A BACKGROUND FOR DISTURBED LAND RECLAMATION AND RESEARCH IN THE ROCKY MOUNTAIN REGION OF ALBERTA

by

E. B. Peterson and H. M. Etter

FOREST RESEARCH LABORATORY
EDMONTON, ALBERTA
INFORMATION REPORT A-X-34

CANADIAN FORESTRY SERVICE
DEPARTMENT OF FISHERIES AND FORESTRY
MAY, 1970

TABLE OF CONTENTS

A BACKGROUND FOR DISTURBED LAND RECLAMATION AND RESEARCH IN THE ROCKY MOUNTAIN REGION OF ALBERTA

by

E. B. Peterson and H. M. Etter[1]

INTRODUCTION

The Setting and the Problem

This report will review current literature, describe operations and controls, and suggest survey and research objectives for reclamation of lands disturbed by surface mining of coal in the Rocky Mountain region of Alberta. However, many of the principles to be discussed apply to other types of strip-mines or to surface disturbances such as road-cuts, quarries and large rock slides; they also apply to other geographic areas such as the Great Plains region of Alberta and Saskatchewan and the Rocky Mountain region of British Columbia.

Coal reserves in Canada have been estimated at 94 billion tons, of which 50 per cent is considered recoverable. Ninety-five per cent of these reserves occur in the three western provinces, with Alberta containing 51 per cent, Saskatchewan 26 per cent and British Columbia 18 per cent (1). In 1968, about 25 per cent of the coal produced in Alberta came from the foothills of the Rockies and about 14 per cent of this was extracted by strip-mining (2). With the prospects for increased consumption of coal by

[1] Research Scientists, Canadian Forestry Service, Department of Fisheries and Forestry, Edmonton, Alberta.

thermal power plants, exports to Japan, and the potential for its use by the metal industry in western United States and western Canada, it is anticipated that there will be markets in the early 1970's for 16 to 17 million tons per annum (1).

The coal industry has been relatively inactive in the past 20 years; during this period eight strip-mining operations in the mountains and foothills of Alberta have disturbed approximately 715 acres (excluding associated roads) (3). At least 32,000 acres could be strip-mined for coal over the next 20 years in the foothills belt between the Crowsnest Pass and the Smoky River (3). Because this acreage is only about 0.02% of the total land area of Alberta, the need for research into methods of reclamation may not appear justified on a land area basis. However, the geographically concentrated nature of surface mining can result in intense hydrologic or aesthetic changes in the environment which in turn can affect an area larger than that which is physically disturbed. No projections are available for the total area which could be affected by all types of surface disturbances in western Alberta.

Political pressures for reclamation stem primarily from a growing concern among the general public and the scientific community over the consequences of a drastically disturbed environment. There were clear indications at the 21st Canadian Conference on Coal that the future of strip-mining in Canada is tied to the success of reclamation programs. Present policies of the Canadian coal industry indicate that reclamation planning must be an integral part of production planning (4). In addition, the 1969 Alberta Public Lands Surface Reclamation Regulations require mine operators to carry out reclamation procedures to the satisfaction of the

Minister of Lands and Forests (5).

It is necessary, therefore, to adapt or develop effective and economical reclamation methods associated with specific land-use objectives for the range of disturbed lands that will be reclaimed in the Rocky Mountain region. The urgency of this problem is increased by the lack of local experience in reclamation and by inadequate knowledge of the rates and magnitudes of environmental damages associated with land disturbances. Solutions to this problem must come from many disciplines. This report emphasizes the contributions that plant scientists, soil scientists and foresters should make in the near future.

Definitions

For purposes of this discussion, the following definitions and terms are understood:

"Disturbed land" means (i) areas from which overburden has been removed in surface mining operations; (ii) areas covered by overburden; and (iii) any areas used in surface mining operations which by virtue of their use are susceptible to accelerated erosion, including all lands disturbed by the construction or improvement of roads (Adapted from (6)). Disturbed land is included in the British definition of derelict land which refers to any land that has been so damaged by industrial use as to be incapable of further use without treatment (7).

"Overburden" and "spoil" are used synonymously to mean all of the strata which lie above a natural mineral deposit and also such strata after removal from their natural state (Adapted from (8)).

"Strip-mining" and "surface mining" mean any mining method or process in which overburnden is removed in order to recover minerals or to determine the location, quality or quantity of a natural mineral deposit (Adapted from (8)).

"Erosion" will be used in a restricted sense to refer to accelerated erosion of the land surface following its disturbance, as opposed to natural erosion which refers to slow weathering and local movement of soil or parent material as part of normal soil and landscape forming processes (Adapted from (9)). Soil conservation, therefore, means the complete or partial prevention of accelerated erosion.

"Reclamation" will be interpreted broadly to include any process that promotes soil conservation and productive land-use of disturbed land (Adapted from (6)). Reclamation (also restoration) involves three distinct phases: (i) prior land-use planning, (ii) physical operations to achieve a suitable topography and (iii) natural or assisted revegetation and subsequent management of reclaimed land. This definition, by the inclusion of planning and revegetation as distinct phases of reclamation, represents an important extension to the interpretation placed upon reclamation in the 1963 Alberta Surface Reclamation Act, which does not explicitly state any requirements for land-use planning and revegetation (10).

Suggested Review Material

There are numerous publications that collectively provide good background information on disturbed land reclamation. In the paragraphs below, we want to single out certain publications that are pertinent to this report. This material is supplemented by a list of additional source material at the end of this report.

The most recent summary of information on the planning, operational and research phases of reclamation will be the published proceedings of the International Symposium on Ecology and Revegetation of Drastically Disturbed Areas held in Pennsylvania, 3-16 August 1969. These proceedings, which are expected to be published by 1971, will include resumes of disturbed land research in Austria, Canada, Czechoslovakia, Denmark, Germany, Iceland, Italy, Japan, South Africa, United Kingdom, United States and Yugoslavia. More than 60 technical papers on the environment of disturbed lands, the adaptability of plants to disturbed lands, modification of adverse environmental conditions, the effects of disturbances on other resources and the status of disturbed land research were presented at the Symposium (11).

Problems of revegetation of derelict lands were reviewed in three papers during the 1964 British Symposium on Ecology and the Industrial Society (12). One of these is W. Knabe's excellent review of world-wide efforts to reclaim industrial waste land, with particular emphasis on reasons for the sparse vegetation (13). Two 1967 reports by the British Ecological Society on the technical advice and research associated with landscape improvement of derelict land provide a useful guide for others who may be planning the establishment of advisory or research units (7, 14).

Literature pertaining to reclamation of strip-mines in the eastern United States was condensed in 1964 into a Digest (15) that is probably the best single reference available on the topics of: spoil characteristics influencing vegetation, forest planting and revegetation, potential uses of strip-mined lands, associated mining methods and reclamation legislation.

A less technical but well illustrated report entitled "Surface Mining and our Environment" (16) provides a rich source of statistical information on: the nature, extent and results of surface mining operations in the United States; the ownership of real property involved in surface mining; appropriate roles of Federal, State and private interests in the reclamation and the use of areas subjected to surface mining operations; and the objectives and overall costs of programs for reclaiming surface mined areas.

