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STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT

PROGRESS REPORT FOR 1977

LAND RECLAMATION PROGRAM

ARGONNE NATIONAL LABORATORY

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Land Reclamation Program
Argonne National Laboratory
Argonne, Illinois 60439

STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT
PROGRESS REPORT FOR 1977

Stanley D. Zellmer
Site Coordinator

December 1978

The Land Reclamation Program is a joint effort of the Energy and Environmental Systems Division and the Environmental Impact Studies Division at Argonne National Laboratory.

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PREFACE

This study was performed as a part of the Argonne National Laboratory Land Reclamation Program, which is sponsored by the Department of Energy, Assistant Secretary for Environment, Office of Health and Environmental Research. The program is a joint effort conducted by Argonne's Energy and Environmental Systems Division and Environmental Impact Studies Division.

The Land Reclamation Program is addressing the need for coordinated applied and basic research into the physical and ecological problems of land reclamation related to the surface mining of coal and the development of cost-effective techniques for reclaiming/rehabilitating mined coal land to productive end uses. The program is conducting integrated research and development projects focused on near- and long-term reclamation problems in all major U.S. coal resource regions including Alaska, and is coordinating, evaluating, and disseminating the results of related studies conducted at other research institutions. The activities of the Land Reclamation Program involve close cooperation with industry and the academic community, and focus on establishing a comprehensive field and laboratory effort. The program has developed working arrangements with eight coal companies at nine research sites throughout the U.S.

Coordinated by Stanley D. Zellmer of Argonne's Energy and Environmental Systems Division, this project is a multidisciplinary approach to reclamation of an abandoned deep coal mine refuse site in the Midwest. Current investigations are monitoring groundwater and surface water quality, aquatic ecosystems, revegetation, soil characteristics, erosion and runoff, soil microbial and soil fauna populations, wildlife, and economic effects of the reclamation effort. This project will provide necessary design data for future reclamation efforts of this type.

Ralph P. Carter, Director
Land Reclamation Program

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Special acknowledgment and thanks are given to Mr. Barry Deist, on-site consultant for this project; without his patience, dedication, and hard work much of the project would not have been possible.

The cooperation and assistance by the supporting agencies of the project is gratefully acknowledged. Mr. Peter Loquercio, Deputy Director of the Illinois Institute for Environmental Quality; Mr. Allen Grosboll, and Lieutenant Governor Dave O'Neal, Executive Director and Chairman, respectively, of the Abandoned Mined Land Reclamation Council of Illinois; and Dr. Roger Dahlman of the Division of Biomedical and Environmental Research, U.S. Department of Energy, were by their support and continued interest, of immeasurable help to the project.

In addition to the individuals listed above, grateful acknowledgment is given to the administrative, secretarial, analytical, and editorial personnel and to the student aides of the Land Reclamation Program at Argonne National Laboratory who have contributed to this project.

STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT PROGRESS REPORT FOR 1977

Stanley D. Zellmer, Site Coordinator

ABSTRACT

The Staunton 1 Reclamation Demonstration Project involves an evaluation of the reclamation process for a deep coal mine refuse system. A typical abandoned midwestern deep coal mine refuse site was selected, final land use was determined, baseline data were collected, engineering plans were developed and implemented, and a post-construction evaluation was begun. The project is a cooperative effort by two state agencies -- the Abandoned Mined Land Reclamation Council of Illinois the Illinois Institute for Environmental Quality* -- and the U.S. Department of Energy through the Land Reclamation Program at Argonne National Laboratory.

Current investigations are monitoring groundwater, surface water quality, aquatic ecosystems, revegetation, soil characteristics, erosion and runoff, soil microbial and soil fauna populations, wildlife, and economic effects of the reclamation effort. The research discussed in this report is a multidisciplinary approach to the concept of ecosystem response to reclamation.

1 INTRODUCTION

1.1 BACKGROUND

Environmental problems created by coal refuse areas are numerous. Before mining, coal and its associated waste material are in equilibrium with the environment. The mining and coal-cleaning operations disrupt this stable relationship and, when waste materials are deposited on the land surface, an equilibrium must be established in the new environment. The natural processes which accomplish the readjustment are very slow. When pyritic materials in the coal refuse are exposed to the atmosphere, oxidation and hydrolization occur and strong acids are formed. Acidic runoff water adversely affects vegetative growth, degrades surface water quality, and causes deterioration of the aquatic environment. Water with high concentrations of sulfate and heavy metals and low pH may enter the local groundwater system (18). Refuse materials become acidic and create unfavorable conditions for establishment and growth of vegetation. Without a protective plant cover, refuse material is easily eroded and the resultant

*Renamed Illinois Institute of Natural Resources in July 1978.

