BIBLIOGRAPHY

OF

MINE WASTE STABILIZATION

J. E. Lease

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PREFACE

This paper was originally done as a literature search for Science Literature, School of Librarianship, University of Denver, in the spring of 1967. The writer showed the article by James, "Stabilization of Mine Dumps with Vegetation," *Endeavor,* 1966, to her professor saying with enthusiasm, "If they can do this (cover and control the sand dumps) in South Africa, we can do it here (Southwestern United States.)"

The quiet reply was, "Good. Why don't you do your literature search on this subject?"

And so it was done, but only back to 1960, using the resources of the libraries of the University of Denver. In February 1970, Mr. Don Baker, Director of New Mexico Bureau of Mines and Mineral Resources, became interested and asked that the paper be brought up-to-date and developed more fully.

In May 1970 the writer was asked to go to Salt Lake City, Utah, to consult with Mr. Karl C. Dean who contributed many of the materials on hard-to-find conferences and symposia.

ACKNOWLEDGMENT

Acknowledgment is gratefully given to Mr. Harold Malinowsky who encouraged the first part of this project; to Dr. James P. Dyke, Library Director, and Mrs. Mildred A. Barrett, assistant Library Director, New Mexico State University Library, who have given assistance and direction; to Mr. Terry Corbett, graduate student who searched the *Bibliography of Agriculture* and other indexes and abstracts to bring the references up-to-date from 1968, and to Mr. George Polsom, graduate student, who helped search PAIS, xerographed materials and helped in many other ways.
TOWARD STABILIZING MINE DUMPS.

When man first learned that certain rocks contained useful materials, and he began to dig in the earth to obtain these materials, he did not have any idea of the future problems resulting from the displaced soil and rocks. Since there was plenty of land, man moved about on every continent on this earth, lured on by the precious ores, to all conceivable places, from ocean depths to plains and to mountain tops. And everywhere he removed the top soil, constructed roads and destroyed some of the natural vegetation, generally contributing to erosion of the land by water and wind, and to the pollution of the air and water.

Over one hundred years ago George Perkins Marsh became alarmed and wrote his book, *Man and Nature*, the conservation classic. In this book he wrote, "The result of man's ignorant disregard of the laws of nature . . . was the deterioration of the land." In 1963 Stewart Udall published his book, *The Quiet Crisis*, in which he discusses our country as a new nation, rich with resources. The use of these resources and the consequent results is simply and effectively told.

Reclamation of land is not new for it was practiced by the shepherds and others of Biblical times who built rock retaining walls on the hillsides to hold the precious rainwater and dug ditches to divert the water to fields.

The reclamation of the sand dunes in the region of Les Landes, southwestern France is one of the greatest achievements of man. Before 407 A.D. this was a forested area, supplying Rome with resin. After the Vandals destroyed the area by leveling the villages, scattering the people, and burning the forests, westerly winds began moving the sand which eventually covered more than 400,000 acres, creating 2 1/4 million acres of marshland.
In 1778 the French Government appointed Willers to create a military port at Arcachon. He presented the principle of "dune fixation." Approximately 20 years later Napoleon assigned Bremontier to control these dunes. A littoral dune was established and reforesting of the sand behind the dune was begun; the marsh lands were drained by Cambrai. Today the forests in this area produce much timber and resin, in addition to supporting numerous health resorts.

In England the abandoned limestone workings at Dudley Castle and Wren's Nest were first planted in trees by the Earl of Dudley about 1815. East Park, Wolverhampton, England, opened in 1896, is the earliest park grown over an area of pit shale and other waste rock as described by Whyte and Sisam. The Midland Reafforesting Association, which was formed in 1903, successfully reforested waste areas in Black County, England.

One of the main objectives of this Association was to prove that it would be worth while from a business view to establish forests on waste land. Waste areas in other European countries and South Africa have been revegetated depending on the type and kind of materials, the climate, and the interest and needs of the people.

