LAND RECLAMATION PROGRAM
ANNUAL REPORT

July 1975 - July 1976

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COAL EXTRACTION & LAND RECLAMATION

ARGONNE NATIONAL LABORATORY

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ANNUAL REPORT

July 1975 - July 1976

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Argonne National Laboratory
December 1976

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INTRODUCTION

The Land Reclamation Program was initiated at Argonne National Laboratory in June of 1975 to address the need for coordinated applied and basic research into the environmental problems associated with the utilization of coal, one of the nation's most abundant energy forms. Between now and the beginning of the next century, our coal reserves are expected to play an important role in future U.S. energy supply and demand.

It is anticipated that the current national coal production of 648 million tons will double by 2000. The major share of this projected increase is expected to be from surface mines, especially because surface mining is more economically advantageous than deep mining. However, surface mining of coal is more disruptive environmentally, and has greater potential to destroy existing ecosystems, impact water quality and alter land usage. There is, therefore, a great need to better understand and evaluate the feasibility, costs, and potential effectiveness of alternative reclamation technologies as applied to surface mining.

Integrated methods to reclaim surface-mined land in the United States have only been recently undertaken, and their effectiveness is either undetermined or poorly understood and not known over a long-term period. In part, this is attributable to poor understanding of geophysical, geochemical, edaphic, and biological phenomena related to land reclamation and the need for planned coordination of interdisciplinary efforts. This deficiency also is a consequence of the lack of a coordinated and comprehensive national land reclamation research program. Research in this field during the past several years has been administratively and technically fragmented, under the sponsorship of a variety of federal and state agencies and private organizations.

It is evident that a well-structured, long-range nationally coordinated program is needed to develop, test, and deploy the most cost-effective techniques and technologies for land reclamation that are currently available. This must be undertaken in consideration of the close relationship between the potential effectiveness of land reclamation and the feasibility of substantial development of U.S. coal resource regions.

The goal of the Land Reclamation Program is therefore to conduct coordinated field and laboratory research and development programs focused on near- and long-term land reclamation problems and land use in the four major U.S. coal resource regions. The program will coordinate, evaluate, and disseminate the results to the coal industry and other research institutions, to provide decision-makers -- in industry, government, and independent research organizations -- with reasonable reclamation options, costs, and implications of long-term land use as the United States develops its energy resources.

1 PROGRAM DEVELOPMENT AND ACTIVITIES

1.1 IDENTIFICATION OF KEY PROBLEMS AND ISSUES

During the year from July 1975 to July 1976, the Land Reclamation Program concentrated on developing a preliminary set of key problems and issues associated with coal extraction and land reclamation in a national context. To identify these problems, the United States was divided into regions that reflect general groupings of parameters that affect and control reclamation after mining. To study these parameters, it was realized that the approach must consider both the distribution of our nation's coal reserves, and the fact that mine sites are essentially specific, but may be generic in nature and research findings at a site may be regionally applicable. Figure 1.1 divides the major coal areas into eight geographic regions: Eastern, Interior (central), Gulf, Northern Great Plains, Mountain, Southwest, Pacific Coast, and Alaska.

A preliminary assessment of the problems that are specific to each region has been completed and includes the following information:

- *Eastern Land Reclamation Problems:* These are related primarily to the acid-forming materials that lie in or adjacent to the coal seam. Soil erosion, siltation, and acid drainage problems have existed for many decades. While considerable effort has been expended to investigate damages caused by acid mine drainage, very little original experimentation has been conducted to determine what techniques and practices can be employed before and during the mining operation to eliminate these problems. Mine spoils retard revegetation dynamics while acid mine drainage does serious damage to aquatic ecosystems. The problem is made more complex because there are thousands of small mining and reclamation efforts.
- *Central Interior Coal Region Problems:* The focus is on areas where coal is currently being extracted from row crop land of high fertility. In most cases, the overburden is inverted, leaving the topsoil 50 to hundreds of feet beneath the surface. Some states have recently passed laws requiring controversial topsoil replacement practices that may not allow successful row crop production because of infertility; there also is a general lack of knowledge concerning the costs and benefits of these alternative practices. The choice among alternative techniques has serious implications for aquatic, hydrologic, and terrestrial ecosystems, and the effectiveness of these techniques must be studied.
- *Gulf Land Reclamation Problems:* These are related mainly to a more humid climate and the impact of heavy rainfall on steeply-sloped topography. Siltation, sediment transport, and erosion problems exist in these areas where high percentages of clay prevent moisture infiltration into the root zone. Thin topsoil in certain areas serves mechanically and

Fig. 1.1 Argonne Is Examining Reclamation Problems in These Eight Regions

chemically to retard revegetation, but, in general, the Gulf region has fewer environmental problems than other areas.

- *Northern Great Plains Subbituminous and Lignite Fields:* Low to moderate annual precipitation inhibits natural revegetation. In addition, in certain areas, the chemical composition of the overburden causes severe saline or alkaline problems that inhibit or retard revegetation after mining. Saline seep problems are especially prevalent in the Williston Basin where groundwater and surface water quality is affected by salts contained in the premining overburden. Alkaline seepage and pumped discharges from surface mines in parts of the Powder River Basin are also known to affect water resources.
- *Rocky Mountain Bituminous and Subbituminous Fields:* Hard, saline soil continues to be a problem in both short- and long-term reclamation efforts. These coal fields are characterized by medium to high relief with thin topsoil and low to moderate annual precipitation. In certain areas the chemical composition of the overburden is highly alkaline and inhibits revegetation, but the principal difficulty is in establishing ground cover subsequent to mining because of inadequate precipitation. In some areas, fragile terrestrial ecosystems have been adversely affected by overgrazing

and poor land management practices. Wind erosion presents a serious problem and techniques must be developed to prevent movement and loss of materials, with their subsequent adverse effects on both aquatic and terrestrial ecosystems.

- **Reclamation and Spoil Problem:** Primarily, difficulty is experienced in developing ground cover suitable for grazing after recontouring of spoil materials. Two factors must be considered: (1) annual precipitation within this region is 6-10 in. or less, and (2) because of the fragile nature of the ecosystem, plant communities are easily destroyed and soil disturbed because of poor land management practices and overgrazing. Protection of revegetated spoil is an additional factor to consider. It is necessary in most cases, because it represents better forage potential than the original communities. Subsequently, sheep flocks gravitate to the reclaimed land and destroy the young plants before they become established. The soil cover is then subject to erosion by wind and water.
- **Reclamation and Reclamation:** Activities are limited primarily to surface mining west of the Cascade Range where rainfall is moderate to heavy. This area accounts for only a small percentage of U.S. surface coal production. Topography is flat to rolling and problems are associated with reestablishment of vegetation, nutrient deficiencies, slope stabilization, transport of surface material prior to plant establishment, and siltation. Environmental problems and issues have not been fully investigated.
- **Arctic Coal:** Mining is currently undertaken only in the interior, at one operating mine. Coal is extracted by stripping and accounts for only a small percentage of total U.S. coal production. Reclamation at the one site is in the formative stage but is presently successful for reestablishment of vegetation following grading, recontouring, and aerial application of grass seed. Fertilizer must be applied every two years. The climate, terrain, short growing season, grazing of native sheep, population control of wolves, and maintenance of vegetation in permafrost are problem areas. Additional difficulties include slope stability, siltation, the requirement of restoring original contour, and aesthetics because of proximity to McKinley National Park. Problems of developing and reclaiming the larger coal field in the Arctic are unknown. In addition to climate and terrain, remoteness, logistics, and the corridors requirement are formidable problems. Extraction and environmental problems for this area will include the Beluga Field in the near future.

A problem matrix is being developed to facilitate identification of region-specific problems and issues. A sample of a portion of this preliminary matrix is illustrated in Table 1.1. During FY 77, a comprehensive problem and issue identification matrix will be completed.

Table 1.1. Preliminary Sample Problem/Issue Identification Matrix
(Does Not Illustrate Full Range of Program Interests)

DISCIPLINE	PROBLEM/ISSUE	REGION							
		EASTERN	GULF COAST	CENTRAL	NO. GRT. PLAINS	ROCKY MOUNTAIN	SOUTHWEST	PACIFIC COAST	ALASKA
HYDROLOGY	OFF-SITE TRANSPORT OF POLLUTANTS	X	X	X	X	X	-	X	X
	WATER MOVEMENT THROUGH ACID SPOILS	X	X	X	X	X	X	X	X
	EFFECTS OF MINING AQUIFERS	X	X	X	X	X	-	X	-
	GROUNDWATER POLLUTION	X	-	-	X	X	-	-	-
	SURFACE WATER POLLUTION	X	X ^a	-	-	X ^a	X	-	X ^b
AQUATIC ECOSYSTEM	OFF-SITE TRANSPORT OF POLLUTANTS	X	-	X	-	-	-	X	X
	SEDIMENTATION FROM SPOIL & REFUSE	X	-	X	-	-	-	X	X
	TOXIC ELEMENTS	X	X	X	X	X	X	X	-
	LOSS OF MICROBIOLOGICAL ACTIVITY	X	X	X	X	X	X	X	-
GEOPHYSICAL	WATER EROSION	X	-	X	-	X	X	X	X
	WIND EROSION	-	X	-	X	-	-	-	X
	SEDIMENTATION FROM SPOIL & REFUSE	X	X	X	X	-	-	X	X
	STEEP SLOPES	X	-	X	-	-	-	-	X ^c
	SLOPE STABILITY	X	-	X	-	-	-	X	X ^b
	CONSOLIDATED MATERIAL ON SURFACE	X	-	-	-	-	-	-	-
	REDUCED INFILTRATION	X	X	X	X	X	X	X	X ^b
	LIMITED WATER HOLDING CAPACITY	X	X	X	X	X	X	X	X
	TOPSOILING REQUIREMENTS	-	X	X	X	X	X	-	-
GEOCHEMICAL	OFF-SITE TRANSPORT OF POLLUTANTS	X	X	X	X	X	X	X	X
	ACID SPOIL	X	-	X	-	-	-	X ^d	X ^d
	ALKALINE SPOIL	-	X ^d	-	X	X	-	-	-
	SALINE SPOIL	-	-	-	-	-	X	-	-
	TOXIC ELEMENTS	X	X	X	X ^e	X	X	X	X
	LEADING	X	X	X	X	X	X	X	X

^aWater availability

^dUncertain

^bPermafrost problems

^eExcept alkaline

^cRapid spring runoff

1.2 CURRENT RESEARCH IDENTIFICATION

The primary objective of this phase of the Land Reclamation Program is to develop a comprehensive basis for delineating, defining, and understanding significant surface mine land reclamation research currently being conducted by others.

