HISTORY OF RECLAMATION RESEARCH

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ABSTRACT

This paper considers the contributions of research to surface mine reclamation in the United States prior to the passage of Public Law 95-87 in 1977 as it influenced the author during the last 35 years. Investigations in geology, ecology, economics, forestry agronomy, recreation and wildlife were reviewed. Research studies were recorded as early as 1920, continuing into 1984, with highly sophisticated techniques. Research has led the way to better reclamation.

HISTORY OF RECLAMATION RESEARCH

Reclamation of surface mined lands is an art -- a practical application of research. The surface mining industry, through its conspicuous alterations of the landscape, has brought about considerable public condemnation which ultimately leads to legislation. This paper will review research contributions prior to passage of Public Law 95-87 in 1977.

In 1949, G.H. Walter[1] wrote, "It is of importance that stripped lands be returned to an economically sound and productive use after mining operations cease. In order to best serve all interested parties, considerable additional information and analyses must be obtained relative to the effects of coal stripping operations and the practicable uses for stripped lands." Walter was pleading for research and communications on a controversial subject -- surface mining and reclamation.

Similarly, H.D. Graham[2] in 1948 concluded that, "if spoil banks can be made productive, strip mining may well counteract the disfavor with which it is now regarded by many people. At the same time, society will gain from a more complete utilization of natural resources. Present evidence does not show a general, widespread success -- it shows, rather, that much has been done and much more can be done, and that, over a long period of time, the interests of the coal strippers and the agriculturists may not be

incompatible."

L.A. Holmes[3], geologist, reported in The Scientific Monthly in 1944, "By turning the spoil banks into forest, pasture, recreational areas, and game preserves, all of them may be used to advantage, and many will return a yearly profit to the owner equally as great as that produced by the land prior to mining".

A review of the early research literature was made by the author in 1947, in which over 35 references on surface mined land reclamation were found.

In 1953, Limstrom[4] published a bibliography on strip-mine reclamation, listing some 80 references. Subjects discussed in these early research efforts were geology, ecology, economics (especially agricultural economics), forestry and agronomy. In 1961 Bowden[5] published a bibliography containing references on geology, acid mine drainage, and the use of mined lands by wildlife in addition to those listed by Limstrom.

In 1958, Knabe[6] published a bibliography covering the European literature, particularly German journals. It also included papers from France, Great Britain, Austria, Poland, the Soviet Union, and Hungary, and provided useful cross-reference sections.

Research started early in the surface mining industry. One need only to review the several bibliographies on reclamation, dating back to 1918, to appreciate the vast

store of technological information available on reclamation. The Mined Land Reclamation Council of the National Coal Association[7] reported in October 1975 that over 700 technical papers and reports had been collected, indexed and abstracted.

ECOLOGY STUDIES

Since early surface mining, nature has demonstrated reclamation potentials. Ecological studies made in 1918 by W.D. McDougall[8], Botany Department, University of Illinois, discussed plant succession on an artifically bare area, a coal mine near Danville, Illinois. In 1928, W.C. Croxton[9], a student of Professor McDougall, published a paper proposing the reclamation of mined lands from the standpoint of natural revegetation.

West Virginia University Agricultural Experiment Station Bulletin 360[10], "Development of Vegetation on Century Old Iron-Ore Spoil Banks" published in 1953, reported on the development of vegetation on iron-ore surface mined lands, varying in age from 72 to 130 years. The results obtained by natural revegetation were of particular importance in helping to determine the future growth of trees and grasses on coal surface mined lands. Plant succession on Missouri surface mined lands, a study of natural revegetation, was reported by V.P. Leftwich[11] in 1974.

ECONOMICS

While surface mining is essentially a rural industry,

objections to this method of mining were made under the theory that taking land from agricultural use in order to obtain the underlying resource (primarily coal) was of interest from an economic viewpoint.

