Chapter 9

Technological Innovation and Research

Contents

List of Tables

Figure

Chapter 9

Technological Innovation and Research

CHAPTER OVERVIEW

Since the first State reclamation laws were enacted in the early 1970s, mining companies and other organizations have undertaken a significant amount of research and developed a variety of techniques for reclaiming surface mined lands in the arid and semiarid regions of the West. The earliest research focused primarily on species adaptability and other aspects of revegetation success. Few data were available, however, and little of the research was supported by laboratory analyses or was based on broad comparative assessments until the mid-l970s. As **more mines were opened in the West, and as reclamation standards covering all types of resources were imposed, more data were collected and analyzed and a better understanding of the nature and properties of the resources being used in reclamation emerged.** This increase in the scope of mining and reclamation in the West, and in the legislative and regulatory requirements for reclamation, also led to more experimentation and innovation in reclamation techniques. Resultant data and analytical interpretation have allowed the major problems in reclamation to be defined, and have provided a scientific basis for interpreting results.

While great strides have been made in Western reclamation technology, and the prospects for the long-term success of reclamation in these regions have brightened considerably, the preceding chapters suggest that additional research still is needed in all disciplines. Although work is ongoing at Western mines that addresses most of these needs, it frequently is limited to site-specific conditions. Without comprehensive comparative analyses of the full range of Western mining environments, research at individual mines will do little to advance the science of reclamation in the West or to improve the cost-effectiveness of reclamation techniques.

To some extent, a limited amount of research always will be fostered by the regulatory programs and the mining companies' need to meet performance and design standards for reclamation. **At present, however, the most critical constraint on research is the lack of available funding.** Also, in some cases, the regulations that impose inflexible design standards can discourage innovation. Finally, the commitment to reclamation in the West that has emerged among coal companies and Federal and State regulatory authorities since 1977 must continue to grow to encompass needed research.

RECLAMATION RESEARCH PROGRAMS

Historically, research on Western surface mine reclamation has been undertaken or sponsored by Federal and State agencies, mining companies and associations, academe, suppliers of reclamation equipment, and organizations such as public interest groups. This research has been stimulated by the need to establish or meet reclamation standards or to develop more cost-effective reclamation techniques, as well as by site-specific reclamation problems. The research generally has been carried out on small dedicated research plots, although formal experimental practices under the Surface Mining Control and Reclamation Act (SMCRA; see ch. 4), and approved site-specific variances or alternative reclamation techniques u rider the State regulatory programs also have been considered avenues for developing innovative methods.

The earliest research programs were established and funded by government agencies in order to set performance or design standards for reclamation and to advance reclamation science sufficiently to meet those standards. Beginning in 1973, the U.S. Forest Service (USFS) administered the Surface Environment and Mining (SEAM) program, which was established to research and develop new technologies for improving the quality of mined lands. SEAM was a partnership among government agencies of all levels and research, land management, industry, and university organizations. From 1973 to 1979, SEAM sponsored more than 150 research and development projects related to the management of mineral lands. The results of the SEAM projects were disseminated through guides that focused on specific disciplines that might be affected by mining (1 3). In 1978, the state of the art in reclamation was deemed sufficiently well developed that the SEAM program changed its emphasis from research and development to assuring that reclamation technology is available (8). Under the auspices of the SEAM program, USFS also published a quarterly computerized listing of reclamation studies related to the Rocky Mountain West, the only bibliographic reference of its kind. The SEAM program was discontinued for budget reasons in 1979.

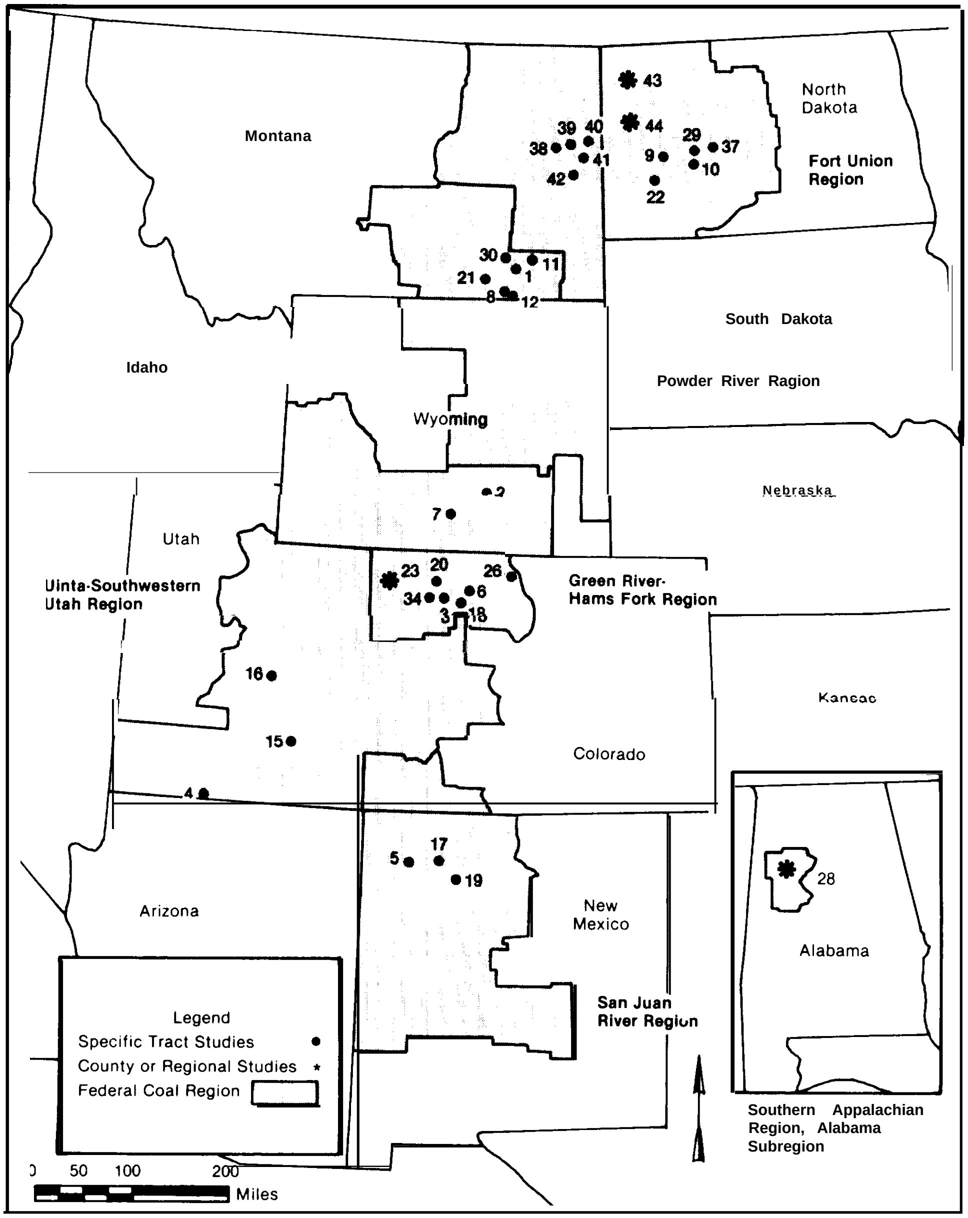
The Bureau of Land Management (BLM) funded Western coal development studies and research from 1974 to 1982 through its Energy Minerals Rehabilitation Inventory and Analysis (EMRIA) program. The EMRIA program was established to gather information about the reclamation potential on coal lease tracts and to develop lease stipulations to assure the achievement of reclamation goals for Federal coal lands. The 36 Western EMRIA reports are a multidisciplinary integration of field and literature data on geology, visual resources, overburden, hydrology, climate, soils, vegetation, and land use; figure 9-1 shows the EMRIA study areas. The studies identified site-specific problems affecting reclaimability, and recommended reclamation measures to deal with those problems (13).