In 1962, Funk (17) published a revised bibliography that included all of the technical citations from an earlier bibliography by Limstrom (18). Other bibliographies by Bowden (19) and Knabe (20) include references on geology, acid mine drainage, the use of spoil banks by wildlife, and European reclamation methods. Because Funk's compilation omitted material covered in Bowden's and Knabe's bibliographies, all three need to be consulted for a complete listing up to 1962. Funk's 1962 bibliography is being up-dated by K. G. Reinhart, Northeastern Forest Experiment Station, Upper Darby, Penna. Also, there are hopes for an international effort at compilation of world literature on the subject of disturbed land reclamation (see 11).

Specialized bibliographies dealing with reclamation of saline and sodic soils (21), with specific reclamation species such as black locust (22) or crown vetch (23) and with specific problems of slope stability of spoil banks (24) are available.

A well-documented history of reclamation legislation exists for the United States but there is little information for Canada or Alberta. The most convenient U.S. summary is the 1964 Digest (15) which includes a synopsis of strip-mine laws for each of Illinois, Indiana, Kentucky, Maryland, Ohio, Pennsylvania and West Virginia. Details of reclamation regulations in specific States may be seen in the West Virginia Reclamation Handbook (6) or the Kentucky Revised Statutes (8). Pros and cons of U.S. Federal mined land reclamation requirements were summarized in 1968 by the Library of Congress Legislative Reference Service (25). Similarly, the 1968 hearings before the U.S. Senate on the subject of Federal-State co-operation in reclamation (26) provide a good summary of attitudes and policies of specific mining industries, mining associations, government agencies, reclamation associations and conservation organizations.

The two most important legislative controls in Alberta are the 1963 Alberta Surface Reclamation Act administered by the Department of Mines and Minerals (10) and the 1969 Public Lands Surface Reclamation Regulations administered by the Department of Lands and Forests (5). Other relevant legislation was reviewed in 1969 by the Alberta Land Preservation Society (2). A more up-to-date review is not possible because provincial committees at both the Cabinet and Departmental levels are currently developing new legislation and regulations in respect to surface mined lands.

An examination of the 1967-68 cumulative index of Canadian Federal Public Statutes (27) revealed no references to reclamation in respect to coal mining, surface mining or disturbed land. The 1947 Act under which the Eastern Rockies Forest Conservation Board operates, contains no reclamation clauses (28).

1969 Field Reconnaissance

Field observations of disturbed and reclaimed land often allow preliminary assessment of the edaphic and climatic factors which may limit revegetation. Observations of the undisturbed environment, either before mining or adjacent to existing mines, may also suggest specific land-use objectives for the reclamation program. With these purposes in mind, a number of active, abandoned and reclaimed strip-mines were visited in Alberta, British Columbia, Pennsylvania, Ohio and West Virginia in 1969.

In the Crowsnest Pass area of Alberta, visits were made to: the Tent Mountain mine, south of Sentinel, and the Racehorse Creek mine north of Coleman, both of which are operated by Coleman Collieries Ltd.; spoil banks, near York Creek south of Coleman, which had been abandoned for approximately 17 years; and the abandoned stripping operation at Grassy Mountain, north of Blairmore, which is now owned by Scurry-Rainbow Oil Ltd. These visits revealed that disturbed lands at elevations near or above treeline (approximately 6500 ft.) provide particular revegetation problems because of steep slopes, unstable overburden, adverse climatic conditions and the lack of topsoil. Studies are required to determine if assisted revegetation should be attempted at these elevations and to develop means to stabilize overburden and control drainage.

At Luscar, Alberta, an operation of Cardinal River Coal Co., a subsidiary of Luscar Mines Ltd. and Consolidation Coal Co. of Pittsburg, was examined. This location appears promising for pilot research to determine the best combinations of plants, fertilizers and mulches to revegetate slopes of various aspects and elevations. Observations of natural revegetation of abandoned mine spoils between Coalspur and Foothills, Alberta, indicated the suitability of this area for the documentation of natural succession on overburden.

The Wabamun Lake operations of Alberta Coal Ltd., a subsidiary of Mannix Co. Ltd. of Calgary, were also visited. Excellent reclamation has been achieved at Wabamun Lake by Calgary Power Ltd. with the advice of the District Agriculturalist by contouring the overburden and revegetating it to alfalfa.

Field observations in Pennsylvania were limited to the bituminous coal zone where active stripping operations and numerous fertilizer, lime and mulch amendment trials were examined. Disturbed land in that area has been successfully converted to cropland and to productive forest. Nineteen species of conifers, 12 deciduous tree species and 18 game-food shrubs have been successfully planted on spoils near Kylertown, Pennsylvania since 1951. Six volunteer species, including aspen, also occurred on these spoils. Height growth of volunteer aspen saplings exceeded that of planted conifers of the same age.

Of particular interest in West Virginia was the practice of placing flyash, a waste product from a nearby coal-burning Power Station, on very acid (pH 3.8) mine spoils as a neutralizing mulch.

Large stripping operations were observed at the Muskingum mine, operated by Central Ohio Coal Co., a subsidiary of Ohio Power Co. and at the Silver Spade Pit of Hanna Coal Co., a Division of Consolidation Coal Co. of Pittsburg. The immensity of these strip mines is matched by the scale of their reclamation program. In the case of Ohio Power's operation, the recreational facilities that had been developed on mined land were impressive. The Hanna Coal Co., near Cadiz, Ohio, had converted mined land to livestock pasture, recreation areas and areas for commercial crown vetch seed production. The value that can be attached to reclamation was revealed by the fact that Hanna Coal Co. makes more profit per acre per year on much of the mined area from crown vetch seed production than it did from coal extraction.

RECLAMATION OPERATIONS

Potential Land-Uses and Reclamation Planning

Reclamation can be planned according to three general approaches (13): (i) site conditions can be accepted as they are after the disturbance, and revegetation attempted with hardy native species; (ii) poor sites can be improved by physical operations and soil amendments before or after revegetation as the need arises; or (iii) a land-use plan can be set before the overburden is handled, and adverse physical or biological conditions corrected concurrently with revegetation. These three approaches represent the historical development of reclamation elsewhere (13), but we see no justification for a Canadian repetition in the 1970's of this evolution. Plans by the Department of Lands and Forests for a broad study of land-use patterns suggest that Alberta may be able to move directly to the approach that involves sophisticated pre-planning. The earlier in the mining process that reclamation plans are made, the more feasible reclamation becomes (29). This approach also implies that reclamation results are better when the topography, geology and vegetation of an area are documented before it is disturbed.

