both visual and radio-telemetry locations there is potential for a comparative analysis between the two methods. This can help us understand the applicability of both methods in this type of environment.

- We sampled vegetation throughout the year.

Vegetation samples were collected to investigate two aspects of mule deer habitat, the habitat structure and the nutritive parameters of the environment. Habitat structure is being investigated by methods

proposed by Canfield (1941). These methods are applied to deer locations and random locations. A statistical comparison is then possible between the two locations to determine if a difference exists.

Analysis of the nutritive aspects of the habitat is designed to determine if there is any correlation between weather variables and forage quality. For this analysis, two forage species were chosen, green rabbitbrush (*Chrysothamnus vicidiflorus*) and crested wheatgrass (*Agropyron cristatum*). These species were chosen due to their availability across the site and their frequent listing in pertinent literature as preferred browse species. These samples are collected once each month except in the spring when samples are collected three times each month. The Analytic Services Laboratory at the University of Idaho will conduct this analysis. It will include determining protein level, trace element and micronutrient content. We will correlate these results with weather data to provide the capability to predict the habitat carrying capacity.

- We performed a pilot study using a limited number of animals to assess the applicability of several software applications and design specifications to habitat use and availability. This preliminary study indicated that preferential habitat use by mule deer is likely on the INEL.

- We obtained several useful Geographic Information System databases from the Center for Integrated Environmental Technologies. These include vegetation, hydrology, utility, and topography coverage of those areas inhabited by mule deer.

- We drafted a comprehensive survey intended to determine concerns of adjacent landowners.

This survey is designed to determine various attitudes of people who may be most affected by the animals that inhabit the INEL lands. It is being developed with the assistance of the Environmental Science and Research Foundation's communication specialist and sociologists from the University of Idaho. The survey will help DOE-ID land managers address some stakeholder concerns.

Important Results

Preliminary findings indicate that mule deer use of the INEL is variable. Some animals maintained their ranges within site boundaries throughout the year, while others moved off the INEL into agriculture areas and adjacent undeveloped areas near croplands.

These movement patterns begin to reveal unexpected behavior. Some animals made seasonal moves as far as 50 km, a surprising distance for mule deer in this habitat. Several animals moved into the lava flows east of the site boundary at a time that seemed to coincide with fawning. This movement was relatively sudden and occurred with several animals at the same time. Also, during the fawning season, animals used areas that provided more visual cover.

Upon the approach of winter most animals returned to the same relative area where they spent the previous winter. Several animals stayed within the same general area for the entire year.

Of the twenty original animals collared, four died. Two were killed by vehicles and two died of undetermined causes.

Products

This study is in the data acquisition stage. Sampling designs were developed and reviewed by project statisticians for their applicability and accuracy. Data collection continued during the entire year, as did visual and radio-location of the collared animals. Software applications are being developed for identifying areas of potential preferred use

within areas that are available to mule deer on site. We obtained data necessary for completing a GPS accuracy assessment and began its analysis. We secured analytical laboratory facilities for vegetation nutrient analysis.

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PLUTONIUM DISTRIBUTION AMONG SOIL PHASES AROUND THE SUBSURFACE DISPOSAL AREA AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Shawki A. Ibrahim[1]

ABSTRACT—The use of total transuranic concentrations as a criterion to assess the potential risk of contaminated soil implies that all geochemical forms of these radionuclides have an equal impact on man and his environment. However, the degree of ecological mobility and bioavailability of these elements are limited, making the above assumption unrealistic. The goal of this project is to study the association of plutonium in six different chemical and mineralogical soil phases as a function of depth in the soil profile. The association is studied using sequential extraction experiments. We collected 100 soil samples from five locations near the Subsurface Disposal Area (SDA) at the Idaho National Engineering Laboratory (INEL). Each location was sampled to 30-cm soil depth in 3-cm layers. All soil samples were dried, mixed, and screened through a 0.5-mm mesh. We selected 10-g aliquots for Pu analysis and for the sequential extraction experiments. Post extraction readsorption was tested by tracer experiments. From this information, we will assess the relative environmental transport of the different chemical and physical forms of Pu.

KEYWORDS: *Plutonium, sequential extraction, Subsurface Disposal Area, environmental transport.*

JUSTIFICATION

From 1954 through 1970, transuranic waste from the Rocky Flats Plant was shipped to the Idaho National Engineering Laboratory (INEL). Markham et al. (1978) reported that 21,000 Ci of ^{239}Pu and 570 Ci of ^{238}Pu were buried at the Subsurface Disposal Area (SDA) of the INEL Radioactive Waste Management Complex (RWMC). The majority of this waste was buried in pits in the SDA. After the pits were filled, they were leveled to grade by covering the waste with approximately 1.0 m of soil. Additional soil (as much as 1.0 m in some locations) was added in the early 1980s to contour the SDA and promote runoff.

Soil samples collected near the SDA indicated Pu contamination outside the SDA perimeter (Markham et al. 1978). Maximum concentrations in surface soil (0 to 4 cm) occurred in the drainage depression near the perimeter of the SDA. Surface water runoff and wind appear to be the primary mechanisms transporting these radionuclides out of the SDA.

Although knowledge about the total concentrations of these contaminants in the soil matrix is important in appraising the potential hazard, these are not sufficient data to assess potential transport and movement in soil and ground or surface water. In order to better understand the availability and mechanisms of Pu transport in the environment, we initiated a sequential extraction experiment of soil from around the SDA. Improving our understanding of transuranic association in soil phases aids in the performance of reliable ecological and human health risk assessments and helps establish tenable and defendable cleanup standards based on the actual mobility of these radionuclides in the environment. This project provides factual data for scientific purposes by an independent, scientifically-established group, which should enhance the public acceptability and credibility of the resulting information.

This work addresses some of the ecological risk and impact assessment requirements of RCRA/CERCLA and NEPA programs at INEL. These programs need site

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specific environmental research to support decisions and documentation for remediation and restoration programs. Additionally, this project provides training for a graduate student in health physics and radioecology. The Department of Energy stated a need for such training to meet long-range environmental restoration goals.

In 1994, after we developed the necessary protocols and procedures, we collected 100 soil samples from five locations near the SDA. Each location was sampled to 30-cm soil depth in 3-cm layers. A gamma spectroscopy measurement was conducted on all field locations. We transported all samples to Colorado State University where we began sample pretreatment and analyses for post-extraction readsorption.

OBJECTIVES

The objectives of this project are to:

- Determine the extent of vertical distribution of Pu isotopes in soil profiles from the SDA.

- Study the association of these radionuclides in six important chemical and mineralogical soil phases controlling their transport in soils and seep waters. The soil fractions obtained by sequential extraction are soluble, exchangeable, carbonate, organic, sesquioxide, and silicate.

- Assess the degree of post-extraction readsorption using radiotracers including ^{234}Th and ^{237}Np.

PROJECT ACCOMPLISHMENTS

- We completed the preliminary sample pretreatment including drying, grinding and sieving for all the samples.

- We completed work using ^{234}Th and ^{237}Np tracers to assess the degree of post-extraction readsorption for the soil sequential extraction.

- We submitted aliquots from 50 soil samples to the CSU Soil Testing Laboratory for general chemical and physical characterization (bulk density, pH, texture, organic and carbonate content, etc.). This effort has been completed and the results will be used to interpret the sequential extraction work.

We will present the factors that control the possible movement and transport of plutonium in the study area under environmental scenarios in a final report.

IMPORTANT RESULTS

- Preliminary data analysis suggest that post-extraction readsorption contribution is minor. Hence, Pu partitioning among the different soil phases can be evaluated with a high degree of accuracy using the proposed sequential extraction scheme.

- Preliminary results from the sequential extraction of approximately 120 soil fractions suggest that plutonium is associated among the different soil phases as follows:

  a) A significant fraction (30 to 40%) of the plutonium is associated with each of the organic and sesquioxides (soil coatings) fractions.

  b) Small fractions (3 to 11%) of plutonium are associated with the soluble, exchangeable, and carbonate fractions of the soils.

  c) The remainder (~15%) of the plutonium is strongly bound to the silicate fraction of the soils.

d) Most of the plutonium inventory at the SDA still resides in the upper soil horizon.

PRODUCTS

- The study site characterization was summarized in a report submitted to the Environmental Science and Research Foundation (Ibrahim and Stone 1995).
- We presented some results from the sequential extraction experiments at the First Annual University of Colorado Public Interest Science Conference held November 4, 1995, in Boulder, Colorado.

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LICHENS AS AIR POLLUTION BIOMONITORS AT THE INEL

Lorentz C. Pearson[1]

ABSTRACT—In previous studies involving lichens as air pollution biomonitors at the INEL, electrolyte leakage tests demonstrated that, in an arid or semiarid climate, lichens are injured most when they are moist from early morning dew. We used Energy Dispersive Spectroscopy (EDS) to assay dispersal and concentration of polluting elements. Manuscripts summarizing 12 years of data were completed and reviewed by DOE in 1995. These manuscripts will be submitted to Great Basin Naturalist and The Bryologist. Regression formulas which convert EDS data into concentration in ppm are included in the Bryologist manuscript and transmission electron microscope photos are in the Naturalist manuscript. We compared the "tissue" vs. the "cell organelle" approaches to EDS analysis in 1995. The results indicate that for uncommon elements the cell approach is the more useful.

KEYWORDS: *Air pollution, biomonitors, energy dispersive spectroscopy, lichens.*

JUSTIFICATION

Since the beginning of the Industrial Revolution in the late eighteenth century, the abundance of some kinds of plants has been decreasing in urban areas and near factories and smelters. This reduction is generally attributed to toxic gases such as sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, hydrogen fluoride, and peroxyacyl nitrates in smokestack effluents. Most lichens are excellent indicators of pollution because they are sensitive to toxic gases. Those that are relatively tolerant, compared to other lichens, are also valuable indicators. From the combination of sensitive and tolerant species present, an air quality index can be constructed to evaluate pollution.

Lichens are also valuable as pollution indicators because they accumulate heavy metals and other polluting elements in their tissues (Rope and Pearson 1990). To more readily identify the chemical elements given off by a point source of pollution, such as the Idaho Chemical Processing Plant (ICPP), we developed a microchemical assay method. James Allen, Wilford Hess, and John Gardner at the Brigham Young University Electron Microscopy Laboratory in Provo, Utah (formerly the Electron Optics Lab) aided in this effort. Thin, free-hand lichen tissue sections are examined by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The relative concentration of each element is calculated with the aid of Gaussian deconvolution and specialized computer software. The method correlates reasonably well with traditional macrochemical methods, is somewhat less expensive, and is environmentally friendly.

We developed this technique to provide the Department of Energy (DOE) with an inexpensive method to assess environmental contamination from hazardous air pollutants and associated risks.

OBJECTIVES

Objectives of these studies at the Idaho National Engineering Laboratory (INEL) include:

- Use lichens as biomonitors to provide a continuous record of atmospheric quality at the INEL and surrounding areas.
- Develop an environmentally friendly microchemical assay method for heavy metals and other polluting elements.

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- Inventory of lichens and other plants (e.g. mosses) that might be used as biomonitors.

- Evaluate the more common and abundant species for their usefulness as biomonitors.

- Publish our results to benefit the public or other scientists engaged in air quality research, environmental protection, conservation, or lichen physiology.

PROJECT ACCOMPLISHMENTS

In 1995, research focused on all these objectives. We placed special emphasis on publishing data for selection of species most useful in biomonitoring studies. Most significantly, we:

- Analyzed 12 years of data, prepared tables, and prepared two articles for publication in scientific journals.

- Examined and analyzed over 100 transmission electron micrographs (TEM) for detecting visible injury to cell organelles such as disruption of cellular membranes.

