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PHOSPHATE MINING: REGULATIONS, RECLAMATION AND REVEGETATION

WAYNE R. MARION, Ph.D.
Department of Wildlife and Range Sciences
University of Florida

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FLORIDA INSTITUTE OF PHOSPHATE RESEARCH

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Florida Institute of Phosphate Research
1855 West Main Street
Bartow, Florida 33830
(813)533-0983

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FINAL REPORT

Wayne R. Marion, Ph.D.

DEPARTMENT OF WILDLIFE AND RANGE SCIENCES
University of Florida
Gainesville, Florida 32611

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FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
1855 West Main Street
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Contract Manager: David J. Robertson, Ph.D.

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PREFACE

Phosphate mining is relatively limited in scope in the United States. Where it does occur, it results in a dramatic alteration of the landscape involving major excavation, affecting woodlands or wetlands and other features of particular significance and environmental concern. These impacts are addressed by regulations governing mining and reclamation of mine sites once the phosphate rock has been extracted. Regulations have evolved over time, as have the techniques for reclamation. Effects of regulations vary from place to place and the diligence of mine operators in performing reclamation work also is subject to wide variation.

Dr. Marion has studied these programs carefully and has accumulated a major body of information about the status of phosphate mining in this country, with special emphasis on ways regulations have been developed and applied. His work on reclamation techniques is exhaustive and reveals that reclamation is done for a variety of reasons, and often results in land-use modifications not always anticipated by those involved in the management of phosphate mining activities.

This is a work that will be of interest and special value to administrators, mine operators, and those concerned about the administrative and political processes through which phosphate mining and reclamation are directed and controlled.

Because of dramatic local alterations and increasing environmental concerns, as well as the long-term consequences of mined land reclamation and use, the activities of phosphate mines, active and proposed, stimulate widely varying concerns and degrees of control. This book provides valuable insights into what has been done and how it has worked thus far. It is a valuable work, rich in information that is useful today and offers a well-researched background against which better decisions can be made in the future.

This book is recommended to all who are involved in any phase of phosphate mining regulation and reclamation, as well as those examining the processes and results of environmental regulation.

Jay D. Hair
Executive Vice President
National Wildlife Federation

Washington, D. C.
1985

The art of land-doctoring is being practiced with vigor, but the science of land-health is a job for the future.

Aldo Leopold 1941

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INTRODUCTION AND PERSPECTIVES

Phosphate rock production in the United States has been increasing over several recent decades to the point of exceeding 50 million metric tons in 1978 (Mew 1980:19). The U.S. remains the world's largest producer of phosphate rock, but this production is strongly dependent upon economic conditions and total world production.

Phosphate mining occurs in several regions of the U.S. including the states of Florida, North Carolina, Tennessee, Idaho, Montana, Utah, Wyoming (Fig. l), and California. Of the total U.S. production of phosphate rock, Florida and North Carolina account for approximately 85%, Tennessee 5%, and western states comprise 10% (Mew 1980). Western states' phosphate production comes primarily from Idaho and very little is produced in the other states mentioned. South Carolina also has large reserves of phosphate, but recovery has not yet been considered economically feasible (Haynes 1982).

It is recognized that phosphate mining results in the extraction of chemicals and other materials useful to man and his survival. Also, the primary incentive for mining is the profit motive of our free enterprise system, with reclamation and environmental concerns frequently considered necessary, but secondary. Reclamation and environmental concerns are a primary focus of this book and they are considered to be an integral part of both the financial and moral obligations associated with mining.

The size of mining operations and extent of disturbance due to phosphate mining in each of these distinct regions are important considerations in depicting the current state-of-the-art in reclamation. Florida dominates phosphate mining in the U.S. and over 165,000 acres (66,800 ha) have been or soon will be disturbed by mining (Fig. 2). In Tennessee, Maury County leads all other Tennessee counties in land area disturbed by surface mining, including about 12,000 acres (4,850 ha) mined for phosphate (T. Rosenberg 1982 News Release). Approximately 4,700 acres (1,902 ha) of land have been disturbed by 4 companies mining phosphate in Idaho and western Wyoming. In North Carolina, where all phosphate mining has thus far been done by 1 company (Texasgulf), about 3400 acres (1,377 ha) have been altered. Phosphate reserves in the Pungo River formation of North Carolina exceed 350,000 acres (141,645 ha). Mining for phosphate in California has been restricted to a few hundred acres disturbed several years ago (H. Record 1983 Pers. comm.), but not yet reclaimed.

Reclamation has been required since the early to mid-1970's in most of these states on land mined for phosphate. Controversial at times, land reclamation has involved a variety of technologies and regulations which reflect the complexity of economical, ecological and political forces involved in the decision-making process. In most cases, reclamation procedures and results have been dictated by economic constraints and, sometimes, by environmental concerns.

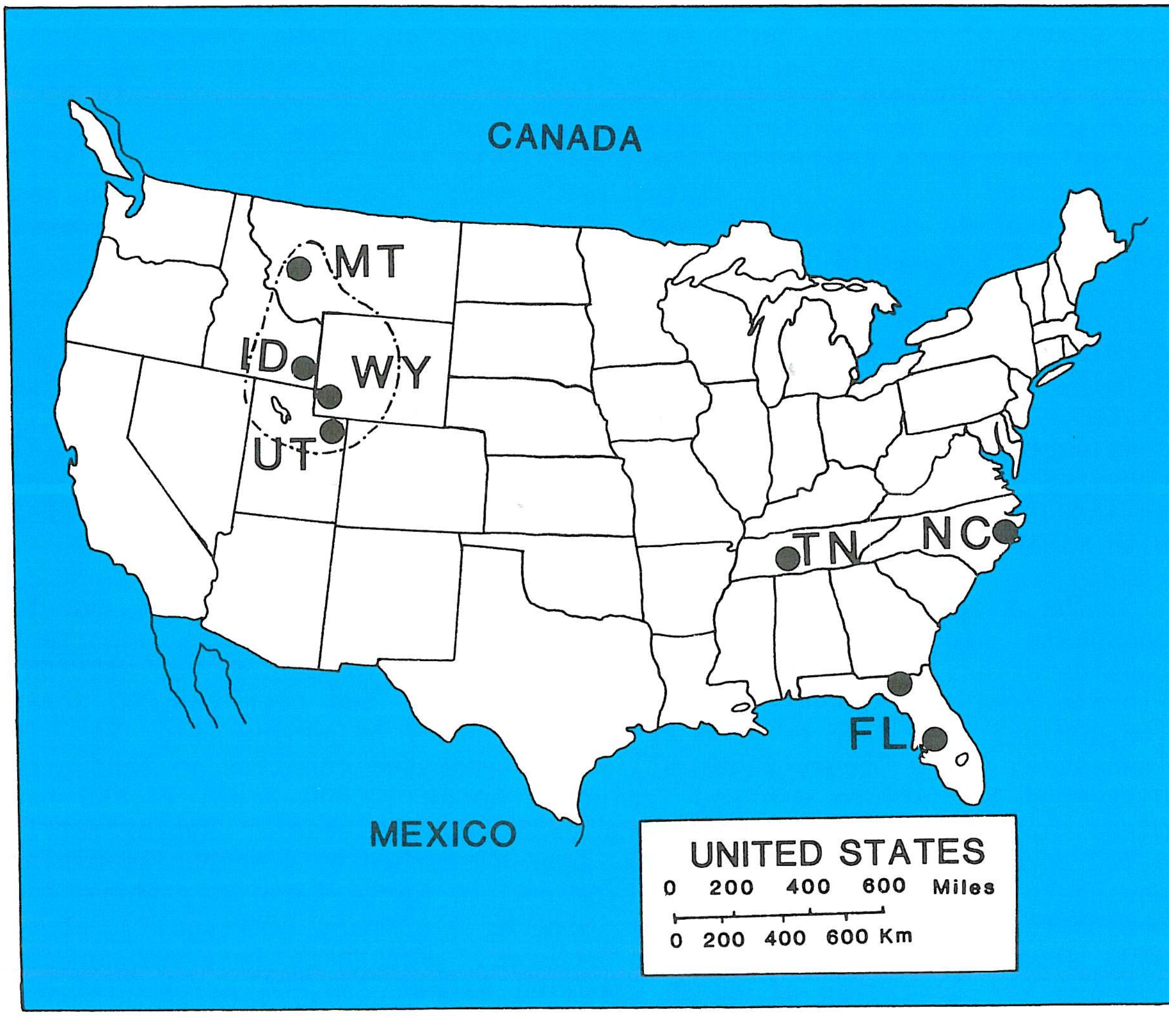

Figure 1. Areas of phosphate rock production in the United States. Note the 4 major areas include Florida, coastal North Carolina, Tennessee, and the western states of Idaho, Montana, Wyoming, and Utah (After Buie et al. 1975).

Figure 2. Typical phosphate mine dragline in Florida and disturbed area prior to reclamation.

This book was written to provide information on a number of phosphate mine reclamation topics from a wildlife habitat management perspective. The author is a Wildlife Ecologist and university professor with approximately 8 years of experience conducting research on phosphate lands in Florida. A major purpose of the book is to describe, compare and discuss phosphate mine regulations, reclamation, and revegetation on a nationwide basis. An attempt will be made to classify the final results of reclamation efforts according to immediate intended use(s) for the land -- agro-economic and natural (or "habitat") systems. Emphasis throughout the book will be on reclamation or restoration of phosphate mined lands to natural (or "habitat") systems. In this context, attempts will be made to distinguish between those reclamation practices considered to be standard or 'traditional' and those considered to be innovative. Several of these terms will be defined in the next section of the book. Secondary objectives of the book are to identify shortcomings of regulations, reclamation, and revegetation with regard to natural (habitat) systems reclamation and to identify associated research needs.

The book provides a blending of applied ecology with "on-the-ground" reclamation on a national perspective. Economic constraints on phosphate mine reclamation will only be examined superficially due to the author's lack of expertise in economics and the exceedingly complex economics of the entire industry in the national and international marketplace. Any misunderstood concepts or biases in this work are solely the responsibility of the author.

Several ecological principles and assumptions provide cornerstones for segments of the book. The first is that varied (diverse) natural plant communities provide important habitats for similarly diverse animal communities. Maintenance or enhancement of plant and animal diversity on the landscape are desirable objectives as they provide both long-term indicators of the "health" of the ecosystem and of our quality of life. Life is indeed enriched by the presence of diverse, natural ecosystems. Human development activities (e.g. farming, highway construction, urbanization, and mining) have caused significant fragmentation of natural ecosystems on a national and global scale. Only recently (Harris 1984) has concern over fragmentation of ecosystems due to human activities been articulated in the context of long-term detrimental impacts on plant and animal communities. Since mining activities result in at least temporary surface disruption and fragmentation of the landscape, another assumption was made that reclamation or restoration to natural (habitat) systems on at least a portion of phosphate mined lands is a necessary and worthwhile objective for present and future generations.

A major hypothesis was developed early in this research effort which stated that the sophistication or maturity of reclamation rules, procedures, and the levels of concern over functions of ecosystems and design of landscapes are directly related to the magnitude of phosphate mining in each state. Further, it was assumed that larger mining operations have greater environmental impacts and proportionately higher public concerns resulting in development of more sophisticated reclamation regulations, procedures and revegetation combinations.

Also, an assumption was made that phosphate reclamation regulations represent, at least partially, the political-cultural desires of the general public. This assumption may not be valid over short-term intervals, but appears to gain validity over the long-term as adjustments are made in the regulations to satisfy concerns of more people. The attempt was made to reveal the major areas of concern from perspectives of those involved with reclamation regulations, This book is an attempt to clarify these relationships and to highlight some alternatives favoring habitation of reclaimed lands by wildlife.