Fig. 1. Location of the Staunton 1 Site

sediment is carried into the adjacent environment. Erosion also exposes fresh pyritic material for oxidation and the cycle is continued. Conceivably, hundreds of years could be required to reclaim an abandoned coal refuse site by natural processes, during which the environment would continue to be adversely affected.

Abandoned mine-refuse areas in unreclaimed condition have no real land use or potential economic value. Often these sites become unauthorized dumps which create public safety hazards. Generally, refuse areas are not aesthetically pleasing and the addition of cast-off materials further detracts from their appearance. These factors, together with the poor environmental status of the refuse area, create a depressed economic market for adjacent properties.

The extent of abandoned coal refuse sites is sizable; current information indicates 9176 ha (22,675 ac) in Illinois have been identified as problem areas associated with past coal extraction and cleaning operations (14). About 3652 ha (9025 ac), or almost 40% of this total area, is exposed coal refuse (14). In Indiana, 149 major unreclaimed coal refuse sites have been identified; these occupy approximately 1712 ha (4230 ac) (24). From a national standpoint, abandoned coal refuse sites represent a significant land area. The U.S. Bureau of Mines estimates that 69,374 ha (171,420 ac) of land have been used between 1940 and 1971 for the disposal of wastes from coal mining and processing and have not been reclaimed (16).

1.2 APPROACH

The primary goals of this reclamation project are to: reduce the quantity of pollutants entering the environment; increase the economic potential of the area; improve the aesthetic value of the locality; and develop, demonstrate, and evaluate methods for reclaiming abandoned coal refuse areas so as to provide the greatest benefit at the lowest cost. With these goals in mind, two state agencies -- the Abandoned Mined Land Reclamation Council of Illinois, and the Illinois Institute for Environmental

Quality -- together with the U.S. Department of Energy, through the Land Reclamation Program (LRP) at Argonne National Laboratory (ANL), developed a cooperative reclamation demonstration program. The demonstration program was initiated with the Staunton 1 Reclamation Demonstration Project.

The project was 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 was the selection of a typical abandoned coal refuse area as a research site. The abandoned Consolidated Coal Company Mine No. 14, located in southwestern Illinois adjacent to the town of Staunton, was typical of abandoned refuse sites in the Middle West (Figure 1). The mine was opened in 1904 and operated for about 17 years. The Herrin (No. 6) coal seam was mined approximately 85 m (280 ft) below the surface. An average work force of 500 men extracted as much as 4550 t (5000 tons) of high sulfur (5%) coal per day. A coal washing plant - the first in the area - cleaned all the coal from the mine.

The total site includes 13.8 ha (34 ac), of which about 9.3 ha (23 ac) required reclamation (see Figure 2). The most imposing evidence of the past mining and cleaning operation at the site was the gob pile. (Gob is a coal mining term for the larger pieces of waste and pyritic material discarded through the cleaning process.) The heap extended about 25 m (82 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 (180 ft) concrete smokestack, a remnant of the mine's power plant, was still standing, but only the foundations of other mine structures remained. The rails from a siding which served the mine had been removed, but the right-of-way was still evident along the southern boundary of the property. The gob pile and the site of the old cleaning plant, tipple, and rail yard occupied about one-third of the total property.

Before the mine was opened, a dam had been built across a deep ravine near the site's north boundary. The 4.5 ha (11 ac) impoundment created by the dam provided water for the mine's power plant and the coal washing operation, and also served as a sump for the slurry, or fine waste material, 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 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 were carried down a small stream to Cahokia Creek about 0.8 km (0.5 mi) to the northwest.

From all appearances the site had been used as a general dump for many years, leaving the ground littered with trash and debris. There was evidence that small game used the 4.5 ha (11 ac) portion of the site

