ANL/LRP-CP-3
Conf-771260--2

ABANDONED COAL MINE REFUSE AREAS:
THEIR RECLAMATION AND USE

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prepared for

Meeting of the
American Society of Agricultural Engineers
Palmer House Hotel
Chicago, IL
December 13-16, 1977

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ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Operated under Contract W-31-109-Eng-38 for the
U. S. DEPARTMENT OF ENERGY

ABANDONED COAL MINE REFUSE AREAS: THEIR RECLAMATION AND USE

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Abstract

There are over 4,000 abandoned deep coal mine refuse areas in Illinois ranging in size from a few acres to as large as 160 acres. These sites produce quantities of pollutants which affect the environment, have no real land value,and are a scar on the landscape. The Staunton 1 Site Reclamation Demonstration Project addresses these problems. It also is developing and evaluating new cost effective methods for reclaiming refuse areas of this type. This program involved determining the final land use for the site, development of detailed engineering plans and specifications for the reclamation effort, a prereclamation environmental inventory, and the implementation of the engineering design. Post-construction evaluation is now in process to determine the effectiveness of the reclamation effort.

Detailed investigations are being conducted to determine surface water quality improvement, the amount of suitable surface cover and amendments required for revegetation, and field evaluation of candidate vegetation species for revegetation. Other research is examining soil microbial populations, soil fauna reactions, and changes in surface material characteristics at the reclamation site. Surveys are being conducted on groundwater quality, affects on the aquatic ecosystem,and wildlife use of the area. An economic evaluation is underway to determine the cost effectiveness of the total effort and individual reclamation procedures.

Preliminary results from the first year's environmental evaluation of various methods tested will be described in detail. An economic assessment, including cost effectiveness, of the first year's work is given.

*This project was funded by the following agencies: Abandoned Mined Land Reclamation Council, State of Illinois Contract No. 31-109-38-3694L; Illinois Institute for Environmental Quality, Contract No. 31-109-38-3694L; U.S. Energy Research and Development Administration, Contract No. 31-109-Eng-38.

Abandoned Coal Mine Refuse Areas: Their Reclamation and Use

The first written record of coal in the United States was made by the French explorers Marquette and Joliet in 1679 when they reported a "cole mine" near the Illinois River. The first actual usage was recorded when a settler in Virginia was granted permission to use coal for his forge in 1702. There are records of a commercial coal mine in the James River coalfield near Richmond, Virginia starting in 1750. Coal from this mine was sold for local use and shipped to Philadelphia, New York, and Boston.

Due to the large tracts of forest to supply fuel in the New World, the coal mining industry grew very slowly. However, in 1840, coal surpassed wood as fuel for the first time. The development of railroads, steel mills, and other fuel consuming industrites made coal mining increasingly important. As industrial development after the Civil War continued, coal consumption increased with the largest increase reported in the decade from 1900 to 1910 (Cassidy, 1973).

Early mines were at coal outcrops or where the seams were near to the surface. Coal was hewed from the bed, selected by hand without processing, and delivered to the consumer. These mining operations produced a minimum of refuse (waste coal and other debris) on the land surface. As demand for coal increased older drift mines were expanded and new mines opened requiring shaft or slope entrances to reach the deeper coal deposits. The use of cutting machines, drills, and mechanical loaders augmented coal production, but reduced the amount of coal selection underground. Continuous miners came into use around 1945 and again increased the volume of unusable material brought to the surface. The demand for cleaner fuels also dictated additional coal cleaning. All of these factors increased the total volume of refuse material deposited on the land surface due to coal extraction and cleaning.

Coal preparation plants produce two major types of refuse material: gob and slurry. The relatively large sized dry material consisting of rock, "hard" or "pyrite coal", and other waste is referred to as gob. In the past, gob, along with the rock and unconsolidated material from access shafts, was generally piled near the mine mouth. Gob piles range in size from a few acres to mountainous heaps covering many acres and containing millions of cubic yards of refuse. Their topography varies from low mounds to high, steep-sided cones.

Slurry consists of coal fines, sand, silt, and clay resulting from the wet processing of coal. Jigging, froth flotation, and dense medium separation, which all became popular during the 1920's and 1930's, produced large volumes of watery waste. In many cases dikes of gob were constructed to contain the slurry material. In rolling country, dams were constructed across ravines and created deep impoundments. Slurry areas are usually flat and almost level due to the deposition of the material by water.