SOURCES OF INFORMATION AND TERMINOLOGY

In addition to his experience, the author spent much of the academic year 1983-84 obtaining information for this book while on sabbatical from the University of Florida. Sources of information for the book include use of a standardized questionnaire, personal interviews and field tours with numerous representatives of phosphate companies, regulatory agencies, consulting firms, local governments and other interested parties in four states (Fig. 1). Also, information was obtained by reviewing appropriate literature and observations of phosphate mine reclamation and trends since 1977. Assessment of the current state-of-the-art of reclamation on phosphate mined lands was made with particular emphasis on applied technology and political-cultural concerns. Questions used to address these topics are presented at the beginning of each of the following sections. All responses to questions were summarized and are presented as concensus opinions on a number of topics.

In addressing the terminology used in this book, two terms immediately come to mind as sources of confusion and controversy--reclamation and restoration. For some, the differences between these terms are just a matter of semantics and they are used interchangeably. However, in dealing with drastically disturbed lands (phosphate and coal mining, oil spills, etc.), restoration is generally believed to be a much more complex and comprehensive process than reclamation. Reclamation is defined as the process of recontouring and revegetating land and water bodies disturbed or affected by mining activities. Restoration is a process which includes reshaping the surface, recreating moisture conditions, revegetating and re-establishing the ecological functions of a landscape unit that existed before mining. Ecological functions include a wide variety of considerations, such as regional drainage patterns, soil profile characteristics, native vegetative communities, and long-term provisions for maintaining diversity of flora and fauna, etc.

Conservationists and environmentalists have generally not been satisfied with the term "reclamation" for several reasons. First, in some regions of the country (e.g. upper Midwest), "reclamation" has been used to describe the draining of wetlands for agricultural production and this is contrary to the objectives of these interest groups. Also, reshaping and revegetating (reclamation) do not appear to be entirely satisfactory as these groups attempt to get industry to "put-it-back-as-it-was". Industry has typically not used the term "restoration" due to the costs involved in restoring the land and the implied long-term commitments to the land. Reclamation has been done for a number of years across the country and there have been many technological advances, but in most cases we are still in the experimental and demonstration phases. Serious consideration of restoration has been relatively more recent and was the subject of a recent book (Berger 1985) and journal series (Restoration and Management Notes). The future promises advances in both reclamation and restoration but, at present, the concepts associated with these terms remain controversial. This book will deal primarily with reclamation as defined above and selected aspects of restoration.

Two revegetation schemes, natural (or habitat) systems and agro-economic systems deserve clarification at this point. Habitat systems were defined as ecosystems that were revegetated primarily with native plants and were not immediately intended for agricultural or commercial uses. Taken in a long-term perspective, reclamation really should be focusing on a successional sequence of plant communities (e.g. *Typha* to *Ludwigia* to Salix) and not on a particular habitat type. Examples of phosphate lands reclaimed to habitat systems include regeneration of scrub forests, shrubs, bottomland hardwoods, and re-establishment of riparian zones and wetlands of various types. Agro-economic systems were ecosystems reclaimed and/or revegetated in a manner to facilitate agricultural production or commercial enterprises such as pastures, citrus groves, pine plantations, row crops, and urbanization.

Reclamation practices were classified by the author into two categories--traditional and innovative reclamation. These terms are essentially self-explanatory and are qualitative based upon history of use and some demonstration of promise for the future.

REGULATIONS

This section will assess political-cultural views affecting phosphate reclamation as indicated from responses to a series of questions on reclamation regulations in each state. These questions were:

(1) Are there federal, state and/or local laws that pertain to your mining operations? If so, please specify the level(s).

(2) Are reclamation rules (laws) well established in your state/region, or are they being revised frequently (every 1-3 years)?

(3) Are these rules being enforced by a single agency or several?

(4) Are the reclamation rules relatively flexible or rather restrictive?

(5) Do the reclamation rules address ecosystem function or landscape design criteria? If so, please explain.

FLORIDA

In response to the initial question, only 5 of the companies from Florida noted Federal laws, whereas all 10 that responded to this question mentioned the importance of state and county laws. The list of agencies in Florida with at least some influence over phosphate mining and reclamation is extensive (Table 1). A number of federal laws, such as the Endangered Species Act, the Clean Water Act, National Environmental Policy Act, and Fish and Wildlife Coordination Act do apply to phosphate mining in Florida, but these do not seem to be a priority concern with local industry. In many cases, federal agencies are relegated to a "review" or "consultation" role in the approval process for new projects. Also, on a national basis, strip-mining laws are not being adequately implemented or enforced by federal agencies (Miller 1985:541); this has been supported by a number of recent court decisions (National Wildlife Federation 1985:33) attempting to enforce these laws.

Major issues associated with phosphate mining in Florida seem to be wetlands restoration, water quality considerations, and the timing of reclamation relative to completion of mining. The Department of Natural Resources (Bureau of Mine Reclamation) is the lead agency in Florida setting up reclamation regulations and the Department of Environmental Regulation controls aspects of water quality and use. Many other agencies at all levels (Table 1) have input into the permitting process with their involvement depending upon the specifics of the case. County requirements for reclamation vary tremendously, as regulations in Hamilton and Polk counties are fairly lenient and flexible, while those

Table 1. Governmental levels and agencies known to be directly involved with phosphate mining and reclamation in Florida,

Level	Agency
Federal:	Army Corps of Engineers Environmental Protection Agency Fish and Wildlife Service Coast Guard
State:	Governor and Cabinet Department of Agriculture and Consumer Services - Division of Forestry Department of Community Affairs Department of Environmental Regulation Department of Natural Resources - Bureau of Mine Reclamation Department of Natural Resources - State Lands Department of Transportation Game and Fresh Water Fish Commission Regional Water Management District
Local:	Regional Planning Council Individual counties

of Hillsborough and Manatee counties are much more stringent. Phosphate mining is prohibited entirely under current ordinances in Alachua and Sarasota counties. County laws and ordinances in Florida regarding phosphate mining are by far the most comprehensive and stringent of any in the nation.

In Florida, all 10 companies responding to the second question said that reclamation rules were frequently revised. In many cases, it is not the rules themselves that are changing, but it is the interpretation of those rules that causes problems and uncertainty with reclamation staffs. Variations in interpretations of reclamation rules by regulatory officials were the most often mentioned sources of frustration for company officials in Florida.

Most phosphate companies (7 out of 10) in Florida responding to the third question indicated that several agencies have input into enforcement of reclamation rules and that often these agencies could not agree on interpretations of the "rules". Reclamation rules in Florida are actually enforced by the Department of Natural Resources and the local county; however, approval of mining permits are affected by input from many others, especially where wetlands are involved.

All Florida companies responding to Question 4 either indicated that Department of Natural Resources (DNR) Reclamation Rules are too restrictive (60%) or are restrictive due to interpretation (40%). None of the Florida companies indicated that DNR rules are sufficiently flexible for their needs.

Two mining companies (AMAX and Estech) expressed the concern that the DNR should not be involved with phosphate mine waste disposal (e.g. clay settling ponds, sand tailings storage areas), but should just regulate reclamation. The following quote from a Florida phosphate mining official summarized several of industry's views on this subject: "The current reclamation rules try to regulate the method of reclamation as well as the final results. In addition, mining permits are filed six (6) months before mining and are difficult to amend to accommodate actual conditions after mining. For these 2 reasons, the existing rules are far too restrictive and inflexible to meet the needs of both the state and industry."

To partially explain this view, it is important to realize that mining (and not reclamation) provides profit for the company; if mining is to be profitable, it must be responsive to changing economic conditions. If reclamation is to play a strong role in mining operations and if mining is to remain a viable free enterprise, then the reclamation rules must be sufficiently flexible to allow unforeseen changes in economic conditions associated with phosphate mining. As suggested by Stroup and Baden (1983:51), incentives often are lacking to improve resource management and a need exists to begin to provide these incentives.

Personnel of the state DNR and Department of Environmental Regulation (DER) are of the strong opinion that, in order for reclamation to be carried out efficiently and economically, these regulatory agencies really need to be involved early in the planning process. This view has some validity since a large part of the costs of reclamation involve moving of reclamation materials.

The majority (70%) of responses to the fifth question by Florida phosphate officials indicated that there are no provisions that address ecosystem function and half (50%) of the responses indicated no provisions for designing landscapes. The remaining responses indicated that landscape design and ecosystem function were at least partially addressed by reclamation rules.

Several years ago, regulatory agencies (especially the DNR) were mostly interested in aesthetic considerations and a timetable for completing reclamation. But with growing environmental conciousness, an increasing extent of mine operations and without an adequate data base on which to make decisions, the DNR has had to adopt a "put-it-back-as-it-was" philosophy of reclamation. Landscape design criteria generally have been limited to sloping requirements for safety and references to restoration of the same landform that existed before mining. The concept of exact replacement of landforms by type and location is one which may facilitate inspections and enforcement, but it also has become very' controversial. In some cases, attempting to "restore" the landform and vegetation that were there earlier may stimulate innovation in reclamation technology; in other cases, attempting to do this may stifle innovation or be totally impractical when long-term land use is considered. This is the nature of the dilemma. A definite need exists for research into short- and long-term landform and land use tradeoffs and criteria for properly assessing the impacts of various decisions.

Although the concept "ecosystem function" is used frequently by academicians and modern ecologists, the practicality of quickly restoring all of the former ecological functions of a mined ecosystem seems remote. Clearly, there are some functions which can be restored (e.g. provision of dry land for forests, flowing water, etc.), but these functions have not been previously identified. As a result, realistic inclusion of "ecosystem function" requirements and criteria into reclamation regulations have not been accomplished. The current working definition of the reclamation-restoration dilemma used in Florida is to "reclaim the land, restore the function". A research need addressing this topic is for an assessment of the resiliency of various ecosystems to perturbations typical of phosphate mining operations. For example, it may be possible to compare all feasibly restored functions with all necessarily restored functions to develop a list of achievable, mandated functional goals for reclamation.

NORTH CAROLINA

Sixteen permits, involving mostly federal and state laws, are required to begin mining phosphate in North Carolina. Federal agencies involved are essentially ones similar to those listed for Florida (Table 1) and the biggest regulatory problems involve air and water quality. The North Carolina Department of Natural Resources and Community

Development and the 9-member Mining Commission (Raleigh, North Carolina) are the primary state-level regulators of phosphate mining through the Mining Act of 1971 (North Carolina General Statutes 1971) and its amendments (North Carolina Administrative Code 1978, North Carolina General Statutes 1981, and North Carolina Administrative Code 1982). The major stated purposes of the Mining Act of 1971 (North Carolina General Statutes 1971:47-48) were to provide:

1) "That the usefulness, productivity, and scenic values of all lands and waters involved in mining within the State will receive the greatest practical degree of protection and restoration."
2) "That from June 11, 1971, no mining shall be carried on in the State unless plans for such mining include reasonable provisions for protection of the surrounding environment and for reclamation of the area of land affected by mining."

Highly regulated aspects of phosphate mining in this state are restoration of wetlands and disposal of phosphogypsum, a by-product of fertilizer production. The local laws relating to phosphate mining in coastal North Carolina are fairly flexible and provisions are relatively easy to meet.