The early 1980s saw the publication of the last relatively comprehensive studies of Western reclamation. In 1981, the National Research Council published reports on the effects of surface mining on soil resources, and of coal mining on groundwater resources (5,6). A cooperative study involving scientists from the U.S. Geological Survey (USGS), Soil Conservation Service (SCS), Office of Surface Mining (OSM), USFS, and BLM was published in 1983 (4). These studies examined the factors affecting reclamation in the West, evaluated the state of the art, and identified research needs and long-term uncertainties about the success of Western reclamation. it is interesting to note that **the uncertainties and research needs identified in these studies, as well as their other findings, remain valid today; little action has been taken in the interim.**

Since the late 1970s, the primary Federal responsibility for reclamation research has rested with OSM. SMCRA includes two basic vehicles for fostering research and innovation in surface mine reclamation: the State mining and mineral resources and research institutes, and the Abandoned Mine Land (AML) reclamation program. Experimental practices at active reclamation sites also may be permitted to encourage advances in mining or reclamation. SMCRA authorized appropriations to assist participating States in carrying on the work of a qualified mining and minerals resources research institute or center at a college or university with a school of mines (or equivalent). The authorization for establishing such institutes was $200,000 in fiscal year 1978, $300,000 in fiscal year 1979, and $400,000 annually for the next 5 fiscal years. The States were required to provide equal matching funds. SMCRA also established an Advisory Committee on Mining and Minerals Resources Research to determine eligibility.

SMCRA authorized research grants ($15 million authorized for fiscal year 1978, to be increased by $2 million per year for the next 6 years, to remain available until expended) to the State mining and mineral research institutes for research and demonstration projects of industrywide application, which could not otherwise be undertaken. These projects could be on any aspects of mining and minerals resources problems related to the mission of the Department of the interior (DOI) and not otherwise being studied, and for training programs. The funding criteria for institutes and grants included a curriculum appropriate to mineral resources and engineering, and submission of annual reports on work accom-

Figure 9-1 .—EMRIA Study Areas



Number Year	Title, State				
1-75	Otter Creek, MT	14-77	Potter Mountain, WY	29-79	North Beulah Study Area, ND
2-75	Hanna Basin, WY	15-77	Henry Mountain, UT	30-79	Cook Mountain, MT
3-75	Taylor Creek, CO	16-77	Emery, UT	34-80	Collum Gulch, CO
4-75	Allon, UT	17-77	Kimbeto, NM	3&80	Fattig Study Area, MT
5-76	Bisti, NM	18-77	Fish Creek, CO	37-80	Garrison, ND
6-76	Foidel Creek, CO	19-78	010 Encino, NM	38-80	Circle 2, MT
7-76	Red Rim, WY	20-78	Lay Creek, CO	39-80	Thirteen Mile Creek, MT
8-76	Bear Creek, MT	21-78	Prairie Dog Creek, MT	40-80	Woodson PRLA, MT
9-76	Horse Nose Butte, ND	22-78	Rattlesnake Butte, ND	41-80	Burns Creek, MT
10-77	Beulah Trench, ND	26-79	McCallum, CO	42-80	S W Glendive, MT
11-77	Pumpkin Creek, MT	27-79	Arkoma, OK	43-80	Williams County, MT
12-77	Hanging Woman, MT	28-79	Overburden Analysts, AL	44-80	McKenzie County, MT
13-77	White Tall Butte, WY				

SOURCE: U.S. Department of the Interior, Federal *Coal Management Program-Draft Envirormental Impact Statement Supplement* (Washington, DC: U.S. Government Printing Office, February 1985), plished and the status of ongoing projects. Actual expenditures for the institutes and research grants were $8,000 in fiscal year 1978, $1.8 million in fiscal year **1979, $745,000** in fiscal year 1980, and $860,000 in fiscal year 1981, when OSM funding ended and responsibility for execution of these provisions of SMCRA was transferred to the Bureau of Mines **(7).**

Specific applied research projects continue to be funded by OSM, either alone or in cooperation with other agencies (see table 9-1). However, OSM'S research funding requests have declined from approximately $1.5 million for fiscal year 1982 to $971,000 for fiscal year 1986 (7). The breakdown for the fiscal year 1986 budget request was:

Subsidence control: $200,000
Hydrologic studies: 180,000
Coal wastes: 220,000
Reclamation/revegetation: 150,000
Staff and administrative support:. ..221 ,000 (12)

SMCRA also required DOI to establish a center for cataloging current and projected research in all fields of mining and mineral resources. Each Federal agency doing mining and mineral resources research was required to cooperate by providing the cataloging center with information on work underway or scheduled. The center was

Table 9-l.– Reclamation Research Funded by OSM in Fiscal Years 1982 and 1983

Project	Funding[a] FY 1982	Funding[a] FY 1983	Cooperating agency
Design manual for sediment control	$ 48,000		
State of the art in alleviating soil compaction	60,000		
Improvement of overburden analytical technology	165,000		
Subsidence damage criteria	72,624		
Regional alluvial valley floor assessment	99,762	$97,238	
Effect of controlled overburden placement on mine soil properties	49,120		
Monitoring an excess spoil disposal site		4,992	
Analysis of performance standards for coordination with Army Corps of Engineers		4,990	
Monitoring of experimental practice for alternative sediment controls		7,000	
Analysis of gaps and duplication in regulatory process; summarize options for further development for coordinated permitting process		5,184	
Monitoring revegetation of a slurry pond site		5,000	
Monitoring a highwall retention practice		6,000	
Identification, evaluation, and demonstration of sediment control technologies		431,957	
Monitoring of mine fire extinguishing experimental practice		3,500	
Economic/environmental feasibility of lignite development in Mississippi		125,000	
Sedimentation/hydrology of surface-mined lands in Appalachian Plateau	100,000	75,000	TVA
Cumulative hydrologic impact information	275,000		USGS
Optimum moisture requirements for establishment of native species in New Mexico	120,000		USFS
Effectiveness of OSM regulation to prevent groundwater contamination	70,000		EPA
Concepts of highwall removal and AOC restoration	200,000		NAS
Aerial photography	90,000		TVA
Sampling procedures for vegetation	47,548		North Dakota
Remote sensing of AML projects	15,000		USFS
Plant materials study to identify plants suited to reclamation	92,000		USDA
Committee on ground failure hazards mitigation research		10,000	NAS
Core Support Program (Mineral and Energy Resources)	55,000	55,000	NAS
Soil survey vs. crop production as productivity measure for bond release on prime farmland		130,033	University of Illinois
National wetlands assessment workshop		10,000	FWS
Technical annotated bibliography of data sources for use by permit applicants		9,900	Indiana State University
Coordination of permitting for surface mining and dredging when mine discharges dredge materials		41,307	Smithsonian Institution
Total	$1,559,054	$1,031,076	

[a]Funding for research projects in fiscal year 19S2 shown only for those projects still in progress in 1983.

SOURCE: US. Department of the Interior, Office of Surface Mining, *1983 Annual Report.*

to classify and maintain for public use a catalog of all mining and mineral resources research by all Federal agencies and by non-Federal agencies of government, colleges, universities, private institutions, firms, and individuals that make such information available. OTA could find no record of this center ever having been established.

Finally, SMCRA required interagency coordination of mining and mineral resources research, including: continuing review of the adequacy of Federal research programs; elimination of duplication of effort; identification of technical needs in various research categories; allocation of technical effort among agencies; review of technical manpower needs; and facilitation of interagency communication. OSM cooperates on research with a variety of agencies, including USGS, the Fish and Wildlife Service (FWS), the Tennessee Valley Authority (TVA), the National Academy of Sciences (NAS), the Environmental Protection Agency (EPA), and USFS (see table 9-1).

Research funds also are available from the Abandoned Mine Reclamation Fund, which is derived from reclamation fees levied on a per tonnage basis on all active mines. Research and demonstration projects related to the development of surface mining reclamation and water quality control program methods and techniques are fourth in order of priority for funding, after emergency and other AML projects. However, the highest priority for AML funding is for the mitigation of past mining effects. Therefore, most of the funds are spent on reclaiming individual sites rather than developing technologies that could be useful in a generic sense. Moreover, as discussed below, AML funds in the Western States tend to be allocated to non-coal sites after the abandoned coal mine emergencies have been abated and the sites have been reclaimed.