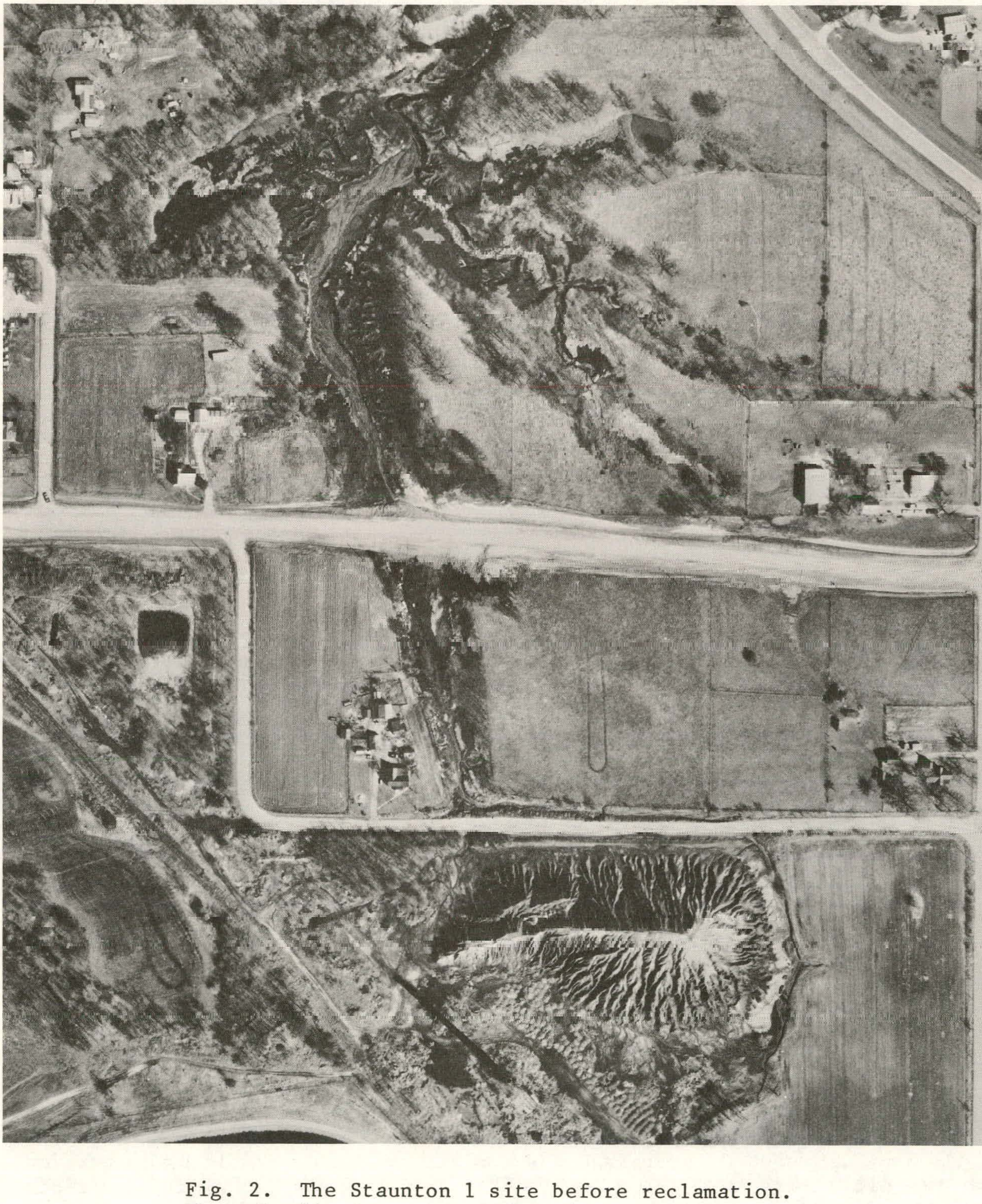

Fig. 2. The Staunton 1 site before reclamation. The gob pile is at the lower right, and drainage from the pile flows northward to the dark slurry area at the upper center.

that was covered with volunteer shrubs, grasses, and trees. It was also evident that the site had been used by off-road vehicles and as a target range for hunters.

Before any reclamation work could begin, the LRP staff held discussions with local officials and regional planners to select a final land use. Suggestions of an industrial park, a commercial center, or a housing development were rejected due to the instability of the gob and slurry material. Since one of the primary goals of reclamation is the mitigation of off-site pollution, the acid runoff from the refuse material had to be controlled and a vegetative cover was essential to control erosion and reduce runoff. Some type of pond and/or water flow control structure was required to provide control of water going off-site. With these considerations in mind, a final land use as a recreational area, wildlife habitat, and ecological area was selected. Detailed engineering plans and specifications were developed to meet the requirements for this final land use.

Baseline monitoring was instituted to assess the prereclamation environmental conditions of the area. Monitoring included: (a) establishment of groundwater and surface water quality parameters; (b) detailed sampling and testing of surface materials to determine the physical properties and chemical characteristics of the refuse material and adjacent soils; (c) a wildlife-use inventory of the site; (d) delineation and evaluation of the aquatic ecosystem of the sites watershed; and (e) a survey of soil microbial populations that are indicative of the fertility of the refuse material and site soils.