In North Carolina the reclamation laws are generally well-established as the State Mining Act of 1971 is still being used. There have been more recent revisions (1973 and 1974), but the reclamation laws are still considered by most to be fairly flexible. Phosphate mining in this state is being overseen by the 9-member Mining Commission and reclamation rules are being enforced primarily by the U.S. Army Corps of Engineers and two divisions (Land Quality and Environmental Management) of state government. With several agencies involved, the potential exists for some problems of interpretation of reclamation rules as described for Florida, but extensive reclamation has not yet begun in North Carolina. It is expected that eventually growth of phosphate mining in North Carolina will result in more extensive and dynamic reclamation regulations.

Reclamation rules in North Carolina do not specifically address either ecosystem function or landscape design criteria. In all states, the same long term research needs exist that were described above for Florida. Reclamation regulations in North Carolina have included specific provisions requiring demonstration of wetland mitigation prior to mining; more recent emphasis has been on reclamation of upland sites.

TENNESSEE

There are no major federal laws that apply specifically to phosphate mining in Tennessee; mining and reclamation are governed mostly by state and local laws. At the state level, mining is regulated by rules of the Tennessee Department of Conservation. The mining law in Tennessee was written up mostly by the local phosphate industry with provisions which were relatively easy to satisfy (C. Hales 1983 pers. comm.).

Reclamation laws in Tennessee are well-established, since there have been only minor revisions since 1980. Enforcement of reclamation rules has essentially been done by a single state agency, the Tennessee Department of Health and Environment (formerly Department of Conservation). Reclamation efforts have been conducted on a relatively small scale and have been noncontroversial.

Reclamation rules in Tennessee are considered to be relatively flexible, particularly when compared to strict laws which dictate reclamation standards for coal mined areas of the region. This was the expected situation due to the very small scale of phosphate mining operations when compared to coal mining. Similarly, neither ecosystem function nor landscape design criteria have been included in reclamation rules due to the small scale of disturbance.

IDAHO

In Idaho, phosphate reclamation is regulated mostly by Federal agencies (U.S. Forest Service and U.S. Bureau of Mines) with some rather weak state laws and no local regulations. Reclamation laws in Idaho are well-established and are considered by most to be very site-specific. Reclamation laws are relatively easy to meet and some political pressure seems to be developing to increase the number and degree of U.S. Forest Service stipulations. Occasionally, U.S. Forest Service stipulations have been revised somewhat based upon U.S. Forest Service research in Logan, Utah. There generally have been few complaints or misunderstandings involving interpretations of the stipulations due to a close working relationship between industry and the U.S. Forest Service inspector.

Enforcement of reclamation stipulations in this state has been mostly under the supervision of a single agency -- the U.S. Forest Service. Although reclamation in Idaho was once very political and controversial in the mid- to late-1970's, it now appears to be considerably less so. Similarly, reclamation rules in Idaho were fairly restrictive in the 1970's, but are considered to be sufficiently flexible now. As in many situations, each mine is considered to be a somewhat unique, site-specific case. Idaho reclamation stipulations also have not addressed either ecosystem function or landscape designs. Primarily, the Idaho stipulations address developing a ground cover for control of erosion, developing pastures for use by domestic cattle and sheep, protecting water quality, and providing some wildlife habitat.

OVERALL

Phosphate-mine reclamation is regulated primarily by state laws and regulations. Federal laws are significant in some situations, but generally to a lesser degree than state laws. Where local mining laws exist, they have generally been written under the strong influence of local industry and are consequently not too difficult to meet. Counties with existing industry and an existing industry tax base tend to write liberal mining laws, while counties without existing mining or with little mining can be more restrictive (e.g. several counties in Florida).

Reclamation laws seem to be relatively well-established with few modifications in North Carolina, Tennessee, and Idaho. Florida reclamation rules have undergone and continue to undergo revision and numerous changes in interpretation. These many changes in interpretation have developed because of an emerging environmental consciousness and an expanding industry in Florida which have resulted in dynamic reclamation goals and legislative growth.

Several agencies are involved in enforcing reclamation rules in Florida and North Carolina, while primarily one agency is responsible in Tennessee and Idaho. This is apparently because agency involvements and legislation tend to grow in response to controversy and phosphate mining has a continuing history of controversy in Florida and to a lesser degree in North Carolina.

Maintenance of flexibility seems to be an important issue in describing reclamation rules. Phosphate company officials generally believe that these rules are too restrictive in Florida to allow them to respond to changing mining and economic conditions. In other states, the reclamation rules seem to be sufficiently flexible. Reclamation regulations in all states do not include either ecosystem function or landscape design criteria, but with sufficient flexibility and increased sophistication among regulators, these criteria may eventually be incorporated into reclamation regulations.

RECLAMATION

In this section, reclamation technology employed and final results will be described and compared by state or region. Also, an attempt will be made to categorize both the conventional and innovative reclamation efforts and make some recommendations regarding appropriate uses for some of these techniques. The following questions addressed issues of extent of site disturbance and reclamation technology being used:

(1) How much land is involved (presently or previously) and has been disturbed during your mining operations?

(2) Under past and current reclamation and technological constraints, how much of the disturbed land on your mine has been (or will be) reclaimed as natural "habitat" systems (as distinguished from agro-economic systems)?

(3) What technology has been used in reclamation to natural "habitat" and agro/economic systems?

(4) Why was this technology chosen for use in your reclamation program?

(5) Was reclamation completed as it was proposed? If not, how has it been modified from reclamation plans?

(6) What has been the source(s) of most of your company's technological information for reclamation of these lands?

(7) Are there readily available guidelines or pools of expertise for you to use? If so, please identify.

Emphasis on the necessity for and final results of reclamation have changed considerably over the last two decades. In most states, reclamation of phosphate-mined land has been required on an acre-for-acre basis since the early- to mid-1970's. Generally, phosphate reclamation requirements have included recontouring the surface and revegetation with a cover of grass within a specified period of time. In many cases, the end product of phosphate reclamation has been pastureland or agricultural land (hereafter referred to as agro-economic systems). As stated by Farmer and Blue (1978:586) however, land reclamation involves more than just recontouring and revegetation of the surface of phosphate mined areas. In some states, more recent consideration has been given to reclamation back to natural ("habitat") systems, as distinguished from agro-economic systems.

Responses to my question regarding total areas being reclaimed to natural systems indicated some confusion or reinterpretation of the term "natural habitat system". In most cases, I attempted to clarify my definition of "natural habitat systems" reclamation to participants during the interview process and I gave several examples. Also, the time scale to be used was designated as one which included data for the present and near future (from approved conceptual or similar plans). In most cases, I believe that projected values for acreages to be reclaimed to natural systems probably represent maximum numbers.

Results of the question regarding natural "habitat" systems reclamation were highly variable from company to company, particularly in Florida. Proportions of lands mined by 10 companies in Florida and reclaimed to habitat systems varied from 3.4 to 83.7 percent, with an average of 42.7 percent. This variability could be caused by a number of factors, including: (a) duration of company operations, (b) site-specific economic constraints of each company in producing phosphate, (c) the relative costs of various types of reclamation, (d) topographic and vegetational features of the landscape prior to mining, (e) the types of reclamation typically used by each company, and (f) different interpretations of what was meant by habitat systems reclamation. The overall average of 42.7 percent in Florida was very likely higher than the proportion of habitat systems already reclaimed due to inclusion of future projections based upon conceptual plans. Future reclamation (as depicted in conceptual plans) may include more habitat systems in response to revisions of wetlands protection ordinances and phosphate reclamation rules in Florida.

FLORIDA

Farmer and Blue (1978:603-606) described in detail phosphate mining methods and some reclamation problems in Florida. Earthmoving technology used in reclamation typically includes use of bulldozers, scrapers, draglines, some trucks, and explosives. Much of the earthmoving is accomplished through hydraulic transport of materials by pumping. Dredging as an initial step in mining was used extensively several decades ago in Florida but currently seems to be restricted to Beker (Florida).

A general impression received in touring 11 phosphate mines in Florida is that, in many cases, a relatively low proportion of mined lands have been reclaimed to date and that a relatively small proportion of already reclaimed lands are in "habitat systems". Part of the reason for this is that, on most mines, 60-70 percent of the landscape becomes quickly inundated as clay settling areas (Wang et al. 1974) and these areas are not available for reclamation for 10-15 years. Other possible reasons for this impression include a general lack of emphasis on reclamation of lands mined in the early 1900's and the very recent increased public concern over reclamation to natural systems.

Conventional reclamation techniques include sand tailings fill, overburden fill, "land and lakes", and crustal development on clay settling areas. Often several or all of these techniques are used in reclaiming a parcel of land. Sand tailings usually are pumped hydraulically through pipes (Fig. 3) from a beneficiation plant or storage site to a reclamation site where this sand is used as fill for recontouring uplands. Overburden fill, generally transported with earthmoving equipment, is frequently used as a surface-layer cap over sand tailings fill (Figs. 4, 5). Careful planning for reclamation when materials to

Figure 3. Sand tailings transported by hydraulic pumping.

Figure 4. Typical overburden capping (6") on sand tailings revegetated with Bahiagrass in Florida.

Figure 5. Overburden capping (6" on sand tailings planted to citrus in Florida (1 year old).

be used are originally transported is useful to retain some reclamation options which might otherwise be lost due to physical or economic constraints.

The term "land and lakes" is used in Florida to describe both a reclamation scheme and a resulting landform in which former mine cuts separated by linear overburden piles become narrow, serpentine lakes separated by smoothly contoured uplands (Fig. 6). These uplands have traditionally been revegetated with Bahiagrass (Paspalum notatum) or Bermudagrass (Cynodon dactylon) and occasionally, a few trees. Clay settling areas, after many years of use for colloidal clay disposal, undergo several stages of vegetational and crustal development prior to capping with sand tailings (Fig. 7). These areas typically have been reclaimed with grasses and have become pastureland in central Florida.

Re-establishment of surface soils with textures, fertility and moisture-holding capacities favorable for plant growth are the biggest challenges to successful reclamation and revegetation of phosphate mined lands. One innovation which shows promise for redeveloping these characteristics in surface soils used in reclamation is the sand/clay mix, involving either physical (by spraying of sand) or hydraulic mixing of sand and clay (Fig. 8). The technology leading to development of the sand-clay mix was originally intended as a means of dewatering and of adding structural stability to clay in settling impoundments. It seems that the characteristics of both the sand and the clay are improved by their mixture. The importance of using at least some sand/clay mix in reclamation is in the establishment of a confining layer to hold moisture near the surface in otherwise porous materials (e.g. sand tailings).

Innovative reclamation involves the use of good quality planting stock and site-specific site preparation and planting techniques. A technique which appears to have merit in facilitating revegetation, particularly in wetland areas, is organic surface layer (muck) transfer and spreading. Not only does this technique quickly increase the organic matter in surface soils, but it provides a ready source of seeds for re-establishing native plants. The value of this technique was widely substantiated in a survey on wetlands establishment and success (Ruesch 1983). Also, the maintenance of natural plant communities in close proximity to the reclaimed site may serve as valuable seed sources. Transplanting or mulching with native, pre-stripped vegetation (mostly herbaceous) appeared to be useful and innovative. This technique has even been successful where stumps from recently cut hardwood trees were transferred to the reclamation site and this resulted in extensive sprouting of young trees from the stumps.

Also, addition of physical amendments to reclaimed landscapes show real promise for augmenting local wildlife habitat. Transplanting dead trees to recently reclaimed sites provide snags for use by birds and other animals for perching, feeding and nesting. There is growing evidence that seeds defeccated by perched birds may serve an important function in revegetation of the local area. Brush piles from adjacent, recently-cleared areas should be developed and maintained to provide cover for various wildlife species. Also, log piles in reclaimed

Figure 6. "Land-and-lakes" reclamation with 4:1 slopes on shorelines and littoral zones, Florida.