While they are not intended to be a substitute for research, SMCRA allows departures from the environmental performance standards—experimental practices—to encourage advances in mining and reclamation or to allow special postmining land uses. OSM may approve experimental practices if they potentially provide as much environmental protection as the performance standards, and are no larger or more numerous than necessary to determine the effectiveness and economic feasibility of the practice. Operators must monitor the effects of the practice to ensure the collection, analysis, and reporting of sufficient reliable data to enable the regulatory authority to evaluate its effectiveness. A staff member from OSM'S Western Technical Center is assigned to be the technical coordinator for an experimental practice to ensure compliance with SMCRA and the regulations.

Since 1979, five formal experimental practices have been approved for the Rocky Mountain West. Two address alternative sediment control (see ch. 8), one (completed in 1982) involved a variance for excess spoil disposal (see ch. 3, box 3-E), one allows the disposal of mine spoil off-site to suppress an underground fire at an abandoned mine, and one involves a variance from approximate original contour in order to leave a portion of a highwall for raptor habitat (see box 9-A).

To compensate for inadequate research funding, OSM personnel would **like to see more applications for experimental practices, especially in the areas of soils science (e. g.,** for soil moisture retention on prime farmland in North Dakota) and revegetation (8). **However, the permitting and monitoring requirements for experimental practices are difficult and expensive to meet. Few companies are willing to meet these requirements for a practice that can only be implemented on a small part of the mine-site unless the economic benefits are substantial (e.g.,** the sediment control plan illustrated in ch. **8,** box 8-B). Furthermore, the acceptance of an experimental practice by OSM actually is dependent on how scientifically proven the practice is in other areas or applications. As a result, experimental practices tend to provide verification of the effectiveness of a reclamation technique, rather than true advances in reclamation science or technology.

Moreover, the State programs in Montana and North Dakota do not allow the regulatory *authorities* to permit practices considered "experimental." In those States, most innovative reclamation methods are introduced through other program provisions (such as the Montana provision for

Box 9-A.—An Experimental Practice for Simulating Rimrock Raptor Habitat[1]

Baseline and monitoring data at this mine documented the presence of rimrock habitat (which was not disturbed by mining), as well as several active golden eagle nests on mine highwalls. As mining activities ceased in 1982 and operations shifted primarily to reclamation, there was an associated influx of golden eagles (four pair) which nested on four remaining highwalls. This highwall nesting activity posed a conflict for the mine operator; Federal and State laws prohibit leaving a highwall but also prohibit disturbing or destroying golden eagle nests.

A cooperative effort involving the mine operator, FWS, Wyoming Department of Game and Fish, and Wyoming Department of Environmental Quality (DEQ) was initiated to formulate the best techniques for resolving this conflict. Following consultation, it was decided that the best approach would be to leave one highwall and try to relocate the other two active eagle highwall nests to artificial nesting platforms (see ch. 3, box 3-P). Choice of highwall was based on the stability of the wall, the quality of nest sites provided by the wall, and the appearance and configuration of the wall in relation to surrounding terrain. The operator submitted an experimental practice request to the Wyoming DEQ and OSM to leave the one highwall, which was approved in 1983.

The associated monitoring program evaluates raptor and other wildlife use (rabbits and hares, small mammals, and songbirds) of the highwall area. Shrub seedings and direct shrub and tree transplants, along with rockpile placements, were made along the base of the wall to provide additional forage and cover for small mammals and rabbits. The effect of lost golden eagle nest sites on the eagle population in the area are not known, but suitable nest sites generally are considered to be a limiting factor on eagle populations in this region of Wyoming. Monitoring of raptor nesting activity has documented an increase in nesting pairs.

[1]See case study mine D in reference 1.

alternative reclamation techniques), or through site-specific variances. Permit applications requesting such techniques variances still must be approved by OSM, however. OSM may require that the proposed reclamation method be permitted as an experimental practice or not allowed, as they did in the case of the alternative sediment control methods at the mine discussed in box 8-B. Many in the coal industry consider this possibility a major constraint on innovation in reclamation methods, Other companies are reluctant to propose innovative reclamation methods because if they are not approved, the company would have to expend additional time and money to revise the permit application and reclamation plan. **Although it is clear from table 9-2, below, that some research and innovation still is undertaken, greater flexibility on the part of OSM and the State regulatory authorities in judgments on proposals for the use of alternative reclamation methods at particular mine-sites, when coupled with adequate monitoring plans, could ease this constraint on innovation.**

Other special reclamation research programs sponsored by Federal agencies include:

- the U.S. Department of Agriculture, through the Agricultural Research Service;
- the USFS' annual Vegetative Rehabilitation and Equipment Workshop, sponsored by the Missoula Equipment Development Center;
- the USFS' Forest and Range Experiment Stations and regional forestry laboratories; and
- the SCS, through their State offices and Plant Materials Centers.

In addition, the Bureau of Mines, National Science Foundation, Argonne National Laboratories, USGS, FWS, NAS, and EPA have funded reclamation research. Most of the reclamation-related research sponsored **by these agencies was discontinued in the late 1970s or early 1980s as the responsibility for such research was assumed by**

Table 9-2.—Summary of Ongoing Research and Innovation at Case Study Mines[a]

Soil and overburden	Surface and groundwater	Revegetation	Wildlife
North Dakota:	***North Dakota:***	***North Dakota:***	***North Dakota:***
ND-A: Special handling of clayey soils **for wetlands** **ND-D: Landform position and mixing of soil types to aid moisture retention in prime farmland** **—Effect of soil type on soil/spoil interface for optimum moisture-holding capacity**	**ND-A: Restoration of wetlands**	**ND-A: Transplanting native vegetation plugs for reestablishing wetlands** **ND-D: Restoration of woody draws** **—Planting, cultural and management practices for achieving grassland diversity** **—Irrigation, grazing, mulch, seed mixes, and topsoil handling and depth studies**	**ND-A: Reconstruction of wetlands** **—Developing criteria for the success of wetland habitat restoration** **—Restoration of woody draws and native prairie on an “acre-for-acre” basis** **ND-D: Reconstruction of woody draws for wildlife habitat**
Montana:	***Montana:***	***Montana:***	***Montana:***
MT-B: Retention of highwall portion as bluff extension —Use of scoria and similar soil over compacted overburden for ponderosa pine substrate —Monitoring vegetation trace metals contents to judge the success of soil reconstruction —100 percent two-lift direct-haul topsoiling MT-D: Sodium migration from **sodic and clayey overburden** **—Topsoil erosion runoff plots**	**MT-B: Extensive site-specific and regional groundwater database** **—Special handling of overburden to protect water quality** **MT-C: State-of-the-art PHC and CHIA analyses for proposed mine adjacent to perennial stream classified as an AVF** **MT-E: Management and use of very large hydrologic database** **—Spoil aquifer hydraulic analyses**	MT-A: Ponderosa pine reestablishment MT-E: Reestablishment of ponderosa pine **—Coulee bottom restoration** **—Sodding of native grassland** **—Special soil handling for landscape diversity** **—Topsoil depth, surface manipulation, native species, legumes, phased seeding, shrub reestablishment, native hay mulch, temporary stabilizer crop, and fertilizer studies**	MT-D: Relocation of sage **grouse strutting ground** **—Nest box program for American kestrels** **—Use of radio-telemetry and other methods to develop monitoring data to determine when impacts are due to mining versus natural variation in populations** **—Landscape diversity through replacement of microsites** **—Identification of preferred forage plants through fecal analyses to develop seed mix**
Wyoming:	***Wyoming:***	***Wyoming:***	***Wyoming:***
WY-A: Detailed highwall map from stratigraphical-geochemical correlation **—Intensive overburden sampling to delineate acid-forming and other deleterious strata as well as wet areas, defining highwall stability, planning shovel moves, etc.** **WY-B: Composite sampling of regraded spoils** **—Watershed erosion monitoring** **WY-D: Nonuniform topsoil thickness** **—Acidic spoil treatments** **—Erosion monitoring** **—Reclaimed geomorphology** **—Monitoring swell and settling** **WY-G: Two-lift direct-haul topsoil in desert ecosystem** **—Use of boron-tolerant species** **WY-K: Nonuniform topsoil thickness**	**WY-C: Potentially acid-forming overburden** **WY-E: Computer modeling to predict groundwater impacts** **WY-G: Alternative sediment control experimental practice** **—State-of-the-art streamflow sampling** **WY-H: Restoration of essential hydrologic functions of an AVF** **WY-K: Formation of surface drainage channels through erosion and deposition**	**WY-A: Effects of nurse crop on establishment of perennials** **—Effects of grazing on species composition** **—Mulching** **—Use of sagebrush “potlings”** **WY-C: Annual grains grown as source of soil organic matter** **WY-D: Methods to reduce competition between vegetation species** **—Planting cottonwoods in drainages** **WY-G: Need for irrigation in arid area** **WY-K: Annual rotation of experimental species** **WY-1: Reconstruction of a playa**	**WY-J: Experimental** practice to leave a highwall portion for raptor habitat