Extensive laboratory growth-chamber studies also were conducted to investigate the effectiveness of various soil amendments and to identify vegetation species that could be used in reclaiming the site. The baseline monitoring phase provided data needed to develop plans for the site, and is now providing a means to measure the effectiveness of the reclamation effort.

Phases I and II of the project were completed by mid-September 1976. The Illinois Department of Transportation aided in obtaining bids for the site development work. Title to the property was acquired by the State of Illinois, and the construction contract was awarded to Marle, Inc. of Springfield, Illinois - the low bidder - on 15 September 1976.

Site development (Phase III) began immediately with the removal of the smokestack and mine structure foundations, and the disposal of accumulated debris. A 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 of its original height (Figure 3). During 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. Because of these difficulties, the pond location was changed slightly. An area adjacent to the slurry area was selected so that the base of the new pond would be in till material rather than in saturated slurry material. A substitution of "Code L Alkali" (a mixture of calcium oxide and calcium carbonate) was made for the ground agricultural limestone that was to be used in the slurry area. This material was chosen because of its ability to both stabilize and neutralize the saturated acidic slurry material. As construction progressed on the pond, the Staunton area experienced its severest winter on record. Above-normal snowfall and extreme cold weather slowed progress on the project. Excavation of the pond, reconstruction of the old dam with water-flow control structures, and grading of the gob pile were all delayed due to the weather. All construction activity stopped 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/cover-material 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 0.15 m (0.5 ft) into the recontoured refuse materials. A layer of 0.3 m (1 ft) of cover material was then placed on the regraded refuse material.

Fig. 3. Rough Grading the Gob Pile Early in the Site Development Phase

Table 1. Seeding Mixture

Species	kg/ha	lbs/ac
Reed canarygrass (Phalaris arundinacea L.)	11.2	10
Tall fescue (Festuca arundinacea Schreb.) "Kentucky 31"	16.8	15
Birdsfoot trefoil (Lotus corniculatus L.)	13.5	12
Ladino clover (Trifolium repens L.)	5.6	5
Cereal rye (Secale cereale L.) "Balbo"	22.4	20

By mid-April, cover material had been applied to all the refuse material. An application of 11.2 t/ha (5 tons/ac) of agricultural limestone, and 135 kg/ha (120 lbs/ac) of each nitrogen, phosphorus, and potassium plant nutrients were made to the recontoured area. These amendments were disked to a minimum depth of 0.1 m (0.3 ft) and a seedbed prepared. The area was then planted - using an agricultural grain drill - with the seed mixture given in Table 1. Seeding, fencing of the site perimeter, and final cleanup were completed by the end of April (see Figures 4 and 5).

During site development, the following tasks were accomplished: (a) all slopes were reduced to 5:1 or less; (b) 179,670 m^3 (235,000 yd^3) of refuse were relocated; (c) an on-site borrow pit providing 30,582 m^3 (40,000 yd^3) of cover material was dug; (d) 1279 t (1410 tons) of neutralizing/stabilizing agents were applied at the refuse/cover-material interface; (e) exposed refuse material was covered with 0.3 m (1 ft) of cover material; (f) 101.6 t (112 tons) of soil amendments (N, P, K, and agricultural limestone) were incorporated into the surface of the 9.3 ha (23 ac) that were seeded with a mixture of grasses and legumes; (g) placement of 99 m (325 ft) of culvert pipe and three concrete water flow control structures; (h) construction of a 0.5 ha (1.2 ac) retention pond; (i) rebuilding of the old dam; and (j) 2240 m (7350 ft) of fencing was installed around the property. Figure 4 is a map of the site following site development.

Throughout the site development phase, the resident engineering duties were carried out by members of the LRP staff. A final inspection was made of the site development work by representatives of the funding agencies on 25 May 1977.

1.3 RECLAMATION RESEARCH

The end of the construction coincided with the beginning of the post-construction evaluation phase. The objectives of this final phase are to: provide an overall assessment of the reclamation effort in order to determine its environmental effectiveness; develop, demonstrate, and evaluate needed technologies for future reclamation efforts; ameliorate potential environmental problems that may develop at the site; and provide the economic