Figure 7. Initiation of capping of 9-year-old clay settling pond with sand tailings, Florida. Trees being crushed and covered (upper left) are the results of natural succession over the 9 year interval.

Figure 8. Hydraulically mixed sand and clay in a clay settling pond, Florida.

streams often provide habitat improvements and cover for fish and wildlife. A recent publication (King et al. 1985) both describes and illustrates numerous possibilities for physical amendments to reclaimed landscapes that favor use by fish and wildlife.

In response to a question regarding the sources of most technological information on reclamation, Florida companies gave a wide variety of answers indicating a variety of sources. Predominant among these responses were in-house expertise and experience (8), followed by demonstrations, meetings and seminars (5), consultants (5), publications (3), and technical assistance from agencies (2). It also was obvious that several individual companies used more than 1 major source for technical information.

There was an apparent heavy dependency in Florida upon using in-house expertise and consultants rather than support and technical assistance from agencies [i.e. Florida Division of Forestry (DOF), Florida Game and Fresh Water Fish Commission (FGFWFC), and Soil Conservation Service (SCS)]. A partial reason for this tendency to develop and use in-house expertise was revealed in responses to the inquiry about the availability of reclamation guidelines or pools of expertise. Most Florida companies indicated that neither guidelines for reclamation nor pools of people with appropriate expertise were readily available to assist the industry.

The reclamation rules of the Florida Department of Natural Resources (1980) were mentioned as providing some criteria (a form. of "guidelines") for reclamation. The need was repeatedly expressed for a reclamation "cookbook" to provide guidelines, especially for the more innovative types of reclamation (e.g. revegetation to bottomland hardwoods or sand pine scrub uplands). Such Habitat Reclamation Guidelines (King et al. 1985) are near publication at this time and should provide significant information to meet these expressed needs. Another frequent comment from representatives of the phosphate industry was that many reclamation alternatives are very site-specific; this may partially preclude the applicability of the "cookbook" approach.

A majority (9 of 11 or 82%) of the phosphate companies in Florida indicated that expertise pools are lacking (or not readily known) and expressed a need for assistance from "experts" with practical knowledge of phosphate reclamation. Those pools of expertise that were mentioned as being available and helpful included the Florida Game and Fresh Water Fish Commission (FGFWFC), consultants, Institute of Food and Agricultural Sciences (IFAS), and the Soil Conservation Service (SCS), It appears that it would be useful for expertise pools to make themselves known and available to provide assistance to the industry.

A wide variety of reasons also were given for a specific reclamation technology being chosen in Florida. These included technology that was: very economical (9), proven by experience (5), most efficient (4), and state-of-the-art (4). Other reasons given were: to meet DNR reclamation rules (3), to match site constraints (2), and advice of consultants (1).

Another indication of efficiency of technology transfer and implementation was the response to the question "Was reclamation completed as proposed or was it modified?". In response, only 2 of 11 (18%) Florida companies indicated that their reclamation proceeds as planned and the other 9 companies (82%) in Florida indicated that reclamation was modified. Main problems causing modifications seemed to be in accurately predicting 6 months before mining the size, shape and locations of lakes and wetlands in reclamation. At this point, it should be stated that mining procedures are directly related to economic considerations and reclamation regulations are directly related to these mining procedures. But, reclamation regulations are not directly related to economics and this is the cause of several ongoing debates between industry and regulatory personnel. Also, reclamation activities have frequently fallen behind schedule in recent years due to poor economic conditions nationwide, the slowdown of phosphate production, and resulting problems with company cash-flow, materials availability, etc. In some cases, reclamation efforts have actually increased relative to phosphate production in order to keep company employees and equipment working.

NORTH CAROLINA

Phosphate mining operations in North Carolina appear to be similar to those in Florida. In both states, open pit strip mining is accomplished using electric dragline excavators. Also, phosphate mining in Florida and North Carolina produces 3 major "waste" by-products: (1) overburden, (2) sand tailings, and (3) phosphatic clay slimes. Also, as in Florida, large quantities of phosphogypsum are produced as part of fertilizer production and this material is stored in large piles near processing plants. The possibilities for reclamation and revegetation of these by-products were discussed in some detail by Farmer and Blue (1978:597-601).

A major difference between mining in Florida and North Carolina involves the depths at which the phosphate matrix lies and the subsequent differences in size of the pits. In Florida, draglines are used to reach the desired phosphate matrix at depths of 10-15 m (Fig. 9). In North Carolina, after an area to be mined has been cleared, dikes are built and the area is flooded. The top 10 m of overburden is then removed with hydraulic dredges and pumped through a slurry pipeline to be dumped into mined-out areas. The diked area is then drained and an additional 20 m of overburden is removed by a dragline. The 30 m deep pits are kept dry by pumping so that the phosphate matrix then can be mined (Fig. 10) using a dragline. The mined matrix is moved by small draglines to a slurry pit and is pumped to the beneficiation plant by a slurry pipeline.

Over half of the 3,400 acres (1,377 ha.) mined for phosphate by Texasgulf in North Carolina have been used as phosphatic-clay settling ponds (Fig. 11), a procedure which generally delays reclamation for many years. During the period of "waste clay" disposal in these diked impoundments, the ponds become important habitats for many avian species

Figure 9. Excavation down to the phosphatic clay matrix (10-15 m) in Florida.

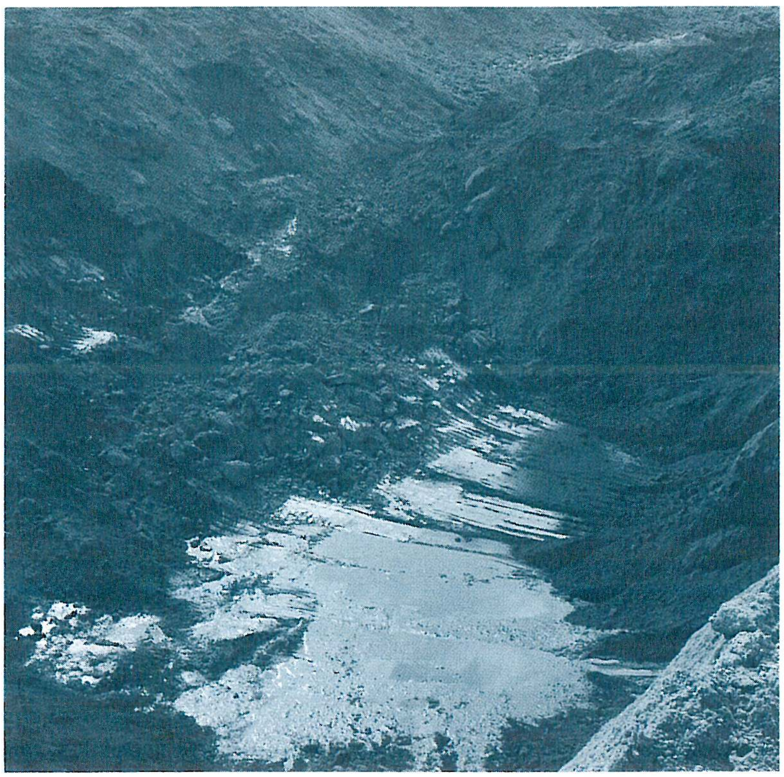

Figure 10. Excavation pit in North Carolina where the phosphatic clay matrix is approximately 30 m deep.

Figure 11. Aerial view of several clay settling ponds along the Pamlico River, coastal North Carolina.

in North Carolina (D. Woodward 1983 pers. comm.) just as they do in Florida (King et al. 1980, Maehr 1980, Montalbano 1980, Marion et al. 1981, Wenner and Marion 1981).

As in Florida, a relatively small proportion of lands disturbed by mining appears to have been reclaimed to date. Traditional reclamation of uplands seems to involve recontouring back to a relatively flat landscape and revegetating the area with grasses. An even smaller acreage (approximately 10 acres or 4 ha.) of mined land is being reclaimed to habitat systems (hardwood reforestation). In fairness to the industry, reclamation technology for hardwood forests is in its infancy; it takes a number of years to re-establish hardwood forest communities and several more years to evaluate the relative success of these efforts. In most cases, the companies should be commended for any efforts in this direction.

The situation with technological information transfer in North Carolina was different from other states and companies visited. At Texasgulf, and to some extent at North Carolina Phosphate Corporation, the major source of technical information was from outside consultants -- particularly those at North Carolina State University. Similarly, the expertise pool most frequently referred to was one that included faculty and staff of N.C. State University. There are no readily available guidelines for phosphate-mine reclamation in North Carolina. Company officials did point out strongly the site-specific nature of reclamation where nearly every site is different and very few techniques will work on all sites.

Much of the reclamation technology in North Carolina appears to be in early developmental stages since relatively little reclamation has occurred. According to Farmer and Blue (1978:599), there are few good examples of reclamation of mined lands in the state; my observations during on-site tours substantiated this claim. In the near future, North Carolina phosphate mining and reclamation will be proceeding on a much larger scale than at present since the 2 active mining companies presently control over 80,000 acres (32,000 ha.) of local reserves. The political/cultural and environmental consequences of mining the potential 350,000 acres of reserves will be severe since they are located beneath the Pamlico and Pungo Rivers (Mew 1980:40).

Reasons given for choosing the technology used in reclamation in North Carolina were that it was readily available and state-of-the-art. Also, reclamation technology and procedures in North Carolina are undergoing continual revision and modification as technology and innovations develop. Good examples of innovative reclamation procedures are outlined in North Carolina Phosphate Corporation's (1983) "Wetlands Mining and Mitigation: A Preliminary Supplemental Environmental Impact Report" in which they present their attempts to demonstrate before hand the feasibility and success of re-establishing salt marshes and palustrine forests.

TENNESSEE

Phosphate mining operations in middle Tennessee are very localized, closely associated with agriculture, and not extensively publicized. The impacts of this mining compared to the operations in Florida, North Carolina and Idaho are minimal. If present production levels in Tennessee are maintained, commercial deposits are expected to be depleted by the year 2000 (Farmer and Blue 1978:595). Most of the Tennessee phosphate lands are deposits of relatively small acreages (average 8 ha) on privately owned lands. These small deposits are excavated, mined out and reclaimed, usually all within a few weeks.

Earthmoving technology is uncomplicated compared to that required in other states. Bulldozers are used to strip off the overburden which averages 2.7 yd. (2.5 m.) but may be up to 6.6 yd. (6 m.) thick. Small draglines with 2.5 $yd.^3$ (1.9 m^3.) buckets are used to mine the "brown rock" ore deposits (Fig. 12). These ore deposits in shallow surface pits average about 2 yd. (1.8 m.) thick in narrow troughs in the limestone bedrock. This phosphatic ore is loaded on trucks by draglines and transported to washing facilities to begin processing. In much of Tennessee's phosphate district, mining close to the processing plants was completed a number of years ago and current hauling distances with trucks and trains average about 25 km.

Traditional reclamation involves bulldozers used to backfill and grade mine sites. Reclamation projects are not always completed due to the presence of limestone outcroppings ("cutters") at or near the surface. Also, the presence of limestone prohibits having clay slurry ponds on mined lands because the limestone drains too easily (R. Jensen 1983 pers. comm.).