Reclamation according to an advance land-use plan provides a basis for evaluating many of the individual steps in the reclamation operation. It eliminates as a sole objective the rapid establishment of a green cover; instead, initial plantings are considered only as a first step in soil conservation. Subsequent vegetation management is usually necessary to achieve the projected land-use. Planning can often result in more than one land-use after mining (Appendix I, Table 1). Furthermore, while it may be a general rule that land productivity before mining is a good indication of its potential after mining (30), there may be situations where a more valuable land-use can be developed after mining. For example, in Illinois a stripping operation that mixed subsurface limestone with surface glacial outwash material created land that was more productive agriculturally after mining than it was before (11). Land-use planners, recreationists and conservationists who think in terms of "mining versus recreation" should realize that restoration of strip mines in areas of high visitor-use can provide the landscape architect with opportunities to create recreational areas with aesthetic appeal at costs that would be otherwise prohibitive (31). This suggestion does not imply that strip-mining should be undertaken in parks or wilderness areas, but points out how pre-planning can help to remove the stigma often placed upon strip-mining.

Reclamation operations can be divided into three categories for purposes of cost analysis (Appendix I, Table 2). Reported costs have ranged: (i) for physical operations, from $150/acre for grading to non-eroding gradients to $4500/acre for auger placement of loess in German agricultural areas; (ii) for surface treatments, from $180/acre for snow-fence to $1800/acre for snowfence, jute netting and mulch together; and (iii) for revegetation, from $50/acre for grass and legume planting to $1250/acre for landscape planting in a recreation area.

In our opinion, reclamation planners in western Alberta should consider game or cattle range the first priority land-use wherever a reclaimed area can produce browse or forage. The recreational potential of bodies of water in reclaimed areas may justify the cost of tree planting in their vicinity. Further surveys may reveal some sites which favor rapid tree growth and warrant regeneration to commercial forest. At elevations near or above tree line, studies are necessary to determine specific land-use objectives. In watersheds, planners should not overlook the possibility that surface mining can improve flood control by providing additional groundwater storage in piles of cast overburden and additional surface storage in last-cut lakes (33). Water quality must be monitored, however. To reduce siltation and excess surface runoff, overburden and haul roads should be revegetated at the earliest possible time. Proper drainage on roads can be accomplished by the construction of cross channels and, if properly managed, such roads can serve as access for recreational use or fire control.

An important requirement for all planning is public realization that the solution of environmental problems is not necessarily synonymous with a retardation of economic development. Ecosystem management and rational use of natural resources can go hand in hand. More specifically, the following guidelines are suggested for the Rocky Mountain region of Alberta:

(i) there should be documentation of land and water resources as they are before mining;

(ii) there should be a predetermined land-use plan for disturbed areas, with highest priority for game and cattle range;

(iii) definite species mixtures should be selected to accomplish land-use objectives and to complement natural revegetation;

(iv) a dense stocking of planted species should be established with random mixing and placement of seedlings on the spoil banks;

(v) reclamation of roads and road-cuts associated with mining should be part of the overall plan; and

(vi) attention should be given to the potential for recreational uses associated with man-made lakes in reclaimed areas.

Physical Steps to Achieve Suitable Topographies

The major physical steps in reclamation are placement of spoil at desired slopes, backfilling the highwall, contouring or terracing, and setting drainage patterns. These operations are often the most expensive steps in the whole reclamation process (Appendix I, Table 2) and need to be closely co-ordinated with associated mining operations.

Overburden should not be allowed to form extremely long slopes (34) or slopes steeper than 35°, since these are subject to rapid water erosion, do not hold moisture well and are difficult to revegetate. Steep slopes often can be avoided by placing overburden in natural depressions or in previous excavations. In the past, where strip-mines in the Rocky Mountain region have occurred on the tops or sides of steep mountain ridges, there has been a tendency to dump the overburden down the steep face of the mountain, leaving a deeply scored surface without sufficient material to moderate the abrupt drops left by highwall excavations. The resulting steep slopes cannot be safely travelled by tractor or other reclamation equipment. Contouring or terracing needs to be undertaken in these and other cases where it is necessary to control erosion, stabilize overburden or restore an aesthetically pleasing topography. Accelerated erosion at the base of the highwall can be counteracted by contouring a long, gentle slope against the highwall (37). A desirable model for terracing is the technique in which sloping topography is terraced twice to give a short and relatively steep upper slope, then a level terrace, a longer medium slope, another level terrace, and finally a long gentle slope (36). Contamination of groundwater and surface drainage by silt or chemicals from the overburden must be avoided; this may require stream re-routing and the development of new drainage channels with moderate slopes.

Where assisted revegetation is to follow, it may be necessary to break up compacted surfaces, adjust the micro-topography or cover with suitable strata to ensure the growth of desired species. The need for scarification or the creation of special micro-sites will depend, however, upon the growth requirements of the species to be used. Experienced reclamation workers have stressed that because dumped spoil surfaces are so variable one needs to go to the highwall to sample the actual chemical or physical characteristics of specific strata to be used for surfacing (34, 35). Once the surfacing stratum has been selected, its placement can then be co-ordinated with the overall mining operation.

Additional Steps to Revegetation

Perhaps the most effective way to stabilize slopes and to promote soil conservation is to establish a network of plant roots in the surface. It follows that revegetation in mountainous regions should be undertaken as soon as possible after a disturbance and before the finer soil particles are washed downhill or into the profile. It is difficult to justify any delay in revegetation in the Rocky Mountain region since there appear to be no major acidity or toxicity conditions which could be moderated by weathering.

At high elevations there often is insufficient suitable material to surface the overburden before revegetation. The adverse conditions which result in these cases can be moderated by applying a mulch at the time of seeding. The main functions of a mulch are: (i) to increase the water-holding capacity of the surface, (ii) to reduce water and wind erosion, (iii) to moderate soil temperature extremes, and (iv) to improve the chemical properties of the surface, such as pH or nutrient content. Common mulches include: straw, wood cellulose, cane fiber, lignosulfonates, calcareous flyash (from coal-burning power plants) and limestone. However, mulching adds to the cost of revegetation (Appendix I, Table 2) and can usually be limited to severe sites. These sites are best determined by field experiments as described later in this report.

Hydro-seeding, hydro-mulching and power-mulching equipment are the most versatile machines now available for revegetation in non-agricultural reclamation programs. These machines are usually mounted on a truck or trailer and have spraying distances of 150-200 feet. While this equipment has been used primarily with grass seeds, other seeds can be applied provided that they are not damaged by the pump or nozzle. The seeds should have rapid radical extension to take advantage of the moisture applied by the hydro-seeder. Fertilizers are often included in the water or mulch applications, although fertilizers containing high percentages of ammonium salts should be used with care since they inhibit the germination of some seeds. In terrain where hydroseeding is impractical, mine spoils can be economically revegetated by direct seeding from a helicopter (38). If greater control over the spacing and survival of plants is desired, as in the case of tree planting, then one to two-year-old seedlings can be transplanted onto the area either in containers or as conventional nursery stock.

The Choice of Suitable Species

There are many natural habitats with low pH, high salinity or high concentrations of elements such as sulphur, nickel or chromium. These habitats are as extreme as industrially disturbed lands but they are rarely devoid of plants, although they do possess a very characteristic vegetation (39). Grasses, for example, can adapt to severe habitats within 50 years or less (40). Ecotypes[1] which have evolved on disturbed lands frequently possess high tolerances to conditions on those particular sites (40), and in mountainous terrain it is often cheaper to utilize these tolerant ecotypes than it is to apply corrective surface treatments (41). Hence, one begins species selection by collecting reproductive material from ecotypes or clones[2] that are established on the oldest disturbed sites in a particular ecological or altitudinal zone. In Britain, this concept has developed to the point that ecotype selection and seed production on the reclamation site are now considered to be as important as surface treatments (40).