Economists who reported on the economics of reclamation in the early days of surface mining include O.E. Kiesling (1931) U.S. Bureau of Mines[12], C.L. Stewart (1939) Illinois[13], H.N. Hall (1940) Kansas[14], H.W. Hannah and B. Vandervliet (1939) Illinois[15], H.D. Graham (1948) Illinois[2], G.H. Water (1949) Illinois[1]. Problems or concerns studied were: Effect of land revaluations on County revenues, tax delinquency, and agricultural cropping value of lands affected by surface mining. Many of these reports discuss possible legislation or remedial action to control surface mining.

In 1914, Coal Age reported agitation against mining of coal by stripping[16]. Efforts were made in the State of Indiana to pass a law forbidding strip mining of coal. A reclamation law was passed in that state in 1941.

In Illinois there were 55 separate legislative actions concerning surface mining recorded during the period from 1929 to 1962[17]. At the Federal level, in 1940, Rep. E. Dirkson, Illinois, introduced H.R. 10079, a bill "to make the contour of the land approximately the same as before the mining operation was begun".

All major coal producing states had reclamation laws

prior to Federal Public Law 95-87.

A comparison of local income derived from surface mining and farming was reported by the Illinois Strip Mine Investigation Commission, 1942[18]. Reports in Illinois show that weighted average gross income of representative farms in 17 counties producing strip coal amounted to $19.23 per acre in 1940. The local income created by strip mines in 1940 was $9,191,676.00. The area mined in the creation of this local wealth or spending power amounted to 2250 acres; the amount of wealth produced was $4,085.00 per acre.

In comparison, therefore, the income derived from one acre of coal represents the entire gross income produced by farming an average acre of land 212 years; or, stated in other terms, the income from one acre of coal is the equivalent to that produced by 212 acres of farm land.

In a similar study by Graham[2] in Knox County, Illinois the income from one acre of coal represents the entire gross income produced by farming an average acre of land 155 years, and in Fulton County, Illinois 288 years. H.N. Hall[14] reported similar numbers in his studies in southeastern Kansas.

FORESTRY

Probably the first extensive attempt at reclaiming surface mined lands was in Illinois where trees were planted. Natural revegetation of trees had been observed and reported. J.P. Schavilje[19] reported that in 1920

six acres in Vermilion County were planted with 9000 trees, consisting of black locust, red pine, jack pine, Scotch pine, tulip poplar, black walnut, white ash, and black ash. Similar plantings were made in Indiana. In 1937 a series of formal tree planting studies on surface mined lands in Ohio was initiated by A.G. Chapman[20]. Paul Seastrom[21], a graduate of the University of Minnesota in Forestry, was hired by United Electric Coal Companies in 1942 to reclaim and use the companies mined lands.

In 1945 and 1946 the Central States Forest Experiment Station, Columbus, Ohio made a survey of the mined lands in the Central States Region, which was followed by forest planting experiments in 1947. These forest planting experiments supervised by A.G. Chapman[20], G.A. Limstrom[22], and others of Central States were made in Ohio, Indiana, Illinois, Kentucky, Missouri, Oklahoma and Kansas.

State Agricultural Experiment Stations also conducted research with trees on mined land. W.C. Bramble and colleagues[23] reported on experiments and observations in Pennsylvania. W.G. Jones[24], labeled "Johnny Appleseed" by Paul Harvey, in 1970 published a beautiful record of work in Pennsylvania, entitled The New Forest. Jones had started reclaiming mined land with trees as early as 1952 on his own land and advising other mining companies.

Knudsen and colleagues in Ohio[25], Merz in Kentucky [26], Nelson Rogers in Kansas[27] and Missouri[28] conducted

early research on reforestation. Freese reported on tree species for planting mined lands in Alabama. Later many acres were seeded by air using shortleaf pine and long leaf pine seed treated with rodent repellant.

Trade associations such as Ohio Reclamation Association (ORA), Kentucky Reclamation Association (KRA), still active today, and Midwest Coal Producers Institute, Inc., as examples, promoted the planting of trees and shrubs.

The Illinois Strip Mine Investigation Commission[18], 1942 reported that evidence introduced by the Illinois Department of Conservation shows that mining companies had been engaged in planting forest trees on mined lands since 1930. Through the period 1930 - 1942 inclusive, 7,028,400 trees were planted. More than 20 different species were used.