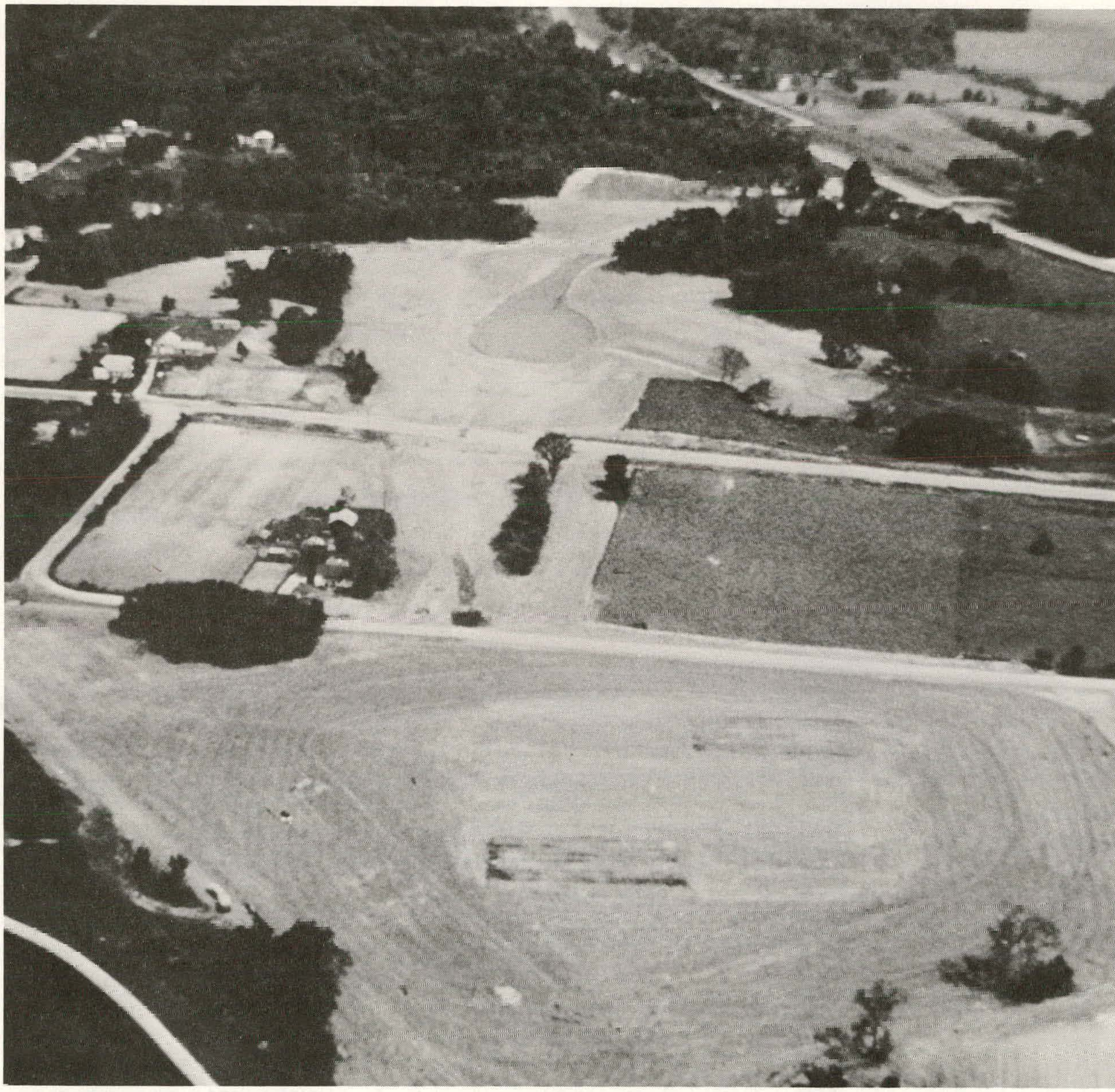

Fig. 4. The site at the end of the development phase. The new pond at the upper center occupies the old slurry area, and the recontoured gob pile displays rectangular study plots.