Major problems of reclaiming mined lands in Tennessee have been largely resolved (Farmer and Blue 1978). Reclamation is required on every acre mined within 90 days of mining (Fig. 13) and 60 percent of the cost of reclamation is paid by the state while the remainder of the cost is provided by the landowner (T. Rosenberg 1982 News Release). Erosion control remains a significant problem on some reclaimed hillsides and attempts to use mulch, terraces and ponds have met with limited success. Erosion has been, and remains, a problem on abandoned unreclaimed lands.

A likely future reclamation problem in Tennessee involves clay ponds resulting from ore beneficiation. These ponds are large, deep reservoirs built in valleys and other natural depressions to facilitate the settling of silt and clay from processing water. This water was obtained from local surface streams and is discharged back into these streams after clarification. The clay settling ponds here are similar in function, but not appearance, to those in Florida and North Carolina.

The phosphatic clays are very slow in drying and current reclamation technology is such that these clay ponds cannot be reclaimed for 20-30 years after construction. As in other states, phosphate settling areas do provide habitats for fish and wildlife for a number of years, particularly if some attempts are made to control dense invading stands

Figure 12. Shallow phosphate strip mine in Tennessee.

Figure 13. Tennessee phosphate mine recently filled and graded for planting soon after completion of mining.

of cattails (Typha latifolia) and willows (Salix sp.). No significant reclamation technology in Tennessee has been applied to settling ponds; it is very possible that the best future use of these ponds will be to retain them as wetlands for the fish and wildlife benefits that they do produce. This is particularly true if desirable littoral vegetation can be established using moist-soil (organic matter transfer) techniques and if water flow through these ponds can be maintained on a long-term basis.

Based upon responses from 1 mining company, the main sources of technological information appear to be in-house experience and expertise. In the past, there was heavier reliance upon advice of county extension agents and personnel of the SCS, but that dependency has diminished considerably in recent years. Also, there are no readily available reclamation guidelines for phosphate mines in this state.

Experience, both recent and historical, was the major reason given for choosing the reclamation technology that is used in Tennessee. The state of Tennessee does not require submission of a detailed reclamation plan and there generally were not any major problems with completing reclamation soon after mining. The major problem with completion of reclamation seems to be controlling erosion on the sloping terrain. Problem areas often require additional attention and manicuring before reclamation will be finalized and approved.

IDAHO

Leasing of phosphate on public lands in Idaho began in 1948 and reclamation was started (by Monsanto Co.) as early as 1958. Although the western phosphate area includes portions of Idaho, Wyoming, Utah and Montana, most of the present mining and proposals for new mining operations are located near the town of Soda Springs, Idaho (Farmer and Blue 1978:587).

Mining in the western field is significantly different from phosphate mining in the southeastern United States and potential direct comparisons are few. In Idaho, phosphate is mined from sedimentary-rock layers that have been severely faulted and/or folded by crustal movements. Mining methods include strip-mining of selected phosphate ore layers in mountainous terrain (Figs. 14, 15) and this results in large, relatively unstable, overburden waste dumps.

The major emphasis in traditional reclamation has been on recontouring with heavy equipment and revegetating of overburden waste dumps to meet the stability and vegetation stipulations developed by the U. S. Forest Service. This agency has a long-standing vested interest since most of the mining is occurring on Forest Service lands. The stated policy of the Caribou National Forest concerning mined land reclamation is: "The short term reclamation objective is the immediate reduction and prevention of erosion, by stabilizing the soil with adaptable plant species. The long term goal is to return the land to an end use similar to that which existed prior to mining at a level of

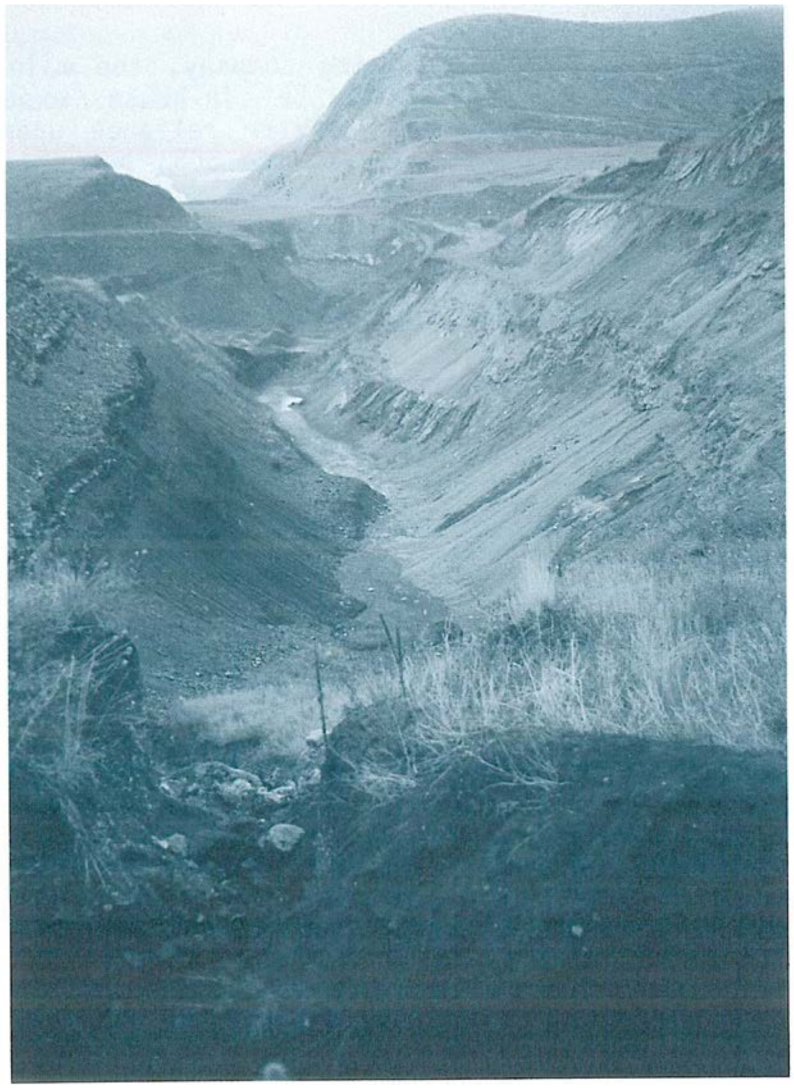

Figure 14. Abandoned phosphate strip mine cut in mountainous terrain, Idaho.

Figure 15. Active phosphate strip mine cut in Idaho.

productivity equal to or better than that previously realized. The reclamation plan which accompanies each mining plan will incorporate a long term revegetation plan."

Landforms and "waste" materials remaining after phosphate mining in the Idaho foothills include limestones, cherts, mined out areas, midland waste shales and catchment basins. The limestones and cherts are usually large, rocky materials offering little potential as a surface covering and they are usually buried during reclamation. The technology of reclamation normally includes procedures intended to meet, but not exceed, the U. S. Forest Service's stipulations on slopes (3:1 or flatter) and on revegetation (67 percent cover over 90 percent of the area within 3 years after mining). Traditionally, waste shale dumps have been simply sloped and planted wherever they existed after mining. A more innovative approach is to schedule mining such that backfilling of mined out areas with overburden materials is possible; this procedure is being encouraged and will probably become more common in the future. Backfilling is both a convenient way of disposing of waste shales and larger materials, and of reducing the possible adverse impacts of high walls. There are both advantages and disadvantages of high walls; they do provide perching and nesting sites for birds of prey (e.g. Peregrine falcons, Falco <u>peregrinus</u>), but tend to interrupt or divert migration routes of big game animals (Kuck 1982) and are thought to be undesirable from an aesthetic perspective.

Two methods of recontouring waste dumps in innovative, aesthetically pleasing ways are "valley fill" and "rolling hills", both developed and used by Monsanto Company. Using the "valley fill" technique, waste shales are dumped into the narrow valley between 2 hills and, upon leveling, this becomes a broad ridge with only minor physical evidence of the origin of the revegetated materials (Fig. 16). With the "rolling hills" technique, waste dump sites are contoured to blend in with the general shape and terracing of surrounding hills (Fig. 17).

After recontouring has occurred, the sites are typically harrowed, fertilized, and seeded with a rangeland drill or by broadcast seeding (Fig. 18). The planting medium more closely resembles chips and pieces of shale than soil, although some topsoil is brought in occasionally to augment the surface layer. Erosion on unplanted slopes presents a big problem; the choice seems to be one of either planting grasses and grass-like plants as quickly as possible on these barren slopes to slow erosion or to plant shrubs and trees and lose upper layers of "soil" by erosion as these shrubs and trees slowly become established in 4-6 years. The former strategy is usually used and areas that were covered with trees and shrubs prior to mining support grasses and forbs for several years after reclamation.

Phosphate mine personnel in Idaho listed the U.S. Forest Service, Idaho Game and Fish Department, and in-house expertise as the major sources of technical information on reclamation. Information from the U.S. Forest Service originated primarily from 2 sources -- the researchers at the Research Laboratory in Logan, Utah and the local office/field inspector for the Caribou National Forest in Soda Springs, Idaho. These

Figure 16. The "valley fill" method of recontouring phosphate waste dumps in Idaho.

Figure 17. Example of the "rolling hills" method of recontouring phosphate waste dumps in Idaho.

Figure 18. Broadcast seeding of recommended seed mixture on slopes of contoured waste shale dump, Idaho.

individuals and supporting agencies were considered by industry personnel to constitute the major pool of expertise involved in reclamation. A commonly expressed idea was that phosphate mine reclamation is mostly common sense and there is no need for additional outside expertise. Use of outside consultants, therefore, was minimal. Also, except for U.S. Forest Service stipulations on reclamation, there were no written guidelines to augment the process of reclamation.

The major reason given by personnel of 4 Idaho companies for choosing the reclamation technology they use was to meet the stipulations of the U.S. Forest Service. Other reasons given for choice of reclamation technology were that they had experience with these procedures and that they were economical for the company to use. In most cases, reclamation in Idaho appears to have been completed as proposed with only minor rescheduling,

OVERALL

To summarize this section, obvious local disturbance of the landscape due to phosphate mining was highly variable from state to state. Minimal site disturbance was observed in Tennessee where mining operations were generally small and reclamation was accomplished quickly. Intermediate local landscape disturbances were noted in Idaho and North Carolina, two states with very localized, medium-sized mining operations. The most obvious and largest site disturbances occurred in Florida, where mining operations generally are very large and a time lag of several years frequently exists between actual mining and completion of reclamation. Also, most of the innovation and experimentation with reclamation is occurring in Florida.

Most companies have developed and use in-house expertise more than any other means in accomplishing the reclamation job. In North Carolina, they seem to rely on expertise of outside consultants more than in any other state. In most states, "pools" of outside expertise on reclamation were either poorly developed or non-existent. Likewise, readily available printed guidelines for reclamation were lacking. Part of the reason for lack of specific reclamation guidelines from state to state seems to be the site-specific nature of phosphate reclamation. Criteria provided in the Reclamation Rules (Chap. 16C-16. 1980) for Florida and the stipulations of the U.S. Forest Service for Idaho provide about the closest facsimiles to written reclamation guidelines. The recently published Habitat Reclamation Guidelines (King et al. 1985) will very likely provide much of this type of information for Florida.

In most states, reclamation technology was chosen based upon economic considerations and previous company experience with the techniques. Also, modifications, revisions, and rescheduling of reclamation activities were found to be common, especially in Florida and North Carolina. These changes in reclamation were due to a number of factors, including advancements in technology, changes in reclamation laws, insufficient materials available for reclamation, and adverse economic conditions. Each of these factors, to some degree, is a function of size of the local industry and its growth trend.