In the fall of 1961 the Central States Forest Experiment Station opened a project headquarters at Berea, Kentucky with a staff of six researchers headed by Mining Engineer Robert May[30]. The expertise of this staff, in addition to May, were a forester, range conservationist, hydrologist, soil scientist, and a civil engineer. The goals of this multi-talented group were (1) to develop methods for restoring strip mined lands to forest resource production and (2) to find practical ways to reduce and prevent damage to the surrounding forest resource during mining. Berea, still very active in research, dedicated a new laboratory

building in 1981. Some of the furniture in this new facility was specially made from cherry, walnut, and white oak trees planted in the 1930's on surface mined coal land. The time period necessary to grow a tree to maturity is the life span of man (3 score and 10). We are just now beginning to see some potential harvests.

Some of the finest hardwood plantings fostered by L.E. Sawyer[31], Indiana Coal Association, are today's living laboratories. "Our Reclamation Future with Trees" by W. Clark Ashby[32], et al, published in 1978, surveyed many of the early experimental tree plantings and mine companies' forests. In the survey, 13,236 trees were measured on 134 plots. Over 700 soil samples were analyzed. This report illustrates how research data was utilized in developing uses and techniques with emphasis on tree plantings.

RESEARCH WITH GRASSES AND LEGUMES

Records reveal that as early as 1920 a few small plots on a graded strip mine area in Vermilion County, Illinois had been seeded with agronomic species[32]. One of the earliest research studies with forage species was conducted in West Virginia and reported in Soil Science Society of American Proceedings[33] in 1945. This investigation was initiated in August, 1943. Its objectives included a study of the factors determining successful plant growth on spoil and the determination of the adaptability of various forage species for growth on such spoil.

The first recorded and sustained use of surface mined lands for pasture production in Illinois began in 1938, when a mining company in Fulton County, Illinois seeded a 300 acre area for pasture[34]. Undoubtedly, others seeing the volunteer forage species flourishing, sporadically grazed their cattle on the lands. Encouraged by these successes, large areas were seeded by coal companies to grasses and legumes in 1946. The varying and sometimes discouraging results obtained indicated that the successful development of pastures on the widely varying soil materials encountered was a problem for scientists in the field of agronomy and animal husbandry.

With research grants often made by the mining companies to the Agricultural Experiment Stations, studies were initiated in 1946 in Indiana[35] and in 1947 in Illinois[36]. The problems investigated were (1) physical, chemical, and biological characteristics of the varying soil materials, (2) species adaptation and productivity, and (3) utilization potential by livestock.

The emphasis was placed on the post mining soil materials, a heterogeneous mixture whose physical and chemical properties are determined by the geologic strata overlying the coal. The new rooting material in Illinois was found to be high in unweathered minerals containing phosphorus, potassium, calcium, and magnesium. Organic matter and nitrogen were low or entirely lacking. Often the soil

material lacked good tilth and structure. This was the ideal medium in which legumes, nitrogen fixers, could grow, accumulating nitrogen for grasses. Mixtures were seeded to be utilized by livestock.

Grasses and legumes were seeded on lands surface mined by the coal companies in Routt County, Colorado, on a voluntary agreement made with the Colorado Industrial Mining Development Boards as early as 1965, prior to the first Colorado Reclamation Act. Mixtures of introduced and native species were seeded. Alfalfa was the dominant species in both frequency and dry matter production (38). Because of the management problem with alfalfa, a non-bloat legume adaptation study was established at the Seneca Mine in Routt County in 1971. Other legume species seeded were Cicer milk-vetch, sanfoin, birdsfoot trefoil, and crown vetch. These plots are still available for study in 1984.

Because the returns from a livestock grazing program were relatively quick, the use of legumes and grasses attracted interest. Where soil material had the required fertility, many areas were seeded to forage species, significantly changing the land use after mining (39).

RESEARCH WITH CEREAL GRAINS--ROW CROPS

Interest in producing grain crops on mined land was high wherever the mined land was graded so that farm machinery could be used. Experimental plots seeded to rye, wheat, and corn were established on graded land in St. Clair County,

Illinois in 1948 (37). Yields comparable to county averages were obtained.