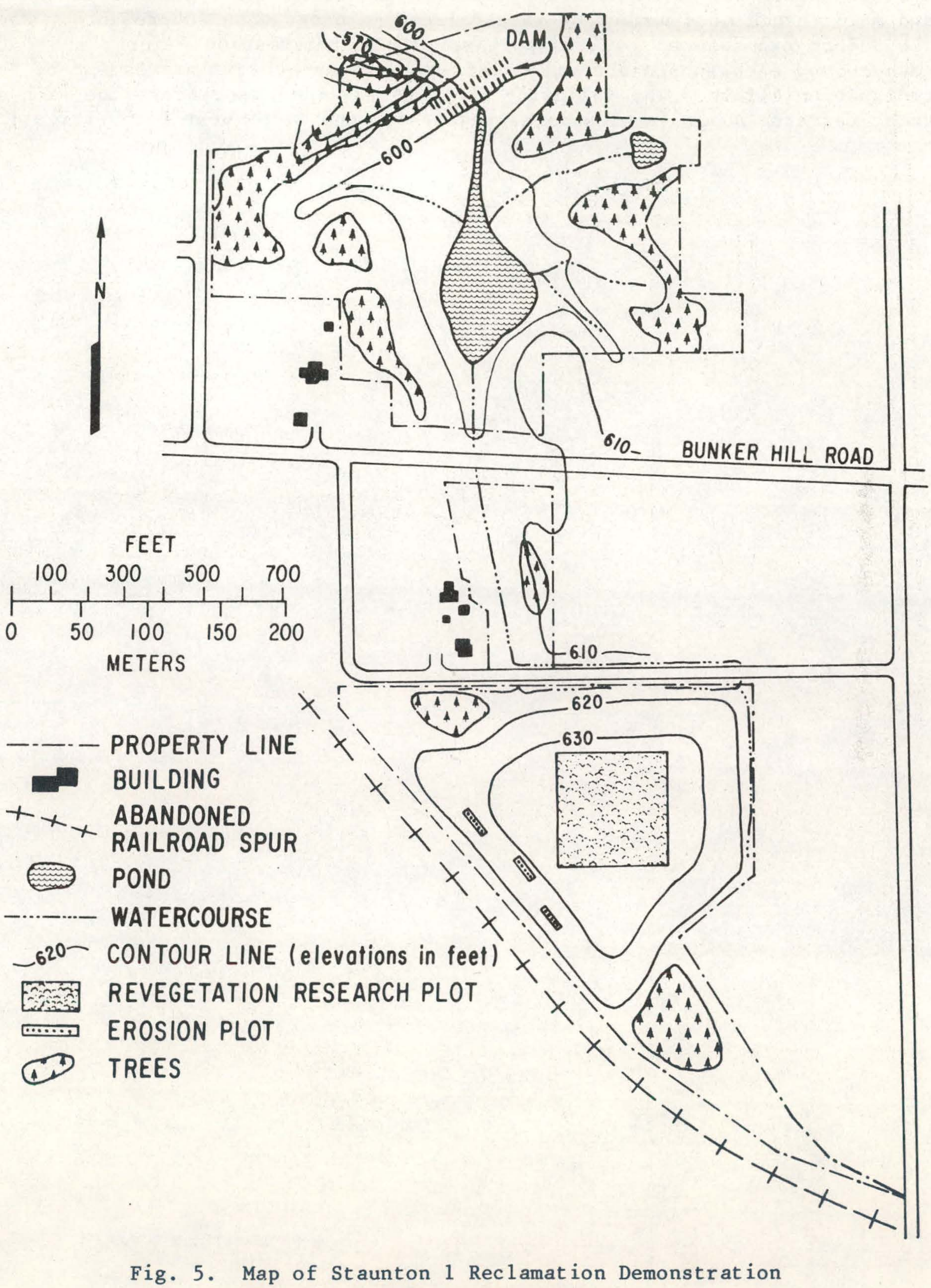

Fig. 5. Map of Staunton 1 Reclamation Demonstration Site After Site Development

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 subprojects. Each subproject examines a specific portion of the reclamation effort, and data gathered by each subproject will contribute to an overall assessment of the reclamation effort. The following sections of this report describe each of these research subprojects and the results of the first year's investigations.

2 GROUNDWATER INVESTIGATIONS

2.1 INTRODUCTION

Water that comes in contact with pyritic coal refuse often becomes highly acidic and can contain high concentrations of sulfate, iron, manganese, and other dissolved solids. Water infiltrates into refuse and percolates through the material, dissolving soluble sulfate minerals (pyrite oxidation products) and leaching other mineral matter (4,11). Highly acidic water can diffuse back to the refuse surface (22), discharge from the base of refuse as an acid seep (2,8,10,22), or infiltrate into underlying geologic materials, possibly polluting local aquifers (9,18). Research that has dealt with impacts to groundwater in refuse disposal areas is virtually nonexistent. Some monitoring wells were placed in the New Kathleen refuse pile (located near DuQuoin, Illinois) prior to its reclamation. The wells indicated that the base of the pile was saturated and contained extremely poor quality water (2).

Water samples collected from 27 monitoring wells that were established at the Staunton 1 site prior to reclamation showed poor quality of water in saturated slurry material, extremely poor quality of groundwater adjacent to the gob pile, and the relatively good quality of groundwater several hundred feet away from the pile and in 13 residential wells that were sampled (18).

2.2 SCOPE

Hydrologic and water quality monitoring is being conducted at the site to assess the mitigating effects of reclamation on the groundwater system. The objectives of this investigation are to determine: the oxidation and leaching processes in the reclaimed coal refuse; rates and processes of refuse leachate movement to the surface water and groundwater systems; physicochemical alteration of coal refuse leachate during groundwater movement; and the overall effect of coal refuse leachate on water resources in the area. Because groundwater flow is relatively slow compared to surface runoff, the immediate effects of reclamation on groundwater quality are expected to be subtle. However, long-term monitoring of groundwater quality in the area is expected to show a gradual improvement because of reduction in pyrite oxidation and leaching rates.