Table 9=2.—Summary of Ongoing Research and Innovation at Case Study Mines[a]-Continued

Soil and overburden	Surface and groundwater	Revegetation	Wildlife
Colorado: CO-B: Aerial and field surveys to monitor swell factors for postmining topography CO-D: Shredded mountain shrub vegetation as mulch in direct-haul topsoiling —Erosion monitoring	*Colorado:* *CO-C:* Experimental practice for valley fill for excess spoil disposal CO-F: Burial of powerplant wastes in backfill	*Colorado:* CO-A: Reclamation of pinon-juniper on massive sandstone CO-D: Live mulch for woody plant reestablishment and complete topsoil removal —Direct transplanting of tree and shrub pads using modified bucket —Omitting seeding of direct haul topsoil CO-E: Use of snowfences for water harvesting —Mulch studies CO-F: Direct transplanting of mature native shrub pads	*Colorado:* CO-D: Detailed characterization and delineation of physical and floral features of elk calving habitat CO-F: Reestablishing premining land uses on postmining topography to facilitate best management practices
New Mexico: NM-B: Use of overburden as topsoil substitute —Use of topsoil quality evacuation system NM-D: Nonuniform topsoil thickness over spoil of varying quality —Sodium migration in a very low precipitation regime —Burial of fly ash with elevated selenium levels	*New Mexico:* NM-C: Comprehensive erosion monitoring program NM-D: Burial of powerplant wastes in backfill	New *Mexico:* NM-B: Use of overburden strata as topsoil substitute growth medium NM-D: Irrigation	*New Mexico:* NM-D: Annual monitoring to provide data on wildlife use of reclaimed areas NM-E: Computer analysis of mapping and telemetry data to determine effects of mining on wildlife

[a]For the key to case study mines, see appendix A in this volume.

SOURCE: Office of Technology Assessment.

OSM. A few discipline-specific research projects relevant to particular aspects of reclamation continue to be funded at a much lower level, however.

Extensive research programs also have been conducted by university research groups, usually in cooperation with particular mines. This research covers studies related to all aspects of reclamation, including climate, soils and soil reconstruction, overburden analysis and handling, revegetation, surface and groundwater hydrology, and supplemental water (1 2). Western reclamation research is ongoing at: Colorado State University; Montana State University —Reclamation Research Unit and Institute for Natural Resources; North Dakota State University—Land Reclamation Research Center; Brigham Young University; University of Utah–Institute for Land Rehabilitation; and University of Wyoming. However, **because a major source of funding for these research groups is the Federal Government, the scope of their reclamation research has been curtailed significantly in recent years.**

Some State agencies also sponsor reclamation research. North Dakota's reclamation law, for example, requires the regulatory authority to provide the legislature with an annual survey of past and present reclamation research, current and future research needs, and projected estimates of funding requirements for conducting and administering reclamation research. This document is a valuable tool for anyone involved in reclamation in North Dakota (14). In Wyoming, however, the legislature has denied research monies to the regulatory authority because it is not intended to be a research agency.

In some cases, mine operators have been required to conduct applied research on specific reclamation situations through permit stipulations. Stipulations requiring monitoring cover: the extent and potential for erosion, recontoured spoil subsidence, overburden chemistry (through groundwater monitoring, leach tests, and mixing studies), soil salinity/sodicity and salt migration, the effects of irrigation water on soil salinity, and molybdenum levels in vegetation on reclaimed surfaces. Other stipulations are requiring operators to conduct research programs to develop criteria for judging the success of wetlands restoration, and to delineate suitable overburden or other alternative materials for topdressing. **As with experimental practices, permit stipulations cannot be considered a substitute for research. Moreover, some industry representatives argue that the incidence of stipulations requiring what they consider to be "basic" research (e.g., the movement of soluble constituents at the spoil/soil interface) has increased as available government funding has declined. It is extremely difficult, however, to draw the line between applied and basic research simply because the results may be applicable** to more than one reclamation situation.

Current Research and Innovation

In addition to the OSM-sponsored research projects listed in table 9-1, research and innovation is ongoing at a number of mines in the West as a result of site-specific conditions (see table **9-2),** either as experimental practices or through other regulatory provisions. This research focuses on the collection of particular sets of data through baseline or monitoring studies, the use of innovative analytical techniques to evaluate reclamation situations, the development and implementation of innovative reclamation techniques, and the development of technical standards for assessing the success of innovative reclamation situations.

Historically, revegetation has been the principal subject of research at Western surface mines, primarily because the revegetation requirements have been in place the longest and because the current regulatory standards for reclamation success focus on revegetation. For the most part, this research has examined means of meeting the standards for production, cover, woody plant density, and species/lifeform diversity (see ch. 8), including means of reducing interspecies competition (see ch. 3). Other studies have emphasized particular revegetation technologies (e.g., irrigation, mulch, fertilization, seed mixes, planting methods); post-revegetation land management (e. g., grazing); or revegetation in special reclamation situations (wetlands, woody draws, coulee bottoms, playas, pinon-juniper communities, ponderosa pine woodlands).

As shown in table 9-2, innovation in soils and overburden focuses on special handling or treatment of acid-, alkaline-, and toxic-forming materials; on landform and other aspects of geomorphology to achieve specific reclamation objectives or postmining land uses; special soil reconstruction techniques (box 9-B; see also ch. 3, box 3-D); the use of overburden strata as topsoil supplements or substitutes; the development of analytical techniques for evaluating overburden, backfilled spoils, and topsoil quality; erosion monitoring; two-lift direct-haul topsoil handling; and nonuniform topsoil thickness.

Because of the length of time needed for groundwater restoration, much of the past hydrologic research has focused on surface water systems. Ongoing research in this area includes drainage channel design and erosion monitoring. In recent years, however, recognition of potential groundwater quality problems has grown, and current research is emphasizing the characterization, analysis, and monitoring of the interaction between backfill and aquifer restoration. Special situations under study include burial of powerplant wastes, restoration of the essential hydrologic functions of alluvial valley floors, and wetlands restoration.

Research and innovation related to wildlife emphasize the development of data and analytical techniques for describing the extent and quality of wildlife habitat and for evaluating the impacts of mining and reclamation on wildlife populations; of better and more effective means of replacing specific habitat components, such as woody vegetation, microsites, rock outcrops, and other aspects of landscape diversity; and of **special reclamation techniques for the restoration** or protection of important habitats, such as wetlands (box 9-B), rimrock (box 9-A; see also ch. 3, box 3-O; and ch. 8, box 8-G), woody draws (see box 3-N), and sage grouse strutting grounds (box 3-Q).

Box 9-B.—The Restoration of Wetlands[1]

At a mine in North Dakota, a multidisciplinary effort focuses on re-creating wetlands for wildlife habitat in prairie potholes. The prairie potholes were formed when blocks of ice calved off the receding glacial ice sheets and then were buried in outwash sediment. The ice melted, and depressions formed that subsequently became clogged with clayey sediments. These low permeability sediments provide the substrate conditions for the pothole wetlands.

Using a special soil reconstruction technique, the clayey soils are salvaged and stockpiled separately, and then replaced and compacted in manmade depressions on the recontoured surface designed to receive run-on water. A continuing uncertainty is the effects of disturbance of the soils on the infiltration capacity of the restored wetlands. Increased infiltration could reduce the water holding capacity of the restored wetland, while a significant decrease in the infiltration rate could affect water quality due to stagnation and evaporation.