Current information indicates 9,183 ha (22,675 ac) in Illinois have been identified as problem areas associated with coal extraction and cleaning. Almost 40%, or 3,655 ha (9,025 ac) of this total area is exposed coal refuse (Nawrot and Klimstra, 1977). In Indiana 149 major unreclaimed coal refuse sites occupy approximately 1,714 ha (4,230 ac) (Wobber, et al., 1974). The U.S. Bureau of Mines estimate that 69,425 ha (171,420 ac) of land have been used between 1940 and 1971 for the disposal of coal mining and processing wastes which have not been reclaimed (Paone, et al., 1974). Disposal of refuse from coal mining and cleaning, when viewed from a national standpoint, represents a significant land area.

Increased recognition and concern of health, safety, and environmental problems associated with coal refuse material have prompted both state and federal regulations. For example, Illinois enacted its first legislation regarding lands affected by coal mining and cleaning in 1962. This act, with subsequent amendments, requires that all toxic waste including mine refuse, be neutralized or buried under 1.2 m (4 ft) of suitable material. However, the Illinois legislation does not require the reclamation of lands disturbed by coal mining or processing before 1 January, 1962. This case is the rule and not the exception. A recent publication, summarizing state reclamation programs, indicates most states have legislation providing for the reclamation of lands affected by coal mining (Imhoff, et al., 1976). Provisions are made for the disposal of waste from active mines, but no state requires reclamation of lands affected by mining and waste disposal before enactment of their legislation. Additional federal and state laws govern off-site effects from refuse areas, but none address the problem created by past mining and processing operations. It is these lands which are commonly referred to as abandoned coal refuse areas.

The problems posed by abandoned coal refuse areas are the production and dissemination of pollutants into the environment, their non-productive state, and their general unappealing aspect. Before coal is mined, it and its associated waste materials are in equilibrium with the environment. When refuse is deposited on the land surface, an equilibrium must be established with the new environment. The production of acidic materials, acid runoff waters and sediments are all symptoms of this readjustment. The natural processes which accomplish this readjustment are very slow. Conceivably, it could take hundreds of years to reclaim an abandoned coal refuse site by natural process and adjacent environments would be adversely affected during the readjustment time.

Environmental problems created by coal refuse areas are numerous. Pyritic material in the refuse is oxidized and, when coming in contact with precipitation, form strong acids. Water, with low pH and high concentrations of sulfate and heavy metals, may enter the local groundwater system (Schubert, et al., 1977). Acidic runoff water downgrade the quality of surface water in the area and the aquatic environment deteriorates. Surface material become acidic and create unfavorable conditions for vegetation establishment and growth. Without a protective plant cover, refuse material is easily eroded and resultant sediment is carried into the surrounding environment. Erosion also exposes new pyrite for oxidation and the cycle is continued.

Abandoned refuse areas in an unreclaimed state have no real land use or potential economic value. Often these sites become unauthorized dumps which create additional public safety hazards. Generally, refuse areas are not aesthetically pleasing and the addition of cast-off materials do not improve their appearance. These factors, when coupled with the environmental status of the refuse area, have a tendency to create a depressed economic market for adjacent properties.

The primary goals of all reclamation projects are to: 1) reduce the quantity of pollutants entering the environment, 2) increase the economic potential of the area, and 3) improve the aesthetics of the locality. With these goals in mind, two state agencies -- the Abandoned Mined Land Reclamation Council of Illinois and the Illinois Institute of Environmental Quality -- and the U.S. Energy Research and Development Administration, now a part of the U.S. Department of Energy, through the Land Reclamation Program (LRP) at

Argonne National Laboratory (ANL) developed a cooperative reclamation demonstration program. A fourth goal was established for the cooperative effort -- develop, demonstrate, and evaluate methods and technologies of reclaiming abandoned coal refuse areas to have the greatest benefit at the lowest cost. The program was initiated with the Staunton 1 Reclamation Demonstration Project.