In addition we:

- Statistically analyzed data for number of species found on the INEL relative to distance and direction from the ICPP.

- Analyzed the level of transuranic elements relative to distance and direction from the RWMC. We used both α-spec and EDS analyses and compared the two methods.

- Compared the broad spectrum or "tissue" technique to the point or "cell organelle" method of measuring the presence and abundance of polluting elements in lichens.

- Identified several specimens and/or had their identification confirmed. This brought the total named and labeled specimens in the INEL Herbarium to 128.

IMPORTANT RESULTS

- The 1995 data demonstrated that the degree of organelle injury, as revealed by TEM, is positively correlated with both distance and direction from the point source of pollution. The number of species is negatively correlated with distance from a point source.

- The data indicate that the tissue technique results in a lower standard error and better evaluation of the quantity for elements like Ca, Fe, Si, and Cu that are present at high levels. However, the cell organelle method is superior for detecting elements that are present in very low quantity. Therefore, for the purposes of most of our studies, the cell organelle method is superior. The data also suggest that the macrochemical α-spec method is far superior to the microchemical EDS method for detection of transuranic elements.

PRODUCTS

We prepared two manuscripts for publication in 1995. These manuscripts are currently under Foundation review and will be submitted to the indicated journals when completed.

- Pearson, L. C. In review. Lichens as bioindicators of air quality at the Idaho National Engineering Laboratory. Great Basin Naturalist.

- Pearson, L. C. In review. Biomonitoring air quality with lichens using electrolyte leakage and energy dispersive spectroscopy. Journal of Environmental Quality.

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ANALYSIS AND PUBLICATION OF SEVEN YEARS OF BREEDING BIRD SURVEY DATA FROM THE IDAHO NATIONAL ENGINEERING LABORATORY

James R. Belthoff[1]

ABSTRACT—Breeding Bird Surveys (BBS) can be used to assess changes in avifauna and assess potential effects of human activities on the environment. Breeding Bird Surveys have been conducted on the Idaho National Engineering Laboratory (INEL) since 1985. The present study objective was to use data from the BBS conducted from 1985 through 1991 to compare avifauna near INEL facilities with birds in remote habitats; identify trends in sagebrush obligate species; and determine the presence, abundance, and population status of species of special concern. The surveys recorded 25,597 individuals representing 90 species. Western meadowlarks (*Sturnella neglecta*), Brewer's sparrows (*Spizella breweri*), sage sparrows (*Amphispiza belli*), horned larks (*Eremophila alpestris*), and sage thrashers (*Oreoscoptes montanus*) comprised 72% of all individuals. Almost half of all species were represented by fewer than 10 individuals. Mean number of birds per stop, average number of species per stop, and species richness did not differ significantly between remote and facility complex routes. However, the complement of species differed. Facility complex routes had more waterfowl species and human-associated species. More birds were observed in cooler, wetter years. We observed five species of special concern. Of these, ferruginous hawks (*Buteo regalis*) and loggerhead shrikes (*Lanius ludovicianus*) had negative trend means and may have declined during the study period.

KEYWORDS: *Breeding birds, sagebrush obligate species, avifauna survey.*

JUSTIFICATION

The Breeding Bird Survey (BBS) is a roadside route survey in the United States and southern Canada, which now has over 3000 survey routes (Bystrak 1981, Robbins et al. 1986). Begun in the eastern U.S. in 1966, the BBS was designed to detect changes in the population levels of whole species. It is now nationwide in scope and is one of the U.S. Fish & Wildlife Service's main information sources for avian population trends across the continent. Because methods are standardized, comparisons across years and regions of the country are possible. Many local or regional assessments have been conducted (e.g., Geissler and Noon 1981, Holmes and Sherry 1988, Sauer and Droege 1990). The BBS has been particularly useful in documenting population declines in birds that migrate to the new world tropics, a group of species collectively known as neotropical migrants (Robbins et al. 1989). Thirteen BBS routes were established on the INEL in 1985. Eight routes were around facility complexes. The other five routes were in relatively remote regions of the INEL. Breeding Bird Surveys have been conducted annually since 1985. Survey routes were censused in June, and the species, numbers, and habitats occupied by breeding birds were recorded. The data generated from this study are particularly important because they provide an opportunity to assess effects of INEL activities on avian communities. The data can also be used to assess how site biodiversity changes over time, to identify important indicator species, and to assess changes in bird species and numbers resulting from INEL activities at specific Waste Area Groups (WAGs). Finally, survey data will allow documentation of patterns of natural multi-year variation in bird populations, which will facilitate comparisons with future study efforts on the site.

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OBJECTIVES

The present study objectives were to analyze data generated from seven years of breeding bird surveys at the INEL, specifically to:

- Examine population trends of resident and migratory species that occupy the area during the breeding season.
- Assess impacts of INEL activities on breeding birds by comparing avifauna within facility sites to those in remote regions.
- Prepare a manuscript for publication in the technical literature.

PROJECT ACCOMPLISHMENTS

Our accomplishments satisfied all objectives.

- The 1985 through 1991 data set was computerized in the proper format and validated.
- We analyzed the data for differences between years and between remote and facility survey routes.
- We prepared and submitted a technical manuscript to the Department of Energy, Idaho Operations Office (DOE-ID) for review.

IMPORTANT RESULTS

The results of several analyses are noteworthy.

- The surveys recorded 25,597 individuals representing 90 species.
- Five species (Western meadowlarks, *Sturnella neglecta*; Brewer's sparrows *Spizella breweri*; sage sparrows *Amphispiza belli*; horned larks *Eremophila alpestris*; and sage thrashers, *Oreoscoptes montanus*) comprised 72% of all individuals.
- Almost half of all species were represented by fewer than 10 individuals.
- All routes supported an average of 16 to 17.5 species for the seven years of the study.
- Of the common species, only the brownheaded cowbird declined in abundance during the study period.
- Brewer's sparrows, sage sparrows, and perhaps vesper sparrows (*Pooecetes gramineus*) increased significantly in abundance.
- Mean number of birds per stop, average number of species per stop, and species richness did not differ significantly between remote and facility complex routes, but the complement of species differed.

Facility complex routes supported more waterfowl species and more "human-associated" species. Several species of raptors [ferruginous hawk, burrowing owl (*Speotyto cunicularia*), Cooper's hawk (*Accipiter cooperii*), merlin (*Falco columbarius*), and Swainson's hawk (*Buteo swainsoni*)] tended to occur more commonly along remote routes.

- Some variation in bird abundance was related to weather conditions. More species were observed during cooler, wetter years.
- Five species of special concern (Mosely and Groves 1994) were detected along the survey routes. Loggerhead shrikes and ferruginous hawks were relatively common. Burrowing owls, white-faced

ibis (*Plegadis chihi*) and long-billed curlews (*Numenius americanus*) were rare. Ferruginous hawks and loggerhead shrikes had negative trend means. Although the trends were not statistically significant, studies of these species and the land management practices that affect them may be warranted.

PRODUCTS

One technical publication was prepared and submitted for DOE-ID review during 1995. It will be submitted to Great Basin Naturalist upon approval.

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THE DISTRIBUTION AND STATUS OF AMPHIBIANS AND REPTILES ON THE INEL: IMPLICATIONS FOR FUTURE SITE DEVELOPMENT AND ENVIRONMENTAL RESTORATION OPERATIONS

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ABSTRACT—We combined habitat measurements from 10 known hibernacula with data layers from the Idaho National Engineering Laboratory (INEL) Geographical Information System (GIS) to develop a predictive map of potential snake den locations on the INEL. Our initial map had a high rate of omission errors, in large part due to the low (30 m) resolution. We are developing a second generation map using higher (2 to 10 m) resolution. Data from new den sites will also be incorporated into our second map. We are radio-tracking 17 Western Rattlesnakes (*Crotalus viridis*) at 11 known den sites during the winter hibernation period to determine the exact locations where the snakes are overwintering. To determine the distribution and population changes of reptiles and amphibians on the INEL, we continued the snake population monitoring program initiated in 1994 at three den site locations. Although hundreds of snakes were captured in our traps, recapture rates are too low to make reliable population estimates. The low recapture rate indicates that snake populations at the three monitoring locations are large. In 1994, the monitoring program detected a new species on the INEL, the racer (*Coluber constrictor*). This year the monitoring program identified another new species for the INEL, the desert nightsnake (*Hypsiglena torquata*). We did not observe or trap any short-horned lizards (*Phrynosoma douglassii*) or leopard lizards (*Gambelia wislizenii*) in 1995. Six Great Basin spadefoot toads (*Spea intermontana*) were trapped at Cinder Butte, and the known ranges of several reptile species were expanded due to new trapping information and visual sightings. New sightings of reptiles and amphibians for the INEL were entered into a computerized database developed in 1994 that will be used to describe the distribution and abundance of these animals on the INEL. We located three spadefoot breeding sites on the INEL in 1995, one of which has never been documented. Because the Big Lost River was allowed to flow on to the INEL for a period of almost 3 months, the spadefoot tadpoles had ample time to fully metamorphose. This may be the first time in 9 years that spadefoots have reproduced successfully on the INEL.

KEYWORDS: *Amphibians, radiotelemetry, rattlesnakes, reptiles, species distribution.*

JUSTIFICATION

Many amphibian and reptile species have biological characteristics that make them sensitive indicators of environmental change. Our primary research goal is to provide indicators of environmental health and change by monitoring the status of amphibian and reptile populations on the Idaho National Engineering Laboratory (INEL). Previous studies of amphibians and reptiles make the INEL an excellent site for long-term monitoring studies. This research also provides information for appropriate management of sensitive amphibian and reptile species. It will improve our knowledge of the distribution of amphibians and reptiles on the INEL so that the Department of Energy (DOE) can avoid negative impacts of human activities on these animals and meet National Environmental Policy Act requirements regarding site developments. Knowledge of rattlesnake distribution on the INEL will help locate new projects or facilities to minimize potentially dangerous (for both species) snake-human interactions. Finally, this project provides an excellent opportunity to inform the public about the environmental value of the INEL. Reptiles, especially rattlesnakes, tend to capture the public imagination and representatives of television, films, and the print media have approached the Foundation affiliates performing this work regarding opportunities to report on their work at the INEL.

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OBJECTIVES

The project objectives for 1995 were to:

- Develop and test a statistical model for snake den site selection and combine it with data layers in a Geographic Information System (GIS) to predict snake den locations.

- Continue monitoring snake and lizard populations at three den sites on the INEL (Cinder Butte, Crater Butte, and Rattlesnake Cave), and lizard populations at Circular Butte and Antelope Butte.

- Determine breeding areas for Great Basin spadefoot toads (*Spea intermontana*) if conditions conducive to breeding occur.

- Continue entering information on species distribution and abundance into a GIS and update dot-distribution maps.

PROJECT ACCOMPLISHMENTS

We constructed our first generation map predicting snake den locations on the INEL.

We characterized the habitats of 10 known snake dens on the INEL and combined this information with the INEL GIS data layers. The resulting map indicated areas on the INEL that have habitat and topographical features similar to known den areas. The omission error on the first generation map was high, largely due to the low resolution of the GIS layers (30 m). We are currently developing a second generation map that focuses on selected sites with a resolution between 2 and 10 m. This map will be tested during the spring and summer of 1996. During the field testing of the first map, three new denning areas were located. The habitat information from these sites will also be incorporated into our second generation map.

- We surgically implanted 17 western rattlesnakes (*Crotalus viridis*) with radio-transmitters (Telonics CHP-2P or Holohil PD-2) and began monitoring these snakes during hibernation at 11 different denning areas.

The data will tell us exactly where the snakes are hibernating, whether or not they are moving during hibernation, and their body temperatures during the winter months and while they emerge from hibernation.