REVEGETATION AND LAND USE

Revegetation of mined lands is linked closely with both the reclamation process and intended future land use. A major effort of the interviews and field tour at each phosphate mine was to identify demonstrated success in revegetation and the types of expected land uses after mining (Table 2). Table 2 was adapted for the resources or special conditions that existed in each state visited.

For the purposes of this study, major landforms or by-products of phosphate mining in Florida were defined as clay settling areas, sand tailings piles, sand/clay mix, "land and lakes", and mined out areas. Stacks of phosphogypsum (Fig. 19) are commonly found near phosphate mines in Florida and North Carolina and are by-products of fertilizer production. Land use categories used here included agriculture (row crops and citrus), rangeland, upland forest (hammock), scrub forest, wetland forest, nonforested wetland, streams, unreclaimed wildlife area, open water, and urban development. For each landform-land use combination, phosphate officials were asked to specifically address the demonstration and degree of success, the relative scale of success, and the origin of the demonstration (planned or unplanned). An in-depth discussion of all combinations in the matrix but those pairings with the highest demonstrated potential will be emphasized.

FLORIDA

According to the Florida Department of Natural Resources (1980) Mine Reclamation Rules, "revegetation" involves "providing either a diverse vegetation, native to the area, capable of self-regeneration at least equal in permanence to the natural vegetation or an agricultural or silvicultural crop suitable to the reclamation program and the surrounding areas". The idea of permanence deserves some discussion as "revegetation" associated with reclamation is usually considered on a short-term basis (1-5 years). Ideally, the longer term (20-30 years) revegetation of a site should be considered particularly with habitat systems because there will be a series of vegetational communities on a site resulting from natural succession. For example, a reclaimed wetland may be revegetated with herbaceous marsh plants, but these eventually may be replaced by shrubs and small trees and then larger trees as natural succession takes its course. Thus, a site originally replanted as a marsh becomes a swamp.

There seem to be at least three reasons for a general lack of concern over long-term revegetation sequences and eventual plant communities. These are: (1) a desire on the part of many landowners to retain maximum "flexibility" in both short-term and long-term land use decisions, (2) the unpredictable nature of future cultural changes (e.g. urbanization, increasing land values, economic concerns, etc.), and (3) our lack of understanding of long-term vegetation sequences on post-mining landscapes resulting from natural succession. All of these items, particularly number (3) above, are topics worthy of further research.

Table 2. Matrix of various post-mining landforms and combinations of revegetation/land use in Florida. Each interviewee was asked to assess the history of demonstration and relative success of each combination. The form was adapted for each state surveyed.

Landform Type	Agriculture (Row Crops & Citrus)	Range Land	Upland Forest (Hammock)	Scrub Forest	Wetland Forest	Non-forested Wetland	Streams	Unreclaimed Wildlife Area	Open Water	Urban Development
	Land Use Category									
Clay Settling Areas										
Sand Tailings										
Sand/Clay Mix										
"Land & Lakes"										
Mined Out Areas										
Gypsum										

Code for use Above

Demonstration and Success:

- ++ = Has been demonstrated; has good potential
- +- = Has been demonstrated; has poor potential
- 0+ = Not demonstrated; with good potential
- 0- = Not demonstrated; poor potential

Scale of Demonstration: S = Small; F = Full Scale

Origin of Demonstration: P = Planned; U = Unplanned

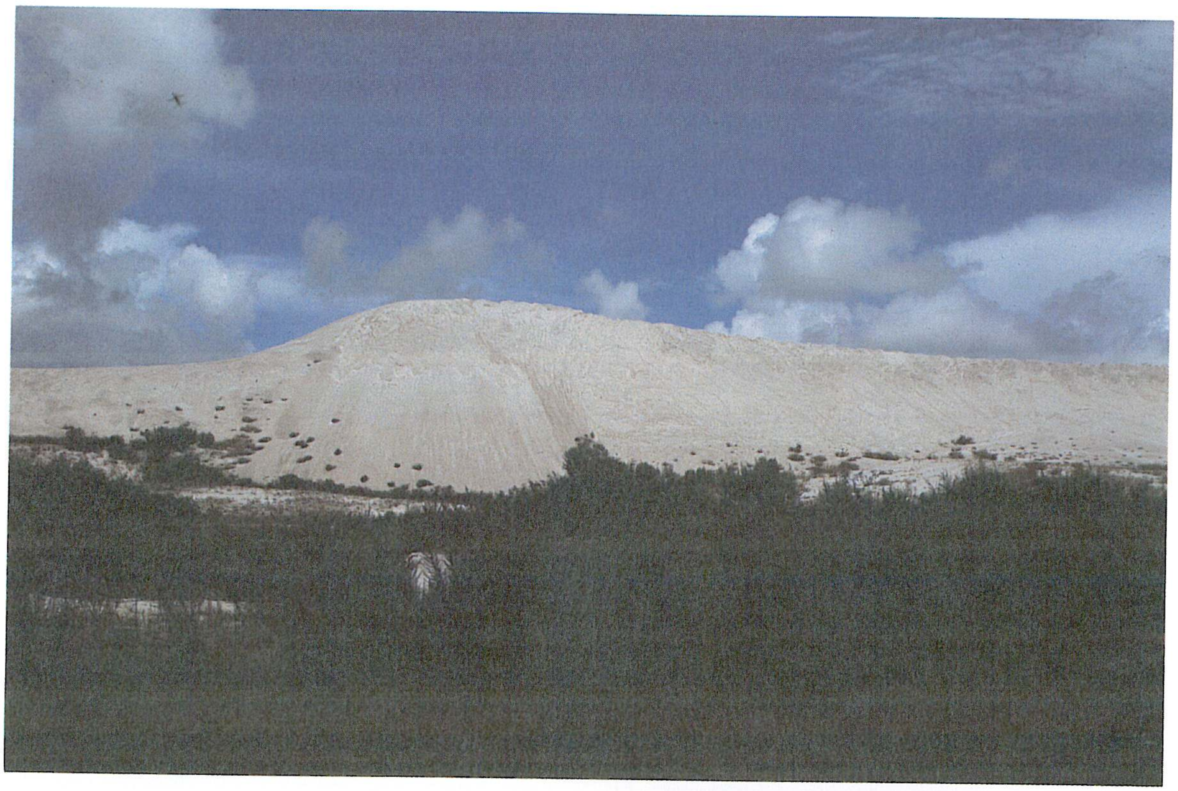

Figure 19. A typical stack of phosphogypsum, a by-product of fertilizer production, being stored on the landscape in Florida.

A number of researchers have evaluated revegetation efforts in Florida for wetland (Bromwell and Carrier 1983, Butner and Best 1981, Clewell et al. 1982, Cornwell and Atkins 1980, EcoImpact 1981a, Gilbert et al. 1981, Haynes 1984, Haynes and Crabill 1984, King et al. 1985, Ruesch 1983, and Wallace and Best 1983) and upland sites (EcoImpact 1980, EcoImpact 1981b, Hawkins 1979, King et al. 1985, Schnoes and Humphrey 1980, and U.S. Bureau of Land Management 1983). Revegetation technology for both wetlands and uplands has involved seeding (broad-casting and drilling), transplanting (bareroot and containerized), sprigging, and mulching. Traditionally, upland reclaimed sites have been seeded with Bahiagrass (Fig. 20), Bermudagrass, or Ryegrass (Lolium sp.) and have become cattle pastures.

In addition, the above mentioned reclamation rules require that a minimum of 10 percent of upland areas be replanted with a variety of indigenous hardwoods and conifers. Some mining companies in Florida are reforesting more than 10 **percent of uplands; much of the emphasis has been focused on planting slash pine (Pinus elliottii) plantations (Fig. 21), and efforts involving hardwoods cannot yet be adequately evaluated. In general, indigenous hardwoods are thought to be more useful to wildlife for food and cover than are softwoods, particularly when the latter are planted in even-age plantations. The reasons for the low level of interest in regenerating hardwoods on phosphate-mined lands are at least threefold: (1) lack of plant materials or seed sources in an adequate supply and at the appropriate times of year, (2) difficulty in establishing certain species and the subsequent slow growth of many hardwoods (compared to slash pines), and (3) the lack of economic incentives or financial rewards for growing hardwoods. A major future incentive may** be **in terms of companies being permitted to mine an area if it can be shown that it is possible to successfully revegetate hardwoods in the area.**

Innovative revegetation efforts with native, herbaceous plant materials show some promise, particularly in the context of mulching with native, pre-stripped vegetation and topsoil. Also, transplanting of herbaceous wetland vegetation (e.g. Arrowhead, Sagittaria spp.; Maidencane, Panicum hemitomon; Pickerelweed, Pontedaria cordata; rushes, Juncus sp.; and sedges, Scirpus sp.) has been successfully demonstrated on several reclaimed wetlands (Fig. 22).

Recent attempts to re-establish scrub vegetation on dry, upland sandy sites by several companies will take much longer to evaluate as to their effectiveness. The ground-level micro-habitats in which scrub species like sand pine (Pinus clausa), scrub oak (Quercus ilicifolia), rosemary (Ceratiola ericoides), prickly pear cactus (Opuntia sp.) are being planted show extremes of temperature, wind and moisture. I **have observed that establishment of scrub forests is a slow process and the** success **of many of these plots (Fig. 23) is yet to be determined. Table 3 illustrates the high demonstrated priority on reclamation to agro-economic uses such as improved pastures, citrus and row crops. These results are similar to those reported by** Marion **and O'Meara (1983) based upon analysis of 10 approved conceptual plans from Florida. Future land use trends predicted by these conceptual plans were an**

Figure 20. Typical 3-year-old Bahia and pangola grass pasture on reclaimed uplands in Florida.

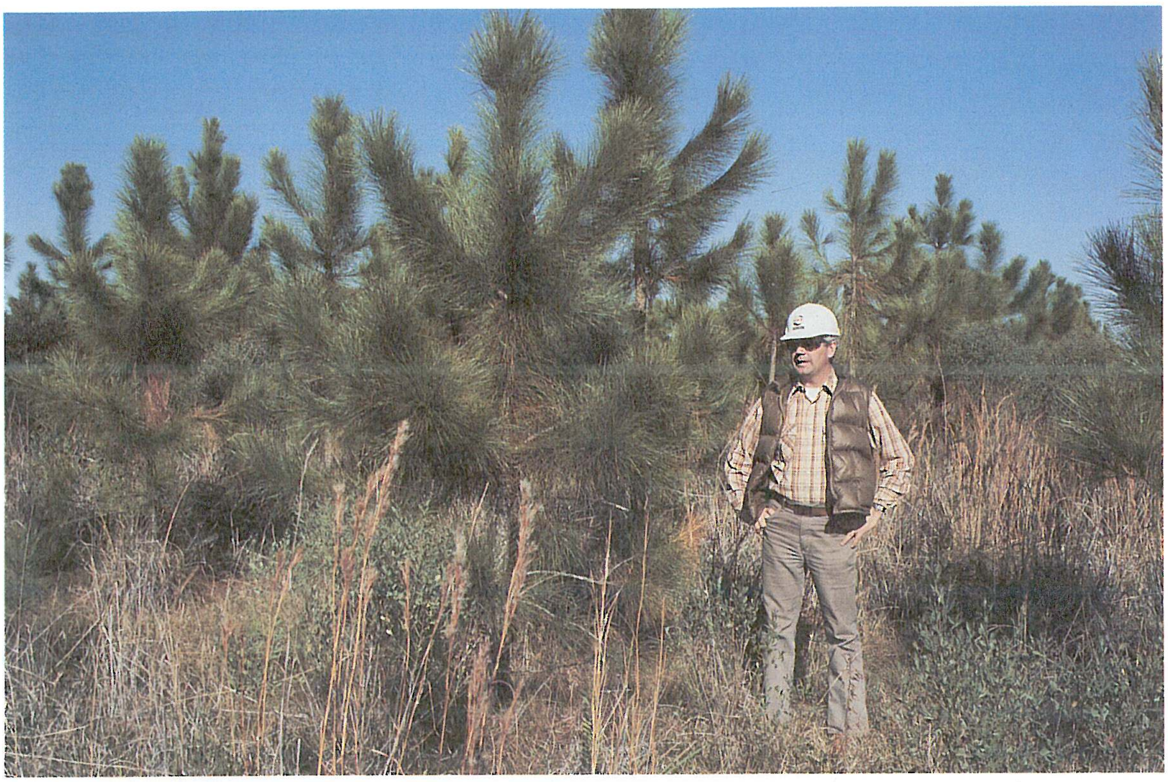

Figure 21. A 4-year-old slash pine plantation established on reclaimed phosphate land in Florida.