In 1952 a three year project followed the original five year project in Illinois. The emphasis was to investigate problems with graded mined land, such as compaction, drainage, organic matter content, and other physical properties. Results of these studies were published as Progress Reports in 1953 and 1955 (40 and 41). It appears that interest in this type of information and, thus funding, waned at that time. In retrospect, had this type of research continued, many of the questions raised as a result of Public Law 95-87 may have been answered.

Tests in Fulton county near Fiatt, Illinois from 1963 through 1965, to evaluate the effectiveness of Leonardite as a soil conditioner, contained check plots where fertilizer was applied to newly graded mined land (42). Corn and soybeans were the two crops used.

Three year wheat yields in Kansas (1972-74) on the research demonstration project sponsored by the Ozark region could be reclaimed to productive use were recorded (43).

It is interesting to note that cereal grains, winter wheat and barley, were seeded by the Montana State University projects directed by Hodder, in an effort to provide a sure, quick way of adding organic matter in the surface of the mined land to promote stability and increase available moisture (44).

Farmers in Illinois, Indiana, Pennsylvania and perhaps other areas were using graded land to grow row crops in the 1960's with varying success. Spindler cites case studies of row crop production in Fulton County, Illinois (45).

A five year intensive research project on row crop production by the University of Illinois Agronomy Department is sponsored by the Illinois Coal Industry. An in-depth study of several soil reconstruction principles for growth of row crops is reported (46). This project was initiated in 1977 and is being continued for another five years. The Iowa Coal Project began to study intensive row crop capabilities in 1979 (47). They report profitable production of crops in some rotations.

HYDROLOGY RESEARCH

As noted earlier one research scientist on the Berea staff in 1961 was a hydrologist, Willie Curtis, who recognized the importance of erosion and sedimentation in surface mine reclamation (30).

Acid mine drainage has been a major problem of the coal industry. Volumes of research findings are available in the literature. However, creation of good quality water areas, where none was before, has been an ameliorating by-product of the surface mining process (48). Surface mine lakes positively affect the storage capacity and water yields of the mined land (49). Spoil resulting from surface mining

does produce significant amounts of flow during severe drought periods, as compared to little or no flow from unmined areas. Peak watershed discharges are reduced and retarded. The "cast overburden" spoil is a massive man-made ground water acquifer, Corbett reports.

Hydrology research was initiated at the Big Sky Mine, Montana in 1969, by Montana State University (50) and expanded by Van Voast, Montana Bureau of Mines in 1970 (51). The hydrology of a final pit water impoundment was evaluated for four years by Montana State University. Montana reclamation regulations of 1972 discouraged water impoundments, therefore special agreements were made to retain a final pit in order to obtain data on the feasibility of such impoundments. It was concluded that the impoundment water is suitable for its intended uses--livestock water, irrigation, and fish production. There appears to be no progressive degradation of water quality (52).

Hydrology research was conducted in Arizona by the University of Arizona under John Thames et al. Erosion and siltation studies on graded mined land, and with topsoil replaced, as well as subsurface water phenomenon were studied (53). One of the interesting projects in Arizona was the water harvesting experiment at the Black Mesa Mine. In this water harvesting project vegetable crops and orchards were planted. The mined lands were graded to catch and direct rainfall to catchment ponds from which it was pumped to the

growing crops as needed. Vegetable crops have been produced and used by the Navajo people. The immediate supervision of the project was by the Kayenta Vocational Agriculture instructor.

Irrigation studies using sprinkle irrigation and drip irrigation for the establishment of permanent vegetation have been conducted in the arid Arizona and New Mexico mining area (54).

In these instances, industry again requested this type of research. The results of this research should alleviate the concerns of those who fear poor (bad) water quality and provide incentives to permit water impoundments in an arid environment (52).

RESEARCH FOR RECREATION

Revegetated surface mined lands with water impoundments are appropriate for a wide variety of recreational uses. Fishing, boating, camping, hunting, hiking, horseback riding, and picnicking are the most popular activities. The presence of good water in lakes and ponds, formed as a result of early mining, is the primary drawing card for recreational activities.