Approximately 50 meetings were held with coal mine operators, state officials, and academic institutions to identify and prioritize problems. Special attention has been given to the Eastern coal province, because a considerable amount of research has already been initiated to solve site-specific problems, and a comprehensive assessment of reclamation needs in the Eastern bituminous coal field was initiated during the second quarter of FY 76. The Land Reclamation Program (LRP) team visited many mines throughout the region; it is evident that reclamation efforts in the Eastern Province have tended to be site specific and somewhat fragmented because there are many mining operations. Duplication of reclamation effort has not been uncommon and most research has been restricted by property lines and political boundaries.

The current research identification effort will include coordination and cooperation with federal and state agencies, as well as with the academic and industrial communities. To reduce reclamation costs, duplication of effort and overlap between ERDA programs and other research efforts must be avoided. Therefore, during the past year, a close liaison has been established with the National Coal Assn. and the Bituminous Coal Research Institute, Inc., and others, to gain information necessary to carry out this mandate. A selected bibliography of significant published reclamation research is about 75% assembled and will be available after January 1977.

The task of gathering information related to surface mine reclamation research will be a continuing effort. However, an important phase of the FY 77 effort will be the analysis of research needs and current research activities. The current research information gathered on the ERDA-sponsored Federal Inventory will be integrated into the Land Reclamation Program. It is expected that this data will be available on a magnetic tape from Oak Ridge National Laboratory by January 1977.

Federal and State Interactions

Representatives from the ANL Land Reclamation Program have met with representatives from federal and state agencies. We have served as research coordinators with the following federal organizations: USDA Forest Service Surface Environment and Mining Division (SEAM), Environmental Protection Agency, USDI Bureau of Mines and Fish and Wildlife Service, and others.

On the state level, the LRP staff has been active in meeting with representatives from the Illinois Institute for Environmental Quality (IIEQ), Abandoned Mined Lands Reclamation Council (AMLRC), The Midwest Coal Producers, Ohio Division of Reclamation, Kentucky Department of Mines and Minerals, North Dakota Reclamation and Siting Division, Wyoming Geological Survey, and others.

Regional Interactions

On a regional level, LRP representatives participated in meetings with the Agricultural Research Service for the State of North Dakota Reclamation Review at Bismarck. We participated in this review because we are conducting a research program on microbiological changes and soil degradation during top-soil storage and soil/spoil layering/revegetation at a North Dakota mine site. We also were asked to participate in a joint workshop in Billings, Montana, with the Old West Regional Commission, USDA Forest Service SEAM, and the Fish and Wildlife Service Western Energy and Land Use Team to discuss interagency coordination. A subsequent research project was developed to avoid duplication of effort in the Rocky Mountain and Great Plains regions.

Coordination for ERDA

The ANL Land Reclamation Laboratory also has been asked by ERDA to perform a coordinating role in coal mined land reclamation. It will serve as a "clearing house" for review of competing research proposals on regional or national problems submitted to ERDA. Our review will focus on important problem areas on a priority basis to avoid duplication of effort and diffusion of resources by ERDA as well as other agencies.

At present, other ERDA/DBER land reclamation programs include: (1) a University of Missouri study on succession on orphan spoils in Missouri, (2) a Montana State University investigation of establishment and stability of vegetation on surface mined land in Montana, (3) a University of Montana program concerning viability of native grasses, forbs, and shrubs for vegetating surface mined lands, (4) a University of Tennessee study of environmental aspects of coal production in Appalachia, and (5) an Oak Ridge National Laboratory project dealing with numeric information exchange for reclamation research.

Preliminary Research Review

During May 1976, the LRP staff produced a document entitled *A Preliminary Review of Current Nationwide Research Activities Related to Surface Mine Land Reclamation*. The following outline identifies those organizations discussed in the report:

I. FEDERAL AGENCIES

- A. U.S. Energy Research and Development Administration, Environment and Safety Reclamation Research
 - 1. National Laboratories
 - a. Argonne National Laboratory

- b. Pacific Northwest Laboratory
 - c. Oak Ridge National Laboratory
- 2. Universities
 - a. University of Missouri
 - b. Montana State University
 - c. University of Montana
 - d. University of Tennessee
 - e. University of Iowa
- B. U.S. Department of Agriculture
 - 1. Agricultural Research Service
 - 2. Soil Conservation Service
 - 3. U.S. Forest Service -- Surface Mined Area
 - 4. Surface Environment and Mining (SEAM)
 - 5. Cooperative State Research Service
- C. U.S. Department of the Interior
 - 1. Bureau of Land Management
 - 2. Bureau of Mines
 - 3. U.S. Fish and Wildlife Service
 - 4. U.S. Geological Survey -- RALI Program
- D. U.S. Environmental Protection Agency
 - 1. Extraction Technology Branch -- Resource Extraction and Handling Division -- Cincinnati
 - 2. EPA Office of Research and Development, Office of Energy Minerals, Western Energy Resource Development
- E. Federal Energy Administration
- F. National Science Foundation
- G. Department of the Army -- U.S. Corps of Engineers

II. REGIONAL ORGANIZATIONS

- A. Old West Regional Commission
- B. Four Corners Regional Commission
- C. Northern Great Plains Resources Program
- D. Interstate Mining Compact
- E. Appalachian Regional Commission
- F. Western Governors Regional Energy Policy Office
- G. Ozark Regional Commission

III. STATE-SPONSORED PROGRAMS

- A. Illinois
 - 1. Illinois Institute for Environmental Quality
 - 2. Greater Chicago Metropolitan Sanitary District
- B. Iowa
 - 1. Iowa Coal Project
- C. Other States

IV. INDUSTRY

- A. National Coal Association/Bituminous Coal Research Institute
- B. Utilities
 - 1. Individual Utilities
 - 2. Electric Power Research Institute

It is expected that the information contained in the report will be updated and published as a Topical Coal Extraction/Land Reclamation Report shortly after January 1, 1977. As stated in the report:

A total of five federal agencies and departments are funding reclamation research associated with understanding the environmental and socioeconomic impacts of the surface mining of coal. Each organization, depending upon its preconceived mission, approaches the funding from a slightly different direction. While much of the current reclamation research is addressing interesting and real site-specific problems, almost all of it has been initiated without a comprehensive national research plan. Duplication and overlap, disorganization, and poor coordination are common faults. There is a strong belief that no one in the government is cognizant of the total reclamation research effort, not even OMB. At this time, there does not exist a clear statement of the problems in a regional or national context. As an example, currently, it is impossible to obtain a good national estimate regarding the amount of land that is disturbed each year by surface coal mining to help define the problem. In addition, the disruptive extraction practices of uranium, oil shale, and other mineral mining require closer scrutiny to determine what research efforts can be undertaken to minimize environmental, health, and socioeconomic impacts.

1.3 DEVELOPMENT OF A 5-10 YEAR PLAN

The development of a comprehensive 5-10 year plan for the Land Reclamation Program is dependent on completing the identification of key problems and current coal extraction and land reclamation research. Because the plan must take into account the complex interrelationships among the multi-discrepancy tasks involved, it is important that it have at its disposal the most current and comprehensive information available.

During FY 76 a significant amount of data was gathered that can be used in the plan, but a comprehensive national coal extraction and reclamation plan will not be available until Tasks A (Sec. 1.1) and B (Sec. 1.2) are completed. It is expected that during FY 77, these two tasks will be completed sufficiently to begin development of the national plan. The preliminary program plan will be subjected to a comprehensive review by knowledgeable persons in the academic community, industrial sector, and state and federal agencies. The purpose of the review will be to modify the plan where necessary and to help set priorities for the research effort.

As an interim effort, the Land Reclamation Program has already initiated the activities shown in Table 1.2.

1.4 TECHNOLOGY TRANSFER

A significant feature of the LRP is the establishment of an active, two-way exchange of information with government, the public sector, the professional community, and the coal industry. This technology transfer program will include

Table 1.2. Land Reclamation Program Elements and Cooperating Organizations

[illegible]

periodic conferences, topical reports, and close interaction with an advisory committee that is representative of the university sector, industrial community, environmentalists, and federal and state agencies.