The project has been divided into the following phases:

Phase I	Planning and Design
Phase II	Baseline Monitoring
Phase III	Site Development
Phase IV	Post-Construction Evaluation

The first task in Phase I of the project was the selection of a typical abandoned coal refuse area as a research site. During the last half of 1975, the LRP staff conducted a study to determine the location, history, and current status of abandoned refuse sites in Macoupin County, Illinois. Attention was given to this area of the state because of poor water quality in Cahokia Creek (Blakeslee, 1967). Communities of the area were also interested in developing an additional source of water for recreational, industrial, and domestic use (Hensy, Meisenheimer, and Gende, Inc., 1971). Argonne researchers identified 29 abandoned deep coal mine refuse sites within the general area. Many of the sites exhibited similar characteristics: 1) lack of vegetative cover (even after 20 to 50 years), 2) highly eroded refuse piles, 3) no economic use of the land, and 4) acid runoff and sediments affecting the useage and value of adjacent properties. With the general project goals in mind, the LRP staff developed a set of site selection criteria. After much discussion, the abandoned Consolidated Coal Company Mine No. 14 (Staunton 1 Site) was chosen.

The abandoned Consolidated Coal Company Mine No. 14, located at the northwest corner of the town of Staunton, was typical of abandoned refuse sites in southwestern Illinois. The mine was opened in 1904 and operated for 17 years. The Herrin (No. 6) coal seam was mined approximately 85 m (280 ft) below the surface. An average work force of over 500 men extracted as much as 4,536 t (5,000 tons) of high (5%) sulfur coal per day from the mine. A coal washing plant, the first in the area, cleaned all the coal produced at the mine.

The total site includes about 13.8 ha (34 ac) of which approximately 9.3 ha (23 ac) required reclamation. The most imposing evidence of the post-mining and cleaning operation at the site was the gob pile. The heap extended about 25 m (80 ft) above the natural landscape and covered approximately 1.8 ha (4.5 ac). The pile was steep-sided and erosion had cut deep gullies into its face. No vegetation had become established on the gob or in adjacent areas affected by the acid runoff and sediment in the 50 odd years the mine had been closed. A 55 m (175 ft) concrete smoke stack, for the mine's electrical plant, was still standing, but only the foundation of the other mine structures remained. The rails from the siding which serviced the mine had been removed, but the right-of-way was still very evident along the southern boundary of the property. The gob pile, site of the old cleaning plant, tipple, and rail yard occupied about one half or 4.8 ha (12 ac) of the total site.

Before the mine was opened, a dam was constructed near the north boundary of the site across a deep ravine. The impoundment created by the dam provided water for the mine's power plant, the coal washing operation, and served as a sump for the slurry produced by the coal washer. All drainage from the site was into this impoundment and, after the mine was closed, the area continued to fill with sediment eroded from the gob pile. This refuse material reached a maximum depth of 9 m (30 ft) and, due to its acidic nature, prevented vegetation from becoming established. About 35 years ago, the dam was breached resulting in erosion of the old slurry area with gullies as deep as 4.5 m (15 ft). Acidic runoff and sediment was carried down a stream bed to Cahokia Creek about .8 km (.5 mi) to the northwest. The area of the old slurry pond was about 4.5 ha (11 ac).

The entire site was littered with tin cans, broken glass, waste building materials, and discarded household goods. From all outward appearances, the site had been used as a general dump for many years. There was evidence that small game used the remaining 4.5 ha (11 ac) of the site which was covered with volunteer shrubs, grasses and trees. It was also evident the site had been used by off-road vehicles and as a target range by hunters.

After the site had been selected, the next task was to determine the final land use for the site. Any future land use was limited by the physical properties and chemical characteristics of the refuse material. It would be important to establish and maintain a protective cover of vegetation to prevent erosion and reduce runoff. Use of the site which would disturb the area would be discouraged.

The Macoupin County Board of Supervisors, officials of Staunton, and the West-Central Illinois Valley Planning Commission were consulted and the needs of the community discussed. An ideal use of the site would be an extension of the existing industrial development adjoining the site. An improved road and a major rail line were nearby and the industrial site would complement the economic base of Staunton. The factors which made the site ideal as an industrial park made it less attractive as a residential development. However, an investigation by an independent soil engineering firm determined both of these future land uses were impractical (Zimmerman, 1976).