Surface mined lands in Illinois were first used for organized recreational pursuits in 1928, when the Pollywogs Club, the grand-daddy of all mined land recreational areas, was organized near Danville for fishing and boating (55).

In 1940 Yeager reported on wildlife management on land

mined for coal and revegetated naturally (56). The value of mined lands for furbearing mammals was reported. In 1946-47, Riley, Kent State University, in Ohio, intensively studied a reclaimed area that was mined in the early 1920's (57). The mined area studied was compared to cropland, forestland and abandoned farmland. Data resulting from these studies indicated a greater wildlife population on the reclaimed areas than on the other adjacent land use units. The reasons for this, according to Riley's research, was that diversified cover, food and water were readily available on the reclaimed area.

The Cooperative Wildlife Research Laboratory, Carbondale, Illinois under the direction of Klimstra has been conducting research on recreational and wildlife management on mined lands since the early 1950's. This organization did intensive research on the Pyatts Research Area in Perry County, Illinois since 1954. The project included studies "to evaluate various methods of manipulating food and cover plantings for the improvement of wildlife habitat and to determine the responses of sportsmen to an unrestricted strip mine hunting and fishing area" (58).

In 1955 Knox College, Galesburg, Illinois establsihed a field laboratory called Green Oaks on mined lands. Knox scientists have restored parts of the original Illinois prairie and returned some of the original animals to the area. The purpose of the station is research, learning how

life relates to land (59).

Lewis, Bulow and others at Southern Illinois University, Carbondale, Illinois have conducted research on surface mine impoundments for the production of fish. One study reported on the suitability of the impoundments for producing marketable channel catfish (60).

The ability of most impoundments on mined land to provide good fishing is reported by Lopinot (61). In 1963, of the 25 largest fish of different species taken in Illinois by hook and line from all lakes and ponds, six species (24%) were caught in mined land waters. The species included bluegill (1963), channel catfish (1963), yellow perch (1951), northern pike (1952), brown trout (1952), and sauger (1963). Needless to say, the demand for fishing these waters is high.

It would be remiss in this historical review to omit the applied research project instigated by the Illinois Conservation Department with the Giant Canada goose. This subspecies of the giant Canada goose was stocked in the strip mine areas of Fulton, Knox, and Peoria counties in 1968. The waterfowl biologist consider the mined areas with thousands of lakes and ponds ideally suited for nesting grounds. Since the proper habitat and protection are provided the geese do nest and produce in the area. Hunting was permitted for the first time in 1982, completing a successful project.

SUMMARY

The need for research on surface mined lands was evident due to public condemnation and paucity of information. Many early mining officials, in attempting to revegetate the mined land, suffered varying and sometimes discouraging results. Basic and applied research in many areas were needed.

The earliest published bibliography by Limstrom in 1953 listed some 80 technical references (4). During the following three decades a tremendous variety of research literature has been published. In 1974 a selected bibliography of Surface Mining and Mined Land Reclamation was published by the Old West Regional Commission of Washington, D.C. (62). This bibliography was an effort to select material that was applicable to mining and reclamation problems in the Great Plains at a time when surface mining was expanding there. The 1337 citations listed were available to the researcher in 1974, prior to Public Law 95-87.

An annotated Bibliography of Illinois Mined Lands -- characterization, utilization, reclamation was published in 1974 (63). This lists 270 reports pertaining to the reclamation of Illinois mined lands, three times more for one state than was available for all states when Limstrom published his first bibliography in 1953.

Argonne National Laboratory has compiled "A Selective Bibliography of Surface Coal Mining and Reclamation Litera-

ture", published in three volumes. Volume 1--Eastern Coal Province (64), Volume 2--Interior Coal Province (65), and Volume 3--Western Coal Provinces (66). Over 3600 references are listed, including government reports, journal articles, symposium proceedings, industrial reports, work shop proceedings, theses and bibliographies. Articles cited were organized in 21 major categories. Citations that qualify for listing in more than one category were reported in full within each appropriate category.

During the past three decades the number of articles and reports written about surface mining and reclamation is very large and is increasing rapidly. The problem now becomes one of avoiding unnecessary duplication and frivolity, conserving cost to society. Essential research must be carried on in an expedient and timely manner.

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