- We continued monitoring at three den sites in order to determine the distribution and abundance of the reptiles and amphibians on the INEL.

- We located spadefoot breeding sites at three different areas along the Big Lost River in 1995: the Big Lost River Sinks and Spreading areas, an overflow pond where the river crosses Lincoln Blvd., and Spreading Area A.

To our knowledge, spadefoot breeding has never been documented in the overflow pond. The river flowed long enough in 1995 for the toads to successfully metamorphose. Therefore, spadefoot populations have probably increased significantly during the past year. To our knowledge, this is the first time in 9 years that spadefoots have successfully reproduced on the INEL. Spadefoots were captured in traps at Cinder Butte, which is located more than 5 miles away from the Big Lost River Sinks. The large distance away from the river suggests that other breeding sites close to Cinder Butte may exist.

- We updated and improved the INEL herpetological database.

This information is currently being used to create dot-distribution maps of the herpetofauna of the INEL and surrounding areas, and will be used in a related project to

test and refine Gap analysis models (Scott et. al., 1993).

Important Results

This year's trapping resulted in the detection of a new species for the INEL, the desert nightsnake (*Hypsiglena torquata*). We captured four nightsnakes at one monitoring location in June 1995. In addition, six Great Basin spadefoot toads (*Spea intermontana*) were captured in traps at Cinder Butte during the summer. This information expanded the known range of the spadefoot toad on the INEL. Three racers (*Coluber constrictor*) were captured in traps in 1995, and a juvenile racer was found and marked at a new denning area located just south of the INEL boundary. Leopard lizards (*Gambelia wislizenii*) were not seen at either Circular Butte or Antelope Butte, although these sites were visited on several occasions during the field season. We observed or trapped sagebrush lizards (*Sceloporous graciosus*) (a federal sensitive species, formerly classified as C2) at all of the monitoring locations. Although we did not trap or observe any short-horned lizards (*Phrynosoma douglassii*), sightings by other INEL workers were incorporated into the INEL herpetological database. Capture of western skinks (*Eumeces skiltonianus*) increased in 1995, with only two captured at Rattlesnake Cave in 1994 compared to seven captured at two monitoring locations in 1995. A summary of the trapping results is given in Figure 1. The data are displayed as the number of individuals captured at each trapping locality, and do not indicate population sizes at the three sites. Although the sites varied in size, trapping effort was equal at all three sites (four drift fence and funnel trap arrays per site). Therefore, smaller monitoring locations such as Rattlesnake Cave, had a higher proportion of the total den area surveyed. This may have resulted in larger numbers of snakes captured at this site. No reliable population estimates could be obtained because of low numbers of recaptured individuals in 1995. However, the low number of snake recaptures at the three monitoring locations indicated that the population numbers are large. More reliable population estimates will be possible using recapture data after the 1996 trapping season.

Products

We gave two technical presentations and two snake safety-training presentations during 1995.

Technical Presentations

- Cooper, S. L. and C. R. Peterson. 1995. A Comparison of the Distribution and Abundance of the Herpetofauna of the Idaho National Engineering Laboratory: 1975 and 1994. Annual Meeting of the Northwest Scientific Association, March 8-10, Idaho Falls, ID.
- Cooper, S. L, and C. R. Peterson. 1995. A Comparison of the Distribution and Abundance of the Herpetofauna of the INEL: 1975 and 1994. Annual Meeting of the Idaho Herpetological Society. November 11, Boise, ID.

Safety-Training Presentations

- Cooper, S. L. 1995. Snake Safety and Herpetofauna of the Idaho National Engineering Laboratory. Presentation to INEL and Foundation employees. June 5, Idaho Falls, ID.
- Cooper, S. L. 1995. Snake Safety and Herpetofauna of the Idaho National Engineering Laboratory. Presentation to INEL general employees. June 29, C.F.A. 690, INEL.

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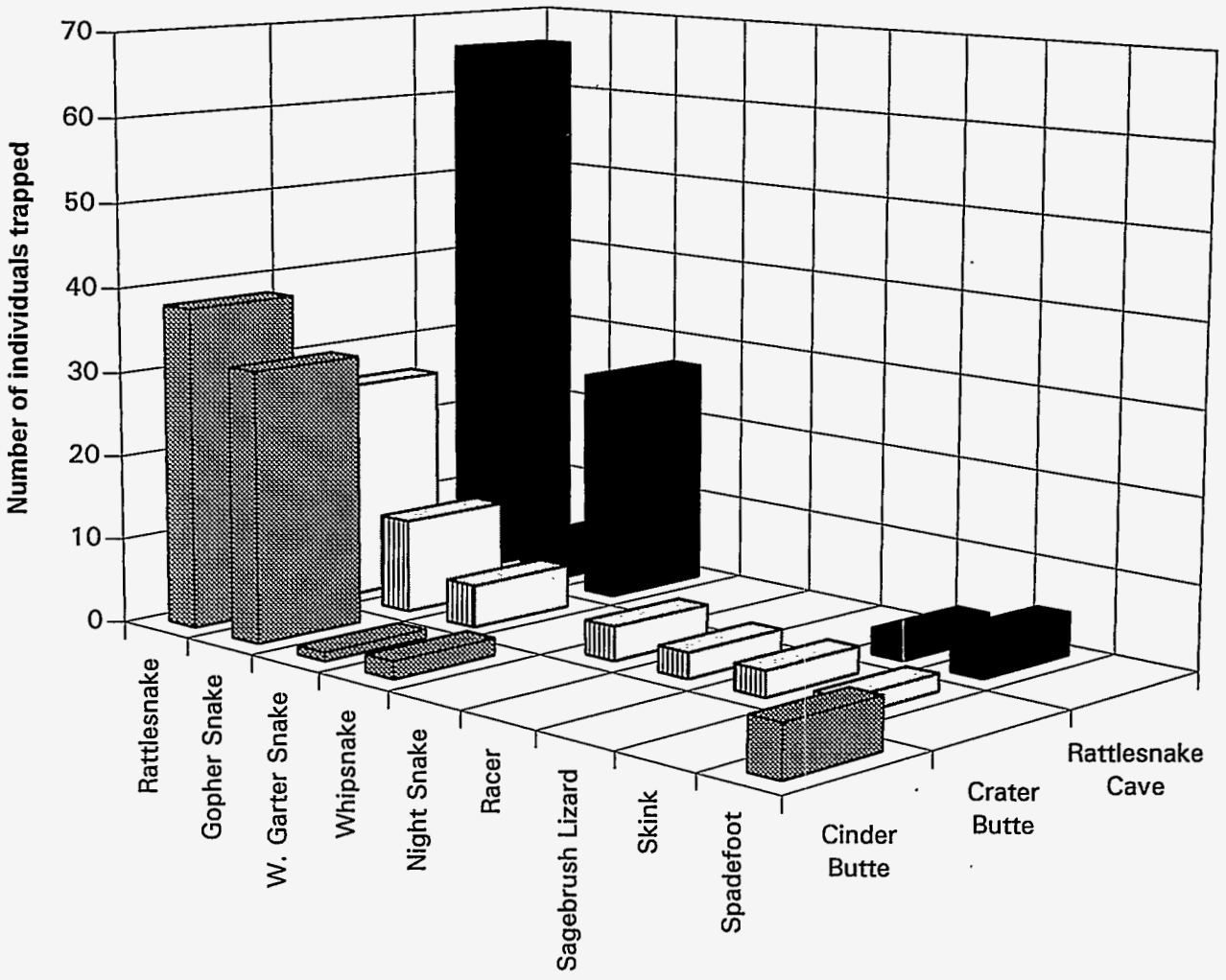

FIGURE 1. THE NUMBER OF REPTILE AND AMPHIBIAN SPECIES TRAPPED AT THREE MONITORING LOCATIONS IN 1995. NOTE THAT THE DATA DO NOT INDICATE TRUE POPULATION SIZES. THEREFORE COMPARISONS BETWEEN SAMPLING LOCATIONS ARE OF LIMITED VALUE.

USING HONEY BEES TO MONITOR ENVIRONMENTAL CONTAMINANTS AT THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT—We deployed bee colonies on the Idaho National Engineering Laboratory (INEL) and its surroundings; periodically collecting and analyzing forager bees for a wide array of chemicals. From residue data, we assessed the presence of radionuclides and organics such as PCBs and mapped distributions of several inorganic elements. We summarized our findings in a series of papers, two of which were accepted for publication in 1995. One paper covers the importance of INEL facilities in relation to deposition patterns of contaminants, such as fluoride (F), to surrounding regions. The other reviews the use of honey bees as environmental monitors. The INEL facilities do not appear to be a significant contributor of F to the region, especially when compared to phosphate ore processing near Pocatello, Idaho. Bees placed near INEL nuclear testing sites accumulated small amounts of several radionuclides, a variety of inorganic elements, and PCBs. However, we also found traces of PCBs in almost every bee sample analyzed, regardless of where the bees were located. We are using Artificial Neural Networks (ANN) to improve our ability to characterize PCB isomers in bee tissues. Finally, bees from the smelter region in Montana had dramatically higher metallothionein levels, as well as depressed levels of essential elements, compared to INEL bees.

KEYWORDS: *Biomonitors, environmental surveillance, honey bees, PCBs.*

JUSTIFICATION

After 40 years of conducting a wide array of activities, including the testing of nuclear materials for national defense, the Department of Energy (DOE) has redirected its attention toward environmental stewardship. DOE's new goals are to bring their sites into compliance with environmental regulations and to reduce health and ecological risks by cleaning up contaminants. Environmental wastes are often contained (e.g., buried wastes) or follow well-defined drainage patterns. However, if the sources or extent of contamination are unknown, costly sampling encompassing large regions may be required.

A more cost-effective solution uses a mobile sampler that covers the area, samples all media, and returns to a fixed location. The honey bee meets these criteria. It has proven to be an efficient multi-media monitor of contaminant dispersion (Bromenshenk 1978, Bromenshenk et al. 1985, 1992, 1995). The National Research Council (1991) and the United States Environmental Protection Agency (EPA)(Warren-Hicks et al. 1989) judged honey bees to be excellent air pollution monitors and useful for *in situ* exposure assessments of aerial, soil-, and water-borne contaminants, including any leakage from stored and buried wastes. The bee research described here constitutes part of the Idaho National Engineering Laboratory's (INEL) operations and waste management monitoring in the context of surrounding ecosystems and off-site industrial facilities.

Much of southeastern Idaho consists of basalt outcrops with few roads, sparsely distributed electrical power lines (that could be used to run monitoring instruments), and little water. The subject of our INEL studies was the degree to which honey bees, especially small nucleus colonies, could withstand these harsh conditions and serve as useful, multi-media monitors of a wide array of pollutants.

We deployed bee colonies on the INEL and sampled colonies at commercial beeyards

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in the surrounding area at a total of 61 locations during four years. We compared the INEL bees to those sampled (under EPA sponsorship) at 42 locations around a Montana copper smelter and bees at a federal facility in Maryland (under Department of Defense sponsorship). Bees were analyzed for radionuclides, fluoride, other trace elements, including heavy metals, and organics such as pentachlorobiphenyls (PCBs). The data were processed using geostatistical procedures such as kriging (Bromenshenk et al. 1985), traditional statistical tests such as F- and Student's t-tests, and multivariate techniques such as a repeated measures discriminant analysis. These analyses were used to characterize multiple chemical exposures and population response to contaminant stress.

Exposing bees to contaminants may result in a wide spectrum of pathological conditions, ranging from death to behavioral dysfunctions. Of particular interest are real-time changes in colony performance that can be monitored electronically and biochemical perturbations that can be assessed by diagnostic biomarkers like metallothionein (Cronn 1991) or acetylcholinesterase (Bromenshenk 1978)] production.