Further investigations determined that the community had need for additional recreational areas. This use would be compatible with the restricted use of the site because of the nature of the refuse material. Types of recreational activities could be limited to maintain the stability of the area. The site was large and other complementary uses could be made of various other parts of the site. Therefore, it was determined the site would be developed as a combined recreational, wildlife, and ecological education area.

Detailed engineering plans and specifications were developed to meet the proposed final land uses. The general plans included: disposal of debris and man-made structures, recontouring the area, the construction of a small pond, and the reconstruction of the old dam with adequate water flow control structures. Following the recontouring of the refuse material, a heavy application of agricultural limestone would be made to neutralize the acidic refuse. These areas would then be covered with a minimum of 0.3 m (1 ft) of cover material which would be obtained on site, as not to disturb adjacent areas. A seedbed would be prepared with the addition of lime and fertilizer and all disturbed areas of the site seeded with a mixture of grasses and legumes. Trees and other desirable vegetation on unaffected areas of the site would not be destroyed.

Baseline Monitoring, Phase II, was instituted to assess the pre-reclamation environmental conditions of the area. A number of shallow wells were drilled and the groundwater analyzed to establish its quality. Samples from the saturated slurry area and from the glacial till near the refuse pile had low pH and high concentrations of sulfate, alkaline earths, and heavy metals.

Other groundwater samples, collected from wells over 91 m (300 ft) from the refuse pile, did not have these leachate constituents. Samples from residential wells of the area were found to contain primarily calcium, magnesium, carbonates, and sulfates, but appeared to be unaffected by the refuse leachate (Schubert, et al., 1977).

Samples, from surface water flows at the site were collected starting in the spring of 1976. Generally, the pH of these samples is low with high concentrations of sulfate, iron, zinc, and cadmium. Table 1 shows the analysis of four typical collections.

Table 1. Preconstruction Staunton 1 Surface Water Quality

Parameter	Concentrations in mg/l (except pH)			
Date	4/15/76	5/13/76	10/15/76	10/22/76
pH	3.9	3.4	2.6	3.1
Acidity	3596	4092	6300	3825
$SO_4^=$	7095	9058	7000	4800
Al	498	607	527	143
Fe	1450	1510	1175	879
Mg	31	20	45	21
Zn	75	71	0.097	41
Cd	0.59	0.66	0.90	0.28
Cu	0.49	0.37	0.47	0.09

Collections of surface material, to a depth of 1.2 m (4 ft), were made from three distinct areas -- slurry pond, gob pile, and adjacent farm field. The availability of various plant nutrients and the suitability of these materials for plant growth were determined by standard agricultural soil analyses. Soil pH, in water, from all areas was extremely low and the field soil was generally low in all available plant nutrients. Both types of refuse material were high in soluble salts and had excessive amounts of zinc and boron which may have interfered with plant establishment growth. Average values for groups of samples collected in June, 1976 are listed in Table 2.

Table 2. Staunton 1 Surface Material Chemical Analysis, June 1976

Sample[a]	pH	Soluble Salts (mhos/cm X 10^{-5})	mg/l							
			P	K	Ca	Mg	B	Mn	Zn	SO_4-S
Field	4.0	20	36	156	383	100	1.8	44.8	8.1	214
Slurry	2.2	235	236	76	1870	100	35.5	5.6	53	3412
Gob	2.2	354	52	103	9758	1680	21.5	7.7	156	8733

[a]Sample averages

Bulk density measurements were made on both gob and slurry material. The average value for the gob area was 0.93 kg/m^3 and 0.88 kg/m^3 for the slurry. Particle size distributions made on all refuse samples indicated there was a general lack of material larger than 25 m (1 in). This was probably due to the coal cleaning process, and not weathering, because this general size distribution was observed throughout the refuse material during the recontouring operation.

Additional surface samples from the site were collected and analyzed for soil microbes. It was observed that both gob and slurry samples had soil microorganisms present, but their total number and the types present were greatly reduced. Soil samples from a nearby farm field did have both the total numbers and types of microbes normally found in cultivated agricultural conditions (Cameron and Miller, 1977).