In South Africa the mining operations of the Witwatersrand gold field have developed huge dumps of finely ground rock, covering 25,000 acres, with some dumps as high as two hundred feet. A permanent cover has been sought for over fifty years; different methods have been tried without success. In 1953 the situation became so serious that all the previous literature was reviewed and the decision was made to develop a permanent cover of vegetation which once established would need no further care or aid. Now after a decade of many trials and tests and hard work, such a cover has been established and is thriving.
Another type of mining more common in the eastern and central part of our country has increased production in the last twenty years. Strip mining removes the overburden of soil and rock which exposes a vein of coal. After the coal has been removed, the operator moves on to another field, often leaving open pits, and spoil banks of loose dirt. Minerals, mainly left exposed to the elements produce adverse chemical conditions. In some cases the sulphuric acid and iron hydroxides have washed into streams, killing fish and plant life. The dirt from the spoil banks has covered some farm lands with much loss of acreage.

In England under the direction of the National Coal Board the area to be overcast (stripmined) is carefully studied and planned before the contract is given to the private company. The first foot of top soil is removed and carefully saved. The next two feet of soil are stockpiled in another place. Then the remaining overburden is removed. After the ore has been removed, the process is reversed, the final top layer is graded, and leveled, seeded and fertilized. And in a comparatively short time the area is producing vegetation according to the original plan.

There is a difference in the two operations for the area in England is smaller, more level than the sites in the United States with more moisture than many places in the United States and rigidly controlled by the government.

Revegetation of mine dumps is desirable for economic returns, bank stabilization, and landscape and amenity improvement. Practical stabilization procedures include physical, vegetative, chemical, and combinations methods. Preplanning of waste disposal, is now a usual practice for many companies beginning new operations.

According to J. M. Francis, Chief Forester, Office Services of Bethlehem Steel, "Reclamation work is as diverse as the number of sites, geographic locations, results desired, type and texture of the waste, local social demands and the incentive or lack of it on the part of the agency or company performing the work."
Geneal principles which have been used follow the basic steps. Because each site is different, the first step is to consult, plan and work with the local agricultural experts regarding materials to be used. The area is tested for pH and neutralized. The fertilizer is added to the sterile soil and rock, the mixtures of commercial seed and/or plants are sewn or planted by hand or air, protection for the vegetation from wind, grazing animals or vandals and enough moisture, usually in a mist form is provided until the growth is well established, and then nature is allowed to take over. Research has shown that commercial grains and grasses are best for starting these plots. Care must be taken in selecting native plants for not all are desirable.

In the United States some individual coal companies have made contributions to the forestation of waste areas since the turn of the century. The Harmon Coal Company of Pennsylvania and the Hanna Coal Company of Cadiz, Ohio, in addition to the Illinois Coal Strippers Association and the Indiana Coal Strippers Association are pioneers in this effort. The first large scale planting of trees was in Indiana in 1928. These companies have reclaimed land with trees, and grasses, and have developed parks which have been given to the communities in which they operate. Many of the state parks in southwestern Indiana are former strip mines. Other areas have been developed for agriculture, pasture, orchards, timber for pulpwood, housing and industrial sites, community water supplies and wildlife preserves.

Much research has been done by the United States Forest Service at the Northeastern Forest Experiment Station, the Central States Forest Experiment Station, the Forest Service Research Station at Darby, Pennsylvania, and the West Virginia and Ohio Agricultural Experiment Stations with the the types of grasses, legumes, and trees to be used as cover vegetation for mine-out areas. In addition the Soil Conservation Service the the Bureau of Mines have contributed valuable research.
The national government has passed some acts of legislation dealing with conservation. The Mineral Lands Leasing Act of 1920 established a plan for the orderly development of mineral sources, including oil, gas, and coal. The Soil Conservation Act of 1935, began a nationwide program of soil and moisture conservation. The Wilderness Act of 1964, gave legislation of the multiple use policy to natural areas and to certain existing wilderness areas. Included in the Surface Mining Reclamation Act of 1968, is the objective to prevent dispoilment of thousands of acres of mining land. Proposed legislation in March 1969 provided for the control of strip mining to prevent the destruction of scenic landscape. The bill called for federal action against offenders in areas in which state legislation fails to cope with the problem. The bill was not acted on by the Congress.