During the past year LRP staff members have met with coal industry representatives in an effort to identify technology transfer linkages that can be developed between the coal industry and the LRP. A partial list of companies contacted includes:

Amax Coal Co.	Manuel E. Glaspell Coal Co.
Arch Minerals	Maran Coal Co.
Asco Coals, Inc.	North American Coal Corp.
Ashland Coal Co.	Pacific Power & Idaho Energy
Bebway Coal Co.	Resource Co.
Bridgeport Mining Co.	Peabody Coal Co.
Consolidation Coal Co.	Peter Kiewit Sons Co.
Cravat Coal Co.	Pioneer Fuel
Energy Enterprises, Inc.	Pittsburgh and Midway Coal Co.
Kelley's Creek Fuel Co., Inc.	U.S. Steel
K.W.D. Construction Co.	Utah International Inc.
Lang Brothers, Inc.	Western Coal Co.
Mairietta Coal Co.	

The activities of the Land Reclamation Program also have involved close cooperation with the academic community in establishing field demonstration sites, undertaking research efforts, and identifying and prioritizing research needs. During FY 76 research grants and consulting contracts were established with academic institutions in most of the major coal resource regions. Colleges and universities participating in the program are:

Arizona State University: characterization and identification of bacteria from soil and spoil samples
 Brigham Young University: stressed-plant breeding study
 Sheridan Community College: stream sampling and water quality
 Southern Illinois University: analysis of periphyton and phytoplankton
 New Mexico State University: analysis of soil samples and mycological characterization
 University of Arizona: validation of water harvesting model
 University of Montana: evaluation of early and late successorial native plant species for revegetation
 University of Wisconsin: analysis of soil and spoil samples

In addition, the following universities or colleges have been visited regarding the environmental problems associated with the surface mining of coal and the thrust of current research. It is expected that these institutions and others will make contributions to the development of the Land Reclamation Program.

Brigham Young University	Kent State University
Chicago State University	Navajo Community College
Eastern Kentucky University	New Mexico State University
Indiana State University	Northern Illinois University
Iowa State University	Ohio State University

Pennsylvania State University	University of Tennessee
Southern Illinois University	University of Tulsa
University of Akron	University of Wyoming
University of Arizona	Utah State University
University of Illinois	Western Illinois University
University of Missouri (Rolla)	West Virginia University
University of North Dakota	

As mentioned in Sec 1.2, there are other federal, regional, and state agencies and organizations that are funding, conducting, or coordinating research activities that relate to surface mine reclamation. During the past year LRP staff members have served on federal and regional planning committees and attended meetings with the following organizations:

Appalachian Regional Commission	Environmental Protection Agency
Department of Agriculture	Four Corners Regional Commission
SEAM Program	Interstate Mining Compact
Department of Interior	Old West Regional Commission
Bureau of Mines	Ozark Regional Commission
Fish & Wildlife Service	U.S. Forest Service
Bureau of Land Management	

1.5 PUBLICATIONS

The publication and eventual dissemination of information developed by the staff is a major task of the Land Reclamation Program. During FY 76 several field and in-house research efforts have developed sufficient preliminary data to warrant transfer to interested groups. The following list identifies topical publications and oral presentations by the LRP staff. Copies of publications are available upon request.

Cameron, R.E., and R.M. Miller, *Algae and Protozoa of Coal Mine Soils and Spoils*, abstract in J. of Phycology (Supplement) 12:9 (1976).

Carter, R.P., *The Environmental Consequence of Coal Production - A Midwestern Viewpoint*, presented at Central States University Inc. Fall Conference entitled "Coal: Processing, Use and Environmental Considerations," Argonne, Ill. (Nov. 1975).

Carter, R.P., R.E. Cameron, and staff of Land Reclamation Program, *A Preliminary Review of Current Nationwide Research Activities Related to Surface Mine Land Reclamation*, report to ERDA Assistant Administrator for Environment and Safety (May 1976).

Dettmann, E.H., R.D. Olsen, and W.S. Vinikour, *Effects of Coal Strip Mining on Stream Water Quality: Preliminary Results*, Proc. Sixth Symp. on Coal Mine Drainage Research of the NCA/BCR Coal Conf. and Expo III, Louisville, Kentucky, pp. 51-63 (Oct. 19-21, 1976).

Dettmann, E.H., and R.D. Olsen, *Assessment of Aquatic Impacts of Western Coal Mining: Some Integrative Approaches*, to be presented and published in proc. of Reclamation of Disturbed Arid Lands Symp. of annual AAAS Meeting, Denver (Feb. 1977).

MacDonald, R.R., *The Role of Data Base Management in Environmental Planning*, presented at Regional Meeting of West Lakes Div. of Assn. of American Geographers, Carbondale, Ill. (1975).

MacDonald, R.R., *Data Base for Surface Mining and Land Reclamation*, presented at National Meeting of Geological Society of America, Salt Lake City (1975).

MacDonald, R.R., *The Regional Environmental Data Base*, presented to National Meeting of the Assn. of American Geographers, New York, N.Y. (April 1976).

MacDonald, R.R., *The Process of Submitting STORET Runs from a Low-Speed Terminal Cassette Tape*, presented to the EPA STORET Symp., Bethany, W. Va. (Sept. 1976).

Miller, R.M., R.E. Cameron, R.M. Johnson, E.E. Staffeldt, and B.C. Williams, *A Preliminary Assessment of the Impact of Topsoil Storage and Surface Mining of Coal in the Soil Microbiota*, abstract in J. of the Arizona Academy of Science 11:39 (1976).

Miller, R.M., and R.E. Cameron, *Some Effects of Topsoil Storage during Surface Mining on the Soil Microbiota*, Proc. Fourth Symp. on Surface Mining and Reclamation, NCA/BCR Coal Conf. and Expo III, Louisville, Kentucky, pp. 131-139 (Oct. 19-21, 1976).

Olsen, R.D., and E.H. Dettmann, *Preliminary Results from a Study of Coal Mining Effects on Water Quality of the Tongue River, Wyoming*, Hydrology and Water Resources in Arizona and the Southwest, 6:59-67 (1976).

Olsen, R.D., and E.H. Dettmann, *Preliminary Results from a Study of Coal Mining Effects on Water Quality of the Tongue River, Wyoming*, presented at annual meeting of Southwestern and Rocky Mountain Div., AAAS, Tucson (April 1976).

Olsen, R.D., and W.S. Vinikour, *Trace Metals in Surface Waters, Fish and Benthos in the Vicinity of a Coal Strip Mine in North Central Wyoming*, to be presented at annual AAAS Meeting, Denver (Feb. 1977).

Vinikour, W.S., *Species Composition and Abundance of Benthic Macroinvertebrates in Relation to Water Quality in Portions of the Tongue River Watershed, Wyoming*, to be presented at annual AAAS Meeting, Denver (Feb. 1977).

Vinikour, W.S., *Incidence of Neascus rhinichthysi (Trematoda: Diplostomatidae) on Longnose Dace, Rhinichthys cataractae (Pisces: Cyprinidae), Related to Fish Size and Capture Location*, Trans. Am. Fish. Soc. (in press).

2 FIELD AND LABORATORY RESEARCH

Field and laboratory research in the Land Reclamation Program constitutes a coordinated program of applied and basic research focusing on the near- and long-term physical and ecological problems of land reclamation in all major U.S. coal resource regions (shown in Fig. 1.1). This work will advance the development of cost-effective techniques for reclaiming and rehabilitating mined coal land for productive end uses. Research demonstration sites identified to date (see Fig. 2.1) include two mines in each of four regions: the Northern Great Plains, Rocky Mountains, Southwest, and Interior. Additional sites will be established in other regions, especially in the East, as the program develops.

2.1 SITE #1: BIG HORN MINE (R.D. Olsen, Site Coordinator)

2.1.1 Water Quality/Aquatic Ecology

A preliminary study of the Tongue River, which began in the summer of 1975, has identified the major potential water quality and aquatic ecosystem impacts related to operation of the Big Horn Mine near Sheridan, Wyoming.

Fig. 2.1. Map of Research Sites

Data were also gathered to provide baseline information for assessment of impacts of future mining. The aquatic investigation included a modeling subproject to optimize identification and subsequent prediction of pollutant production, transport, and ultimate fate within the aquatic ecosystem. Biological investigations included detailed studies of algae, benthos, and fish.

The study results are being compared and integrated with previous and ongoing research efforts on the Montana reach of the Tongue River in order to investigate the extent and significance of mining impacts in the entire Tongue River watershed.

Approach

During the early summer of 1975, available data on water quality were obtained from the Big Horn Mine and various state agencies. On the basis of these data, and the need for additional data, it was decided that water quality analyses would include temperature, dissolved oxygen, specific conductance, turbidity, suspended solids, pH, alkalinity, hardness, chloride, fluoride, silica, sulfate, nitrogen, phosphorus, and 20 metals.

With the assistance of area maps, and in consultation with mine and state representatives, a field survey was made of the watershed, specifically along the Tongue River and Goose Creek. Eight collection sites were subsequently chosen, and comprehensive water quality and biological monitoring was begun with the cooperation of Sheridan Community College. At the same sites, biotic samples were collected for metal analysis to determine the fate and significance of metal discharges in mine effluents on benthic invertebrates, algae, and selected fish species. Dye transport studies have been performed to determine transport time and dilution potential for mine effluents which are of primary importance in the water quality modeling project. Mass balance analyses were conducted for appropriate water quality parameters.