Figure 22. Herbaceous marsh plants (2-3 months old) successfully transplanted on the edge of a reclaimed wetland in Florida.

Figure 23. A 3-year-old scrub forest demonstration plot in Florida.

Table 3. Landforms resulting from phosphate mining in Florida and current principal post-reclamation land uses.

Landform	Current Principal Uses
Clay Settling Areas	Rangeland (improved pasture) Non-forested wetland Unreclaimed wildlife area
Sand Tailings	Agriculture (row crops and citrus) Rangeland (improved pasture)
"Land and Lakes"	Rangeland (improved pasture on uplands) Non-forested wetland Open water
Mined Out Areas	Non-forested wetland Unreclaimed wildlife area Open water

increase in agricultural lands and improved pastures with a corresponding decrease in native rangelands. Also depicted in the conceptual plans is an increase in wetlands as a result of phosphate mining. Two other major responses on the questionnaire used in this study were an undemonstrated, high potential for row crop production on sand/clay mix and no readily apparent uses for phosphogypsum.

NORTH CAROLINA

Revegetation efforts are proceeding on several small plots affected by phosphate mining in North Carolina. Nine species of trees are being tested on replicated experimental plots at the Charles Tract owned by Texasgulf. My observations were that on these plots the survival and growth of the 9 tree species planted (red maple, Acer rubrum; black alder, Alnus serrulata; green ash, Fraxinus pennsylvanica; bald cypress, Taxodium distichum; sweet gum, Liquidambar styraciflua; white cedar, Thuja occidentalis; poplar, Populas sp.; sycamore, Platanus occidentalis; and water oak, Quercus nigra) were highly variable from species to species (Fig. 24). Follow-up evaluations by consultants and company personnel (W. Ashton 1982 pers. comm.) have indicated that bald cypress, green ash, black alder, and sycamore had the best survival and growth and should be recommended for future hardwood reforestation programs.

The more traditional revegetation efforts in North Carolina have included successful use of seed mixtures like tall fescue (Festuca spp., Fig. 25), ladino clover (Trifolium repens), annual ryegrass, and coastal bermuda-grass on well-fertilized, reclaimed overburden uplands (Farmer and Blue 1978:599). Also, several recent innovative efforts directed by Dr. W. W. Woodhouse, Jr. from Raleigh, North Carolina have been made toward establishing ground-cover vegetation on gypsum piles (Fig. 26). It is still too early to assess the relative success of these trials; likewise, an evaluation of the quality of the reclamation "soil" being developed in attempts to mix phosphatic clay and gypsum would be premature at this time.

A major part of the innovative revegetation technology in use in North Carolina involves mitigation to re-establish salt marsh habitats on disturbed sites. These techniques have been thoroughly described and documented by Woodhouse et al. (1972, 1974)) Woodhouse (1979), and Broome et al. (1982, 1983). These authors have successfully demonstrated establishment and growth of black rush (Juncus roemerianus) and several species of cordgrasses (Spartina alternifolia, S. cynosuroides, and S. patens) on disturbed sites.

Several plots of re-established marsh vegetation (Fig. 27) are the initial stages of an effort by North Carolina Phosphate Corporation (NCPC) to demonstrate "up front" mitigation as part of the application procedures for mining permits. for brackish tributaries. This stepped mitigation plan and alternatives are described in a document entitled "Wetlands Mining and Mitigation: A Preliminary Supplemental Environmental Impact Report" which was provided as supplemental information to the Final Environmental Impact Statement (North Carolina Phosphate

Figure 24. A hardwood forest revegetation plot on disturbed lands in North Carolina. Tree species present included eastern red cedar, sycamore, sweetgum, cypress, and red maple.

Figure 25. Tall fescue and sweetclover planting (1 month old) on mined land in North Carolina. Topsoil was transferred to this site from an adjacent, cleared site.

Figure 26. Revegetation trials on a phosphogypsum stack in North Carolina. Species planted were wheat, barley, rye, redtop clover, and tall fescue on plots of topsoil, gypsum and a mixture of phosphatic clay and gypsum.

Figure 27. Mitigation plots to re-establish several species of Spartina and other saltmarsh vegetation in North Carolina.

Corporation 1977) on this mining operation. This document, along with the "Response Document" (North Carolina Phosphate Corporation 1983), will very likely set a nationwide precedent for mitigative measures involving wetlands.

A major concern of environmental agencies and organizations that reviewed the wetlands mitigation document was the presumed 2-3 year timetable for demonstrating and evaluating the relative success of these mitigative measures. Comments from reviewers indicated that a number of them believed that recovery of wetland functions and productivity would very likely take considerably longer than a few years. In response, the mining company (NCPC) has indicated that it will be 8-10 years following initiation of mitigative measures, in most cases, before these areas are finally evaluated prior to mining.

Another major concern is the degree to which these mitigative demonstration plots (surface disturbance, but unmined) are truly representative of mined wetland areas (with soil profile disruption). In general, it is extremely difficult (if not impossible) to reconstruct a functioning soil profile on strip-mined lands that is similar to premining conditions. Nevertheless, it is apparently too early to adequately address all strengths and weaknesses of these mitigative efforts.

The only response linking landforms to eventual land use in North Carolina was obtained from Texasgulf Co., the only company actively engaged in mining and reclamation. Actual reclamation accomplished by this company has been minimal since several mined areas were quickly converted to clay settling areas and this has postponed reclamation on this land. Landforms considered were clay settling areas, sand tailings, clay/gypsum mix, "land and lakes", and phosphogypsum. Land use categories included agriculture (row crops), rangeland, upland forest (hammock), wetland forest, non-forested wetland, streams and open water.

Clay settling areas in North Carolina, not yet reclaimed, are open water until vegetative succession covers portions of the area with emergent plants (eg. <u>Phragmites communis</u> and <u>Typha</u> sp.). Sand tailings were believed to have high demonstrated potential for row crop production (along with heavy applications of fertilizer) and improved pastures, and some undemonstrated potential for revegetation as an upland forest. Clay/gypsum mix is being tried as a reclamation soil and it is showing good initial results -- particularly when used as a cap for revegetating gypsum piles. As in Florida, piles of phosphogypsum resulting from processing of fertilizer are becoming an increasingly obvious landscape feature (see Fig. 19) since Texasgulf Co. produces 5.5 million tons of phosphogypsum per year and only about 100,000 tons per year are sold to peanut farmers in North Carolina as a soil supplement.

True "land and lakes" reclamation has not been adequately demonstrated in North Carolina, but it is expected to be a major long-term type of reclamation. As predicted by Farmer and Blue (1978:601), short-term land uses on these reclaimed lands probably will involve farm (pasture) or forest lands situated in a land-and-lakes setting. Present plans indicate that approximately 96 percent of the lands to be mined by North Carolina Phosphate Corporation are currently in pine plantations owned by the Weyerhauser Co. It is, therefore, logical to predict that a sizeable proportion of these lands will be reclaimed back to pine plantations.

As in Florida, reclamation in North Carolina will very likely occur with a strong emphasis on agro-economic considerations, rather than natural ecosystem concerns. A well-known consultant in North Carolina stated that it would be best to reclaim much of the area back to wetland forest, but this possibility did not receive any mention by company officials I interviewed. Natural ecosystem considerations undoubtedly will receive more future emphasis when attempts are made to begin mining phosphate reserves under the Pamlico and Pungo Rivers. A strong wetlands protected and mitigation policy is likely to be followed where Corps of Engineers Section 404 permits are required prior to mining.

TENNESSEE

In Tennessee, the intended land use after reclamation is clearly known, which contrasts sharply with Florida, North Carolina and Idaho where the ultimate intended land use is only vaguely known. Phosphate mining in Tennessee is generally just a small-scale, temporary disruption. The owner of the land generally specifies the vegetation used in post-mining reclamation and this is frequently pasture grass or grains.

Typically, the reclaimed area receives an application of fertilizer and lime prior to reseeding with a seed drill. Generally, reclaimed sites are planted and retained in a grass cover for several years (Fig. 28) prior to growing crops (e.g. corn, barley, soybeans, oats and alfalfa). Typical species planted during reclamation, depending upon time of year, include fescue, sweetclover (*Melilotus* sp.), Sudangrass (*Sorghum vulgare*), weeping lovegrass (*Eragrotis curvula*), sorghum (*Sorghum bicolor*), orchardgrass (*Dactylis glomerata*), and sericea lespedeza (*Lespedeza cuneata*).

In Tennessee, there is a general lack of emphasis on reclamation of phosphate mines back to natural "habitat" systems. In some cases, natural succession has been allowed to continue and the results look very natural within a few years. Two examples of this were: (1) natural stands of black locust (*Robinia* pseudoacacia) and hackberry (Celtis *occidentalis*) which developed on old, reclaimed mines and (2) reclaimed pastures and croplands, unmowed for several years, were invaded extensively by native forbs, shrubs, and trees. Thus, it was possible to re-establish natural vegetation on these lands, but this option was not a priority with landowners.

In general, landowners dictated future land uses on mined areas and they were opposed to planting trees as a part of reclamation. Pines do not grow well in south-central Tennessee and there was no readily available market for softwoods. Hardwoods grow in this region, but

Figure 28. A reclaimed pasture (4-5 years old) in Tennessee.

their slow growth offers a rather poor return on an investment (R. Jensen 1983 pers. comm.).

In Tennessee, the options following mining are much less complicated than in other states. Major landforms are large, deep slurry ponds (Fig. 29) and shallow, narrow strip mines. The slurry ponds are being retained as open water areas with abundant fish populations and some use by waterfowl. Probably the best "reclamation" plan for these ponds is to retain them in the future as lakes (R. Jensen 1983 pers. comm.). As in Florida, a future need for maintenance of these lakes and wetlands is a dependable, long-term water supply (currently being provided by the mining operations).

Mined areas have fertile soils and are quickly reclaimed as either farmlands (for growing corn and alfalfa) or as pasturelands, with most of the land becoming pasture. There has been some small scale, urban development on reclaimed land and the potential for this use appears to be high as long as the soils are allowed to settle for seven years (an FHA requirement).

Similar to Florida and North Carolina, it appears that phosphate mine revegetation and land use is strongly dictated by agro-economic considerations. Disruption due to mining is minimal and the land is essentially being returned to uses similar to the pre-mining conditions.