Many of the states have passed laws, now tightened, to enforce closing the pits, leveling the spoil banks, and replanting the area. The North Dakota Reclamation Law of 1969, was patterned after the Illinois Act and is one of the most strict in the country. The operators are required to present a plan of reclamation to the State. After surface mining operations are completed the operators must carry out the reclamation of the mined land to provide any of a number of uses, including forestry, grazing lands, crop lands, and wildlife habitats, recreational land, home or industrial sites. It is unlawful to surface mine if the overburden exceeds ten feet without a permit. Where possible, operators must assist in impounding water for lakes or ponds by constructing necessary dam. Montana's Reclamation Law of 1967 is based on the Colorado Law. In Montana the reclamation of the land is in accordance to the highest potential use available. Approval is given by the Montana Bureau of Mines and Geology, which makes an annual inspection of each site. The mining company may receive a refund for the cost of the reclamation up to a maximum of 1/2 the annual license tax. The Wyoming Reclamation Law of 1969 requires the construction of dams where lakes should form, adequate covering of acidic materials, and the filing of leases, maps and reports by operators to show lands reclaimed. It is no wonder that the Society of Mining Engineers reports that this recovery technique (strip mining) is declining in popularity, partly due to fewer reserves and the added cost of reclamation.
Karl C. Dean reports "the most innovative study of the Bureau of Mines has been the development of a combination chemical-vegetative stabilization method. The use of proper chemicals in conjunction with vegetative growth can have several advantages. The chemical can be of benefit by (1) preventing sand blasting of the plants, (2) retaining moisture in the tailings by decreasing evaporation, (3) aiding in germination by absorbing heat, (4) adding organics, and (5) preventing reflection of the sun's rays back onto the plant."

(Dean, Karl C...Utilization and Stabilization of Solid Mineral Wastes...p16)

At Kennecott's McGill, Nevada, 10-acre plot where tailings are located in a climatically harsh site for vegetation with a short growing season, wide temperature range, and annual rainfall 8.37 inches, the primary objective of stabilization against wind erosion and native plants coming in was achieved in one year.

In Arizona the different mining companies are working individually for reclamation. Phelps Dodge Corporation, Arizona's largest copper producer announced the creation of a new Division of Environmental Engineering and Research, July 1, 1970. The main office will be in Tucson under the direction of Dr. James D. Forrester.

Reclamation of the mine dumps and tailing dams has begun in central Arizona at Miami Copper Company. Dirt from the nearby areas was brought in to cover the tailings dams and then planted with domestic grasses and grains and native shrubs.

San Manuel

South of Tucson, Anaconda Mining Company spent half of their first six years of operation of their new Twin Buttes mine for the removal of 230 million tons of overburden. Over 206 million tons of materials were used in constructing three square-U shaped dikes. These dikes serve as a dam to impound the mill tailings, to prevent wind exposure and to provide a screen from residential areas and highway views. Built with bases 1,000 feet wide, the dikes are terraced on the outside to a width of 250 feet at the top. The benches are 30 feet wide with 50 foot lifts for a maximum height of 200 feet. Landscaping work
began on the south. The soil and rock were fertilized and native shrubs and grasses were seeded and planted on the slopes. The areas were sprinkled only until the plantings were established. After three years the growth can be seen in figures 1 and 2. Figure 3 by the writer shows where the landscaping stopped for one period. A return visit in the spring of 1971 showed a great improvement and the spread of the grasses; the wildlife was beginning to return to the area, including javalina.