The wildlife component of monitoring consists of general observational surveys once per week through spring and summer and twice per month during fall and winter. These surveys are performed on undisturbed habitats, on disturbed areas being mined, and then on reclaimed areas following mining. Wildlife success determinations are being developed, based on monitoring data of wildlife utilization of the reclaimed habitat. Criteria are being developed on which to base success judgments.

[1]See case study mines: A in reference 14; C in reference 16; ND-2 in reference 15; and A in reference 1.

RESEARCH NEEDS

Each of the technical reports prepared in support of this assessment identified research needs based on the literature and on discussions with mining company, regulatory authority, and environmental group personnel, as well as academic and independent researchers (see vol. 2). These research needs are summarized in table 9-3 and discussed briefly below. In many cases, the needs cut across disciplines. For example, the definition and characterization of deleterious overburden was identified as a research need by both soil scientists and hydrologists, but problems with such overburden also would affect the quality of revegetation and, therefore, ultimately the quality of wildlife habitat.

Baseline and Monitoring Data

Table 9-3 lists four different data-related problems that must be resolved to ensure continued improvement in the prospects for the long-term success of reclamation in the West; these are discussed in detail in chapter 5. Three of these involve data that are needed but for which valid, standardized collection methods do not exist. First, reliable interpretations of the results of laboratory methods for generating chemical data about overburden are not available. Tests for selenium, nitrates, and acid-forming potential are particularly suspect (see ch. 5, box 5-C, and ch. 8). Industry already has begun research on some aspects of this problem, but additional work is needed.

Second, standardized methods for collecting data on flow and water quality in surface streams —especially ephemeral streams—also are lacking (see chs. 5 and 6). Because total suspended solids levels are a performance standard specified in SMCRA, meaningful surface water quality data are doubly important (see ch. 7). Third, standard methodologies for collecting quantitative data about the physical and floral features of wildlife habitat are not available. These are needed to provide a basis for development of design criteria for mitigation features such as rock piles and nesting boxes. Data on large mammals, raptors, and migratory birds are of regional concern, making

Table 9-3.—Research Needs for Western Surface Mine Reclamation

Soil/overburden	Hydrology	Revegetation	Wildlife
Baseline and monitoring data:			
Standardize laboratory techniques for chemical analysis of overburden for development of valid baseline data Develop a valid test for predicting the acid or base potential of postmine spoils in the West Develop quality assurance programs for chemical laboratory analyses Develop a methodology for determining sampling intensity for overburden and recontoured spoils that accounts for inherent variability in physical and chemical properties	Develop a standardized methodology for surface water quality data collection, especially for ephemeral streams Develop a digitized hydrology database to organize data on a regional level and make them readily accessible Develop a methodology for using monitoring and other data to verify and refine predictive techniques used for PHCS and CHIAS Standardize laboratory techniques to analyze overburden for chemical characteristics detrimental to water quality	Evaluate the need for collection of long-term data on erosion, productivity and cover to evaluate soil-thickness requirements and erosion control methods	Standardize definitions and quantitative measurement methodologies for physical and floral features of wildlife habitat
Predictive analytical techniques:			
Develop techniques for “ predicting spoils properties, particularly weathering and movement of salts into the root zone Improve erosion prediction techniques and quantitative methods for comparing erosion potential of reclaimed and undisturbed lands Develop techniques to predict long-term consolidation and settling of resaturated spoils-aquifers and the subsequent reduction in permeability in re: overburden lithology and mining technique	Develop methods for predicting site-specific post-mining spoils-water quality particularly for: a) quantifying amount of deleterious material needed before special handling imposed, and b) predicting effect of settling and consolidation of spoils in re: spoil permeability Improve models of cumulative regional groundwater quality impacts of groundwater passing through spoils of multiple mines Define conditions under which recharge by surface infiltration is ‘desirable and develop methods for restoring this recharge capacity	Develop and validate statistical models for revegetation success that incorporate environmental baseline and reclamation monitoring data	Develop standardized quantitative habitat quality assessment methods Further development of analytical techniques similar to the FWS “HEP” model for predicting site-specific impacts of mining on wildlife Develop methods for predicting regional and cumulative impacts to wildlife Improve ability to differentiate between changes in wildlife populations caused by mining versus natural phenomena
Standards and evacuation of raclamation success:			
Evaluate plant monitoring as means of detecting undesirable trace elements in recontoured spoils and soil	Develop quantitative criteria for evaluation of surface and groundwater hydrologic restoration Develop specific criteria and methods for applying the TSS standard Refine the definition of “effective sediment control” in light of ongoing research	Improve methods for incorporating climatic and temporal variation into revegetation success standards Develop methods for adjusting performance standards based on reference areas to incorporate the range of conditions on an entire mine-site Improve methods for evaluating lifeform, seasonal, and landscape diversity Develop technical standards for shrubs and other vegetative communities, where needed	Develop design standards for the size, configuration, density of habitat enhancement and replacement, particularly physical features such as shrub patches and rock outcrops

Table 9-3.—Research Needs for Western Surface Mine Reclamation—Continued

Soil/overburden	Hydrology	Revegetation	Wildlife
Reclamation techniques:			
Examine techniques for soil resource optimization, especially over benign spoils Quantify costs and benefits of one-lift versus two-lift direct haul soil handling and their effects on revegetation Determine effectiveness of overburden mixing for various mining equipment, in terms of mitigating the effects of toxic overburden	Determine effectiveness of various alternative sediment control methodologies Develop criteria and guidelines for disposal of power-plant wastes in backfill Develop methods of improving spoils-aquifer hydraulics and water quality through materials handling: —Using available geological materials to construct conduits through spoils areas —Through placement of granular soil layer below the rooting zone Develop technical guidelines for special-handling procedures required for various types of detrimental overburden to protect groundwater quality	Improve means of establishing woody plant density and general vegetative diversity Continue research on establishment of special plant communities (pinon-juniper, woody draws, native grasslands, etc.) Evaluate utility of various types of mulch under differing environmental conditions (e.g., climate) Evaluate use of variable topsoil and subsoil thicknesses for establishing different kinds of vegetation communities	Continue research on reconstruction of special habitats (wetlands, woody draws, pinon-juniper, etc.) Develop means of establishing landscape diversity
Basic research:			
Determine rate at which nutrients recycle and organic matter accumulates in replaced soil Evaluate need to monitor chemical and physical changes in reconstructed soils to predict long-term soil characteristics	—	Continue developing plant materials with broad genetic variability Define the specific ways in which various groups of soil microbiota affect nutrient cycling and recovery of revegetated land Examine degree of pertubation a rehabilitated ecosystem can absorb without a major shift in species composition	Establish a clearinghouse for data and research in the West Evaluate extent to which habitat availability is limiting to wildlife populations in the West

SOURCE: Office of Technology Assessment.

standardization particularly important because the data may have many users.

The fourth data research need listed in table 9-3 involves data management, which is a significant problem. Chapters notes that in disciplines such as hydrology, the large amounts of raw data being collected can make its analysis very difficult and time-consuming. Yet both data and analyses are highly quantitative and regional sharing of data is extremely important. **If the enormous amounts of hydrologic and other data being collected in the West are to be useful and accessible, guidelines or criteria (e.g., a scoping system) for the baseline and monitoring data that need to be collected, and some sort of digitized data management system need to be developed. Precisely how these data management options should be implemented and what standard forms for input data should be required are themselves important topics for research.**

Analytical Techniques and Predicting Reclamation Success

As is clear from chapter 6, analytical techniques currently in use range from highly quantitative and sophisticated in hydrology, to intuitive, qualitative professional judgments in wildlife. OTA

found a need to improve analytical techniques used to predict the impacts of mining and to formulate reclamation plans in all of the disciplines studied. In areas such as hydrology, existing analytical tools are impressive, but so are the obstacles to and uncertainties in the analyses. Many of the highly quantitative computer models **for** analyzing hydrologic restoration are quite new, and data on actual hydrologic impacts will become available slowly. The validity of these models cannot be known for many years, but ideally, models should be constantly recalibrated as monitoring data are collected and model assumptions refined in light of actual events.