It is extremely important to carry out thorough screening before a species is used in a large-scale reclamation program. For example, in areas of drought, screening of species solely on the basis of drought hardiness has revealed useful shrubs, herbs and weeds (42). When a stringent evaluation technique is established, very few species pass the test. In the last 10 years only 15 species and varieties have been approved by the Soil Conservation Service for use on specific sites in northeastern United States (43). Until results of screening tests are available in Alberta, the best approach is to use candidate species which possess as many as possible of the following characteristics:

(i) native or naturalized species;

(ii) ability to regenerate naturally on industrially disturbed land, or in severe natural habitats such as avalanche slopes, eroding river banks, recent glacial moraines or wind-blown ridges;

---

1 Ecotype - distinct populations or races within a plant species which owe their most conspicuous characteristics to the selective effects of local environments.

2 Clone - all the offspring derived by asexual (vegetative) reproduction from a single sexually produced individual.

(iii) proven effective in reclamation work elsewhere;

(iv) high value for specific land-use objectives;

(v) readily reproducible in large quantities by natural or artificial means;

(vi) low water and nutrient requirements;

(vii) high rate of root dry-matter production; and

(viii) nitrogen-fixing ability.

A preliminary list of candidate species has been prepared for western Alberta (see Appendix II). Of those plants listed, highest priority should be given to native species that are indicated as pioneers on Alberta spoil banks. By listing weeping love-grass, crown vetch and black locust, we suggest that screening tests be conducted with these widely used reclamation species. Weeping love-grass is particularly useful for rapid and dense coverage of an area. This grass is a short-lived perennial that grows best on warm sites, but it is not palatable to cattle (44). In contrast, crown vetch is eaten by cattle and is an effective legume for sites with pH above 5.0. Of all the tree species used for revegetation in eastern United States, black locust has been best for a quick cover on all sites because of its hardiness, rapid early growth and ability to spread by root sprouts. Black locust has been established on denuded slopes in eastern British Columbia (45).

Species of grasses and legumes that provide a rapid, protective cover should be given priority in initial seeding (8), although they are often misfits for a long-term plan of vegetation management (11, 29, 37).

There is widespread experience in the use of grass and legume seed mixes for hydroseeding by coal companies and reclamation associations in the United States, by the Alberta Department of Lands and Forests and by the Department of Highways in Alberta and British Columbia. There is little biological basis from which to expect widespread success of these commercial mixes at altitudes greater than 6,000 feet in the Rocky Mountain region.

RECLAMATION CONTROLS

Because surface disturbances have deleterious effects on the biological and physical environment, it is logical to consider them as a form of pollution (46), the control of which falls partly within the realm of environmental forestry in western Alberta. Biologists can contribute to the formulation of control measures by ensuring that they are compatible with ecological principles and local environmental conditions. Wherever legislative controls involve detailed regulations, it is important that these regulations be based upon proven reclamation practices. Therefore, the synthesis of detailed regulations for Alberta should await the development of standards and practices which are based upon a disturbed land survey, reclamation research and operational experience in Alberta.

The costs of controls must be socially shared when surface disturbances are viewed as a component of public pollution (47, 48). One method of distributing these costs and of achieving efficient control is to levy uniform charges within designated regions (47). This approach has the advantage that operators can adjust to the required charges in the most economical way by either paying them or by reclaiming to a specified standard. It is advantageous to have such regionally designated charges based on ecological criteria, land-use potentials and public demands for acceptable reclamation. A system of charges that varies with ecological zones is compatible with the concept of advanced land-use planning as recommended in the previous section of this report, and it could serve indirectly as a control upon the location of surface mining sites. The establishment of significantly higher charges in a particular zone would discourage surface mining in that area. This approach hopefully would prevent the repetition in Canada of the major weakness in the United States control system, which is the relative lack of governmental control over the location of mining sites (29).

Dales (47) has put forth an imaginative approach to the implementation of a regionally differentiated charging scheme for water pollution control and has invited it to be tested in other aspects of environmental management. We think that Dales' approach could be the basis of economical and effective disturbed land reclamation controls in Alberta.

RECLAMATION SURVEY AND RESEARCH

Disturbed Land Survey

In the Rocky Mountain region, one of the most pressing needs is a survey of all types of surface disturbances to provide background information that can be used to establish reclamation standards and set research priorities. Also, there is little point in putting emphasis on planning or controls without a mechanism for monitoring and inspecting disturbed areas (49). A continuous survey should gradually document the following for existing and proposed disturbed areas in Alberta:

(i) the area of physically disturbed land and its geographic relation to streams, lakes, roads, towns etc.;

(ii) the designated land-use;

(iii) proposed reclamation plans;

(iv) any deviations from established reclamation standards;

(v) potential influences on water quality and aesthetics in the environment beyond the area of disturbed land;

(vi) the climatic zone (51);

(vii) the biophysical land classification at the land type level (50), and;

(viii) characteristics of highwall or fresh spoil material which predict its plant growth potential, mass stability (53) and erodibility.

This survey would logically be carried out by the Alberta Department of Lands and Forests with the advice of the reclamation research co-ordinating committee described below.

Research Co-ordination and Advisory Committee

Before any reclamation research is initiated in Alberta, we suggest that a co-ordination and advisory committee be set up which would include engineers, provincial administrators, scientists and others, all of whom are personally involved in reclamation at the operational level. As many as possible of the following specialties should be represented on the committee: mining engineering, resource economics, environmental plant science, land and wildlife management, soil conservation, hydrology, surface geology and landscape architecture. The committee would provide advice and research co-ordination to local mining companies, the Department of Lands and Forests, the Canada Department of Fisheries and Forestry, and the Alberta Research Council. Ideally, the impetus for this committee should arise from the surface mining industry and the provincial government. Specific tasks of the committee would be to:

(i) consider means for implementation of the rationale for revegetation research and the other specific research objectives given below;

(ii) recommend general research priorities; draft individual research projects; and suggest for each project the potential contribution of various agencies, the manpower requirements, the location of work areas, the timing of operations and, if possible, the economic justification;

(iii) interpret research results for the solution of reclamation problems encountered by local operators;

(iv) give technical advice to the disturbed land survey group for environmental monitoring and inspection;

(v) assist in the establishment of reclamation standards in Alberta, and;

(vi) oversee the preparation of a reclamation handbook for Alberta.

Eventually, this committee could operate within a Reclamation Association in which technical advice, materials and equipment are shared among the members. Using the Ohio Reclamation Association as a model, such an association would operate as a non-profit organization under Articles of Association to which each operator subscribes. The broad objective of the association would be to foster the development of effective and economical means of reclaiming disturbed lands and to assist members in the application of these methods. Such an association should also make its technical knowledge and services available to others. As in the Ohio example, direct services could include aerial surveys and mapping, soil and water testing, land- and water-use studies, specific guidance for steps in reclamation, fish stocking programs and seeding and planting programs. Such an association would not be a research agency but rather an organization for putting research results into practice. In this capacity, it would encourage and sponsor research and could conduct experiments to demonstrate research findings[3].