American Smelting and Refining Company north and south of Tucson in working with a local nursery is using still another method of stabilization. Holes have been dug near the edge of the bank, filled with a basic soil, and planted with eucalyptus trees. The sides of the benches have been planted with grass and then covered with straw until the grass is established.

In the summer of 1970 work was begun on a test plot of the New Cornelia Mine at Ajo, Arizona. The tailings had weathered for nine years. A small amount of sawdust was mixed in the top layer of tailings and water from the sewage settling dam which is just below the for irrigation. test plot was pumped up and used. At the time of the writer's visit all the salt cedar cuttings from the previous summer and the present spring were thriving, as was the wild bermuda grass and some of the oleanders. A trial vegetable plot was being tried.

In northern New Mexico landscaping work is being done at the Pittsburg-Midway strip mine near Gallup. In southern New Mexico both Kennecott Copper Company and Phelps Dodge are working towards similar ends near Silver City.

There is other work being done which has not been mentioned here.

Of special interest to reclamation work is a new shrub, the Arnot Bristly locust which was developed at the USDA Soil Conservation Service Big Flat, (New York, plant materials center. An open branched shrub which grows rapidly and thickens providing a dense canopy and good leaf litter for soil protection the shrub has been successfully grown in acid soil with a pH of 4.0 and in alkaline soil with a pH of 7.15. It is drought resistant and thrives on low-fertility sites, but does not compete with established vegetation. It spreads by root suckers, particularly on coarse soils and may be propagated by seedlings.
Perhaps good community publicity could be developed by speaking before local Garden Clubs and requesting supplies of the bearded iris. This iris requires a sunny location, shallow well-drained soil, and little moisture. The spreading rhizomes hold the soil and the plants serve as a wind break for smaller plants, plus providing color in the spring.

The writer has grown up in the southwestern part of the United States and has long been concerned with erosion of soil from overgrazing, from stripping the land of natural vegetation for real estate development, and from mining. Now that a vegetative cover has been developed for land which is similar to the western states, and for another region which is in the western states, the writer hopes that there will not be too long a lag before work of this type is done here at each mine and range of land which has been changed by man.
Reclamation of land is not new, but the reclamation of mine dumps and tailing dams is comparatively recent. Effective vegetative covers have been developed but there is a need for more research to be done in this area of conservation. And there is a need to let the general public know what is being done.

Some successful work has been done with the mine dumps of finely-ground rock which have caused dust storms in South Africa and in Nevada. Work for a vegetative cover of the strip-mines in the central and eastern parts of the United States in a different climate has been successful. Additional work in Europe, Japan and the Hawaiian Islands has been described in other reports.

The cost of the rehabilitation of the land has to be added to the cost of producing the ore. Legislation by the states is increasing, but there is some federal control coming as more and more people become concerned. The writer would like to see more work done, especially in the western United States.
Because so much work has already been done in stabilizing coal mine dumps, the main goal of this paper is to aid and assist those people and mining companies who operate west of the Mississippi River in the United States. The reclamation work in the western part of this country may require methods and materials which are different from those procedures used in the eastern half of this country, so papers on alkaline, radium and saline soils, sand dunes, sand and gravel pits, copper and gold mines are included. The book by Whyte describes stabilization of industrial dumps, including ceramic dumps, as well as mining dumps.

Reports range from historical work to the latest symposium to be published in 1971. The papers presented in the proceedings of the International Symposium on Ecology and Revegetation of Drastically Disturbed Areas, University Park, Pennsylvania, August 1969, are identified by the ** at the end of each reference. Copies of the abstracts of the papers may be obtained from the New Mexico Bureau of Mines and Mineral Resources.

For this paper most of the literature available was found in periodical articles. There is little book material yet on this subject, but there is brief information in text and in pictures in some books on conservation. One of the problems has been to find reports of conferences, symposia and institutes which are not published in the usual media and indexed or abstracted by the reference services used here. For this reason the writer is aware that some excellent work may not be included.