Accomplishments

Results to date suggest that water quality impacts induced by operation of the Big Horn Mine are probably minimal and are small compared to other land use effects in the watershed. While concentrations of some chemical parameters (e.g., Na^+ , Ca^{+2} , SO_4^{-2} , and HCO_3^{-1}) in pumped mine discharge exceed ambient river levels, concentration increases measured in the Tongue River downstream of the mine appear to be minimal, apparently due to substantial dilution of effluents upon release to the river. Concentrations of potentially toxic metals were low at all sampling sites, including mine effluents, but temporal and spatial variability were found in both water samples and aquatic biota.

On the basis of water quality data gathered to date, sodium and sulfate appear to be the chemical parameters most likely to be increased in the Tongue River by future mining activities. However, it should be noted that both sodium and sulfate have very low toxicities to aquatic biota, and that it does not presently appear likely that any constituent will be increased to levels sufficient to preclude major water uses (i.e., irrigation and stock watering).

The data from biological surveys completed to date suggest that fish and macroinvertebrate densities and species diversity in the various stream reaches sampled appear to correlate with nutrient concentrations, with those sites having the highest nutrient concentrations supporting larger and more diverse communities. The more highly enriched reaches also support larger and more diverse plant communities. Goose Creek had abundant growths of periphyton and the river weed *Podostemum ceratophyllum*, and the reach of the Tongue River downstream of the confluence and mine supported abundant *Cladophora* mats and other periphyton, while that portion of the Tongue River sampled which was upstream of the mine has only sparse mats of *Cladophora* and other periphyton.

Data from an investigation of infestation of longnose dace, *Rhinichthys cataractae*, by the trematode parasite *Neascus rhinichthysi* show trends similar to those of fish density, with infestation and parasite numbers highest in those reaches having the highest nutrient levels. This probably reflects the higher community productivity, with resultant enhancement of opportunities for parasite-host interactions. A tendency for high productivity to favor a high incidence and intensity of parasitism in fish is not unexpected. All of these data suggest that the biota are responding mainly to large scale water quality trends rather than mine-related impacts.

Results of the long-term multidisciplinary investigation will allow definitive conclusions to be drawn concerning the direct short-term impacts and long-term chronic effects of current strip mining practices in the Tongue River watershed, as well as prediction of impacts that are likely to result from future expansion of surface mining.

2.1.2 Aquatic Modeling

Mining may impact aquatic systems through interruption of aquifers, seepage and surface discharge of wastewaters, and surface runoff and erosion. Assessment of mining impact on aquatic systems is site specific, depending on the nature of the local terrain, hydrologic regime, coal chemistry, and the mining methods used. Because of the multiplicity of interactions within the aquatic system, and the complexities of spatial and temporal trends in data acquired in most mining situations, models are often useful, or even necessary, for quantitative impact assessment.

The purpose of the aquatic modeling subprogram is twofold. One objective is to determine impacts of coal strip mining on a given aquatic system; the second objective is to identify and adapt modeling and other integrative methodologies useful in assessing aquatic impacts inherent to coal mining in Western regions. Whenever possible, these methodologies are intended to have predictive capabilities as well as aiding in assessment of present impacts.

Past efforts have centered on evaluating water quality impacts of the Big Horn Mine near Sheridan, Wyoming, on Goose Creek and the Tongue River. These two streams flow through the mine, have been rerouted through old strip mine pits, and receive mine effluents.

Approach

The modeling and water quality/aquatic ecology subprograms have cooperated in design of the sampling program on the Tongue River and Goose Creek. During the preliminary study, a steady state model was used to assess the mine's impacts on these two streams by using water chemistry and discharge data upstream of the mine to calculate anticipated concentrations of water quality constituents downstream of their confluence on mine property. These calculated concentrations were compared with observed downstream concentrations in order to estimate the mining impact. Watershed-wide surveys of specific conductance were also made in order to identify water quality trends on a larger spatial scale to provide a meaningful context for observed mining impacts.

Data obtained by other groups (mainly state and federal agencies) on river discharge, water quality, irrigation, land use, and soils in the Tongue River watershed were assembled. These data have been useful aids in planning the research at the Big Horn site.

Work during the next few months is anticipated to include application of a time dependent dynamic simulation model to Goose Creek and the Tongue River in the mine vicinity in order to refine the data analysis by taking into account time delays in material transport through the streams and pits. Further tasks will include a compilation of water quality information indicating potential modeling needs at Western coal mine sites, and exploration of methods for coupling water quality and biotic models for mining situations.

Accomplishments

Analysis of water quality data using the steady-state model has shown that any changes in the concentrations of conservative ions induced in the Tongue River by the Big Horn Mine as presently operated are of the order of, or less than, day-to-day variations in ambient water quality. Preliminary results from use of the steady-state model to simulate worst-case effects of future expanded mining in the watershed suggest that substantial numbers of additional mines along the Tongue River (assuming effluents similar to present mines and no control of pollutants) could result in measurable changes in water quality. Efforts are underway to refine the model and to provide the input data necessary for a more precise and realistic appraisal of the potential effects of anticipated expansion of coal extraction activities in the Tongue River watershed.

The watershed-wide surveys of specific conductance indicate that water quality changes occurring in upstream portions of the Goose Creek and Tongue River watersheds are large compared with water quality changes in the vicinity of the mine.

There has been a close working relationship between the modeling and the water quality/aquatic ecosystems subprograms throughout this project. This is reflected in three joint papers presented by these two groups at past and upcoming professional meetings (see pp. 13-14).

2.1.2 Geophysical/Geochemical Studies

In much of the West, shallow water wells are an important water supply for stock watering, irrigation, and domestic purposes. The primary aquifers that supply shallow groundwater in sufficient quantities are coal beds, scoria, sandstone, and particularly river alluvium. Temporary and permanent changes in groundwater recharge, flow direction and rate, residence time, chemical characteristics, storage quantities, and discharge conditions can all be caused by mining.

Because the Powder River Basin is characterized by sparse vegetation and variable precipitation patterns, where extended periods of drought are interrupted by brief, intense storms, the potential for severe erosion problems on spoil material and increased sediment loading to aquatic systems may result from mining. Developing methods to rapidly reestablish and sustain vegetation cover is essential to minimize erosion and sediment transport.

A major factor controlling plant growth will be soil moisture quality and availability. The presence of toxic concentrations of ions in the soil zone (e.g., sodium), low infiltration and moisture retention characteristics of spoil material, and lack of essential plant nutrients in spoil material can all inhibit revegetation efforts.

Approach

Initially the research has been designed to identify and assess specific geophysical or geochemical conditions that might be active or potential environmental problems. Work at the Big Horn Mine includes studies of (1) the dynamic hydrologic and hydrochemical systems that are present in two active mine pits, (2) the groundwater system (physical and chemical) in post-mining spoil material, and (3) the geophysical and geochemical properties of various spoil types that are being created at the mine and the effects that these properties have on plant reestablishment, slope stability, and runoff-water quality.

By studying the hydrology and chemical quality of water entering the mine pit, sources and transport processes of specific ions in the mine discharges can be determined. This type of research will provide data necessary for the stream water quality modeling (Sec. 2.1.2), enable the prediction of the quantity and quality of future discharges from these pits, and aid in developing methods for estimating quantity and quality of discharges from new mines in the region.

Studies of groundwater in saturated spoils will yield data necessary to evaluate the impact of mining on groundwater flow systems and water quality and the interrelationships of subsurface water in spoil and adjacent river water.

Studies on spoil properties (chemical and physical) will aid in determining spoil conditions which will enhance revegetation, reduce surface-water runoff and erosion, and reduce leaching rates in spoil.

The data collected and observations made during FY 76 were necessary to formulate a more detailed and comprehensive research plan to be implemented at the beginning of FY 77.

Accomplishments

During the past year, data have been collected concerning all aspects of the mining operation; the data include mine maps, coal production figures, drill logs of overburden, mining equipment information, history of past mining in this area, and hydrologic data from limited previous studies at the mine. Discussions with coal company personnel also have explored future mining plans for the site and environmental problems that might be encountered during mining.

Observations at the two currently active pits were made to determine the source (e.g., coal, overburden, spoil), rates, and quality of groundwater entering the pits. The Scott-Haymeadow pit, operating adjacent to the Tongue River, is experiencing high rates of seepage (about 3 cfs) from the river. The concentrations of major ions in the discharge water are higher than in the adjacent river and reflect changes, either seasonal or short-term, in river water chemical characteristics. The Zowanda pit is deriving most of its water (about 0.2 cfs) from storage in the coal seam being mined. The chemical characteristics of this water are dissimilar to those of the receiving stream, but resemble local groundwater. No major changes in chemical quality due to mining are evident, but changes in flow patterns are readily apparent.

Groundwater observation wells in old spoil material were constructed for a short-term hydrologic study by Dr. Perry Rhan, South Dakota School of Mines, during the summer of 1975. Upon completion of his study, these wells were abandoned. To further extend the knowledge of chemical quality and flow systems of groundwater in spoil material, seven of the wells have been renovated for monitoring during FY 77.

Limited numbers of spoil samples were collected to determine the range of physical and chemical conditions that presently exist. In addition, double-ring infiltrometer tests were conducted on various spoil types at different locations and at undisturbed sites to determine relative rates of infiltration under these conditions.

Data and observations collected during FY 76 have been used to develop comprehensive and detailed research plans, including instrumentation, monitoring, and sample collection, that have been implemented in the beginning of FY 77. These plans include overburden sampling to establish physical, chemical, and mineralogic characteristics of individual lithologic units; monitoring surface water runoff rates and quality under variable surface conditions; monitoring rates and quality of water being discharged from the two active pits under variable hydrologic conditions; and monitoring groundwater flow and quality in spoil material.