OBJECTIVES

Our objectives were to:

- Map chemical distributions from a variety of unique sources.
- Compare contaminant levels in bees to levels reported for other environmental samples.
- Contrast residue concentrations in INEL bees with bees from other parts of the United States.
- Determine levels of specific biomarkers in INEL bees versus bees from industrial areas in Montana.
- Evaluate the importance of INEL facilities as contributors to regional contaminant deposition patterns.
- Assess the feasibility of using bees as self-sustaining monitors in a semi-arid desert.

PROJECT ACCOMPLISHMENTS

In 1995, we focused on finalizing data analysis and publishing results. In addition, we developed improved instrumentation and additional methods to overcome significant interference problems and, thus, complete the PCB analyses. We completed all statistical analyses, the PCB re-analysis of INEL bee samples, and nearly all the application of ANN techniques to PCB characterization. Two articles were accepted for publication, another two were submitted for publication, and two more are nearly complete.

Our honey bee pollution monitoring research received a medal from the 1995 Computerworld Smithsonian Program. As part of that honor, we submitted materials for a "time capsule" for future generations to discover in the Smithsonian archives. Our work also appears on the Computerworld Smithsonian home page (http://innovate.si.edu/nominee/ee4.html).

We developed a research home page on the Internet (http://www.umt.edu/staging/BEE/Index.htm) to facilitate reporting of our research activities, provide an on-line educational and research resource, and create a "virtual" research group for honey bee and environmental research.

IMPORTANT RESULTS

Our results suggest that facilities at the INEL intermittently release fluoride (F). This only affects localized areas on the INEL, and probably contributes little to the surrounding area (Bromenshenk et al. In Press.). Our results further indicate that foraging bees accumulate small quantities (often barely

detectable) of ^{60}Co, ^{137}Cs, and ^{51}Cr near some of the nuclear testing facilities, especially colonies near waste ponds. Other inorganic elements, ranging from aluminum to zinc, display a variety of distribution patterns. Some elements appear to be related to INEL sources, and others seem to be from natural sources (e.g., artesian wells, volcanic soils), agricultural chemicals, or private industries.

Bees located near waste ponds at the Test Reactor Area and the Loss of Fluid Test facility appear to have accumulated low levels of PCBs. Trace levels of PCBs were common in most bee samples from throughout the region, including sites in Montana. This is consistent with similar reports of widespread PCB accumulation by bees at many locations in Connecticut (Anderson and Wojtas 1985).

Comparison of bees from the INEL to bees from a smelter region in Montana revealed: 1) differences in metallothionein levels, which were higher in smelter bees exposed to cadmium, and 2) changes in the relative values of essential elements, which were lowest in bees near the smelter.

This comparison provides two methods for ranking site risks to bees. One method consists of assessing the physiological condition of bees, as evidenced by production of metal-binding proteins. This is relatively time-consuming and costly. The other method uses depressed values of essential elements such as Cu and Zn to indicate physiological changes. This may be more cost-effective than assessing protein production.. However, we do not know how applicable this will be for other field studies, given the complex interactions of contaminant exposure and other environmental stressors.

PRODUCTS

Our 1995 products include the following technical reports:

- Bromenshenk, J. J., R. C. Cronn, and J. J. Nugent. In Press. Monitoring Fluoride with Honey Bees in the Upper Snake River Plain of Idaho. Journal of Environmental Quality.

- Bromenshenk, J. J., J. L. Gudatis, and R. C. Cronn. Submitted. Post-Closure Assessments of Industrial Complexes with Honey Bees. Environmental Contamination and Toxicology.

- Cronn, R. C., and J. J. Bromenshenk. Submitted. Radionuclide Accumulation in Honey Bees at the Idaho National Engineering Laboratory. Journal of Environmental Quality.

- Bromenshenk, J. J., G. C. Smith, and V. J. Watson. 1995. Assessing Ecological Risks in Terrestrial Systems with Honey Bees. Pages 9-30 In: F. M. Butterworth, L. D. Corkum, and J. Guzmán-Rincón, eds. Biomonitors and Biomarkers as Indicators of Environmental Change. Plenum Press, New York, NY.

This was an Invited Paper at the International Symposium on Biomonitors as Indicators of Environmental Change, June 7, 1994, Windsor, Canada.

- Bromenshenk, J. J., G. C. Smith, and V. J. Watson. Honey Bees as Monitors of Ecosystem Conditions and Human Health. Invited thematic paper presented at the International Conference on Tropical Bees and the Environment, March 11-15, 1995, Pedu Lake, Kedah, Malaysia.

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DIVERSITY OF THE ANT FAUNA AT THE IDAHO NATIONAL ENGINEERING LABORATORY: IMPLICATIONS FOR WASTE MANAGEMENT

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ABSTRACT—Early work identified 22 species of ants at the Idaho National Engineering Laboratory (INEL). Our initial assessment of the ants of the site reveals that there are at least twice that many species, including at least one new to science. To build a baseline understanding of the INEL ant fauna, its diversity, and abundance, we will produce an annotated checklist of the ants of the INEL, which can be used in various waste management and ecological investigations. We met our objectives for this second year of work. We continued curating historical collections by pinning and labeling hundreds of ant specimens. We are working with various experts to identify and verify some of the ant specimens collected. We collected additional specimens at the INEL during 1995, especially associated with a 1994 burn area. We continued computerizing the data by constructing database programs and by entering several thousand ant specimens. A poster about the project is currently on display at the Orma J. Smith Museum of Natural History, Albertson College of Idaho, and is viewed by thousands of visitors annually. Three scientific publications are in preparation and nearing completion.

KEYWORDS: *Ant fauna, entomological curation,* Pogonomyrmex, *spp.,* Myrmica *spp.,* Lasius *spp., insect waste intrusion.*

JUSTIFICATION

Ants are an important and ubiquitous component of the semi-arid land ecosystem. Their biomass can exceed the collective biomass of all vertebrates in arid land ecosystems. They contribute to soil processes and energy cycling. Some species can significantly alter soil moisture and water infiltration characteristics, and can unearth buried wastes and contaminated soils. Others can change vegetation patterns and thereby affect hazardous waste storage areas. Knowledge of the species composition and distribution over an area is important for long-term waste management decisions, as well as comprehensive land stewardship.

We have collected ants at the Idaho National Engineering Laboratory (INEL) since 1986. Many important contributions were made during this time. Our current work continues curation and begins data entry.

OBJECTIVES

The 1995 objectives of this project's work plan were to:

- Continue curating historic collections.
- Continue determining historic collections.
- Conduct sampling during the field season to fill collection gaps.

PROJECT ACCOMPLISHMENTS

CONTINUE CURATING HISTORIC COLLECTIONS

We made substantial progress toward achieving this objective, which is to be completed in 1996. Further progress was made on organization of the entire ant collection at the Orma J. Smith Museum of

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Natural History, which will facilitate the INEL ant research. A protocol was established for curation of ant specimens by technicians. This protocol included the use of maps, standard specimen preparations and deposition, and the building of a computer database. Foam-core mounted INEL maps are used to display ant collection localities during curation. We obtained three California Academy of Science (CAS) insect cabinets, complete with 72 CAS glass-topped drawers, to house the pinned ant specimens from the INEL. This ensures space for the pinned ant specimens as they are curated. Several hundred field vials of ants were sorted; more than 2,000 individual ant specimens were pinned and labeled. All ants collected during 1994 were curated. Ants pinned and labeled to date were placed into the new drawers. Additionally, several books were purchased which will aid with ant identification and help us determine the ecological role of the ants collected.

We also began curating historical INEL collections, which means that our backlog of pinned ants was labeled and placed correctly into the collection. Now, nearly all of the 1,150 nest collections by Clark are curated.

When completed, sets of voucher specimens will be deposited in the entomological collections at the Orma J. Smith Museum of Natural History, Albertson College of Idaho, Caldwell (CIDA), the William F. Barr Entomological Museum, University of Idaho, Moscow, and with individual taxonomic specialists who are working on the material. Thus, they will be readily available to the scientific community for future studies.

Thousands of additional invertebrate specimens, primarily pitfall trap material, were curated and entered onto the CIDA database. These are also being placed into this museum's collection. The Foundation provided an additional entomology cabinet, drawers, and other supplies to aid in this effort.

As mentioned, ant and invertebrate specimen data collected during 1995 and previous years are in the process of being computerized. The application used for cataloging the specimens permits storing individual counts and preserves sample identity. Such a database ultimately facilitates extraction of the data for distribution and ecological analyses. At this point we estimate a third of the INEL ant collections are computerized.

Continue Determinations of Historic Collections

We sent specimens of ants in the genera *Formica* and *Myrmica* to Dr. Andre Francoeur, Universite du Quebec, Chicoutimi, Quebec, Canada, in 1994. We are awaiting his identification verifications. Dr. Francoeur is the North American expert on these genera. He will describe the new species of *Myrmica* discovered on the INEL (Jackson *et al.* 1991). We will provide biological and ecological information to the paper. Once we have these reference materials, we will be better able to complete the identification of our INEL ant specimens and prepare our revised list of ants of the Site.

We continued investigating the whereabouts of the original ant collection made on the INEL in the 1960s by Allred and Cole (1971). We maintained contact with the Monte L. Bean Life Sciences Museum, Entomology Department, Brigham Young University, Provo, UT, and Los Angeles (CA) County Museum. These two museums are likely locations for early INEL specimens, though none have been located to date. We have an additional lead in Utah and are presently following it to see if anything is known about the location of the material. This problem points to the need for properly curated and documented voucher specimens in ecological work.

We received the identified INEL specimens of the ants of the genus *Lasius* from Dr. Edward O. Wilson and Stefan Cover

(Harvard University). The majority was *Lasius crypticus* Wilson which was previously reported from the site (Allred and Cole 1971). Our collections did turn up one species not previously reported from the INEL, *Lasius neoniger* Emery. This ant was collected at the Central Facilities Area (CFA). We plan additional collections to determine if the ant is found in other areas.

Sampling During Field Season to Fill Collection Gaps

Blom made general ant collections, including additional sampling of *Lasius* at CFA, in conjunction with June trips to the INEL.

We developed an invertebrate sampling design for technicians comparing faunal communities in areas affected by the 1994 range fire on the west edge of the INEL with nonburned areas. Two circular plots of 50-m radius were established. One plot was placed within the burn area and the other in an adjacent area outside the burn. Two sampling runs were completed by an Idaho Falls high school teacher and three students. Initial curation of these samples (n=792) was initiated by the high school team and continues with our technical assistance.

Miscellaneous Education and Outreach Accomplishments

A poster (Blom et al. 1991a) showing some aspects of this project is on display at the Orma J. Smith Museum of Natural History. The poster is viewed by thousands of students and other Museum visitors annually.

Important Results

Blom showed that harvester ant burrowing is an important consideration in waste burial (Blom 1990, Blom et al. 1991b). As these studies focused on one species, *Pogonomyrmex salinus*, there is a great need for adequate knowledge about the habits and ecology of the other ant species on the INEL. By doubling the known number of ant species on the INEL and expanding the collections of other invertebrates, this project contributes to the environmental restoration and waste management missions of DOE.

A museum specimen-level data management system was implemented for accession and vouching of the INEL invertebrate samples. Thus, knowledge about these arthropods and their ecological roles is available for management decisions.

Products

We made progress three papers resulting from this project:

- Clark, W. H., P. E. Blom, and P. J. Johnson. First Draft. *Gonasida elata* LeConte associated with *Pogonomyrmex salinus* Olsen nest soils in southeastern Idaho (Coleoptera, Tenebrionidae, Asidinae; Hymenoptera, Formicidae, Myrmicinae). Proceedings of the Entomological Society of Washington.