Often the development of analytical techniques is interrelated. Adequate methods for predicting the effects of spoil oxidation, which affects both water quality and vegetation potential, are lacking. Without valid chemical data on overburden (see above) and an ability to predict the effects of and the potential for oxidation in replaced spoils, operators will continue to have difficulty in delineating deleterious overburden and in knowing how to treat such material during mining and reclamation.

Evaluation of Reclamation Success

The development of success standards and bond release criteria are still in their infancy and a great deal of both regulatory and research work remains to be done. Because intermediate and final bond release and success determinations probably will focus on vegetation and hydrology, most of the research required will be in these areas. Two challenges in the evaluation of revegetation success are to develop standard systems that incorporate: 1) the effects of temporal and climatic variation on vegetation, and 2) a workable measure of landscape diversity. One difficulty is that diversity and ecosystem function (nutrient and energy cycling) may not be fully reestablished within the 10-year liability period.

Very little work seems to have been done to develop methods of evaluating hydrologic restoration. Where performance standards exist, there is little indication as to how they will be applied after reclamation is complete. Research is needed to develop specific quantitative criteria for evaluating virtually all aspects of hydrologic success and to determine how best to compensate for the long time required for reestablishment of aquifers and for the infrequent occurrence of peak flow events to test drainage restoration. In addition, newly developed reclamation techniques, such as the alternative sediment control measures being used at several Western mines, may require refinement of design criteria.

Reliance on vegetative and hydrologic success to determine success in soils, overburden, and wildlife is, in itself, a proposition that could bear researching. Similarly, if the physical and floral features of wildlife habitat can be quantified, as suggested above, specific design criteria for habitat and for wildlife mitigation measures (e.g., rock piles and shrub patches) can be developed and evaluated.

Reclamation Techniques

While major improvements have been made in reclamation techniques since 1977, OTA identified several areas in which new techniques need to be developed, or quantitative comparative analyses of the benefits of emerging techniques undertaken. **For soils and overburden,** these include an examination of soil resource optimization in terms of both soil quality and quantity (rather than quantity alone), and of the effectiveness of overburden mixing to dilute deleterious material for different dragline and truck-and-shovel operations. In addition, the effects of one-lift versus two-lift direct-haul topsoiling on revegetation performance standards need to be quantified in different regions, soil situations, and vegetation conditions.

Aspects of revegetation needing additional research in particular regions and site conditions include the ability to reestablish woody plant density and special plant communities (e. g., pinon-juniper woodland, native grasslands, woody draws, wetlands); the use of variable topsoil and subsoil thicknesses for establishing different kinds of vegetation communities; the effects of grazing on revegetation; and the utility of various types of mulch under different ecological and climatic conditions. **Wildlife will benefit both from research on means to establish special commu-**

nities and from improvements in methods for establishing diversity over the mine-site landscape.

For surface and groundwater hydrology, continued or additional research is needed on the effectiveness of alternative sediment control methods under various site-specific conditions, on the disposal of powerplant wastes in backfill, on methods for improving spoil-aquifer hydraulics and water quality through materials handling, and on guidelines for the special handling of various types of overburden materials that may be detrimental to groundwater quality. A major focus of the latter should be the trade-offs between extensive baseline overburden trace metal analyses combined with special handling and/or burial of deleterious overburden, versus post-reclamation monitoring and corrective action should problems arise. Related areas of inquiry are the number of inches of cover needed over acid-, alkaline- and toxic-forming overburden to protect revegetation; the methods for delineating deleterious strata; and the best place for burying deleterious materials.

In addition, many of the existing and planned reclamation areas of Western mines have longer slopes and smaller drainage densities than existed premining or that exist on adjacent undisturbed areas. Research needs to be conducted to determine whether the hydrologic balance is being protected in terms of erosional stability and infiltration/runoff relationships in such reclaimed areas.

Basic Research

As noted previously, there frequently is a fine line between basic and applied research. **When the results of site-specific research are documented carefully and disseminated publicly, they often can provide incremental advances in the science of reclamation in the West. However, research projects incorporating comparative analyses at many sites have the potential for larger improvements in reclamation technology and the understanding of reclamation science.** For example, several mines are examining the importance of landform position, slope, and aspect for moisture retention for particular vegetation types under specific ecological, physical, and climatic conditions. In order to improve the long-term prospects for the productive capability of reclaimed lands throughout the study region, this research would need to be expanded to cover the full range of different precipitation zones, vegetation, and soil types, etc., and the results disseminated and analyzed on a comparative basis.

Besides the specific research needs already discussed, OTA identified a need for more basic research in the following areas: the extent to which habitat availability limits the size and distribution of wildlife populations in the West; the rate at which nutrient and organic matter cycles reestablish in replaced topsoil; further definition of the specific ways in which various groups of soil microbiota affect nutrient cycling and recovery of revegetated land; continued development of plant materials with broad genetic variability; and the degree of perturbation a rehabilitated ecosystem can absorb without a major shift in species composition or ecosystem function (e.g., productivity).

FUNDING AND OTHER CONSTRAINTS ON RESEARCH AND INNOVATION

Constraints on research and innovation in Western surface mining may be imposed by the cost of research and limited budget resources, by regulations that impose strict design standards for reclamation or restrictions on innovation, by a lack of knowledge of past research, and from attitudes toward the role of and need for research. The most critical constraint probably is the lack of available funding for reclamation research, which frequently is very expensive. As discussed previously, research funds are limited and have declined significantly in the last few years, primarily due to Federal budget cuts. **OTA recognizes the realities of Federal budget cuts in the face of massive deficits, yet other sources of reclamation research funding need to be sought at the Federal level, in State governments, and in the private sector.**

At the Federal level, there are three potential sources of increased funding for reclamation research. First, a substantial amount of money accrues to the Federal Government through their 50 percent share of the royalties and bonus payments on Federal coal leases. These monies go into the general treasury fund, rather than being earmarked for the cost of administering the leasing program or for any other special purpose. Because these monies are derived from the extraction of Federal coal, it would be in the public interest to use some of these revenues for reclamation research to ensure that the overlying Federal lands are as productive, in the long term, as they were before coal leasing and development.

Second, SMCRA imposes a permit application fee, which may be less than but may not exceed the actual or anticipated cost of reviewing, administering, and enforcing the permit. This provision could be amended to increase the fee to create a dedicated research fund, with the amount either fixed or proportional to the size of the mining operation being permitted.

Third, as noted above, research funds are available from the Abandoned Mine Reclamation Fund. Total projected income for the AML Fund from its inception in 1978 to its scheduled termination in 1992 is estimated at $3 billion. As of September 1983, $1.32 billion had been collected, Under SMCRA, 50 percent of this money is returned to the States from which it came in the form of grants **for** AML programs and projects. The Federal share of $658.5 million is to be spent at the discretion of the Secretary of the Interior. As of September 1983, about $16 million had been used to carry out the inventory and perhaps $50 million had **gone to administrative costs.** The use of these discretionary funds is controversial, and currently is being studied by several groups, including the House Committee on Interior and Insular Affairs and the National Research Council.

These latter two options essentially shift the burden of funding research to the private sector, but the Federal Government still would be responsible for allocating the resulting funds and still would absorb a portion of the funds for administrative costs. The latter is a source of controversy because approximately 23 percent of OSM'S research budget and 8 percent of the Federal AML share have gone to administration and staff support.

The Federal Government also might expand its use of permit stipulations to require coal companies to perform and monitor research projects, analyze the data, and disseminate the results. This option has fewer administrative costs to the government, since there would be no research funds to oversee, but still would require OSM Staff supervision of the research itself. **Permit stipulations, however, should not be considered a substitute for general research, because they are intended to address site-specific reclamation uncertainties.**

State government options for funding reclamation research are essentially the same as those for the Federal Government, with the addition of severance taxes and of legislative appropriations for those States whose budgets are healthier than the Federal Government's. The States collect severance taxes from coal mining, as well as their share of bonuses and royalties from leasing. Table 9-4 shows the tax rate for severance taxes, DOI estimates of potential State revenues from the Federal leasing program and from severance taxes under various coal production scenarios, and the State allocation of severance taxes.[1] The primary purpose of both severance taxes and the Federal revenue-sharing is to mitigate the social and economic impacts of coal development (e.g., population increases resulting in overloaded services such as schools, health facilities, etc.). Under the Federal Land Policy and Management Act

[1] Note that the figures in table 9-4 do not reflect the proposed sequestering of a portion of the States' share of Federal mineral leasing revenues as a result of the Gramm-Rudman-Hollings budget cuts. Preliminary estimates by DOI were that Wyoming could lose $8.9 million in anticipated revenues in fiscal year 1986; New Mexico, $6.7 million; Colorado $1.9 million; and Montana, **$900,000.** An **estimate was not available for North Dakota at the** time **of this writing. The** legality of such sequestration under the Mineral Leasing Act is in dispute (11).