2.1.4 Microbial Succession Studies at Midden Water Creek Mine (R.M. Miller, Coordinator)

The revegetation dynamics of orphaned spoils help provide an understanding of the natural processes that must be manipulated in successful reclamation

efforts. Little is known about the recovery dynamics of the soil microbiota on orphaned spoils. The soil microflora constitute an essential element of nutrient cycling and act as poorly understood symbionts for stabilizing the much needed vegetation. Also, the fate of these organisms under a variety of past practices provides the only means at hand for offering a sound basis for future reclamation in areas of complex nutrient problems.

The Hidden Water Creek area, due to its previous history, lends itself to this particular type of investigation. The presence of both orphaned spoils more than 25 years old and active mining should enable one to examine both successional sequences as well as the consequences of current technologies on both above- and below-ground biotas.

Approach

Experiments are being designed to determine both the numbers and types of microorganisms at selected depths in orphaned spoils and in adjacent undisturbed overburden. Also being investigated are the physical and chemical characteristics of the soil and spoil environment. This study is seeking to define a relationship between shifts in microbial populations and diversities and changes in the chemical and physical makeup of the spoils. From the data gathered it is hoped that the regional recovery dynamics for the soil microbiota on orphaned spoils can be ascertained. This information will then be utilized with data collected for revegetation success and mycorrhizal establishment to evaluate succession under natural conditions on orphaned spoils.

Accomplishments

During the past year, 14 soil and spoil samples were collected and are being analyzed for their biotic and abiotic properties. Preliminary data indicate that the physical and chemical nature of the spoil material influences both the kinds and abundances of the microbial populations with the sandstone and shale spoils being least desirable. Areas where clinker is present have good microbial population levels and revegetation success.

2.2 SITE #2: INDIAN HEAD MINE

2.2.1 Effects of Soil/Spoil Layering, Interface Response, Soil Amendments, and Different Water Regimes on the Germination, Root Development, and Plant Vigor of Candidate Species for Mine Reclamation (R.R. Hinchman, Coordinator)

Up to the present time, preliminary laboratory studies have been conducted with materials obtained from the Indian Head Mine near Zap, North Dakota. Bulk samples of the alkaline/sodic spoil and topsoil were collected at this site during FY 76 for use in future laboratory studies to evaluate growth and survival of revegetation species under simulated drought conditions. Additionally, aseptic collections were made for microbial and abiotic analyses in the laboratory.

2.2.2 The Effects of Topsoil Storage and Segregation on Soils and Microbiota in the Northern Great Plains (R.M. Miller, Coordinator)

The development of a suitable environment and substrate for optimal plant growth and root development is essential to land reclamation. In nature, this development is accomplished through the formation of a suitable soil profile, which includes a surface, or A, horizon and a subsurface, or B, horizon. This development is very important, especially in view of requirements in a number of states, where surface mining regulations now require the segregation and replacement of "topsoils," where topsoil has been defined as having favorable properties necessary for plant growth and desirable for reclamation. The term "topsoil" in reclamation practice is therefore defined rather loosely, and can consist of the A horizon, or the A and part or all of the B horizon. These topsoils may be stockpiled for several years prior to replacement over the recontoured spoil piles. The surface material is deposited and packed layer by layer, forming what is commonly called a topsoil storage pile. These piles may exceed 20 m in height, and may be stored for periods of time up to the lifespan of the mining operation.

Approach

The objectives of this investigation were: (1) to investigate the fate of the soil microbiota during topsoil segregation and storage, (2) to determine the number and type of microorganisms at several depths in the topsoil storage piles and adjacent undisturbed soils, (3) to determine shifts in microbial populations associated with chemical and physical changes in topsoil storage piles of different ages, and (4) to determine changes in the chemical and physical characteristics of the soils induced by changes in microbial activity. The physical, biological, and chemical characteristics of soil samples, from all the LRP research sites except the Jim Bridger Mine and Goose Lake Prairie State Park, were analyzed at Argonne and by three university subcontractors: New Mexico State University; Arizona State University, Tempe; and the University of Wisconsin.

Accomplishments

A preliminary assessment indicates that topsoil stockpiling leads to a disruption of the soil properties as well as of microbial character. These disturbed soils characteristically have an increase in bulk density with a decrease in porosity, a decrease in water holding capacity, and a reduction in the amount of organic matter. These soil characteristics, along with the depth of the storage pile and time of storage, appear to have a substantial impact on soil microbiota. The implications of these findings in terms of successful reclamation of surface mined land need intensive and lengthier study.

2.2.3 The Impact of Topsoil Segregation on Mycorrhizic Formation (R.M. Miller, Coordinator)

A logical extension of the soil biota investigation is a study on the role of mycorrhizae in the revegetation process. It is known that microorganisms in the rhizosphere can increase or decrease the absorption of inorganic

nutrients by plant roots. These effects depend on the chemical ion, its availability, and the physical conditions in the rhizosphere. For example, mycorrhizal species have been shown to be more efficient than other plants in the uptake of phosphate. Also, in legumes phosphate stimulates nodule production and the rate of nitrogen fixation.

Since very little is known about the fate of mycorrhizal organisms under topsoil storage conditions and their subsequent role in the revegetation process, it will be important to study the role of these poorly understood symbionts for stabilizing vegetation. This phase of the soil biota investigations will be started during FY 77.

2.3 SITE #3: JIM BRIDGER MINE (B. B. Green, Site Coordinator)

Research at the Jim Bridger Mine is addressing two major problems associated with mined land reclamation: water availability, and restoration of productivity in shrub-grass ecosystems. Low amounts of precipitation limit the water available to plants in semi-arid grasslands. Frequency distribution and the seasonal occurrence of precipitation are also important factors. About half the annual moisture is in the form of snow. Considerable moisture is subsequently lost to the ecosystem, and a snowfall management system is needed. It is also essential that vegetative productivity be restored for grazing fauna. This must be considered from the viewpoint that (1) mine spoils in arid areas usually represent harsher conditions than the native undisturbed sites and (2) native plants which germinate and become established in mine spoils can exhibit both reduced growth and survival.

2.3.1 Vegetative Adaptations to Stressed Ecosystems

Approach

This study addresses the response of selected species to extraction and reclamation in a semi-arid shrub-grassland ecosystem, considered typical of much of the mined land in the West. Both biotic and abiotic responses will be considered. The research is divided into monitoring, productivity analyses, population dynamics, and energy allocation studies; it began in April 1976.

Accomplishments

Macroclimate monitoring systems for precipitation (Fig. 2.2) and temperature have been installed, and microclimatic measurements, including humidity, soil moisture, and net radiation, will begin in the coming year.

Biomass clipping studies have established quadrat size for the productivity studies, and early summer and fall samples have been taken on a native undisturbed grassland site which functions as a control. Productivity sampling on the reclaimed areas will not be implemented until next spring.

Fig. 2.2. Researchers Installing Precipitation Gauge at the Jim Bridger Mine

A phenological index has been developed for one shrub (*Atriplex confertifolia*) to aid in interpreting population dynamics data; indices will be developed for other key species in the following season. Juveniles of shadscale (*A. confertifolia* and *A. gardnerii*) and wheatgrass (*Agropyron* sp.) were marked on the reclaimed areas for population analyses.

In addition, energy allocation studies have been designed and will be initiated in the coming year.

2.3.2 *Assessment of Water Availability through Selected Soil Amendments and Surface Manipulations*

Approach

Moisture availability is one of the most limiting factors in the revegetation of surface mined lands in semiarid regions of the West. This subproject addresses the effects of various soil amendments and surface manipulations on the amount of moisture available for plant growth. Precipitation data will be combined with information on runoff volume for any given storm, as well as the quantity of moisture available for plant growth. The physical properties and chemical characteristics of surface material will be established. This research began in April of 1976.

Accomplishments

A precipitation gauge has been installed to monitor local rainfall. Runoff/sedimentation plots have been constructed to measure the amount of sediments and water lost in any given storm. Representative samples of surface material have been collected for chemical analysis, and soil bulk density measurements have been taken.

An automated system of soil psychrometers to monitor soil moisture and soil temperature will be installed in the coming year. Additional study plots will be established in areas that have been mesic-pitted. Water infiltration rates for the various treatments will be determined. Additional root zone soil samples will be analyzed for essential plant nutrients and possible phototoxic elements.

2.3.3 Assessment of Various Reclamation Technologies on the Recovery Dynamics of the Soil Microbiota in the Green River Basin at Black Butte Mine and Jim Bridger Mine

Approach

Reclamation efforts in the Green River Basin are restricted by various environmental factors, principally by low annual precipitation (15-25 cm), which normally comes in the form of snow. This factor, along with the short growing season and the high evapo-transpiration rate, makes revegetation a formidable challenge. The success of any reclamation technique must consider the fate of the soil organisms in conjunction with the revegetation process. This becomes even more apparent when mycorrhizae are considered, especially since their fate during the mining process is uncertain. Since production has not begun at the Black Butte Mine, the site is being used for the collection of baseline data. In arid environs the soil microbiota also play a very important role in nitrogen availability and much of the $\text{NH}_4\text{-N}$ comes directly from autotrophic nitrogen fixers.