- Blom, P. E., D. A. Schoep, and W. H. Clark. First Draft. Observations of cicada nymphs, *Okanagana annulata* Davis (Homoptera: Cicadidae) and the harvester ant *Pogonomyrmex salinus* Olsen (Hymenoptera, Formicidae) in southeastern Idaho. Great Basin Naturalist.

- Clark, W. H., and P. E. Blom. First Draft. Bibliography of the harvester ant genus *Pogonomyrmex*. Outlet to be determined.

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RADIONUCLIDE CYCLING IN PLASTIC LINED EVAPORATION PONDS AND EFFECTS ON RADIONUCLIDE LEVELS IN AND RADIATION DOSES TO WATERFOWL AND WATERFOWL HUNTERS

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ABSTRACT—We are conducting research to determine the fate of radionuclides released as liquid effluent into two double-lined evaporation ponds at the Test Reactor Area (TRA) on the Idaho National Engineering Laboratory (INEL). To determine the fate of radionuclides at the TRA ponds, we must quantify all inputs to, and losses from, those systems. We emphasize determining potential radionuclide transport from the ponds, especially transport to humans via waterfowl that have spent time on the ponds. The total activity of radionuclides in the effluent released to the ponds to date was more than 110 Ci, 98% of which was tritium. Most of the remaining activity was ^{60}Co, ^{137}Cs, and ^{51}Cr. We determined inventories of gamma emitting radionuclides, tritium, strontium, and transuranics. More than 140 samples were collected and more than 264 analyses were conducted during 1995. About 39% of the tritium activity remained in the ponds. About 30% of the gamma activity was found in the water column. We collected fourteen ducks from various INEL ponds. No contamination was found in the edible portion of the five ducks collected from TRA but external contamination was detected on one of the birds. We conducted 133 routine surveys on the ponds to record the number and species of birds using them. Twenty-five of the 66 bird species recorded were waterfowl. Samples of tumbleweeds, which are known to blow in and out of the ponds, showed average concentrations of 3.7±0.4 nCi/g for gamma emitting radionuclides and 1.95±0.16 nCi/g for ^{90}Sr. Five swallow nests were collected from the TRA facility. Preliminary results show contamination in the nests. Average exposure rates as measured on the shore and at the surface of the water in the ponds were 1.53 mR/d and 2.87 mR/d, respectively. Average sediment loads were estimated to be 0.8 g/cm^2 on the west pond and 1.6 g/cm^2 on the east pond. Pond evaporation was modeled and the model calibrated.

KEYWORDS: *Ponds, Test Reactor Area, waterfowl, radionuclides.*

JUSTIFICATION

Two lined ponds were constructed during the summer of 1993 to replace percolation ponds at the Test Reactor Area (TRA). Many studies were conducted over the lifetime of the percolation ponds (Morris 1994) and much was learned about radionuclide cycling in, and transport from, such ponds. Radionuclides tended to become bound with the sediments of the percolation ponds (Ibrahim and Culp 1989, Millard 1986) such that the potential for transport of large amounts of radioactivity was limited and the potential for doses to humans was consequently small. In contrast, little is known about radionuclide cycling in a lined-pond system. Initially, with very little sediment present, radionuclide behavior will likely be different from a non-lined percolation pond. Without sediment, radionuclides may be more available (i.e., in the water column) to waterfowl and other birds, thereby increasing the likelihood of contaminant transport from the pond and, potentially, to humans. Also, radionuclides remaining in the water column will have less shielding. This may result in higher exposure rates on and around the ponds. Because the central concept in hazardous waste management is to keep waste isolated from the environment and humans, the question of whether lined-pond systems have a greater potential for environmental exposure than percolation ponds must be answered.

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Understanding the behavior of radionuclides in a lined-pond system is also important for other reasons. The environmental assessment for the lined ponds (U.S. Department of Energy 1991) said that studies of waterfowl using the pond would be initiated to determine whether they constitute a significant pathway of contaminants to humans. In addition, because waterfowl are protected under The Migratory Bird Treaty Act, information on the effects of contamination on waterfowl in lined ponds is needed. Also, the use of lined evaporative ponds is likely to increase due to public concern for the Snake River Plain Aquifer. Other percolation ponds are already being replaced by lined evaporation ponds (e.g., at the Test Area North [TAN] facility) so knowledge of radionuclide behavior in evaporation ponds is essential. These data can also be used in support of Ecological Risk Assessment. The analysis of the potential radiation dose to humans from migrating waterfowl will be included annually in the *INEL Site Environmental Report* as mandated by DOE Order 5400.1.

Objectives

In order to determine the fate of radionuclides in lined ponds, this project has the following objectives:

- Determine the potential for transport of radioactive contamination off-site by waterfowl that use the lined ponds, and the potential for radiation dose to humans from eating them.

Waterfowl visitation rates and residence times on the ponds were determined by visual observation. Waterfowl were collected and radionuclide concentrations were determined for whole body, external, and the edible fractions. Doses to both the duck and the person potentially consuming it will be based on these analyses.

- Determine the transport of radionuclides from the ponds by vectors other than waterfowl.

Barn swallows and mourning doves use the ponds regularly. We plan to collect and analyze specimens of both species to determine dose and estimate the amount of transport from the ponds via these birds.

Tumbleweeds are known to blow into the ponds, become contaminated, and then blow out. We are counting, collecting, and analyzing wind-blown vegetation to quantify transport.

- Determine radionuclide cycling in the ponds through time.

We continue to sample several components of the pond system, including, but not limited to, water, suspended materials, sediment, vegetation, waterfowl and other species. In 1995, samples were examined for gamma-emitting radioactivity with a subset being analyzed for transuranic activity. Samples were collected at least once every month in order to document temporal changes.

- Create a dynamic model of radionuclide cycling in the pond system to be used to estimate future potential radiation doses to waterfowl and humans.

- Compare these results with the potential for doses to waterfowl and humans determined from the previously used percolation pond system.

Project Accomplishments

This project has resulted in a number of accomplishments. In 1995 we:

- Collected observation data throughout the year to determine visitation rates and residence times for waterfowl.

We made 133 daily visits at randomly selected times during 1995. On each visit numbers and species of birds using the ponds were recorded. In addition to daily observations, we conducted six long-term observation periods in which an observer monitored the pond throughout all daylight hours. Each observation was conducted on a randomly selected day.

- Collected Samples of pond components.

During 1995, 140 samples were taken from the ponds and surrounding area. Of those samples, 31 were water, 29 were sediment, 40 were seston, 16 were tumbleweeds, 10 were swallow nests, and 14 were ducks.

- Analyzed samples of pond components for gamma-emitting radionuclides. A subset was analyzed for strontium and transuranics (all water samples were also analyzed for tritium).

We conducted 264 analyses on the pond component samples.

Of the 14 ducks collected, five were taken from the TRA ponds and five were taken from the Ft. Hall area as controls. A total of nine ducks were collected from ponds at TAN, the Idaho Chemical Processing Plant, and Argonne National Laboratory West. These birds will be used for comparison purposes. Eleven waterfowl were analyzed for gamma emitting radionuclides during 1995.

- Recorded the number of tumbleweeds in the ponds in daily surveys.

- Replaced 18 dosimeters on and around the ponds each quarter.

These dosimeters were initially placed in late 1994. These data will be used to calculate doses to birds spending time at various locations on the ponds.

- Collected 92 sediment samples, each covering 4 cm^2, from across the bottoms of both TRA ponds.

We dried and weighed the sediment. Multiple measurements over time will allow estimates of sedimentation rates and, with concentration data, radionuclide inventories in the sediment.

- Developed and calibrated an evaporation model for the evaporation ponds.

The model was constructed using the Penman equation (McCuen, 1989) and meteorological data from a National Oceanic and Atmospheric Administration weather station near TRA. It estimates evaporation from the ponds. After validation, this model will allow predictions of water depths within the ponds which, along with radionuclide kinetic data, will also allow predictions of radionuclide inventories within the water. Since tritium acts essentially identical to water, this model only needs input data to predict tritium inventories over time.

- Took monthly water quality measurements including pH, conductivity, temperature and dissolved oxygen.

IMPORTANT RESULTS

We observed 14 bird species using the ponds that were not observed during 1994. Of these, six were waterfowl. The number of bird species observed using the ponds over the entire study thus far is 66, of which 25 were waterfowl species. According to research conducted from April 1989 through October 1991 (Cieminski 1993), 68 bird species were observed at the, now reclaimed, TRA percolation ponds. Our data show that the species richness of the TRA evaporation ponds ranks 6th out of 22 waste ponds on the INEL.

Based on input records from the Radiation Measurements Laboratory at TRA, 110 Ci were released to the evaporative ponds between August 1993 and May 1995. About 98% of the total activity was tritium with about 2% gamma emitting radionuclides and small amounts of ^{90}Sr and transuranics. An average of about 39% of the tritium activity remained in the water column; the other 61% was released to the atmosphere. An average of 30% of the gamma emitting activity was found to remain in the water column. A large portion (40 to 90%) of the gamma activity found in the water column was associated with seston (particulate matter). Concentrations in filtered water and sediment averaged 9.4 pCi/g and 150 nCi/g, respectively. In the old percolation ponds at TRA, filtered water concentrations averaged about 2,500 pCi/g while the sediment averaged about 77 nCi/g.

No contamination was detected in the edible portion of any of the ducks analyzed (five ducks from TRA and six collected in 1994 from off-site). At least one duck from TRA did have external contamination (concentration in the feathers and skin of about 146 ± 44 pCi/g).

Average concentrations found in the tumbleweed samples were 3.7 ± 0.4 nCi/g for gamma emitting radionuclides and 1.95 ± 0.16 nCi/g for ^{90}Sr. Numbers of tumbleweeds found in the ponds were highly variable and very dynamic. More then 500 tumbleweeds have been counted in the ponds at once. In very short time periods the number of tumbleweeds can drastically change. More than once, numbers fluctuated by more than 200 tumbleweeds during one day. A sample plan was developed to determine the average mass of the tumbleweeds and their travel distances in order to estimate transport from the ponds.

Preliminary results from the swallow nests show elevated radionuclide levels in all five nests collected from TRA.

Exposure rates around the evaporation ponds ranged from 0.7 mR/d on shore in winter (with snow cover) to over 11 mR/d directly on the liner in the middle of the pond. Averages for 1995 were 1.53 mR/d on shore and 2.87 mR/d on the water.

Average sediment loads in the ponds were estimated to be 0.8 g/cm^2 in the west pond and 1.6 g/cm^2 in the east pond.

PRODUCTS

This study is in the data collection phase. No publications were produced in 1995. However, we established our sampling methodologies and are continuing to collect quality data to meet project objectives.

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IODINE-129 EFFLUENTS FROM THE ICPP: LONG-TERM CONCENTRATIONS IN ANIMAL THYROIDS AND VEGETATION ON AND OFF THE INEL

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ABSTRACT—Previous investigations show that ^{129}I concentration and $^{129/127}I$ ratios are elevated in some environmental media both on and near the Idaho National Engineering Laboratory. The transport pathway and the long-term trends have not been determined. This study analyzes ^{129}I concentration and $^{129/127}I$ ratios in sagebrush (*Artemisia tridentata*) and mule deer (*Odocoileus hemionus)* and pronghorn (*Antilocapra americana*) thyroids. This analysis will increase our understanding of the mode of transport of ^{129}I off-site, and its potential dose to big game animals. We are also analyzing the long-term trends in ^{129}I contamination in the environment, particularly following shutdown of the Idaho Chemical Processing Plant. Sample analyses of big game thyroids was completed and data analyses are underway. Analysis of sagebrush samples was suspended pending these results.