---

[3] Further information available from: Executive Secretary, Ohio Reclamation Association, 88 East Broad Street, Columbus, Ohio. 43215.

Rationale for Revegetation Research

The following three steps describe the basic rationale for revegetation research which we suggest for Alberta:

Step 1. Well designed field experiments are set up by applying various combinations of candidate species, NPK fertilizers and mulches on spoil banks with representative micro-environments and altitudes. The objective of these experiments is to define the critical environmental factors which limit or promote early plant growth of a limited number of species on as wide a variety of disturbed sites as possible. Candidate species would be selected from those that have pioneered on nearby disturbed land (see Appendix II) or have been used successfully in reclamation elsewhere. In these initial experiments the plants are seeded with a hydroseeder unless the seeds are damaged by the machine, in which case they are broadcasted. Mulch and fertilizer are applied with the hydroseeder. Next, observations are made of the germination and early growth of planted and volunteer species on the experimental plots, perhaps at 2 weeks, 1 month, 6 months and 1 year after seeding. The objective of these observations is to determine the causes of mortality, of inadequate growth, and of abundant growth. Associated environmental factors such as water relations, surface texture and stability, NPK relations, surface and air temperatures, pH and metal toxicities of the surface material, and wind or water erosion patterns are monitored.

Step 2. Since only a limited number of species (e.g. 10) are employed in Step 1 these species may not prove adequate in that they may not become established or may not meet specific land-use objectives such as game food, erosion control, shelter, aesthetics or wood production. It may be possible, therefore, to improve upon the original selections of plants or treatments by greenhouse or nursery screening tests. In such screening tests, specific field conditions found to limit plant growth or survival, e.g. drought or low temperature, are simulated and the performance of a wide range of species is determined under these conditions. The objective of these screening tests is to isolate species and treatments that will improve the effectiveness of the revegetation achieved in Step 1. Propagation facilities adequate for the production of seeds or clonal material for these screening tests are established early in Step 2. These tests are also the appropriate place to introduce newly identified species or surface treatments into the overall program. Over a period of years the field experiments and screening tests, therefore, evolve into proven reclamation practices.

Step 3. Once suitable reclamation practices have been defined, there remains the task of increasing the scale and minimizing the cost of each operation. Large plant propagation facilities are established near the planting sites, methods of planting other than hydroseeding are assessed, methods of managing vegetation are developed and the local cost of reclaiming to specific land-uses is calculated. Finally a reclamation handbook (6) is written to outline proven practices and acceptable reclamation standards.

Other Specific Research Objectives

Specific research objectives which cover revegetation, land-use evaluation and reclamation in a broader sense are discussed below. These objectives are based upon recommendations made at the 1969 Pennsylvania Symposium (11) and upon our analysis of priorities for disturbed land reclamation research in North America and particularly in western Alberta.

A. Research is required to provide criteria that will assist governments in deciding where surface mining should or should not be allowed. This research must be based upon a study of the projected influences of surface mining upon other natural resources such as water, natural beauty or wildlife. There should be tests of recently developed methods of quantifying landscape aesthetics (52) and of environmental monitoring before and after disturbances.

B. Research is required to provide detailed criteria that will assist operators in choosing and implementing specific land-use objectives for each reclamation program. This research should determine the importance of assisted revegetation at elevations above 6000 feet. Since game range and watersheds are obvious land-uses in many parts of western Alberta, these should be studied first.

C. There should be research into specific mining techniques and physical operations to achieve suitable topographies (see RECLAMATION OPERATIONS). This research should include situations where overburden may not be covered by topsoil or vegetation and should be co-ordinated with the research on implementation of specific land-uses (see B above). Determination of the surface micro-topography that is optimal for revegetation and moisture retention should be a part of the study.

D. Research should be conducted to define physical and chemical characteristics of highwall strata and overburden material which predict mass stability, erodibility, revegetation capability and potential for groundwater, stream and lake pollution. These criteria should be incorporated into a field guide for use by the disturbed land survey group and would eventually become part of the reclamation handbook for Alberta.

E. Research on natural revegetation of industrially disturbed lands and of severe natural habitats should be undertaken to provide information on trends and rates of ecological succession. This research should also include studies of plants normally not associated with reclamation, such as mosses (54), blue-green algae (54), weeds (42) and agricultural crops (55, 56). Species identified by this work would be introduced into Step 2 above. Part of this research should be co-ordinated with the definition of characteristics which predict revegetation capability (see D above). These investigations should also be co-ordinated with the proposed establishment of an international seed exchange for reclamation species (see 11).

F. To assist in the choice and propogation of suitable species both for screening tests and ultimately for large-scale production, research is required on the life cycles of certain poorly-documented species.

G. The influences of silt, hydrophobic coal-dust and soluble chemicals on stream flora and fauna and on the quality of water for man's use should be studied. This research is particularly important where disturbed lands could affect mountain watersheds and should be co-ordinated with the definition of characteristics which predict the potential for water pollution (see D above).

H. Within the context of pre-planned land-uses (see A and B above), studies should be undertaken to assess the economic, social and administrative advantages of implementing an ecologically differentiated charging scheme as a reclamation control (47).

I. There should be a continuous search for new treatments which can correct severe surface conditions. This research should consider bark of native trees (57), certain pulp-mill liquors, sewage (58), fly-ash (61) and other industrial wastes for use as mulches on mine spoils. An investigation of the use of polymers produced by yeast for the stabilization of mine spoils (59), coupled with means of culturing yeast on oils derived from coal (60), is an example of research that could be conducted. Effective treatments identified by this work would be introduced into Step 2 of the rationale for revegetation research.

REFERENCES CITED

1. Whittaker, W. C. 1968. Coal - suddenly it's a hot item. Alta. Bus. J. 2: 42-47.

2. Alberta Land Preservation Society. 1969. Coal mining damage in Alberta. A Brief Submitted to the Government of Alberta. 38p.

3. Whittaker, W. C. 1969. Statement to social issue forum on strip mining. 15 February 1969. Calgary.

4. Lafleur, C. (ed.). 1969. Proceedings of the 21st Canadian conference on coal. Dominion Coal Board, Ottawa. 123p.

5. Government of Alberta. 1969. Public lands surface reclamation regulations. O. C. 1962/69. Edmonton.

6. West Virginia Department of Natural Resources. 1969. Reclamation handbook. Division of Reclamation. 64p.

7. Ranwell, D. S. (ed.). 1967. Sub-committee report on landscape improvement advice and research. J. Ecology 55: 1p - 8p.

8. Kentucky Department of Natural Resources. 1966. Kentucky revised statutes relating to strip mining and reclamation. Chapter 350. Division of Reclamation. 46p.

9. Soil Survey Staff. 1951. Soil survey manual. U.S. Dep. Agr. 503p.

10. Province of Alberta. 1963. The surface reclamation act. Chapter 64 of the Statutes of Alberta, 1963, with amendments up to and including 1967. 16p.