Refuse material was transported to the ANL facilities where extensive studies were conducted in growth chambers to evaluate various types and amounts of soil amendments which could be used in the reclamation effort. A number of plant species were also appraised for germination and early growth in amended gob and slurry (Dvorak, et. al., 1977a). Results from these investigations were used to determine soil amendment types and levels and vegetation species to be planted on the site.

Detailed engineering plans and specifications for site development or construction phase of the project were completed during the spring and summer of 1976. The resources of the Illinois Department of Transportation were utilized to obtain bids for the site development work. Title to the property was acquired by the State of Illinois and construction contract was awarded to Marle, Inc. of Springfield, Illinois, the low bidder, on September 15, 1976.

Phase III, Site Development, began with the removal of the smoke stack, mine structural foundations, and the disposal of accumulated debris. The borrow pit was opened and suitable cover material removed and stockpiled. Within six weeks, rough grading had reduced the gob pile to approximately one-third its original height. During the rough grading of the slurry area, the contractor experienced problems moving equipment over the saturated slurry material. Dewatering of the slurry was attempted by using drainage channels and by pumping with little success. Due to the difficulties encountered, the location of the pond was changed. An area was selected so the base of the pond would be in the till material rather than in saturated slurry material. A substitution of 'Code L Alkali'* was made for the ground agricultural limestone to be used in the slurry area. This material was chosen because of its capacity to stabilize as well as neutralize the acidic, saturated slurry material. As work progressed on the construction of the pond, the Staunton area experienced its severest winter on record. Above normal amounts of snowfall and the extreme cold weather slowed progress on the project. Excavation of the pond, reconstruction of the old dam with water flow control structure, and grading of the gob pile were all delayed due to the uncommon winter weather. Construction activities ground to a halt for two weeks in February.

Rough grading of the site was nearly completed when construction activities resumed and the application of neutralizing materials at the refuse/suitable cover interface began. Ground agricultural limestone was applied at the rate of 220 t/ha (98 tons/ac) on the gob area and 'Code L Alkali' at 153.8 t/ha (68.6 tons/ac) on the slurry area. These neutralizing agents were incorporated to a minimum depth of 15 cm (6 in.) into the surface of the recontoured refuse materials. A layer of 0.3 m (1 ft) of suitable cover material was then placed on the regraded refuse material.

By mid-April, all refuse material had been covered with suitable cover material. An application of 11.2 t/ha (5 tons/ac) of agricultural limestone and 135 kg/ha (120 lbs/ac) each of nitrogen, phosphorus, and potassium plant nutrients were made to the reclaimed area. These amendments were disked in to a minimum depth of 10 cm (4 in.) and a seedbed prepared. The area was then

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*A mixture of calcium oxide and calcium carbonate available from the Mississippi Lime Company. Use of the product does NOT imply endorsement by fundings agencies.

planted using an agricultural grain drill. The seed mixture included: Reed canarygrass (*Phalaris arundinacea* L.), 11.2 kg/ha (10 lbs/ac); Tall fescue (*Festuca arundinacea* Schreb.), Kentucky 31, 16.8 kg/ha (15 lbs/ac); Birdsfoot Trefoil (*Lotus corniculatus,* L.), 13.4 kg/ha (12 lbs/ac); Ladino Clover (*Trifolium repens* L.), 5.6 kg/ha (5 lbs/ac); and cereal rye (*Secale cereale* L.), 'Balboa', 22.4 kg/ha (20 lbs/ac). Seeding and fencing of the site perimeter were completed the last week in April. Minor hand work and final clean-up was accomplished on April 29, 1977, the day the construction contractor left the site.

During the construction phase of the project, the following tasks were accomplished: approximately 179,670 m^3 (235,000 yd^3) of refuse material were relocated; 1,279 t (1,410 tons) of neutralizing agents applied to 7.3 ha (18 ac) of refuse; about 30,582 m^3 (40,000 yd^3) of suitable cover material were extracted from a borrow pit and placed over recontoured refuse; 99 m (325 ft) of culvert pipe and three concrete water flow control structures installed; 101.6 t (112 tons) of soil amendments were incorporated into the surface of 9.3 ha (23 ac) which were then seeded; and 6,718 m (7,350 ft) of new fence was constructed. A final inspection was made of the site development work by representatives of the funding agencies on May 25, 1977. This event was attended by local and state officials, interested parties, and various media personnel.