KEYWORDS: *Iodine-129 concentration, iodine-129/127 ratios, mule deer, pronghorn, thyroids.*

JUSTIFICATION

The Idaho Chemical Processing Plant (ICPP) began processing radioactive waste in 1953. As part of plant operations, approximately 3.7 GBq y^{-1} (0.1 Ci y^{-1}) (U.S. Energy Research and Development Administration 1977) of ^{129}I was released to the atmosphere until October 1988, when the waste calciner was shut down for renovation. Much of this ^{129}I became incorporated into the ecosystem on and near the Idaho National Engineering Laboratory (INEL).

Previous studies reported above background levels of ^{129}I on and off the INEL. These levels were found in several environmental media including vegetation (McGiff 1985), waterfowl tissues (Halford and Markham 1984), rabbit thyroids (Fraley et al. 1982) and mule deer thyroids (Markham et al. 1983). Concentrations in vegetation decrease with distance from the ICPP. However, ratios of ^{129}I to the stable nuclide of iodine, ^{127}I, in mule deer harvested at Craters of the Moon National Monument and Monida Pass, on the Idaho/Montana border were 12-15 times background ratios. This indicated that contamination from the INEL was carried to those locations, probably by wind. None of the past studies occurred over a long enough time period to determine long-term trends in ^{129}I contamination on and off the INEL. In particular, current data do not allow productive estimates of long-term trends in ^{129}I contamination after the ICPP is shut down.

While ^{129}I in the environment is not expected to present a significant radiological health risk, it does present a significant public relations risk, principally because of its 16-million year half-life. In the public mind, long half-life is associated with extreme hazard. In addition, although the total dose was small, ^{129}I was responsible for 92.1%, and 20.5% of the dose to the maximally exposed individual in 1993 and 1994, respectively (Mitchell 1994, Mitchell et al. 1995). Iodine-129 is expected to become a permanent component of the environment because of its long half-life, and because some of its chemical forms readily bond to organic materials. It is expected to continuously cycle through the food chain and deliver radiation dose to humans and nonhuman organisms. For us to respond to public concerns and

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adequately assess human and ecological risks, we need to understand the patterns and mechanisms of ^{129}I cycling in the sagebrush steppe. It is also important that we understand the long-term consequences of ^{129}I contamination for human and environmental health.

Finally, iodine is an essential element in human nutrition and scientists have invested a great deal of effort in studying its cycling in the environment (Hanson 1963, Kocher 1981). Iodine-129 serves as an analog for stable iodine and our work here helps increase the understanding of that system.

For all these reasons, our overall goal is to understand ^{129}I cycling in the environment. However, it will benefit to DOE to determine the extent of environmental contamination and demonstrate a low level of hazard to the environment. The current project objectives reflect that short-term goal.

OBJECTIVES

The two primary objectives to this study are to:

- Analyze pronghorn and mule deer thyroids (collected on- and off-site over approximately the past 20 years) for ^{129}I concentration and $^{129/127}I$ ratio.

These samples have been analyzed by Accelerator Mass Spectrometry and data analyses are underway. Because these samples were collected over a long period, they will allow us to determine long-term trends in ^{129}I contamination, including the trends to be expected when the ICPP is shut down. Understanding these trends are important for an assessment of the human and ecological risks posed by INEL activities. These data will also be incorporated into a model of iodine cycling. In addition, we will estimate the thyroid doses delivered to the animals from ^{129}I, enabling us to determine part of the long-term consequences of environmental contamination by ^{129}I.

- Determine whether $^{129/127}I$ ratios are elevated (compared with world-wide background) in sagebrush collected at Craters of the Moon National Monument, Monida Pass and various on-site locations.

Analysis of the thyroid data will show whether ^{129}I exists at elevated levels in the areas where the sagebrush samples were collected. Therefore, this objective has been suspended pending the results of data analysis on the thyroid samples.

PROJECT ACCOMPLISHMENTS

- We completed analysis of 63 mule deer and pronghorn samples for ^{129}I concentration and $^{129}I/^{127}I$ ratio. Data from these samples are currently being analyzed.

IMPORTANT RESULTS

Isotopic ratios ($^{129}I/^{127}I$) range from $0.2x10^{-6}$ to $600x10^{-6}$. This may be compared with an average ratio of $0.2x10^{-6}$ for pronghorn thyroids from Wyoming (Brauer et al. 1973). Preliminary analysis indicates that thyroids collected on the INEL have greater ratios than those collected offsite. The greatest ratios occurred in samples collected in 1987 and 1988, a period just prior to the calciner shutdown.

PRODUCTS

This project is in the data analysis phase. No products are completed.

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SURFACE WATER PENETRATION AT THE SUBSURFACE DISPOSAL AREA

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ABSTRACT—Various EPA and DOE regulations require that shallow-land burial sites for low-level radioactive wastes remain effective for at least 100 years. Primary to the success of a waste management site is the capability to keep wastes isolated from water. At the Idaho National Engineering Laboratory, most of the annual soil moisture recharge results from precipitation that occurs during the months when plants are dormant (October - March). Changes in management strategies at the Subsurface Disposal Area (SDA) have resulted in differences in soil covers, thickness, land contours, vegetation types, and proximity of buried wastes to roads and ditches. Each of these factors influences soil moisture dynamics in the protective soil caps. Since 1988, we have measured soil moisture at 20-cm intervals to depths of 1.6 m on seven study sites within the SDA. Our measurements occurred mostly during the late winter, early summer, and fall. Throughout that period, precipitation during the non-growing season ranged from 46.6% to 135.5% of normal (99.7 mm). Soil moisture recharge was generally ≤ 40-cm deep for all areas and years except for 1989, 1993, and 1995. In some study plots during those years moisture reached depths of 1.0, 1.4, and 1.0 m, respectively. Although 1.0 - 1.4 m is greater than much of the original cover thickness, it is less than present soil thicknesses over most of the SDA.

KEYWORDS: *Infiltration, soil moisture recharge, Subsurface Disposal Area, volumetric soil moisture.*

JUSTIFICATION

Effectively isolating hazardous wastes in shallow-land burial sites requires managing the annual influx of moisture into the soil to prevent drainage into the waste zone (Fisher 1986, Nativ 1991). This is particularly crucial for waste management sites, such as the Subsurface Disposal Area (SDA) at the Idaho National Engineering Laboratory (INEL), that are located above a significant aquifer. In much of the semi-arid west, including the INEL, the highest soil water content (recharge) occurs following snow melt and spring rains (Anderson et al. 1993). Soil recharge dynamics are influenced not only by the amount and timing of precipitation, but by soil type, vegetative cover, and topographic features. For example, soils high in silt or clay have a much higher water holding capacity, and consequently lower hydraulic conductivity, than soils with a greater sand content; soils lacking vegetation are likely over several years to accumulate more moisture that penetrates deeper than vegetated soils (Anderson 1993); and a sloping soil surface directs surface water elsewhere and presumably reduces infiltration.

Contaminated wastes have been buried in trenches and pits at the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex on the INEL since the 1950's. Early disposal practices were naive by today's standards, and did not always adequately isolate wastes from the environment. Since then, different waste management strategies have been implemented to improve waste isolation. Perennial grasses have been planted over much of the SDA to reduce erosion. High clay-content soil mined from a nearby playa has been added to the original soil cover in many areas to reduce infiltration, correct for soil settling (subsidence) and provide a thicker soil barrier against burrowing animals. Drainage ditches and contoured soil covers were constructed to promote runoff from the protective caps and reduce the consequences

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of flooding events. The impact of these practices on soil water dynamics is not fully known.

Any waste management strategy that affects the balance between moisture input and moisture withdrawal impact the effectiveness of the soil-plant cover system. For example, contouring the soil cover may reduce soil moisture recharge and subsequently decrease the vigor of the vegetation cover. Other Foundation research at the INEL has shown that 1.6 m of the playa soil is sufficient to store the record amount of precipitation recorded on the INEL from October through March. Our research has also shown that a vigorous stand of plants will deplete all the available (not chemically bound) soil moisture during the following growing season (Anderson et al. 1993). However, not all wastes at the SDA are under a soil mantle as thick as 1.6 m.

Results of this long-term study will provide information on the impacts of different waste management strategies on annual and multi-annual soil water dynamics that will be useful to DOE-ID for making informed waste management decisions to meet regulatory targets.

OBJECTIVE

This study has two related long-term objectives:

- Monitor and compare the fluctuations in soil moisture content in the soil profiles of areas within the SDA likely affected by different management strategies.

The study plots include: (1) an area covered with high clay-content soil, leveled, but not contoured, and planted with crested wheatgrass (*Agropyron desertorum*) [Plots 11 & 12]; (2) an area with similar history but adjacent to a roadway where drainage ditches and road maintenance likely influence infiltration [Plot R]; (3) a level area covered with high clay-content soil and allowed to revegetate naturally [Plot A]; (4) the top of a domed area contoured with lake bed high clay content soils and planted with a blend of crested wheatgrass (*A. desertorum*) and streambank wheatgrass (*A. dasystachum*) [Plot T]; (5) the lowest edge of the contoured area [Plot E]; (6) a level area where grasses were planted in deep native soils [Plot 34]; and (7) an area where grasses were planted in shallow soils (ca. 40 cm) over a basalt shelf [Plot L].

- Monitor and compare the maximum depth of moisture infiltration into soils at the areas described above.

Neutron hydroprobe access tubes were installed to depths of up to 1.6 m in each of the seven study areas at the SDA. Soil moisture was estimated at 20-cm depth increments periodically during the growing season and in the late winter. We found that soil moisture is static during the winter, becoming dynamic coincident with soil thawing in the spring.

Specific objectives for 1995 included:

- Taking field measurements and estimating soil moisture for each plot after snow melt and periodically during the growing season.

- Analyzing the entire data set from 1988-1995.

PROJECT ACCOMPLISHMENTS

- We took field measurements and calculated estimates of soil moisture nine times from January through August.

Above average precipitation (136 % of the 45-year average) during the non-growing season (October through March) resulted in soil moisture recharge to depths ≥ 80 cm for all but two plots. Recharge in Plots R (near a

roadside ditch) and E (at the edge of the contoured cover) reached 60 cm.

- We analyzed and compared soil moisture data from 1988-1995.

Maximum recharge depths were examined by graphing volumetric water content at 20-cm depth increments for each sampling date. Soil moisture recharge was ≤ 40 cm deep for all plots in 1988, 1990, 1991, 1992, and 1994. In 1989, 1993, and 1995 some study plots were wetted to 1.0, 1.4, and 1.0 m respectively. Infiltration below 60 cm occurred following every winter (October through March) with average or greater precipitation (Table 1).

- We generated spring and fall volumetric soil moisture profiles for all plots and sample dates. A scattergram summarizing these data since 1988 was prepared (Fig. 1).

Spring volumetric soil moisture contents were generally lower than those found in other Foundation studies (Anderson et al. 1993, Anderson and Ratzlaff this volume). This was a likely consequence of mowing the standing vegetation on the SDA in the fall. Fall volumetric soil moisture generally exceeded that in other studies, suggesting either differences in the lower limits of extraction by plants, or soil differences in water holding capacity.

TABLE 1. ANNUAL PERCENTAGE OF AVERAGE PRECIPITATION (99.7 MM WATER EQUIVALENT) FALLING DURING THE NON-GROWING SEASON (OCTOBER THROUGH MARCH) AT THE INEL, MAXIMUM DEPTH OF RECORDED INFILTRATION (RECHARGE), AND AVERAGE SPRING AND FALL VOLUMETRIC SOIL WATER CONTENT ON STUDY PLOTS AT THE SUBSURFACE DISPOSAL AREA.