Finding or deciding on subject headings to use in guides, indexes, and abstracts was the main problem in this study. The writer began by searching with the James article, "Stabilizing Mine Dumps with Vegetation," September, 1966, issue of Endeavor, using the subject headings of agriculture, botany, and engineering science.
Using these headings in the *Reader's Guide* (May 1945-March 1970), the writer included conservation, erosion, man-influence in environment, mines, natural resources, reclamation of land, soil, vegetation, and weathering. Conservation was too wide a subject. The other subject headings had nothing related to the specific area. The most fruitful heading was reclamation of land.

The *Engineering Index* (1907-March 1970) under the heading reclamation of land referred the writer to see also coal mines and mining—land reclamation. The *Industrial Arts Index* (1945-1957) which became the *Applied Science and Technology Index* (1957-March 1970) used the heading of reclamation of land. The *Bibliography of Agriculture* (July-December 1943-1969) began using the headings mining, reclamation and reclamation of land until 1948 and then dropped the first heading. The *Agriculture Index* (1960-1964) became *Biological and Agricultural Index* in September 1964 (1964-1969) and used the headings reclamation of land; beginning with September 1954 the additional heading of spoil banks was used.

In government publications the *Monthly Catalog of the United States Government Publications* (1945-June 1970) listed entries under reclamation of land. In the *List of U. S. Bureau of Mines Publications and Articles* the headings vary from strip mines—abandoned, vegetation studies, coal stripping costs—reclaiming land, coal mines, land rehabilitation to strip mines—land rehabilitation problems. From the Publications Distribution Branch, Bureau of Mines, *Reports of Investigations and Information Circulators* several entries were found while visiting at Salt Lake City. These were separate lists and no headings were used.

The *Dictionary Catalog of the National Agricultural Library 1862-1965*, v. 51 PUB - REF used the heading of reclamation of land. The *Library of Congress Catalog—Books: Subjects* gave the headings reclamation of land, alkali lands, and sand dunes. Citations are given to these references only for some may be difficult to obtain elsewhere.

Subject Guide to *Books in Print*, 1969, has a limited amount of materials under reclamation of land but not all could be considered.
The public catalog at the University of Denver library lists books for conservation under the subject heading of reclamation of land. A more thorough search of the catalog was not done there in 1967. Browsing in the classification 331.0973 and looking in specific books was more profitable. At New Mexico State University library the public catalog lists the subject headings of strip mining, strip mining—congresses, quarries and quarrying—congresses, hydraulic mining—congresses, botany—Pennsylvania, botany—ecology, mining engineering. Found in this library, the book by R. O. Whyte and J. W. B. Sissam, The Establishment of Vegetation on Industrial Waste Land has served to give early background information for this paper. The Index of Genera and Species given in the appendix should be of value.

Newspaper indexes used were: The New York Times Index (1945-1969) which referred the writer to reclamation, land, see coal, U.S. reclamation; Researchers Guide to Arizona News in the Arizona Republic (v.1, pt. 2, July-December, 1966) used the subject headings mining industry see also copper and copper industry; Index to Arizona News in the Arizona Daily Star, (1963-1965) referred the writer to copper, mining industry see also copper and copper industry. The librarian at the Arizona Daily Star has given assistance in searching to bring the references up-to-date.


In the work of coal mine reclamation in the United States the names of C. A. Limstroom from the Central States Forest Experiment Station, G. L. Lowry and F. H. Struthers from the Ohio Agricultural Experiment Station, W. C. Bramble from Pennsylvania Agricultural Experiment Station, and E. H. Tryon from West Virginia Agricultural Experiment Station are prominent. Foreign names and countries represented are how W. Knabe from Germany and L. Kroikowski in Poland.

In the work of gold mine reclamation work the names A. W. James and D. Chenik are outstanding.

For copper mine reclamation work the name of Karl C. Dean is leading the field today.

In the area of plant tolerance to salts the name of Leon Bernstein is prominent.
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