11. Hutnik, R. J. and G. Davis. 1969. Program, International symposium on ecology and revegetation of drastically disturbed areas. Penn. State Univ., University Park, Pennsylvania.

12. Goodman, G. T., R. W. Edwards and J. M. Lambert (eds.). 1965. Ecology and the industrial society. 1964 Symp. Brit. Ecol. Soc., Blackwell Sci. Publ. Oxford. 395p.

13. Knabe, W. 1965. Observations on world-wide efforts to reclaim industrial wasteland. p. 263-296. IN: Ecology and the industrial society. Blackwell Sci. Publ., Oxford. 395 p.

14. Goodman, G. T. (ed.) 1967. Sub-committee survey of the nature of the technical advice required when treating land affected by industry. J. Ecology 55: 27p - 34p.

15. U. S. Department of Agriculture and Soil Conservation Society of America. 1964. A digest : strip-mine reclamation. Eastern Region, U.S. Forest Serv. 69p.

16. U. S. Department of the Interior. 1967. Surface mining and our environment. A Special Report to the Nation. U.S. Gov't. Printing Office. 124p.

17. Funk, D. T. 1962. A revised bibliography of strip-mine reclamation. U. S. Forest Serv. Central States Forest Exp. Sta. Misc. Release 35. 20p.

18. Limstrom, G. A. 1953. A bibliography of strip-mine reclamation. U. S. Forest Serv. Central States Forest Exp. Sta. Misc. Release 8. 25 p.

19. Bowden, K. L. 1961. A bibliography of strip-mine reclamation : 1953-1960. Univ. Mich., Dep. Conserv. 13p.

20. Knabe, W. 1958. Beitrage zur Bibliographie uber Wiederurbarmachung von Bergbauflachen. (Contributions to the bibliography on reclamation of mined areas). Wiss. Z. Humboldt Univ. Berlin. 7: 219-304.

21. International Institute for Land Reclamation and Improvement. 1967. Annotated bibliography on reclamation and improvement of saline and sodic soils, 1960-1966. Bibliogr. No. 6. Int. Inst. for Land Reclam. and Improv. P.O. Box 45, Wageningen, the Netherlands. 43p.

22. Funk, D. T. and B. A. Roach. 1961. Black locust : a bibliography. U.S. Forest Serv. Central States Forest Exp. Sta. Misc. Release 33. 40 p.

23. Mills, E. L. 1964. Vegetating spoil banks with crown vetch. p 15-16. IN: Proc. Crown Vetch Symp., Penn. State Univ., University Park, Pennsylvania.

24. Hoffman, G., R. B. Curry and G. O. Schwab. 1964. Annotated bibliography on slope stability of strip mine spoil banks. Ohio Agr. Exp. Sta., Res. Circ. 130. 92 p.

25. Siehl, C. H. 1968. Mined land reclamation requirements, pro and con. Libr. Congr., Legislative Ref. Serv. TN 23A. NR 106. 41p.

26. U.S. Senate. 1968. Surface mining regulation. Comm. on Interior and Insular Aff. U.S. Gov't. Printing Office. 375 p.

27. Government of Canada. 1968. Statutes of Canada 1967-68. 16-17 Eliz. II. p 317-341.

28. Government of Canada. 1947. An act respecting the protection and conservation of the forests on the eastern slope of the Rocky Mountains. Statutes of Canada 1947. 11 Geo. VI. p 311-327.

29. Bosselman, F. P. 1969. The control of surface mining : an exercise in creative federalism. Natur. Resources J. 9: 137-165.

30. Krause, R. R. 1969. Fuels, land and the future. p. 23-27. IN: Lafleur, C. (ed.). Proceedings of the 21st Canadian conference on coal. Dominion Coal Board, Ottawa. 123p.

31. Fenton, M. R. 1969. Transformation of strip-mine areas into areas of natural beauty. IN: Program, International symposium on ecology and revegetation of drastically disturbed areas. Penn. State Univ., University Park, Pennsylvania.

32. Whitt, D. M. 1968. Surface-mined land. How much? What next? Soil Conserv. 33: 123-125.

33. Agnew, A. F. and D. M. Corbett. 1969. Hydrology of a watershed containing SCS reservoirs and coal surface-mining activity, south-western Indiana. Ibid. reference 31.

34. Krause, R. R. 1969. Predicting mined-land soil potential. Ibid. reference 31.

35. Knabe, W. 1969. Development and application of the Domsdorf ameliorative treatment on toxic spoil banks in lignite open-cast mines in Germany. Ibid. reference 31.

36. Olschowy, G. 1969. Landscape planning on an ecological basis. Ibid. reference 31.

37. Miles, V. C., R. W. Ruble and R. L. Bond. 1969. Performance of plants in relation to spoil classification in Pennsylvania. Ibid. reference 31.

38. Zarger, T. G., J. A. Curry and J. C. Allen. 1969. Seeding of pine on coal spoil banks in the Tennessee Valley. Ibid. reference 31.

39. Bradshaw, A. D., T. S. McNeilly and R.P.G. Gregory. 1965. Industrialization, evolution and the development of heavy metal tolerance in plants. p. 327-343. IN: Ecology and the industrial society. Blackwell Sci. Publ., Oxford. 395 p.

40. Goodman, G. T., C. E. R. Pitcairn and R. P. Gemmell. 1969. Ecological factors affecting growth on sites contaminated with heavy metals. Ibid. reference 31.

41. Berg, W. A. and W. G. Vogel. 1969. Aluminum and manganese toxicities of plants grown in acid coal-mine spoils. Ibid. reference 31.

42. Nielson, R. F. and H. B. Peterson. 1969. Establishing vegetation on mine tailings waste. Ibid. reference 31.

43. Rufner, J. D. and W. W. Steiner. 1969. Evaluation of plants for use on critical sites. Ibid. reference 31.

44. Vogel, W. G. and W. A. Berg. 1968. Grasses and legumes for cover on acid strip-mine spoils. J. Soil and Water Conserv. 23: 89-91.

45. Thirgood, J. V. 1969. Disturbance and revegetation in Canada. Ibid. reference 31.

46. Berkowitz, N. 1969. The probable environmental effects of coal mining and combustion in western Canada. p. 37-42. IN: C. Lafleur (ed.). Proceedings of the 21st Canadian conference on coal. Dominion Coal Board, Ottawa. 123 p.

47. Dales, J. H. 1968. Pollution, property and prices. Univ. of Toronto Press. 111 p.

48. Mishan, E. J. 1967. The costs of economic growth. Staples Press, London. 190 p.

49. Haagen-Smit, A. J. 1965. Benchmark surveillance. p. 102-110. IN: Restoring the quality of our environment. Report of the President's Sci. Adv. Comm. 317p.

50. Lacate, D. S. 1969. Guidelines for bio-physical land classification. Can. Forest. Serv. Publ. 126A. 61p.

51. Longley, R. W. 1968. Climatic maps for Alberta. Alberta Climatol. Comm., Dep. Geogr., Univ. of Alberta, Edmonton. 8p.