Phase IV, Post-Construction Evaluation, began on April 30, 1977. The objectives of this phase are: 1) to provide an overall assessment of the reclamation effort to determine its environmental effectiveness; 2) to develop, demonstrate and evaluate needed technologies for future reclamation efforts; 3) to investigate and ameliorate potential environmental problems which may develop at the site; and 4) to provide the economic assessment necessary to transfer the most cost-effective reclamation techniques to future projects. These objectives are being met by the establishment and maintenance of a number of interrelated demonstration projects. Each project is examining a specific portion of the reclamation effort, and the combination of information from each individual investigation will provide the overall assessment of the reclamation effort. At the present time, research projects have been established at the site and almost six months of data have been collected, but only limited analyses of the data have been completed.

Thirty-two new monitoring wells were drilled in the study area during the summer. Twenty-three of the wells are into the recontoured gob or the underlying till, six are in the slurry area and the remaining three in till surrounded by slurry material. The wells range in depth from 5 m (5.5 ft) to 27.4 m (30 ft). Water levels and water quality sampling will begin later this winter.

By present indications the quality of surface water at the site has substantially improved relative to preconstruction conditions. Acidity, sulfate, and heavy metal concentrations have decreased and pH has increased. Surface water analyses from five post-construction collections are listed in Table 3.

Table 3. Post-Construction Staunton 1 Surface Water Quality

	Concentration in mg/l (except pH)				
Parameter	4/15/77	5/11/77	6/16/77	7/14/77	8/16/77
pH	4.0	4.1	4.2	7.2	8.4
Acidity	156	228	222	6.3	0
$SO_4^{=}$	1275	1200	1600	788	500
Al	58.7	51.8	42.4	1.02	.60
Fe	10.0	.71	1.46	.74	.08
Mg	7.93	8.5	10.6	3.89	.64
Zn	12.6	11.3	10.9	.31	.02
Cd	.24	.20	.22	.02	< .01
Cu	< .05	< .05	< .05	< .05	< .05

The aquatic ecosystem in the newly created pond on the site and in Cahokia Creek have been sampled three times during the summer of 1977. Many samples are still unprocessed, but limited information indicates the new pond is showing signs of developing a stable and diverse invertebrate community. Data from the creek samples indicate the impacts from the site drainage are probably too sutble to be factored from the overriding influence of other unreclaimed refuse piles within the watershed.

A site-wide vegetation evaluation was initiated. Five study plots, representing four micro-climates found on the site, were selected. Plots A and B are on south and north facing slopes, respectively, Plots C and E are on a nearly level, poorly drained area and Plot D is on a well drained, gentle slope. A number of replicated subplots were marked within each plot and measurements were taken from each. A point-frame method was used to estimate the percentage of plant cover and individual seeded species and invaders were identified. Data from the July 1, 1977 observations are recorded in Table 4. From the preliminary data, differences can be noted, however, additional data are needed before definite trends can be established. Additional observations were made during the growing season, but at this time the data have not been processed.

Table 4. Staunton 1 Vegetation Study, July 1977

	Percent Cover[a]				
Species	Plot A	Plot B	Plot C	Plot D	Plot E
Cereal Rye	9.9	22.6	50.7	26.5	30.0
Reed Canarygrass	1.9	0.8	9.1	2.5	0.7
Tall Fescue	0.2	0.0	5.9	2.4	3.4
Birdsfoot Trefoil	0.2	1.6	2.5	2.2	1.6
Ladino Clover	0.0	0.0	3.9	1.3	0.2
Invading Monocot	11.1	0.1	3.6	5.9	0.2
Invading Dicot	2.3	0.0	8.5	4.7	0.2
Total Percent Cover[b]	23.5	24.8	70.7	37.8	34.1

[a]Average of 20 replications.

[b]Multiple hits with a single pin counted as a single hit; maximum total percentage cover equals 100.