Accomplishments

During the past year, seven soil samples have been collected and have been analyzed for their biotic and abiotic properties. Preliminary data indicate that these soils vary considerably with SAR's ranging from 0.9 to 50.0 and electrical conductivities ranging from 220×10^{-6} to 9500×10^{-6} mhos/cm. These properties, along with a high soil pH of 8.0 to 8.5, indicate potential reclamation problems. With regard to microbiota the bacterial population levels are usually about 2×10^5 organisms/gm dry wt of soil, with disturbed sites' populations being slightly lower. The predominant bacterial species encountered for each of the samples were for physiological groups, with undisturbed sites having a higher percentage of psychrophiles while disturbed sites had a higher number of thermophiles. Further soil and spoil samples will be collected as mining and reclamation activities progress.

At this time it is anticipated that LRP research activities at the Black Butte Mine will remain minimal during the coming fiscal year. As mining activity increases, our interest at this site will also increase with emphasis on research concerning reestablishment of the below-ground ecosystem being of top priority. It is anticipated that this research will emphasize reestablishing below ground symbionts (mycorrhizae) as well as autotrophic nitrogen fixers.

2.4 SITE #4: BLACK MESA MINE (R.L. Carter, Site Coordinator)

Need for Water Harvesting (a cooperative project with the University of Arizona)

There is a need to evaluate techniques and collect data on runoff characteristics of strip mine spoil treated for runoff harvesting in the Southwest. Runoff harvesting offers the promise of much greater returns than revegetation, both economically and socially, particularly in the Black Mesa area of northern Arizona. Runoff harvesting could be an important alternative use of reclaimed mine spoil in arid and semi-arid regions. It should be possible to establish small family farms, develop agriculture, and provide water for domestic and stock use with selected techniques.

Reclamation efforts in these regions have been addressed almost entirely to the establishment of vegetation, with the objective of returning the land to its former use, usually grazing. Most of the range land in the Southwest is leased for grazing at about 8¢/acre/year. The present cost of reclaiming strip mine spoils for that purpose is greater than \$1,000/acre and could increase to \$5,000/acre depending upon state regulations.

Approach

The spoil of the Black Mesa Mine is ideally suited for determining the effectiveness of water harvesting for establishment of small farms with associated agriculture, including a potable water supply for domestic and stock use. The spoil is fine-textured, has a reasonable level of fertility, a low salt content (for Arizona), and contains no toxic materials. The pH is neutral. The runoff water meets proposed EPA standards for drinking water in terms of the total salt content and its components. Rainfall is low but adequate -- as indicated by extensive water harvesting research in southern Arizona, where rainfall is considerably less -- to permit a number of crops to be successfully grown using this technique.

A feasibility study is presently underway at the University of Arizona that will help determine optimum ratios of runoff harvesting to concentration areas for a variety of crops and for maintaining reservoir stability for the climate of the Black Mesa. The methods developed should be applicable to other strip mine areas in the arid Southwest. However, actual data is needed to estimate the required parameters for the validation of a mathematical model that can predict the potential of runoff harvesting techniques on strip mine spoils; other models also are being considered. The program will provide baseline data and information that will lessen the health and environmental impacts of surface mining in the Southwest and determine the effectiveness of alternate land uses.

Accomplishments

Preliminary site investigations began during the spring of 1976 and four water harvesting treatment plots have been designed. Contract negotiations

with the University of Arizona were not completed in time to commence gathering field data during the spring and summer of 1976. Field plots are in preparation for the 1977 season and it is expected that preliminary results will be available during September/October of that year.

2.5 *SITE #5: SAN JUAN MINE (H.W. Miller, Site Coordinator; a cooperative study with New Mexico State University)*

The resources of the arid Southwest are being developed to support the economic growth of other areas of the United States. The San Juan Mine was approved for operation by the New Mexico Coal Surface Mining Commission providing that the surface mined land would be reconditioned. The mining company is to initiate extensive and possibly expensive land reclamation that will return the land to its owners in a condition "equal to or better than" it was prior to the commencement of the mining operation.

The evidence has been reviewed concerning the evaluation of the condition "equal to or better than." Suggestions of plant density or carrying capacity are important, but they can be very transient and dependent upon minor manipulations or modifications induced by man. The physical and chemical soil conditions and climax microbial populations appear to be much more stable parameters on which to make realistic decisions as to the success of a particular reclamation procedure.

Approach

Research efforts are being undertaken by New Mexico State University personnel at the mine site in addition to the mine company's own reclamation work. Plot treatments and responses are being studied through soil, plant species, amendments, mulch, and irrigation manipulations. Plots have also been established in spoils of known composition to study microbial succession and decomposition on wheat straw, grass, and wood chips, and to evaluate each of these prospective amendments.

In conjunction with the above investigations, the LRP is cooperating with investigators on a program to help identify alternative techniques for restoring below-ground soil microflora. The soil microflora constitute an *essential* element of nutrient cycling and act as a poorly understood symbiont for stabilizing vegetation. The fate of these organisms and their rates of mineral transformation under a variety of past practices provide the only means at hand for offering a sound basis for future reclamation in areas of complex nutrient problems.

The main effort is a study of topsoil storage in the arid Southwest. With regard to topsoil, the microflora present in undisturbed surface soil are in a dynamic aerobic environment, approaching microaerophilic conditions with increments of meteoric precipitation. This environment is drastically altered during the storage of topsoil, approaching or becoming an essentially anaerobic environment. Since nitrification bacteria are strictly aerobic in nature, and important in nitrogen availability, it will be important to follow nitrification and denitrification activity as well as mineralization in these soils.

Accomplishments

Preliminary data indicate that undisturbed surface soil at the San Juan site may present problems in revegetation unless part of the sodium is removed. The spoil material also shows a high SAR value. This, along with the high nitrate levels encountered for both spoils and the lower depths of the undisturbed surface, indicates a moisture movement problem. These factors could affect revegetation from the air-water relations and a probable salt problem from the higher nitrate contents. Data on a few more parameters are needed before soil chemical and microbiological data can be compared for initial evaluation.

2.6 SITE #6: NAVAJO MINE AND AREA (D.O. Green, Site Administrator; a cooperative study with Utah International, Inc. and Brigham Young University.)

Plant response is determined by interactions between the plants and their environment. There are many variables, such as: growth medium, meteorology, elevation, latitude, topography, biochemical influences (i.e., grazing, trampling, etc.), and microbiological influences (i.e., nitrification, pestilence, etc.). Whenever one or more of the environmental factors changes, plant reaction also changes. The reaction may be manifested by increased or decreased plant vigor or a change in species composition. Support for this concept is demonstrated by specific plant species occurring in relatively specific environments. Each plant species or subspecies copes with a specific combination of environmental parameters. This occurs continually by four general processes: (1) hybridization between existing species, (2) autopolyploidy (multiplication of chromosomes), (3) mutation, and (4) introduction of candidate species from other similar areas. Research at the Navajo Mine is concerned with developing species that are tolerant of the harsh conditions generated by surface mining in the Southwest.

Approach

The study is concentrating on *breeding* and *selecting* plant species and varieties for use in revegetating surface mine spoils in the arid Southwest. The nature of this project will necessarily require an effort of some years to determine its success. ERDA, represented by Argonne's LRP, and Utah International Inc. have entered into a contract with Brigham Young University to undertake this study.

Accomplishments

The research plan, which emphasizes studies of drought tolerance, was developed during the final quarter of FY 76. In research plots in spoil material at the Navajo Mine, the effect on plants of different combinations of fertilizer and water is being examined. In addition, Dr. Howard Stutz, principal investigator, and his staff have been collecting seeds from selected shrubs and grasses in Utah, Wyoming, Arizona, and New Mexico. Extensive greenhouse tests have been started at Provo, Utah. Selected plants will be

moved to onsite test plots during FY 77. During the next year, the two test plots at the Navajo Mine will be maintained and seeds from the successful plants will be introduced in the study to develop optimum plant strains for revegetation.

L. J. 172 "g": 1000 *Edward Smith Mine (E. J. Condon, Site Coordinator)*

Acid mine drainage in surface water has received much attention in past and current research projects throughout the East and Midwest, but very little work has been done to determine the magnitude of the pollution and transport processes that occur in groundwater systems. Some data are available on contaminated groundwater in surface mined areas, indicating that the water quality is often very poor, with high concentrations of acid, iron, sulfate, and other constituents normally found in mine drainage. However, the overall impact of acidic spoils on groundwater systems has not been evaluated and the extent and seriousness of this problem may be much greater than presently realized.

This project is investigating the dynamic processes of acid production at an abandoned mine in Grundy County, Illinois, and the transport of acid into adjacent ponds and groundwater systems. The acidic spoil -- being reclaimed by Argonne in a separate project funded by the Illinois Institute for Environmental Quality (IIEQ) -- is owned by the state, which plans to annex it, after reclamation, to the adjacent Goose Lake Prairie State Park.

Even though vegetation may successfully be reestablished on the spoil slopes, oxidation of pyrite and acid production in the spoils may persist. If this is the case, then transport of acid, sulfate, and metal ions may be a continual, long-term environmental problem. Acidic groundwater discharging into the "acid" ponds could prohibit the successful reclamation of these ponds. Groundwater transport of pollutants could also endanger the quality of water in other nearby ponds that are, as yet, unaffected.

Approach

The IIEQ project began in the fall of 1975 and is currently investigating the effects of various reclamation techniques on surface water runoff rates and quality. The mine spoil area has already been regraded, subdivided, and reclaimed with various surface treatments and plant species (work funded by the State of Illinois). As part of the ERDA-funded subproject, porous-ceramic cups and/or piezometers are being installed in these plots to evaluate which reclamation technique(s) can minimize the continued oxidation of pyrite and transport of pollutants into the groundwater system.