52. Leopold, L. B. 1969. Landscape esthetics. Nat. History 78: 37-45.

53. Fowler, W. B. and H. W. Berndt. 1969. Fluorescent materials index soil movements. U.S. Forest Serv., Res. Note PNW-107. 7p.

54. Dean, K. C., R. Havens, K. T. Harper and J. B. Rosenbaum. 1969. Vegetative stabilization of mill mineral wastes. Ibid. reference 31.

55. Hodgson, D. R. and W. N. Townsend. 1969. The amelioration and revegetation of pulverized fuel ash. Ibid. reference 31.

56. Hill, R. D. 1969. Reclamation and revegetation of 640 acres of surface mines - Elkins, West Virginia. Ibid. reference 31.

57. Bollen, W. B. 1969. Properties of tree barks in relation to their agricultural utilization. U.S. Forest Serv. Res. Paper PNW-77. 36p.

58. McCormick, L. H. 1969. The chemical quality of percolate resulting from the application of sewage sludge and effluent to acid strip-mine spoils. Ibid. reference 31.

59. Rothwell, F. M. 1969. Nodulation of various strains of Rhizobium with Robinia pseudoacacia seedlings planted in strip mine spoil. Ibid. reference 31.

60. Pirie, N. W. 1969. Food resources - conventional and novel. Penguin Books. Middlesex, England. 208 p.

61. New Scientist. 1968. New use for coal down on the sewage farm. New Scientist 37: 138.

62. May, J. T., C. L. Parks and H. F. Perkins. 1969. Establishment of grasses and tree vegetation on spoil from kaolin clay strip mining. Ibid. reference 31.

63. Heide, G. 1969. Pedological investigations in the Rhine brown coal area. Ibid. reference 31.

64. Jacoby, P.W. 1969. Revegetation treatments for stand establishment on coal spoil banks. J. Range Manage. 22: 94-97.

65. Schlatzer, G. 1969. Some experiences with species in Danish reclamation work. Ibid. reference 31.

66. Cromwell, S. M. 1969. Recorded discussion. Ibid. reference 31.

67. Striffler, W. D. 1967. Restoration of open-cast coal sites in Great Britain. J. Soil and Water Conserv. 22: 101-103.

Additional Source Material

A. Suppliers of plant materials for reclamation:

1. Sharp Bros. Seed Co., Healy, Kansas - commercial source of seed for weeping love-grass (*Eragrostis curvula*) and other reclamation species.
2. United States Department of Agriculture, Forest Service Headquarters, Washington, D.C. - source of seeds for shrub and tree species.
3. Rothamated Experimental Station, Harpenden, Herts, England - source of *Rhizobium* nodules, as distinct from cultures.

B. Audio-visual materials:

1. Ohio Reclamation Association, 88 East Broad St., Columbus, Ohio. 43215 - for a 25-minute 16 mm. color and sound film on strip mining and reclamation.
2. United States Government Printing Office, Superintendent of Public Documents, Washington, D.C., 20402. - for copies of:
   (a) Surface mining and our environment, Catalogue No. I 1.2:M 66/3 ($2.00).
   (b) Study of strip and surface mining in Appalachia, Catalogue No. I 1.2:M 66/2 ($1.00).

C. Additional references not cited in text:

Biesecker, J. E. and T. R. George. 1966. Stream quality in Appalachia as related to coal-mine drainage, 1965. U.S. Geol. Surv. Circ. 526. 27p.

Davis, G. 1966. The co-operative research program in Pennsylvania. p. 55-61. IN: Coal mine spoil reclamation symposium proceedings. Penn. State Univ., University Park, Pennsylvania.

Donald, K. G. 1969. Production and reclamation planning, Kaiser Resources Limited. p. 28-36. IN: C. Lafleur (ed.). Proceedings of the 21st Canadian conference on coal. Dominion Coal Board. Ottawa. 123 p.

Eshbaugh, F. P. 1949. The place of research in relation to certain phases of strip-land reclamation in Kansas. Kansas Acad. Sci. Trans. 52: 149-159.

Grandt, A. F. and A. L. Lang. 1958. Reclaiming Illinois strip coal land with legumes and grasses. Univ. Illinois Agr. Exp. Sta. Bull. 628. 64 p.

Knabe, W. 1964. Methods and results of strip-mine reclamation in Germany. Ohio J. Sci. 64: 75-105.

Kohnke, H. 1950. The reclamation of coal mine spoils. Advances in Agron. 2: 317-349.

Lane, R. D. 1968. Forest Service reclamation research. Mining Cong. J. 54: 38-42.

Limstrom, G. A. 1960. Forestation of strip-mined land in the central States. U.S. Dep. Agr., Agr. Handbook 166. 74 p.

Limstrom, G. A. and G. H. Deitschman. 1951. Reclaiming Illinois strip coal lands by forest planting. Univ. Illinois Agr. Exp. Sta. Bull. 547. 50 p.

Lorio, P. L. and G. E. Gatherum. 1966. Growth of eastern cottonwood in relation to coal-spoil characteristics. Iowa State J. Sci. 41: 41-53.

May, R. F. and W. D. Striffler. 1966. Watershed aspects of stabilization and restoration of strip-mined areas. p. 663-671. IN: Proceedings of the International Symposium on Forest Hydrology. Pergamon Press, Oxford, England.

McKeever, I. 1963. Guide for classifying and revegetating strip mine spoil in Pennsylvania. U.S. Dep. Agr., Soil Conserv. Serv. 23p.

Plass, W. T. 1966. Land disturbances from strip-mining in eastern Kentucky. 1. Upper Cumberland Coal Reserve District. U.S. Forest Serv. Note NE-52. 7p.

__________ 1967. Land disturbances from strip-mining in eastern Kentucky. 2. Princess Coal Reserve District. U.S. Forest Serv. Note NE-55. 8p.

__________ 1967. Land disturbances from strip-mining in eastern Kentucky. 3. Licking River Coal Reserve District. U.S. Forest Serv. Note NE-68. 6p.

__________ 1967. Land disturbances from strip-mining in eastern Kentucky. 4. Big Sandy Coal Reserve District. U.S. Forest Serv. Note NE-69. 7p.

__________ 1967. Land disturbances from strip-mining in eastern Kentucky. 5. Hazard Coal Reserve District. U. S. Forest Serv. Note NE-71. 7p.

_______________ 1967. Land disturbances from strip-mining in eastern Kentucky. 6. Southwestern Coal Reserve District. U.S. Forest Serv. Note NE-72. 8p.

Reinhart, K. G. (Compiler). 1962 to present. Partial bibliography of strip-mine reclamation. Mimeo. interim bibliogr. of U.S. Forest Serv., Northeastern Forest Exp. Sta., Upper Darby, Pennsylvania.

Rogers, N. F. 1951. Strip-mined lands of the western interior coal province. Missouri Agr. Exp. Sta. Res. Bull. 475. 55p.

Struthers, P. H. 1964. Chemical weathering of strip-mine spoils. Ohio J. Sci. 64: 125-131.