Year	Precipitation (% of normal)	Maximum infiltration depth (cm)	Average Volumetric soil water content (%)	
			Spring	Fall
1988	46.6	40	18.3	17.0
1989	98.3	100[1]	20.7	17.0
1990	54.2	40	18.1	16.7
1991	48.1	40	17.6	17.1
1992	50.4	40	20.4	17.1
1993	130.4	140[2]	23.9	19.4
1994	63.7	40	19.4	16.7
1995	135.5	80[3]	20.2	17.1

[1] Infiltration reached this depth on two plots.
[2] Infiltration reached this depth on two plots.
[3] Infiltration reached this depth on six plots.

IMPORTANT RESULTS

A record amount of precipitation was received during the nongrowing season (October 1994 through March 1995). This did not result in a record recharge depth, likely because the fall, 1994 soils were the driest recorded in this study. Examination of

the data since the beginning of the study revealed several patterns. Plots 11 & 12 (planted with crested wheatgrass, no contouring, and imported soils) generally had the lowest spring and fall volumetric soil water content. Plot L (shallow native soils over a basalt shelf) generally had the highest volumetric soil moisture content in the spring. Plots E and R (near a drainage ditch at the edge of a large contoured area and near a road) consistently had the highest fall volumetric soil water content. Since the beginning of the study, the depth of spring soil moisture recharge was usually less for the study areas near roads or drainage ditches than for other study sites. Average or greater precipitation during the nongrowing season from October through March consistently wetted spring soils to depths of ≥ 80 cm. This is deeper than the 1.5-feet (0.5-m) soil cover originally placed over much of the SDA. The additional 2-4 feet (0.6 - 1.2 m) of soil placed over most of the SDA in 1979 (Truitt 1984, J. Bishoff, personal communication) produced a total soil thickness that appears adequate to preclude moisture drainage into the waste zone for the precipitation conditions experienced during most years of this study.

PRODUCTS

A technical manuscript from this research is being prepared. An article summarizing this project was prepared and is being redrafted for distribution in the *Foundation Focus*. The study was described during several presentations summarizing waste management research on the INEL.

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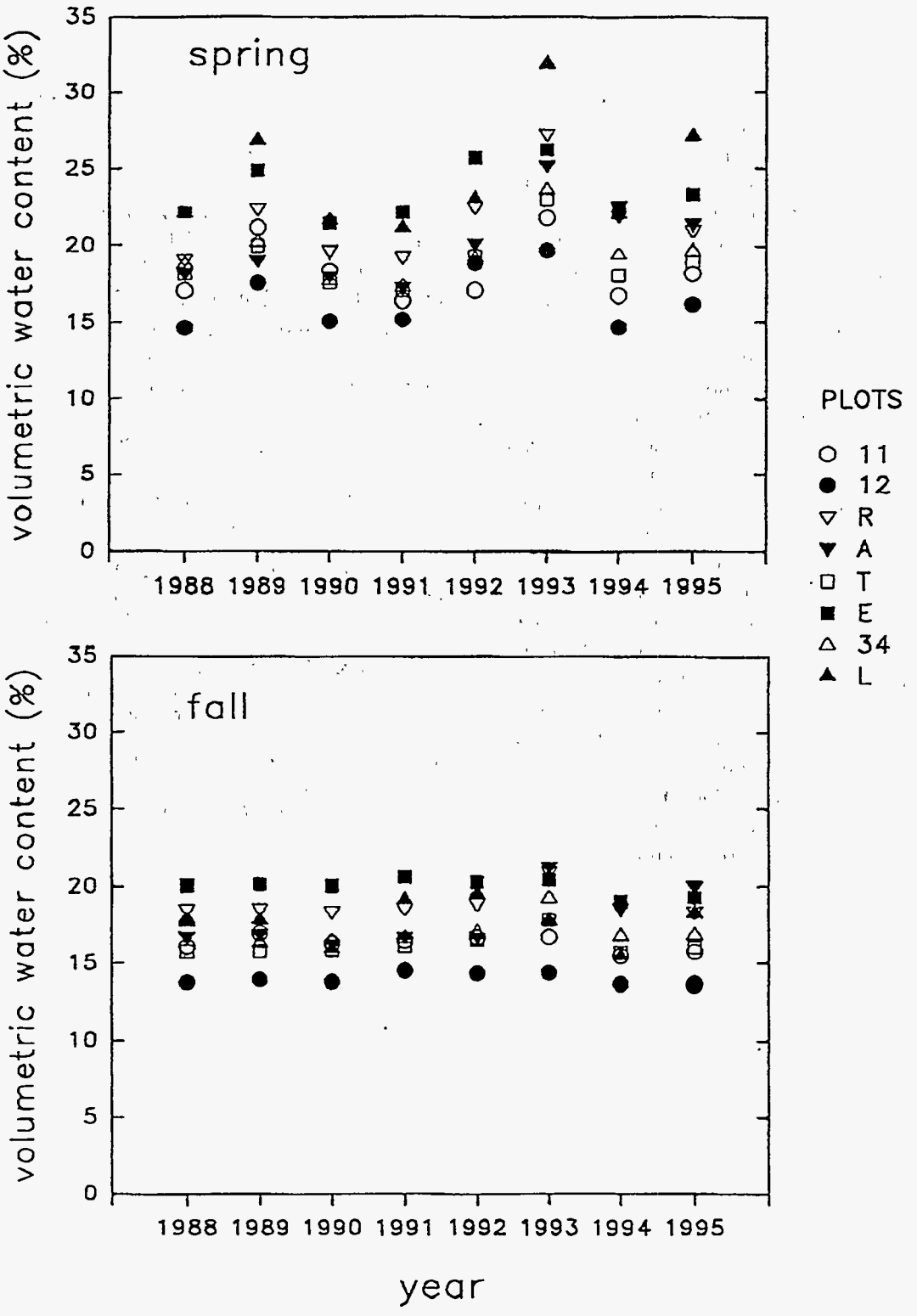

FIGURE 1. VOLUMETRIC WATER CONTENT (%) IN AREAS OF DIFFERENT WASTE COVER TREATMENTS IN THE RADIOACTIVE WASTE MANAGEMENT COMPLEX AT THE IDAHO NATIONAL ENGINEERING LABORATORY. WATER CONTENTS ARE GIVEN AT PEAK RECHARGE (SPRING) AND MAXIMUM DEPLETION (FALL) FROM 1988 - 1995. PLOT CODES ARE DEFINED IN THE TEXT.

TRACE ELEMENTS AND ORGANICS IN SURFACE SOILS AT THE SUBSURFACE DISPOSAL AREA

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ABSTRACT—Samples of soil excavated by small mammals and adjacent, nonexcavated soils were collected previously from the Subsurface Disposal Area (SDA) and analyzed for trace elements and organic pesticides. Although several trace elements were found in higher concentrations at the SDA than in background areas, all fell within the ranges found naturally throughout the region (Rope et al. 1988). Over all transects, Hg was found at higher concentrations in nonexcavated soils than in excavated soils, possibly from industrial operations at SDA. The organic pesticide Aldrin was found in soils excavated by small mammals at the SDA in concentrations of up to 18 μg kg^{-1}. It was not found in nonexcavated soils. To explain the presence of Aldrin in these samples, further samples were collected from the Big Lost River spreading areas south of the SDA. These samples were analyzed in 1995. No Spreading Area sample contained Aldrin above detection limits. Although no records or institutional memory of Aldrin use exists, this implies that the Aldrin detected in earlier sampling was derived from either INEL operations or Rocky Flats waste stored at the SDA.

KEYWORDS: *Aldrin, soils, Subsurface Disposal Area, trace elements.*

JUSTIFICATION

Since 1952, radioactively contaminated waste has been disposed at the INEL Subsurface Disposal Area (SDA). Due to deterioration of waste containers, contamination has occurred in SDA subsurface soils. Other hazardous waste components, including trace elements and organics, are buried with the radioactive waste at the SDA.

Trace elements and organics have increasing political visibility relative to radioactive contaminants and, similar to radioactive contaminants, they have potential for dispersal through biotic pathways. Thus, it is important to understand and monitor the ways in which these contaminants might be transported in the environment. One potentially important means of transport is small mammals bringing contaminants to the surface in soil excavated by their burrowing. This contaminated soil is then available for dispersal by wind.

Radionuclide transport by biota was well investigated at the SDA. Arthur and Markham (1982) estimated that 270 kBq y^{-1} of radioactivity was exported from the SDA by coyotes due to their consumption and subsequent elimination of contaminated small mammals (Arthur and Janke 1986). Approximately 49% of deer mice (*Peromyscus maniculatus*) and 20% of kangaroo rats (*Dipodymus ordii*) inhabiting the SDA encounter areas of buried radioactive waste or contaminated soil (Arthur et al. 1987). Burrowing by these small mammals transports transuranics to the surface (Arthur and Markham 1983). Arthur et al. (1987) estimated that 844 kBq y^{-1} of mixed radioactivity was deposited on the surface of the SDA by burrowing deer mice and dispersing deer mice transported 310 kBq y^{-1} from the SDA.

A relative wealth of information is available concerning radionuclide transport by biota at the SDA. However, no published studies report similar investigations of trace elements and organics. Therefore, our objectives were to determine whether concentrations of trace elements and organic pesticides are greater in SDA surface soils

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than background areas and to determine whether small mammal burrowing has brought trace elements and organic pesticides to the soil surface. Samples of soil excavated by small mammals and adjacent, nonexcavated soils were collected from the SDA and analyzed for trace elements and organic pesticides. Although several trace elements were found in higher concentrations at the SDA than in background areas, all fell within the ranges found naturally throughout the region (Rope et al. 1988). Over all transects, Hg was found at higher concentrations in non-excavated soils than in excavated soils, possibly as a result of industrial operations at SDA. The organic pesticide Aldrin was found in small mammal excavated soils in concentrations up to 18 $\mu g\ kg^{-1}$. It was not found in nonexcavated soils. As a result, we expanded our objectives in 1994 to include determining if Aldrin entered the SDA in cover soil that was contaminated by upstream agriculture.

Objectives

To meet the overall objectives of the study, the following objectives were established for 1995:

- Analyze the soil samples collected in 1994 for Aldrin.

In 1976, a new soil cover was placed on some of the SDA study areas. The soil for this cover came from the spreading areas, an area into which the Big Lost River overflow is diverted during high water years. Thus, Aldrin found in the small mammal excavated soils may have been used as a pesticide in the agricultural fields upstream from the SDA and washed downstream into the spreading areas, contaminating the soil used to complete the cover. To determine the origin of the Aldrin, we required additional soil samples from the spreading areas.

Project Accomplishments

We collected and analyzed 12 additional soil samples from undisturbed areas, inactive borrow locations, and active borrow locations in the spreading areas.

Important Results

Spreading Area samples did not contain Aldrin above detection limits. Although no records or institutional memory of Aldrin use exists, this implies that the Aldrin detected in earlier sampling was derived from either INEL operations or Rocky Flats waste stored at the SDA.

Products

No products have resulted from this study to date. These results will be summarized in a 1996 report.

Literature Cited

Arthur, W. J. and D. H. Janke. 1986. Radionuclide concentrations in tissues of wildlife occurring at a solid radioactive waste disposal area. Northwest Science 60:154-159.

Arthur, W. J. and O. D. Markham. 1982. Ecological vectors of radionuclide transport at a solid radioactive waste disposal facility in southeastern Idaho. p. 574-580 *in* M. A. Faraday, ed., Proceedings of the International Conference on Radioactive Waste Management. Winnipeg, Manitoba.

Arthur, W. J., O. D. Markham, C. R. Groves, and B. L. Keller. 1987. Radionuclide export by deer mice at a solid radioactive waste disposal area in southeastern Idaho. Health Physics 52:45-53.

Arthur, W. J. and O. D. Markham. 1983. Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho. Journal of Environmental Quality 12:117-122.