A monitoring and sampling program has been developed. This includes (1) a detailed water sampling of acid ponds and unaffected ponds on a monthly basis, (2) measurement of water levels and water sample collection from wells already in existence in the area affected by the spoils, and (3) construction of additional piezometers for groundwater monitoring. The resulting data, in addition to the data being collected for the project sponsored by the State of Illinois, will be used to evaluate the magnitude of impact, if any, that

the acid mine spoils have on groundwater quality. By studying the flow direction, rates, and quality of groundwater, this subproject will also evaluate the impact that subsurface mine drainage has on adjacent ponds in the nearby state park.

Accomplishments

Work is still being done to devise a comprehensive and effective study plan: water samples have been collected from ponds and analyzed, drilling contractors are being contacted to determine methods and costs for drilling observation wells, and data have been collected on the few wells already in existence. The full study will get underway in FY 77.

2.8 SITE #7: MACOUPIN COUNTY REFUSE RECLAMATION (J.E. Selimon, Site Coordinator)

Past deep coal mining activities and the associated coal cleaning operations have left many coal refuse sites across the Midwest. For example, the Cahokia and Silver Creek watersheds and many other areas of Macoupin County, Illinois, are dotted with coal refuse areas, and the water quality of these creeks has been severely affected by surface drainage from the refuse piles. Sediment-laden discharges are also a significant problem; many channels have become blocked with silt and require occasional, costly dredging. Because of the detrimental environmental impacts of these abandoned mine sites, the LRP has undertaken a demonstration reclamation project at one refuse area in Macoupin County (Fig. 2.3).

Approach

The Macoupin County project has four principal goals: (1) to quantitatively determine the extent to which the environment has been affected by a typical refuse site, (2) to develop reclamation methodologies applicable to the area, (3) to assess the reclamation efforts tested at this site, and (4) to provide a basis for application of reclamation technologies to other abandoned mine sites.

The study is a consortium effort of three organizations: the ERDA-funded LRP and two State of Illinois organizations: the Illinois Institute for Environmental Quality (IIEQ) and the Abandoned Mined Lands Reclamation Council (AMLRC). The project has a major management advantage in that all its phases are under the control of a single research unit -- the Argonne LRP.

Accomplishments

The project consists of four consecutive phases; Phases I and II, discussed below, are completed or well underway; both have been funded jointly by ERDA and IIEQ. Phase III, site development, will begin in September 1976, and Phase IV, post-development monitoring, in January 1977.

Fig. 2.3. The 72-Year-Old Gob Pile at the Macoupin County Research Site Is 600 ft Long, 80 ft High, and Covers 4 Acres. The Total Affected Area Includes 34 Acres

Phase I (Nov. 1975-April 1976). In Phase I, the Staunton site was selected as a research site following a survey of a number of sites. The abandoned Consolidated Mine No. 14, northwest of Staunton, Illinois, is typical of coal refuse sites in west central Illinois and was therefore selected for study. The refuse pile and adjoining affected land includes about 34 acres; the pile itself is about 80 ft high and has an estimated volume of 130,000 yd³. The pile is steep-sided, entirely barren, and deeply eroded. Vegetation in adjacent areas has been impacted by the acid runoff, and the drainage courses are clogged with sediment. The site has been abandoned for 50 years. It has been used as a dump and has become littered with building material wastes, broken glass, tin cans, and discarded household goods.

Considering the needs of the local community and the nature of the refuse material, it was determined that a final land use for recreation and wildlife habitats would be desirable. A complete set of engineering plans and specifications was subsequently developed with these final land uses as well as research needs in mind. Plans were also finalized for detailed sampling and monitoring programs in various scientific disciplines applicable to the reclamation plan.

Phase II: Baseline Monitoring (April 1976-Sept. 1976). The baseline monitoring was used to assess the pre-development environmental conditions of the study area. Monitoring included: (1) establishment of groundwater and surface water quality parameters, (2) detailed sampling and testing of surficial materials to determine the physical properties and chemical characteristics of the refuse material and adjacent soils, (3) a wildlife-use inventory of the site, (4) delineation and evaluation of the aquatic ecosystem of the study watershed, and (5) a survey of the soil microbial populations that are indicative of the fertility of the refuse material and site soils.

Extensive laboratory growth chamber studies also were conducted to investigate the effects of various soil amendments and identify vegetation species that could be used in reclaiming the site. This baseline monitoring program has provided data needed to develop plans for the site, and will provide a means of measuring the effectiveness of the reclamation effort.

Cost-Sharing. The project is a major undertaking, with costs shared by the three sponsors. This effort is a unique experiment in cooperation between state and federal agencies to develop cost-effective reclamation techniques. A cost breakdown by phase is listed in Table 2.1.

Table 2.1. Cost Breakdown for Macoupin County Project

Phase	Federal Funds	State Funds	
	ERDA (\$10 ³)	IEQ (\$10 ³)	AMLRC (\$10 ³)
I (Planning and Design)	15	15	--
II (Development of Baseline Monitoring)	50	50	--
III (Site Development)	--	--	492
IV (Establishing and Monitoring of Research Demonstration Plots)	50	50	50
TOTAL	115	115	542

2.2 LABORATORY RESEARCH (H.W. Hinchman, Coordinator)

The laboratory research being conducted within the Land Reclamation Program is, in most cases, closely associated with ongoing or planned projects at the specific field sites discussed in Secs. 2.1-2.8. These laboratory studies all utilize coal-mined land materials (spoil, gob, topsoil, etc.) from one or more of the field sites, but most of the experimental manipulation is done in the laboratory under controlled conditions. The objectives of these studies are of a generic nature, i.e., applicable to one or more of the nation's coal-producing regions. This section summarizes a semi-autonomous laboratory study which is primarily biological.

2.2.1 *Revegetation Research -- Evaluation of the Growth of Grasses and Legumes on Spoil or Gob Covered by Topsoil*

Regulations requiring all surface mine spoil to be graded and covered with a layer of previously segregated topsoil have recently been enacted by several states. However, very few data are available on the growth and success of plant species used for revegetation under these conditions. Laboratory studies have therefore been designed to characterize the germination, survival, growth, and early success of grasses and legumes growing on layered material consisting of acid strip mine spoil (from the Goose Lake Prairie site) or mine refuse (gob from the Macoupin County site) covered by topsoil, as compared to topsoil, spoil, or gob alone.

Atmosphere

In these growth chamber experiments, particular attention has been given to the response of the roots, both in biomass production and gross morphology, upon encountering the interface between the topsoil and the spoil or gob material. This response is of prime importance in predicting the long-term success, vigor, and quality of a stand, especially under conditions of drought or toxic spoil material. In similar layered-pot experiments, the nitrogen-fixing ability of legumes is being investigated. (Figs. 2.4 and 2.5 illustrate various aspects of the pot experiments.)

Four series of experiments to evaluate plant growth on layered materials have been completed to date. The growth media used were: (1) topsoil over acid spoil, (2) topsoil over unamended gob, (3) gob amended with fly ash or lime over unamended gob, and (4) topsoil over limed gob. A series utilizing Macoupin County site topsoil over limed gob is currently in progress.

Accomplishments

The results of the layered-pot experiments have shown, in general, that if the seeds of the tested species of revegetation plants germinate in a medium with a pH above 5.5 and the subtending layer of material has a pH above 3.5, the roots will penetrate the interface and satisfactory growth will take place. These experiments are providing data being used to develop seed mixtures for the revegetation of the Macoupin County site, and to plan field plot studies to evaluate long-term revegetation success.

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Equipment necessary to perform in situ experimental work and Laboratory tests has been purchased. This includes a Model 400 Perkin Elmer Atomic Absorption Spectrophotometer. A heavy duty station wagon also has been purchased that enables the staff to gather necessary samples and data at all of the research sites. Samples are returned to ANL for analyses in presently equipped laboratories or subcontracted to vendors outside the laboratory until facilities are available.

Fig. 2.5. Layered-Pot Plant Studies at Argonne

3 MODEL DEVELOPMENT AND GENERIC ASSESSMENT

In view of both the rapid changes in reclamation technology and regulatory mandates for reclamation, the ability to reasonably predict the outcome of an extraction/reclamation endeavor is vital to both the regulatory and industrial communities as well as the public sector to ensure the continued availability of coal without the creation of unacceptable environmental degradation.

This element of the Land Reclamation Program focuses on the development of aquatic and terrestrial models that can predict the environmental changes that will occur as a result of the application of selected reclamation techniques. These activities depend heavily upon data inputs from the field and laboratory portions of the program. While aquatic and terrestrial ecosystem models have been developed for a variety of systems in recent years, models do not exist which are suitable for practical application to surface mining problems. The LRP modeling effort is therefore assessing hydrological and biological data that already have been gathered to determine if they will be useful input for this activity.

The long-range goal of the modeling effort will be the development of a specialized subset of predictive models that are regionally sensitive. It is important that the modeling effort attack the problems with a multidisciplinary program effort and take into account the interrelationship of the components.

Because of the close linkage between the aquatic modeling effort and the water quality and aquatic ecosystem studies, the FY 76 modeling effort has been discussed in Sec. 2.1, Big Horn Mine. Budget constraints prevented initiation of a more comprehensive and broad-based modeling effort.