Table 9-4.—State[a] Severance Tax Rates and Projected Revenues

Severance tax rate	Basis	1983 production (tons)	Severance tax allocation	Year	DOI estimate of coal (thousand dollars royalty and severance tax revenues[b,e]): No new leasing	PRLA and emergency leasing	Continued leasing
Colorado:							
$00.60	Per ton	10,535,211	**50% severance tax trust fund**	1990:			
			50% distributed as follows:	Royalties	$13,200-$14,000	$13,200-$14,000	$13,200-$14,000
			–80% to local governments in impacted areas	Severance taxes	12,000-12,600	12,000-12,600	12,000-12,600
				1995:			
			–15% to communities in proportion to number of residents employed in mines	Royalties	16,200-17,100	16,200-17,100	16,200-17,100
				Severance taxes	13,200-13,800	13,200-13,800	13,200-13,800
				2000:			
				Royalties	19,100-27,800	19,100-22,900	19,100-21,400
				Severance taxes	14,400-21,000	14,400-17,400	14,400-16,200
Montana:							
24,62%	% taxable value	29,477,000	50% 10 permanent trust fund	1990.			
			1.5% to alternative energy R&D	Royalties	14,700-15,100	14,700-15,100	14,700-15,100
			8.5% to local impact assistance	Severance taxes	113,400-116,100	113,400-116,100	113,400-116,100
			10% to education trust fund	1995.			
			5% to State public school equalization aid	Royalties	24,000-25,700	24,000-25,700	24,000-25,700
				Severance taxes	118,000-126,400	118,000-126,400	118,000-126,400
			0.5% to county land planning	2000:			
			1,25% to renewable resources	Royalties	25,500-41,700	25,500-43,400	25,500-37,000
			1,5% to parks and cultural projects trust	Severance taxes	125,400-205, 00	125,400-213,700	125,400 - 82,300
			1 % to conservation districts				
			0.5% to State library commission				
			19% to general fund				
New Mexico:							
$00.50	per ton	20,439,402	100% to permanent fund including principal and interest payments	1990:			
				Royalties	11,900	11,900	12,700
				Severance taxes	14,000	14,000	15,000
				1995:			
				Royalties	14,700-17,800	14,700-17,800	14,700-17,800
				Severance taxes	17,000-20,500	17,000-20,500	17,000-20,500
				2000			
				Royalties	17,800-23,100	17,800-27,000	17,800-27,000
				Severance taxes	18,500-24,000	18,500-28,000	18,500-28,000
North Dakota:							
$00.85	per ton	18,471,000	35% for impacted localities	1990:			
			15% trust fund for loans to	Royalties	2,700	2,700	2,700
			local governments	Severance taxes	20,400	20.400	20,400
			20% to coal-producing	1995:			
			counties as follows:	Royalties	4,300	4,300-4,900	4,300-4,900
			–30% to Cities based on population	Severance taxes	28,000	28,000-31,400	28,000-31,400
				2000:			
			–40% to county government	Royalties	4,400	4,800-5,600	4,800-6,900
			–30% to school districts	Severance taxes	28,000	30,600-35,700	30,600-43,400
			30% general fund				
Wyoming:							
13 5%	°/o taxable value	108,321,269	Divided among:	1990:			
			–impact fund	Royalties	56,300-69,900	56,300-69,100	55,300-69,100
			–capital facilities account	Severance taxes	242,600-300,300	242,600-297,200	238,300-297,200
			—cities and counties	1995:			
			–water development	Royalties	88,200-145,200	88,200-142,900	88,200-142,900
				Severance taxes	261,300-419,700	261,300-413,500	261,300-413,500
				2000:			
				Royalties	117,200-172,300	115,500-178,300	115,500-202,000
				Severance taxes	338,330-495,500	333,600-510,200	333,600-572,300

[a]Includes all coal regions within a State.
[b]U.S. Department of the Interior, *Federal Coal Management Program—Draft Environmental Impact Statement Supplement* (Washington, DC: U.S. Government Printing Office, February 1985).
[c]From 1984 Keystone Coal Industry Manual, estimated from surface mines.
[d]ICF, Inc., "Economic Assessment of Effects of Royalties, Severance Taxes, and Diligent Development Requirements on Coal Production, Prices, and Consumer Costs," draft final report submitted to the U.S. Department of Energy, June 1982; Southern States Energy Board, State *Severance Taxes* (Atlanta, GA: December 1981).
[e]Ranges shown reflect low-high production levels.

of 1976, however, the States' share of Federal leasing revenues may be used for any public purpose. Given the total projected revenues from both sources, funds could be made available for research into mitigating the environmental impacts of coal development.

The State share of AML funds is projected to total $1.5 billion by 1992. As of September 1983, $484.7 million had been distributed to 23 States. In the Western States studied for this assessment, most of the abandoned coal emergency and high priority sites have been abated, and the States have begun using their share of the AML Fund for noncoal sites (e.g., abandoned uranium mines). While the States have broad discretion on how they use their share of these funds, there are a variety of research needs related to the mitigation of abandoned coal mines, in addition to the research needs of current surface mining reclamation. Because these funds are derived from active coal mines, the coal industry would prefer to see the funds returned to addressing their problems. Moreover, abandoned surface mine areas often are ideal sites for reclamation research.

Many States also have a "reclamation fee" as part of their permitting programs to cover administrative expenses (equivalent to the permit application fee under SMCRA). As with the Federal fee, the State reclamation fees could be increased to create a dedicated research fund.

The ***coal industry*** **also could assume the responsibility for reclamation research through formal or informal cooperative efforts.** This is the approach taken by the electric utility industry, through the Electric Power Research Institute (EPRI; see box 9-C). Such an approach has been adopted informally by five coal companies in Illinois, who contribute a total of approximately $200,000 annually plus field plots to support research on prime farmlands performed by university agronomists (9). Similar efforts in the Western States include the Western Soil and Overburden Task Force (an industry group), which is working on improving laboratory methods and quality assurance in soil and overburden analysis to improve the possibility of developing soil and overburden resource information; the Gillette Area Groundwater Monitoring Organization, which compiles groundwater data collected by its member coal companies and publishes them in annual reports; and the Western Reclamation Group, which evaluates the technical aspects of reclamation methods and regulatory requirements.

Box 9-C.—EPRI: A Cooperative Industry Research Organization

EPRI is a national organization that conducts research and development (R&D) for the electric utility industry. EPRI is the successor to the Electric Research Council (ERC), which was organized in 1965 to encourage all sections of the industry to join in cooperative sponsorship of electric energy research. In 1969, ERC set up a Task Force to draw up a blueprint for utility industry R&D through the year 2000. Concurrently, ERC worked out the details for an industrywide organization to provide direction and support for R&D. The result was EPRI, which incorporated both ERC and the Edison Electric Institute's R&D programs.

EPRI is supported by voluntary contributions from its members, which include investor-, public-, and cooperatively owned utilities and government agencies involved in power production. Guidelines were established under which member companies were asked to contribute at a level proportional to the number of kilowatt-hours sold (0.1 mill/kWh in 1974). R&D is not actually conducted at EPRI offices; but at universities, manufacturing plants, utility sites, or wherever else needed skills and facilities exist. Advisors on EPRI's R&D agenda include: the Board of Directors of 15 executives from member utilities; a Research Advisory Committee of 24 senior research directors and presidents of utilities that works with EPRI's senior staff on technical program agendas; and a 25-member Advisory Council drawn from the research committee of the National Association of Regulatory Utility Commissioners and a section of the public (2).