Rope, S. K., W. J. Arthur, T. H. Craig, and E. H. Craig. 1988. Nutrient and trace elements in soil and desert vegetation of southern Idaho. Environmental Monitoring and Assessment 10:1-24.

APPENDIX A

TECHNICAL PRESENTATIONS DURING 1995

- Anderson, J. E. Meeting the challenges: ecological solutions. Symposium on Ecological Aspects of Waste Management. Annual Meeting of the Northwest Scientific Association, Idaho Falls, ID.

- Anderson, J. E. Rationale and experimental details of the PC/BE. State of Idaho INEL Oversight Committee.

- Anderson, J. E. Using natural ecosystem processes for keeping water from reaching interred hazardous wastes. Symposium on Ecological Engineering: a New Paradigm for Ecology. Annual Meeting of the Ecological Society of America, Snowbird, UT.

- Blom, P. E. and J. W. Laundré. Challenges to waste repositories: animal intrusion. Symposium on Ecological Aspects of Waste Management, Annual Meeting of the Northwest Scientific Association, Idaho Falls, ID.

- Brewer, R. and R. C. Morris. A case study for evaluating ecological risks. 1995 Conference on Hazardous Wastes and Materials, Pocatello, ID.

- Bromenshenk, J. J., G. C. Smith, and V. J. Watson. Honey bees as monitors of ecosystem conditions and human health. Invited thematic paper presented at the International Conference on Tropical Bees and the Environment, Pedu Lake, Kedah, Malaysia.

- Cooper, S. L. Snake safety and herpetofauna of the Idaho National Engineering Laboratory. Presentation to INEL and Foundation employees, Idaho Falls, ID.

- Cooper, S. L. Snake safety and herpetofauna of the Idaho National Engineering Laboratory. Presentation to INEL employees, Central Facilities Area, INEL, ID.

- Cooper, S. L., and C. R. Peterson. A comparison of the distribution and abundance of the herpetofauna of the INEL: 1975 and 1994. Annual Meeting of the Idaho Herpetological Society, Boise, ID.

- Cooper, S. L. and C. R. Peterson. A comparison of the distribution and abundance of the herpetofauna of the Idaho National Engineering Laboratory: 1975 and 1994. Annual Meeting of the Northwest Scientific Association, Idaho Falls, ID.

- Duffin, E. K. Snowmelt erosion research at the Idaho National Engineering Laboratory. Utah State University Rangeland Resources Graduate Seminar, Logan, UT.

- Duffin, E. K. and J. P. Dobrowolski. Evaluating snowmelt erosion from simulated waste burial trench caps. Annual Meeting of the Northwest Scientific Association, Idaho Falls, ID.

- Flake, L. D. Raptor studies on the INEL. Classroom Presentation in Ornithology at South Dakota State University, Brookings, SD.

- Flake, L.D. Bird studies on the INEL. Classroom Presentation in Orinthology at South Dakota State University, Brookings, SD.

- Ibrahim, S. A. The environmental transport of plutonium and related cleanup issues. First Annual University of Colorado Public Interest Science Conference, Boulder, CO.

- Limbach, W. E. The design of the Protective Cap/Biobarrier experiment. Field seminar presentation to Colorado State University graduate students at the study site on the INEL.

- Limbach, W. E. The effect of seed priming on the growth of thickspike wheatgrass in competition with cheatgrass. Annual Meeting of the Northwest Scientific Association, Idaho Falls, ID.

- Limbach, W. E. The effect of seed priming on the growth of thickspike wheatgrass in competition with cheatgrass. Annual Meeting of the Society for Range Management, Phoenix, AZ.

- Limbach, W. E. Using local plant materials for vegetating a severely disturbed site in southeastern Idaho. Annual Meeting of the Society for Ecological Restoration, Seattle, WA.

- Limbach, W. E. and S. P. Hardegree. The effects of seed-priming on the growth of *Elymus lanceolatus* in competition with *Bromus tectorum*. Annual Meeting of the Ecological Society of America, Snowbird, UT.

- Morris, R. C. An experimental comparison of protective caps for burial of hazardous waste. DOE Technology Information Exchange Workshop, Cincinnati, OH.

- Morris, R. C. Potential dose to humans from game animals. Radiation Environmental Monitoring and Surveillance course, Idaho State University, Pocatello, ID.

- Morris, R. C. and Y. McClellan. Addressing ecological concepts in ecological risk assessment. Second World Congress of the Society of Environmental Toxicology and Chemistry, Vancouver, British Columbia, Canada.

- Morris, R. C. and T. D. Reynolds, chairs. Ecological aspects of waste management. Annual Meeting of the Northwest Scientific Association, Idaho Falls, ID.

- Rasmuson, K. E. Growth and physiological responses of *Bromus tectorum* to increasing levels of salinity. Annual Meeting of the Ecological Society of America, Snowbird, UT.

- Rasmuson, K. E. Growth and physiological responses of *Bromus tectorum* to increasing levels of salinity. Annual Meeting of the Northwest Scientific Association, Idaho Falls, ID.

- Ratzlaff, T. D. Soil water dynamics in sagebrush steppe habitats. Annual Meeting of the Idaho Academy of Sciences, Pocatello, ID.

- Ratzlaff, T. D. and J. E. Anderson. Annual soil water recharge and extraction in a cold desert steppe in southeastern Idaho. Annual Meeting of the Ecological Society of America, Snowbird, UT.

- Ratzlaff, T. D., K. E. Rasmuson, T. R. Bowlin, J. E. Anderson, and R. S. Inouye. The historic and present distribution of *Bromus tectorum* on the Idaho National Engineering Laboratory. Annual Meeting of the Northwest Scientific Association. Idaho Falls, ID.

- Reynolds, T. D. Research parks and NEPA: two decades of symbiosis. NEPA25 Conference, Washington, DC.

- VanHorn, R. L., N. L. Hampton, R. C. Morris. Screening radionuclides for ecological risk assessment at the INEL. Second World Congress of the Society of Environmental Toxicology and Chemistry, Vancouver, British Columbia, Canada.

- Warren, R. W. Cover demonstration at Hill Air Force Base. DOE Technical Information Exchange Workshop, Cincinnati, OH.

APPENDIX B

PUBLICATIONS BY FOUNDATION RESEARCHERS DURING 1995

TECHNICAL PUBLICATIONS

- Anderson, J. E., R. S. Nowak, K. E. Rasmuson, and N. L. Toft. 1995. Gas exchange and resource-use efficiency of *Leymus cinereus* (Poaceae): Diurnal and seasonal responses to naturally declining soil moisture. American Journal of Botany 82:699-708.

- Anderson, J. E. Submitted. Meeting the challenges: Ecological solutions - a soil-plant cover system. Proceedings of the Symposium on Ecological Aspects of Waste Management.

- Belthoff, J. R., L. R. Powers, and T. D. Reynolds. In review. Breeding birds at the Idaho National Engineering Laboratory, 1985-1991. Great Basin Naturalist.

- Blom, P. E., D. A. Schoep and W. H. Clark. Draft. Observations of cicada nymphs, *Okanagana annulata* Davis (Homoptera: Cicadidae) and the harvester ant *Pogonomyrmex salinus* Olsen (Hymenoptera: Formicidae) in southeastern Idaho. Great Basin Naturalist.

- Blom, P. E., J. B. Johnson, S. K. Rope and B. Shafii. Draft. Radionuclide concentrations in soils associated with the harvester ant, *Pogonomyrmex salinus* Olsen (Hymenoptera: Formicidae), nesting in a shallow waste disposal area. Science of the Total Environment.

- Bromenshenk, J. J., G. C. Smith, and V. J. Watson. 1995. Assessing ecological risks in terrestrial systems with honey bees. Pages 9-30 *in* F.M. Butterworth, L.D. Corkum, and J. Guzmán-Rincón, eds. Biomonitors and biomarkers as indicators of environmental change. Plenum Press, New York, NY.

- Bromenshenk, J. J., R. C. Cronn, and J. J. Nugent. In press. Monitoring fluoride with honey bees in the upper Snake River Plain of Idaho. Journal of Environmental Quality.

- Bromenshenk, J. J., J. L. Gudatis, and R. C. Cronn. Submitted. Post-closure assessments of industrial complexes with honey bees. Environmental Contamination and Toxicology.

- Cieminski, K. L., and L. D. Flake. 1995. Invertebrate fauna of wastewater ponds in southeastern Idaho. Great Basin Naturalist 55:105-116.

- Cieminski, K. L., and L. D. Flake. In revision. Avian communities of wastewater ponds in southeastern Idaho. Proceedings: Annual Conference on Wetlands Restoration and Creation.

- Cieminski, K. L., and L. D. Flake. In revision. Common nighthawk diel activity patterns at desert ponds. Journal of Field Ornithology.

- Cieminski, K. L., and L. D. Flake. In revision. Mule deer and pronghorn use of wastewater ponds in a cold desert. Great Basin Naturalist.

- Cieminski, K. L., and L. D. Flake. In revision. Swallow activity patterns on desert ponds. Journal of Field Ornithology.

- Clark, W. H., and P. E. Blom. Draft. Bibliography of the harvester ant genus *Pogonomyrmex.*

- Clark, W. H., P. E. Blom and P. J. Johnson. Draft. *Gonasida elata* LeConte associated with *Pogonomyrmex salinus* Olsen nest soils in southeastern Idaho (Coleoptera, Tenebrionidae, Asidinae; Hymenoptera, Formicidae, Myrmicinae). Proceedings of the Entomological Society of Washington.

- Cronn, R. C., and J. J. Bromenshenk. Submitted. Radionuclide accumulation in honey bees at the Idaho National Engineering Laboratory. Journal of Environmental Quality.

- Hansen, R. W. and L. D. Flake. 1995. Ecological relationships between nesting Swainson's and Red-tailed hawks in southeastern Idaho. Journal of Raptor Research 29:166-171.

- Hansen, R. W. and L. D. Flake. 1995. Nest structure cohabitation by raptors in southeastern Idaho. Journal of Raptor Research 29:32-34.

- Hansen, R. W. and L. D. Flake. Revised. Owl occurrence in the sage-steppe desert of southeastern Idaho. Great Basin Naturalist.

- Hansen, R. W. and L. D. Flake. Revised. Wintering and prebreeding raptor populations on the Snake River Plain of southeastern Idaho. Journal of Raptor Research.

- Laundré, J. W. Draft. Effect of ground squirrel burrows on plant productivity in a cool desert environment. Oecologia.

- Laundré, J. W. Draft. The relationship between carbon isotope ratios and sagebrush productivity. Ecoscience.

- Morris, R. C. and R. A. Warren. Draft. An assessment of risk from external exposure to radiation from contamination brought to the surface by biological activity at the SL-1 and BORAX-I sites. Environmental Science and Research Foundation, Idaho Falls, ID. 30 pp.

- Pearson, L. C. Draft. Lichens as bioindicators of air quality at the Idaho National Engineering Laboratory. Great Basin Naturalist.

- Pearson, L. C. Submitted. Biomonitoring air quality with lichens using electrolyte leakage and energy dispersive spectroscopy. Journal of Environmental Quality.

- Rasmuson, K. E. 1995. 1995 Progress Report: DOE-EPSCoR State of Idaho Energy Production and Environmental Management Traineeship.

- VanHorn, R. L., N. L. Hampton, and R. C. Morris, Principle Investigators. 1995. Guidance manual for conducting screening level ecological risk assessments at the INEL. INEL-95/0190. Lockheed Idaho Technologies Company, Idaho Falls, ID. 524 pp.

POPULAR ARTICLES

- Hansen, R. W. Revised. Hawks of Idaho's high desert. Idaho Wildlife.
- Hansen, R. W. and L. D. Flake. Revised. Prairie biologists in the desert. South Dakota Conservation Digest.

KEYWORD INDEX

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