4 DATA MANAGEMENT AND INFORMATION SYSTEMS DEVELOPMENT

(R.R. MacDonald, Project Coordinator)

A key activity of the Land Reclamation Program is the development and dissemination of data and information regarding techniques, technologies and research in the field of mined land reclamation. The information systems program has therefore been organized to include the design and implementation of a land reclamation data acquisition and management system and a comprehensive, computerized bibliographic reference library. The data system has been designed to organize, store, retrieve, process, and display information acquired through LRP activities, and similarly, to utilize the system for related information and data generated as a result of parallel programs conducted at other research institutions.

The project coordinator and staff have met with data management system representatives from all of the ERDA national laboratories in an effort to coordinate data management activities. Steps will be taken to insure that the LRP effort does not duplicate systems under development at other laboratories and federal agencies.

4.1 CONSOLIDATION AND EXTENSION OF INFORMATION STORAGE, RETRIEVAL, ANALYSIS, AND BROKERAGE SYSTEMS RELATED TO SURFACE MINING EFFECTS AND EFFECTS OF ENERGY-RELATED POLLUTANTS AND TECHNOLOGIES

Recent efforts in reclamation and land use planning have indicated the need to develop and extend current baseline data management systems such as the existing Argonne Mine Land Reclamation information system and the Oak Ridge National Laboratory information system. In addition, there is a need to identify information gaps and develop data acquisition techniques to complete baseline information.

Approach

This information system will be subdivided into parts. First, a library program will be developed to locate the information that is available in the main information storage system and identify the way in which the user may obtain this information. Second, the main information system will be enlisted, and the sorting of user data completed. Third, the information will be prepared in either graphic or tabled form for output to users. This will include use of remote graphic terminals, microfilm plotters, and micro fishe output either in addition to, or in place of, the standard line printer output and paper graphics.

The objectives of this project are to (1) establish a common concept of geographic data to expedite interchange of information; (2) establish the definition of terms to aid in describing concepts and products; and (3) divide the information system into two independent parts: the geographic base file and the associated data file, in order to maintain physical independence of geographic data from other data and to be able to integrate geographic data with other data using a geographic identifier as the linking mechanism.

Accomplishments

The GEOCODE-EESIRS project reviewed existing data management systems. The standards and design of the information retrieval system have been formulated, and the graphic interfaces for the information system are being acquired and tested. The standards for the statistical interfaces are being designed. The types of data that are to be stored by this information system are in tabular form. Collaboration with the other national laboratories has been maintained to ensure coordination.

To implement this project, an extensive search of available geographic information systems was conducted, with several being selected as possible candidates for the geocoded information system. The review of all systems was undertaken to include reports in the open literature along with coordination with federal and state agencies, the academic community, and the private sector. Most notable are reports by (1) the International Geographical Union entitled *A Report to the Geography Program of the United States Geological Survey Concerning the Development of Geographic Data Handling Capability* and (2) a USGS-sponsored program conducted by Argonne.

Five operational systems were selected for review and acquisition; these are as follows (order does not imply priority):

- Minnesota Land Management Information System (MLMIS)
(primarily data)
- The Environmental Planning Programming Language (EPPL)
- Canadian Geographic Information System (CGIS)
- Land Use and Natural Resource Information System (LUNR)
of New York
- Oak Ridge Regional Modeling Information System (ORRMIS)
- Polygon Information Overlay System (PIOS) of San Diego
County, California

In addition to these systems, selected federal projects were reviewed. These included (1) Land Use and Data Analysis (LUDA) Program of the Geography Program of the United States Geological Survey on land use/land cover interpretation processes and associated software development in support of the LUDA Program, (2) work in progress, at ERDA laboratories, on geographic information systems (the ERDA Inter-Laboratory Working Group for Data Exchange was particularly helpful in providing this information), (3) the SEAM project of the U.S. Forest Service for information on its GELO program, and (4) the EPA STORET program.

4.2 BIBLIOGRAPHIC INFORMATION RETRIEVAL SYSTEM (BIRS)

There is a need for a system that can store and rapidly retrieve bibliographic abstractual and personal commentary data on articles, reports, and other reference materials. The system needs to support the use of the less voluminous libraries of information required for many forms of research work. This library system must have the ability to store free text evaluation, or

commentary, as well as bibliographic data, and must permit real-time, interactive inquiry and report generation. Computer technology needs to be applied to this process for acquiring and cataloging reference materials to support a long-term research effort.

Approach

This system was designed, using System 2000, to be a generalized data management system to allow the interchange of information among research groups. The completed bibliography includes title, abstract, and publication information and is cross referenced by keyword, author, subject category, geographic locality, and data information. A further goal of this project is to develop a report writing feature that will give researchers a final draft form of the bibliographic information.

Accomplishments

In 1976 approximately 3000 bibliographic entries were coded into the BIRS program. The bibliographic retrieval system was designed for operation by the general data management system System 2000. The information system of entries in energy and environmental studies is in operation. As more entries are coded they are being added to the system. Figures 4.1 and 4.2 are examples of the information required to code an entry into BIRS, and the type of output provided in response to a request for references in a certain subject area, respectively.

4.3 CURRENT ENERGY RESEARCH INFORMATION SYSTEM (CERIS)

It has been determined that a system is needed to store and subsequently rapidly retrieve current energy research formats. Computer technology will be applied in development of this system.

Approach

The development of this system will be initiated by taking the Federal Inventory data and putting the information into a format to be used as a System 2000 data base such as in the BIRS system. The adaption of this information to a System 2000 data base should be an aid in energy and environmental research being sponsored by ERDA/DBER by adding the flexibility needed to interchange information between research groups. Once the data base has been developed from the Federal Inventory, a form will be prepared to keep the system updated as new information becomes available.

Accomplishments

Current research information was studied and a design was subsequently established for a general data management system that will accept the required information. Current research information was reviewed and the program standards established.

BIBLIOGRAPHIC REFERENCE MATERIAL STORAGE AND RETRIEVAL SYSTEM

1. TITLE:

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2. CORPORATE AUTHOR:

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3. AVAILABILITY: (Check One)

☒ FES LIBRARY ☐ OFFICE

BADGE NO.

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4. MAJOR CATEGORY: (See Instructions)

☐ AIR POLLUTION	☐ ENVIRONMENTAL IMPACT	☐ RECLAMATION TECHNOLOGY
☐ BIOLOGY	☐ STATEMENTS	☐ REFERENCE
☐ COAL CONVERSION	☐ GEOLOGY/GEOPHYSICS	☐ SOCIOLOGY
☐ COAL EXTRACTION	☐ HYDROLOGY	☐ SOCIOECONOMIC IMPACT
☐ DEMOGRAPHY	☐ INTEGRATED ASSESSMENTS	☐ ASSESSMENT
☐ ECONOMICS	☐ NON NUCLEAR NON FOSSIL	☒ SOIL SCIENCE
☐ ENERGY COMPARISONS	☐ NUCLEAR FUEL CYCLE	☐ TRANSPORTATION
☐ ENERGY FACILITY SITING	☐ OIL FUEL CYCLE	
☐ ENERGY FORECASTS	☐ OIL SHALE FUEL CYCLE	

5. AUTHOR(S): (Last Name, Initials Only)

O	M	O	D	T	,	H	W	;	S	C	H	R	O	E	R	,	F	W	;	P	A	T	T
E	R	S	O	N	,	D	D																

6. PUBLICATION DATE: (Month, Year)

8. DATA DATE: (Year or Years)

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10. FIRST LEVEL SUB-CATEGORY (See Instructions)

11. SECOND LEVEL SUB-CATEGORY

C H A R

C H E M

Fig. 4.1. Information Coding for BIRS

12. GEOGRAPHIC LOCATION:

N	D																		

16. PUBLICATION:

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18. KEYWORDS: (See Instructions)

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24. ABSTRACT: (Maximum Number of Characters is)

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25. FUNDING AGENCY:

N	A																					

SEE INSTRUCTION MANUAL FOR AN EXPLANATION OF EACH OF THE ABOVE.

PRINT/NAME/ENTRY WHERE C18 EQ SOIL:

TITLE* THE PROPERTIES OF IMPORTANT AGRICULTURAL SOILS AS CRITERIA FOR M
INED LAND RECLAMATION

AVAIL* SS6R

MAJCAT* SS

PD* 1975, 1

DD* NA

SUB1* CHAR

SUP2* CHEM

REF* ND

POPDESC* ND STATE BULL #492

AGEN* NA

AUTH* DEPT OF SOILS, ND STATE U

AUTH* DODD, JH

AUTH* SCHRDER, JH

AUTH* PATTERSON, DD

KN* SOIL

KN* STRIP MINING

KN* RECLAMATION

KN* SOIL CLASSIFICATION

KN* SOIL PROPERTIES

KN* SOIL QUALITIES

KN* SOIL PROFILES

ABS* THE PURPOSE OF THIS REPORT IS TO REVIEW THE PUBLISHED & AVAILABL
E DATA & THE

ABS* PRESENT KNOWLEDGE OF THE PROPERTIES OF EXTENSIVE KINDS OF SOILS
IMPORTANT TO

ABS* FARMING & RANCHING IN WESTERN NORTH DAKOTA. THE RELATIONSHIP OF
SOIL

ABS* PROPERTIES TO SOIL USE & PRODUCTIVITY COULD PROVIDE MUCH INFORMA
TION PLUS

ABS* IDENTIFY AREAS OF NEEDED RESEARCH.

ABS* ED**7/75

Fig. 4.2. Sample BIRS Output