Such a cooperative structure for industry-funded research would be more equitable than the current situation in which a few companies shoulder the burden of research through experimental practices and permit stipulations. As with EPRI, advisory committees comprised of industry representatives, supplemented with academic, regulatory, and interest group personnel, could evaluate the need for particular types of research in different ecosystems, with the research results disseminated to all members as well as to regulatory authorities, academic researchers, and other interested parties. Because the coal industry, unlike the electric utility industry, is competitive, the antitrust implications of a formal cooperative research organization are unclear.

A second set of constraints on research and innovation in surface mining reclamation results from legislation or regulations that impose rigid design standards or place strict limitations on innovation. The design standards in SMCRA and the regulatory programs cover sedimentation control technologies, topsoil thickness and suitability, and approximate original contour and highwall reduction (see chs. 4 and 7). As discussed in chapter **8, research to date** suggests that there may be some situations in which these standards either may unnecessarily increase the cost of reclamation or may even undermine efforts to improve the quality and capability of the land. On the other hand, design standards for these aspects of reclamation generally are easier to enforce than performance standards, especially in disciplines where there are few if any monitoring requirements or criteria for evaluating reclamation success. The main problem is how to encourage innovation while maintaining regulatory control (see box 9-D).

While limited research on alternatives to these design standards is underway in the West (see notes on mines MT-B, ND-D, NM-D, WY-G, WY-J, WY-K in table 9-2), it **must either be carried out under the stringent requirements for a formal experimental practice, or the permit applicant must obtain a variance. The difficulty and cost of either avenue poses a significant obstacle to the extension of this research to other mining situations.**

Box 9-D.—Regulatory Control of Innovation[1]

A situation at a mine in northwestern Colorado illustrates a conflict where both the mining company and the regulatory authority are restricted by regulations written at a time when improvements in revegetation technology were not foreseen.

At issue is a request by the mine to have the seeding requirement waived on areas receiving direct haul topsoil. The company asserted that seeding was unnecessary due to abundant volunteer growth from seeds and vegetative parts within the relocated soil, which had been treated before removal with a tractor-mounted shredder, producing "live" mulch from existing vegetation. The regulatory authority, although cognizant of the effectiveness of the treatment, was unable to grant the waiver because to do so would have conflicted with the Federal requirement for seeding or planting. The company responded that the presence of viable seeds and potentially regenerative roots in the soil constitutes seeding and planting and leads to the establishment of plants better adapted to the site than are available in commercial seed mixes. The regulatory authority also was reluctant to set a precedent that could lead to similar requests in areas that were not as suitable for this procedure, especially since the waiver would occur without compliance with the State requirements for prior regulatory approval of field trial design.

At present, the two parties have agreed to handle the matter as a minor revision to the permit, rather than a waiver or technical revision as previously sought. This will allow formal approval of the proposed practice as a field trial and continued monitoring of its effectiveness at this mine.

[1]See case study mine CO-1 in reference 15.

One option is to incorporate alternative sets of design standards in State guidelines, with approval of their use at a particular mine depending on site-specific environmental and operational conditions. Guidelines are more flexible than regulations, but some State regulatory authorities are reluctant to use them (they are not allowed under the North Dakota legislation). **A second option for encouraging innovation while maintaining regulatory control would be to keep design standards but make maximum use of the phrase "unless otherwise approved by the regulatory authority" or to liberalize the requirements for a variance or experimental practice.** Design standards could be enforced strictly when necessary, and innovation encouraged when possible.

In either case, the regulatory authority should ensure that shifts from design to performance standards, or variances from design standards are backed **up with strict criteria for evaluating the success of the reclamation, and with requirements for monitoring and analysis of the resulting data.** ultimately, however, judgments about a proposed practice's success must depend heavily on the technical expertise within the regulatory authority.

A third set of constraints on research and innovation results from a lack of data or of knowledge about past research. In areas where reclamation problems are just beginning to be recognized, baseline or monitoring data may not be available, or analytical techniques may not have been developed. For example, the potential for, effects of, and best means of handling acid production from spoils are not understood, yet only in Wyoming are studies of the acid-base potential routinely required in baseline overburden studies, and uncertainties about the results of such studies remain unresolved (see ch. 8). Similarly, there has been very little research on the optimum depth of soil as a function of soil quality. Present baseline analyses do not evaluate characteristics such as the organic matter in, or moisture-holding capacity of, either the reclaimed soils or recontoured spoil, and soil suitability generally is based on chemical and physical parameters. Therefore, regulatory programs that require the salvage of all suitable soil may not be optimizing soil depth,

Furthermore, **there are few vehicles for dissemination of reclamation research results.** In some cases, companies may prefer to keep such information confidential for competitive reasons. But even when competition is not a concern, reclamation specialists at mines, regulatory agencies, and other research groups must rely on word-of-mouth and infrequent conferences or symposia to learn about research and innovation at Western surface mines. **Regular publication of research/innovation newsletters by regulatory authorities and regular compilation of a bibliography on reclamation research (similar to the publications previously issued by the USFS' SEAM program) would greatly assist information dissemination.**

Finally, **attitudes toward the role of and need for research on Western surface mine reclamation can pose a significant constraint on research and innovation.** Reclamation research, including documenting the effectiveness of i nnovative practices, can be expensive. As a result, each of the parties-coal companies, and Federal and State regulatory authorities–tends to believe that the economic responsibility for such research lies with one of the other parties. Implementing the options for increased research funding discussed previously would alleviate this problem. But the commitment to meeting the legislative standards for reclamation that has emerged among all of these parties since 1977 must continue to evolve to ensure that attitudes toward research also change.

A second aspect of this problem is the allocation of limited Federal research monies among Eastern, Midwestern, and Western reclamation problems. Western (and Midwestern) regulatory authority personnel and coal operators argue that a disproportionate amount of such funds is dedicated to Eastern mining situations and problems. To resolve this dispute, **OSM should undertake a study, with participation by operators and regulatory authorities from all parts of the country, to ascertain regional research needs and determine the priorities and relative costs of meeting those needs.**

CHAPTER 9 REFERENCES

1. Cedar Creek Associates, "Wildlife Technologies for Western Surface Coal Mining," contractor report to OTA, August 1985.
2. Electrical World, *The Electric Century* 1874-1974 (New York: McGraw-Hill, June 1, 1974).
3. ICF, Inc., ***Economic Assessment of Effects of Royalties, Severance Taxes, and Diligent Development Requirements on Coal Production, Prices, and Consumer Costs,*** draft final report submitted to the U.S. Department of Energy, June 1982.
4. Narten, Perry F., et al., ***Reclamation of Mined Lands in the Western Coal Region,*** U.S. Geological Survey Circular 872, 1983.
5. National Research Council, *Coal Mining and Ground-Water Resources in the United States* (Washington, DC: National Academy Press, 1981).
6. National Research Council, ***Soil, Coal and Society*** (Washington, DC: National Academy Press, 1981).
7. Office of Management and Budget, *Annual Budget Summaries* (Washington, DC: U.S. Government Printing Office, various years).
8. Office of Surface Mining, Western Technical Center, personal communication, 1985.
9. Personal communication to OTA from companies involved, 1985; see also ***Reclaiming Prime Farmlands and Other High-Quality Croplands After Surface Coal Mining,*** OTA Staff Memorandum, 1985.
10. Southern States Energy Board, ***State Severance Taxes*** (Atlanta, GA: December 1981).
11. "State Mineral Receipts Slated for Hefty Cut," ***Inside Energy,*** Jan. 20, 1986.
12. U.S. Department of the Interior, ***Budget Justifications, FY 1986: Office of Surface Mining*** (Washington, DC: U.S. Department of the Interior, 1985).
13. U.S. Department of the Interior, ***Federal Coal Management Program–Draft Environmental Impact Statement Supplement*** (Washington, DC: U.S. Government Printing Office, February 1985).
14. Walsh, James P., and Associates, "Soil and Overburden Management in Western Surface Coal Mine Reclamation," contractor report to OTA, August 1985.
15. Western Resource Development Corp., and J. Bunin, "Revegetation Technology and Issues at Western Surface Coal Mines, " contractor report to OTA, September 1985.
16. Western Water Consultants, "Hydrologic Evaluation and Reclamation Technologies for Western Surface Coal Mining," contractor report to OTA, August 1985.