Whyte, R. O. and J. W. B. Sisam. 1949. The establishment of vegetation on industrial waste land. Commonwealth Agr. Bur. Joint Publ. 14. 78p.

APPENDIX I

Table 1. Review of land-uses on United States reclaimed lands (from 32).

Potential Use	Percent of reclaimed areas
Woodland	39.2
Wildlife habitat	38.6
Farm and forest recreation	27.2
Pastureland	17.8
Rangeland	13.3
Ponds and reservoirs	9.9
Residential, institutional and industrial	6.5
Cropland	3.4
Unspecified	8.6
More than one of the above (multiple use)	64.5

APPENDIX I

Table 2. Summary of reported disturbed land reclamation costs.

Operation Performed	Location	No Acres	Cost per Acre[1]	Ref.
A. Spoil placement:				
1. Grading to non-eroding gradients	U.S.avge.	284,000	$151	(16)
2. Grading for drainage control	U.S.avge.	567,000	196	(16)
3. Grading to allow forage harvesting	U.S.avge.	242,000	207	(16)
4. Grading to allow tree planting	Ohio	-	300-3000	(34)
5. Grading for high-use recreation park	Pennsylvania	80	1250	(31)
6. Grading clay spoils for erosion control	Georgia	-	2000	(62)
7. Wet method of loess placement	Germany	-	2030	(63)
8. Dry(auger)method of loess placement	Germany	-	4050-4850	(63)
B. Surface treatment (material & labour, excluding seed costs):				
1. Snowfence	Wyoming	-	180	(64)
2. Straw mulch	Wyoming	-	273	(64)
3. Jute netting	Wyoming	-	1375	(64)
4. Snowfence and jute	Wyoming	-	1555	(64)
5. Jute and mulch	Wyoming	-	1827	(64)
6. Snowfence, jute and mulch	Wyoming	-	1827	(64)
C. Revegetation:				
1. Grass & legume planting	U.S.avge.	242,000	53	(16)
2. Tree planting	W. Virginia	640	84	(57)
3. Grass seeding	W. Virginia	640	164	(57)
4. Grass and tree mixture	W. Virginia	640	194	(57)
5. All plantings & seedings on 823 sites	U.S.avge.	1,760,000	232	(16)
6. Hydroseeding	W. Virginia	640	374	(57)
7. Hydroseeding plus tree planting	W. Virginia	640	454	(57)
8. Landscape planting for recreation	Pennsylvania	80	1250	(31)
D. Total Reclamation:				
1. Basic reclamation and planting for wildlife habitat	U.S.avge.	439,000	419	(16)
2. Total reclamation for pasture land	U.S.avge.	242,000	610	(16)
3. Total reclamation of 6000 trees/ acre	Denmark	-	640	(65)
4. Domsdorf ameliorative method	Germany	-	810-1010	(35)
5. Total reclamation to wood lot	Britain	-	1100-3000	(67)
6. Total reclamation to intensive agriculture	Britain	-	2200-5800	(67)
7. High-use recreational park	England	50	6000	(66)

[1] Excluding administrative and planning costs.

APPENDIX II

Preliminary list of species to be tested for revegetation in the Rocky Mountain region of Alberta[1]

Botanical name	Common name	Native or naturalized in Alberta	Pioneer on Alberta mine spoils	Nitrogen-fixer	Location where used in reclamation
		TREES			
Populus tremuloides	aspen	X	X	-	East. U.S.
Populus balsamifera	balsam poplar	X	X	-	?
Pinus contorta	lodgepole pine	X	X	-	U.K.
Pinus banksiana	jack pine	X	?	-	?
Pinus flexilis	limber pine	X	?	-	?
Pinus albicaulis	whitebark pine	X	?	-	?
Picea engelmannii	Engelmann spruce	X	?	-	?
Picea glauca	white spruce	X	?	-	?
Betula papyrifera	white birch	X	?	-	East. U.S.
Acer negundo	box-elder	X	?	-	Germany
Robinia pseudoacacia	black locust	-	-	X	U.S., Trail, B.C.
Elaeagnus angustifolia	Russian olive	-	-	X	Denmark, U.S.
		SHRUBS			
Alnus viridis	green alder	X	?	X	?
Alnus tenuifolia	mountain alder	X	X	X	?
Sambucus racemosa	elderberry	X	X	-	?
Betula occidentalis	river birch	X	?	-	?
Shepherdia argentea	buffaloberry	X	?	X	Denmark
Prunus pensylvanica	pincherry	X	?	-	Denmark
Shepherdia canadensis	Canada buffaloberry	X	?	-	?
Elaeagnus commutata	wolf willow	X	?	X	?
Potentilla fruticosa	shrubby cinquefoil	X	?	-	?
Juniperus communis	low juniper	X	?	-	?
Juniperus horizontalis	creeping juniper	X	?	-	?
Arctostaphylos uva-ursi	bearberry	X	?	-	?
Symphoricarpos albus	snowberry	X	?	-	?
Spiraea lucida	spiraea	X	?	-	Genus in Denmark
Rhododendron albiflorum	rhododendron	X	?	-	?
Rosa spp.	rose	X	?	-	Genus in Denmark
Amelanchier spp.	serviceberry	X	?	-	Genus in Denmark
Salix spp.	willow	X	?	-	Genus in Denmark
Caragana arborescens	caragana	X	-	X	Utah, Alberta
Dryas drummondii	mountain avens	X	?	X	?

APPENDIX II (cont'd.)

Botanical name	Common name	Native or naturalized in Alberta	Pioneer on Alberta mine spoils	Nitrogen-fixer	Location where used in reclamation
		SHRUBS			
Ceanothus velutinus	sticky laurel	X	?	?	?
Caragana pygmeae	dwarf caragana	-	-	X	?
		GRASSES, HERBS, AND LEGUMES			
Melilotus alba	white sweet clover	X	X	X	U.S.& Europe
Melilotus officinalis	yellow sweet clover	X	X	X	U.S.& Europe
Trifolium repens	white clover	X	X	X	U.K.
Phleum pratense	timothy	X	X	-	U.K.
Medicago sativa	alfalfa	X	?	X	U.S., Europe Alta.
Lupinus spp.	lupine	X	?	X	N.W. Europe
Coronilla varia	crown vetch	-	-	X	East U.S.
Agrostis stolonifera	red-top	X	?	-	U.K.
Festuca ovina	sheep fescue	X	?	-	U.K.
Agropyron cristatum	crested wheatgrass	X	?	-	Utah
Plantago lanceolata	plantain	X	?	-	U.K.
Phacelia spp.	scorpionweed	X	X	-	Genus in Germany
Astragulus spp.	milk-vetch	X	X	-	?
Sedum stenopetalum	stonecrop	X	X	-	?
Corydalis aurea	golden corydalis	X	X	-	?
Epilobium angustifolium	fireweed	X	X	-	?
Equisetum arvense	horsetail	X	X	-	?
Penstemon nitidus	penstemon	X	X	-	?
Eragrostis curvula	weeping love-grass	-	-	-	East U.S.

[1] X indicates Yes; - indicates No; ? indicates not known.