IDAHO

Up until about 1970, attempts at revegetation on overburden waste dumps occurred predominantly on a trial-and-error basis (Farmer and Blue 1978), but more recent revegetation attempts have been planned in advance and are included in mining plans. The slope and aspect of an area plays a key role in the success of revegetation efforts in Idaho. Under natural conditions, nearly level to gently sloping areas favor growth of grasses, forbs, sedges and shrubs. Aspens grow in moister areas along drainages, especially on east-facing slopes. Southerly and westerly slopes generally support grass and sagebrush vegetation with patches of brush such as mountain mahogany (*Cercocarpus* sp.), bitter-brush, and some juniper. Richardson and Farmer (1983:380) warned against trying to re-establish vegetation on south and west-facing slopes of dark spoils due to extremely high surface temperatures. Under natural conditions, conifers typically grow on north and northeasterly slopes where the snow accumulates in the winter and remains until late spring (U. S. Dept. of Interior 1982).

Traditionally, mining companies revegetate their waste shale dumps using a seed mixture recommended by the U.S. Forest Service (Table 4). This seed mixture is predominantly grasses (Fig. 30) and, although established grasses reduce soil erosion, they also inhibit the re-establishment of trees and shrubs which are vital components of resident big game habitats. U.S. Forest Service researchers have been attempting to demonstrate establishment of shrub species on waste dumps and have had limited success (U.S. Dept. of Interior 1982, Richardson and Farmer 1983, Monsen and Shaw 1983). In most cases, shrub establish-

Figure 29. A deep slurry pond used to clarify water used in phosphate processing in Tennessee.

Table 4. Seed mixture recommendation for revegetating phosphate waste dumps in Idaho (from Richardson and Farmer 1983).

Plant Species	Application Rate (pounds/acre)
Intermediate wheatgrass (*Agropyron intermedium*)	4
Bitterbrush (*Purshia tridentata*)	4
Mountain brome (*Bromus marginatus*)	3
Lincoln brome (*Bromus inermis*)	3
Great Basin wildrye (*Elymus cinereus*)	3
Beardless wheatgrass (*Agropyron spicatum*)	3
Alfalfa (*Medicago sativa*)	3
Western wheatgrass (*Agropyron smithii*)	3
Manchar brome (*Bromus inermis*)	2
Orchardgrass (*Dactylis glomerata*)	2
Timothy (*Phleum pratense*)	2
Pacific aster (*Aster chilensis*)	2
Utah sweet vetch (*Hedysarum boreale*)	2
Sagebrush (*Artemisia tridentata*)	2
Rabbitbrush (*Chrysothamnus nauseosus*)	2
Sanfoin (*Onobrychis viciaefolia*)	2

Figure 30. Established grassland vegetation (2 years old) resulting from use of the U.S. Forest Service recommended seed mixture on a phosphate waste shale dump, Idaho.

ment and survival have been more successful on plots following treatment with ROUNDUP to kill the grass cover or on bare strips along the contour between grass plantings (Fig. 31). Thus, apparently the best scheme and schedule for re-establishing vegetation on waste dumps is one which incorporates grasses and legumes for soil stability and erosion control on much of the area and suitable shrubs (Fig. 32) on remaining bare areas to stimulate redevelopment of big game habitats.

The regeneration of stands of aspens (Populus sp.) to provide food and cover for big game animals on reclaimed lands has been a subject of special concern for U.S. Forest Service researchers. It had long been believed that aspen could not regenerate itself naturally on disturbed (reclaimed) sites, but several recent examples indicate that aspens can naturally re-establish themselves on waste shale dumps (B. Williams 1983 pers. comm.). An innovative, useful technique that was demonstrated by one company is to leave as much native vegetation as possible at the edge of the mine cut (see Fig. 15). These perimeter "islands" of native vegetation facilitate the process of re-establishing native plants on the reclaimed waste shale dumps.

Typical revegetation options include sagebrush-grasslands, aspen forests, Douglas fir-lodgepole pine forests, tall shrub forests and riparian vegetation (e.g. willows). Agricultural lands for row crops and pasturelands were not a major revegetation consideration. Mined-out areas required backfilling prior to surface reclamation and revegetation with a sagebrush-grassland and eventually, a Douglas fir-lodgepole pine community.

Midland waste shales provided the most potential as a substrate for a variety of revegetation combinations. Most midland waste shale "dumps" were re-contoured and planted by broadcasting the mixture of seeds recommended by the U.S. Forest Service (Table 3); this results in a grassland-sagebrush community. Eventually, as natural succession proceeds, midland waste shales are expected to support Douglas fir - lodgepole pine forests, tall shrub forests, aspens, and some willows in riparian areas. Catchment basins, initially unvegetated, will eventually revegetate as a grassland-sagebrush community with some willows growing in wetter areas.

The Idaho situation is somewhat unique compared to the other states previously discussed. The highest demonstrated success with revegetation involved establishment 'of a mixture of grasses (see Table 3) on midland waste shales. These revegetation efforts could not be easily categorized as agro-economic or natural "habitat" systems oriented and included elements of both. Local political pressure to open up reclaimed sites to cattle and sheep grazing suggested agro/economic motives for the reclamation. However, overriding concerns for re-establishing ground cover (to control erosion), maintaining water quality and re-establishing wildlife habitat reflected the multi-purpose objectives of the U.S. Forest Service, caretaker of the majority of these lands.

In general, attempts to revegetate phosphate mined lands in Idaho were directed at minimally meeting the stipulations set forth by the

Figure 31. Shrubs planted on bare strips between grass plantings on reclaimed waste shale in Idaho.

Figure 32. An experimental plot with 7-8 year old shrubs growing on waste shale dump in Idaho.

U.S. Forest Service. The emphasis of these stipulations was on revegetation primarily with non-native grasses to attain the acceptable standard for revegetation (67% cover over 90% of the area within 3 years after mining). A major consideration underlying decisions about revegetation and scheduling was political pressure on the U.S. Forest Service to develop pasturelands and to open them up as soon as possible after reclamation to grazing by sheep and cattle.

OVERALL

Most phosphate mining situations in the United States are strongly oriented toward agro-economic revegetation and land use. In Florida, the emphasis seems to be on providing reclaimed lands for improved pastures, citrus groves and row crops. Revegetation of uplands also has included an emphasis on establishing slash pine plantations in north Florida and eventually, in North Carolina. Incentives for re-establishing hardwoods seem to be lacking in Florida, North Carolina, and Tennessee but making permission to mine contingent upon being able to reclaim forested wetlands may provide necessary future incentives. Wetland revegetation with native plants (especially herbaceous) has been repeatedly demonstrated with success in Florida. Similarly, mitigation with salt marsh vegetation shows good potential in coastal North Carolina.

Pre-mining and post-reclamation vegetation and land use were most similar in Tennessee, where pasturelands are mined and quickly returned to similar cover and use. In Idaho, a combination of concerns over erosion control and over providing grazeable lands has led to the emphasis on revegetation of waste dumps with non-native grasses. Overall, the current emphasis on revegetation to facilitate agro-economic uses appears strongest in Florida and Tennessee, with high potential for similar future emphasis in North Carolina and Idaho.

SUMMARY

This effort was undertaken to identify the current national status of phosphate mining considering 3 main aspects -- regulations, reclamation, and revegetation. Where possible, comparisons are made between states relative to levels of development and sophistication in these areas. Attempts were made to identify traditional and innovative reclamation techniques being used in the four states visited. Also identified and discussed were shortcomings of regulations, reclamation and revegetation with regard to natural (habitat) systems reclamation and associated research needs. Finally, an effort was made to highlight those reclamation alternatives which favor maintenance of floral and faunal diversity.

A major hypothesis was confirmed during this study: that the magnitude of phosphate mining in each state directly affects the sophistication of environmental concerns, reclamation regulations and procedures. In general, larger mining operations disturb more land resulting in greater public concerns and increased sophistication of reclamation regulations, procedures and revegetation combinations.

REGULATIONS

Phosphate reclamation regulations are primarily developed and enforced by state agencies in the eastern United States (Florida, North Carolina and Tennessee). With the exception of several counties in Florida, local laws have a tendency to be weak in most areas due to strong political influences. Since the Surface Mining Act of 1977 was never extended to include phosphate mining, there has been little involvement of federal laws in reclamation itself. Federal regulations have been applied mostly to air and water quality, safety standards, etc. In the western states, federal stipulations for reclamation are relatively more important than state regulations since much of the mining is occurring on federal lands. Federal agencies have strong vested interests in the outcome of these reclamation activities.

Reclamation standards and regulations are fairly well established and stable in North Carolina, Tennessee, and Idaho. In Florida, reclamation regulations are rather continuously undergoing revision due to strong political involvement by many agencies and special interest groups and to a general lack of concensus over ultimate reclamation objectives. As a result, reclamation regulations have seemingly been most controversial in Florida, followed by North Carolina, Idaho (very controversial in the mid-1970's), and Tennessee. In Florida, reclamation regulations are considered by most phosphate companies to be too restrictive; they are considered to be relatively flexible in other states. In no state have phosphate reclamation rules developed in sophistication enough to seriously incorporate ecosystem function or landscape design criteria, although Florida seems to be on the threshold of including these criteria.

RECLAMATION

In general, phosphate reclamation has involved a recontouring of the surface and revegetation with a cover of grass within a specified time interval. Reclamation technology in most states has been chosen based upon extent of disturbance, economic considerations, and previous company experience. Extent of local disturbance of the surface due to phosphate mining was minimal in Tennessee, intermediate in Idaho and North Carolina, and extensive in Florida. Economic constraints have been major determinants of the reclamation technology employed, with the less expensive techniques being the most widely used.

In most states, non-industry "pools" of expertise on phosphate reclamation are either not available or not widely recognized and used by the industry. Most phosphate companies use their own, in-house, expertise for implementing reclamation. Consultants seem to be more widely used for selected problems in Florida and North Carolina than in Idaho and Tennessee. Florida and Idaho seem to have the most explicit written reclamation rules, although printed "guide-lines" depicting a variety of reclamation options are lacking. In many respects, phosphate reclamation is site-specific and this has partially hampered the development of specific reclamation guidelines and options for each state. Florida will soon have such guidelines available (King et al. 1985).

REVEGETATION

Revegetation efforts on phosphate mined lands have most often been oriented toward agro-economic purposes and away from reestablishing natural ecosystems. Florida seems to be relatively advanced in attempting to demonstrate a variety of revegetation options, although much of the emphasis in that state has been and remains with reclamation to promote agro-economic uses (improved pastures, citrus, and row crops). Similarly, revegetation to establish pasturelands is being practiced extensively in Idaho and Tennessee. In Tennessee, the pre-mining vegetation and land use were nearly identical to the post-mining vegetation and land use pattern. Attempts to re-establish scrub forests (Florida), hardwoods and forested wetlands (Florida and North Carolina) have occurred on a limited basis and it is still too early to adequately evaluate the relative success of these efforts. In general, financial incentives for revegetation with hardwoods are lacking; but other incentives (e.g. permission to mine) are likely to assume stronger future importance. Pine plantations are planted on reclaimed uplands in Florida and very likely this will be the case in North Carolina.

Revegetation of at least a portion of mined lands back to natural conditions appears to be a worthy, long-term goal to provide fish and wildlife habitats and for future recreational needs of people. Further innovative research into a variety of reclamation/revegetation options and educational efforts to publicize these options would facilitate progress toward this long-term goal. Economics is expected to continue to dictate many aspects of phosphate mining. A major challenge remains to provide the encouragement and incentives for the industry and private landowner to strive to retain plant and animal diversity on the landscape.

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