2.3 RESULTS

Forty-five new monitoring wells were drilled in the study area during summer 1977. Ten of the wells are located in gob, 11 are in slurry material, and 24 are located in till that surrounds and underlies the coal refuse areas (Fig. 6). The wells range in depth from 2 m (6.6 ft) to 12 m (39.4 ft). Monitoring of water levels and collecting of samples from the 45 new wells, the 2 prereclamation monitoring wells that remained after site development, and 15 residential wells is performed three times yearly. Data from the first two sampling periods indicate:

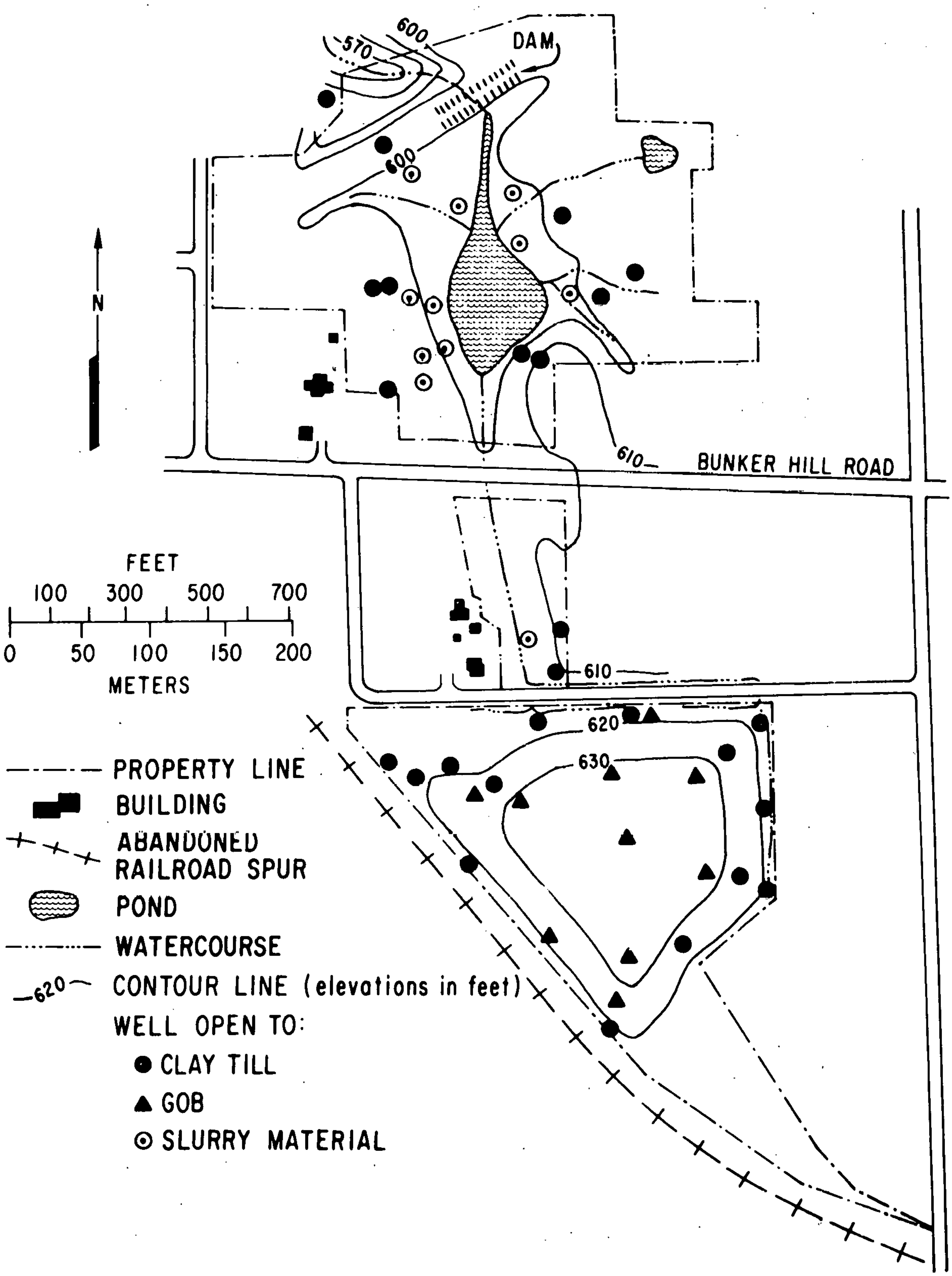

Fig. 6. Location of Groundwater Observation Wells

1. Oxidation and dissolution in the recontoured gob is continuing, as evidenced by elevated temperature and extremely poor quality of water at the base of the pile.