The revegetation research area at the site was established to determine cost-effective means of achieving long-term vegetation success on highly acidic (pH < 3.0) refuse material. The three major parameters being evaluated in this study are depth of suitable cover material, liming rates, and plant species. Replicated plots 21.3 m x 21.3 m (70 ft x 70 ft) were constructed for each of eight treatments. Four suitable cover depths, 0 cm, 15 cm (6 in.), 30 cm (12 in.), and 61 cm (24 in.) and two liming rates, 112 t/ha (50 tons/ac) and 224 t/ha (100 tons/ac), are being evaluated. A total of seven species of grasses and legumes were seeded on the plots. Germination rates, plant density, plant cover and biomass were determined for each treatment. Space does not permit the detailed discussion of all treatments (Dvorak, et al., 1977b). However, it can be reported that the 0 cm (bare refuse) cover depth treatment was ineffective in establishing any plant species. This may have been due to dry conditions following seeding last spring. This study will be continued for the next four growing seasons.

The relationship of slope angle and depth of suitable cover material to erosion rate and runoff water quality is being examined. Three slopes, 3:1, 5:1, and 7:1, and three cover depths, 0 cm, 15 cm (6 in.), and 30 cm (12 in.), are being compared. Preliminary data indicates differences do exist between the steepest slope and the other two slopes tested. Runoff volumes were also higher on slopes with no cover material. However, this may be due to the general lack of vegetation on these slopes. Complete analyses of all data, including runoff water quality, are not available at this time.

Soil samples have been collected from the site. Limited results from these analyses indicate the physical properties and chemical characteristics of the cover material have not changed appreciably over the relatively short time they have been in place. These tests also suggest that additional application of lime and fertilizer will not be needed for the coming growing season.

Soil microbial populations and communities involved with plant nutrient transformation and availability are being monitored. Data from samples collected at the site this year are somewhat puzzling. Mycorrhizae which normally infect grasses were not present on planted species, but were found to be associated with some of the invader species which are "not supposed" to be infected. Another puzzle from the site was that larger numbers of species were found in samples from the cover material than in samples from undisturbed areas. Additional research and data analyses are needed in this area to solve these mysteries.

An experiment was conducted to determine the survival rate of earthworms in the newly created soil environment. Three enclosures were constructed and installed in the recontoured and covered refuse material. The enclosures contain approximately 1 m^3 (1.3 yd^3) of soil and refuse and had perforated walls to permit normal water movements through the material. A known number of worms were introduced into each enclosure in early June. In late September, the containers were excavated, but attempts to locate the worms were fruitless. The non-survival of the worms may have been due to an extended dry period in June and a general lack of plant cover in the enclosures. Additional experiments of this type are being planned for the coming year.

Wildlife inventories have been made at the site on a monthly basis starting in mid-May of 1977. Frogs were observed in the new pond at that time and a reproducing population was present by the late summer. Insects of a number of species have been regularly trapped on the reclaimed area. Live traps have recorded the presence of small rodents (prairie deer mice, white-footed mice, and meadow voles) on the recontoured area. Various species of birds also frequent the site and cottontail rabbits are a usual sight. Recently, a muskrat was observed in the newly created pond and numerous signs of white-tailed deer are present on the site.

The economic evaluation of reclamation efforts are usually difficult. It is relatively simple to add the cost of land acquisition, development of plans and specifications, actual construction and resident engineering to determine the total expenditures for any one project. This total cost can be divided by a convenient unit, acres reclaimed or yd^3 of refuse, to calculate the average unit cost of reclamation. The other factors within the equation, the benefits, are much more difficult to assess. The dollar value of an improved environment or a more appealing landscape is impossible to estimate. Replacement or treatment cost are often calculated to supply the missing factors. This, too, can be misleading because of unknown or untested data.

Other economic evaluations can be made by comparing pre-reclamation property values, tax rates, or economic growth of the area with post-reclamation values. It is the opinion of residents of the Staunton area that the market value of adjacent properties have doubled resulting from the reclamation effort. This theory is untested, because only one small property has been sold in the area after the completion of the effort. Additional data, available in time, will prove if this theory is correct.

The cost effectiveness of various treatments are somewhat easier to establish. Preliminary data indicate refuse material must be covered to establish plant growth. The cost associated with the placement of suitable cover material on refuse can be calculated. Therefore, the effectiveness of this treatment can be associated with a dollar value. The same observation can be made for the slope angle and runoff water quality research. Cost data for the various methods or treatments are available. Additional data, collected over time, will determine the effectiveness of each method tested at the Staunton 1 Reclamation Demonstration project site.

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