2. Site development has increased infiltration rates into the pile and thereby increased seepage rates from the north and east bases of the pile.

3. Groundwater levels have increased and groundwater quality has slightly improved in the slurry area as a result of surface water being ponded.

4. Groundwater quality has not changed noticeably in till surrounding the recontoured refuse material and in residential wells.

An experiment involving 36 modified lysimeters was assembled in the summer to monitor the effects of various surface treatments on the quantity and quality of water percolating through 1 m (3.3 ft) of refuse material. The surface treatments involve a combination of (a) 0, 0.3 m (1.0 ft), or 0.6 m (2.0 ft) of cover material; (b) lime at a rate of 224 t/ha (100 tons/ac) or no lime at the refuse/cover-material interface; and (c) vegetation or no vegetation. Rainfall is allowed to percolate through the lysimeters and samples are collected at the base. A limited number of sample collections so far indicate water of very poor quality. Leachate pH ranges from 1.5 to 3.1, and the acidity ranges from 7500 to 125,000 mg/L ($CaCO_3$ equivalent); the lowest acidity values occurred in the columns containing an application of cover material.

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3 SURFACE WATER QUALITY

3.1 INTRODUCTION

A prereclamation study of surface water quality at and near the reclamation site revealed significant environmental degradation resulting from erosion and acidic drainage from the refuse area. During dry periods the effluent flow rate from the site was low (i.e., ~3.2 L/s, or ~50 gpm) and was neutralized, presumably by groundwater seepage, before reaching Cahokia Creek. During or following periods of heavy rainfall, the flow rate was significantly higher (e.g., 19-25 L/s, or 300-400 gpm) and was not neutralized before discharging into Cahokia Creek. During wet periods, the quality of the effluent at the site (Table 2: Prereclamation) and at the point of discharge to Cahokia Creek was very poor. The water was very acidic (pH 2.5-4, with cold acidity of 3500-4000 mg/L) and contained extremely high concentrations of toxic heavy metals and other soluble constituents such as sulfate. The following metals were present in on-site surface water at concentrations toxic to aquatic and amphibious biota: aluminum, arsenic, cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc. Toxic levels of aluminum, cadmium, copper, iron, and zinc entered Cahokia Creek during heavy rainfall periods.

3.2 SCOPE

Creation of the new landform at the site has modified the flow of surface water. In addition, covering the acidic refuse material and establishment of vegetation have affected the quality of surface water. The

Table 2. Surface Water Quality

	Prereclamation		Site Development		Post-Development			
	4/15/76	5/13/76	3/18/77	4/15/77	5/11/77	6/16/77	7/14/77	8/16/77
pH	3.9	3.4	3.1	4.0	4.1	4.2	7.2	8.4
Alkalinity	0	0	0	0	0	0	36	38
Acidity	3596	4092	1393	156	228	222	6.3	0
Sulfate	7095	9058	1850	1275	1200	1600	788	500
Aluminum	498	607	159	58.7	51.8	42.4	1.02	0.60
Iron	1450	1510	119	10.0	0.71	1.46	0.74	0.08
Manganese	51	19.5	11.4	7.93	8.5	10.6	3.89	0.64
Zinc	75	71	26.7	12.57	11.33	10.94	0.31	0.02
Cadmium	0.59	0.66	0.44	0.24	0.20	0.22	0.02	0.01
Copper	0.49	0.37	0.05	0.05	0.05	0.05	0.05	0.05

NOTE: All values except pH are in mg/L.

objectives of this subproject are to determine the effects of the reclamation effort on surface water quality on the site and to assess the subsequent changes in water quality in Cahokia Creek.

These objectives are being met by measuring the surface water flows at two points on this site. Samples are collected from these flow monitoring stations and from the on-site ponds to evaluate water quality. There are two ponds on the site: the new pond created during the site development phase, and an older, much smaller pond unaffected by the mining operation and located approximately 106 m (350 ft) northeast of the new pond. Periodic sampling of Cahokia Creek is done to assess the subsequent changes of water quality.

3.3 RESULTS

Site drainage was impounded by a dam which was closed during site development. Since closure of the dam, discharge from the site has occurred only in conjunction with significant rainfall. The new pond has a surface area of about 0.5 ha (1.2 ac) and a maximum depth of approximately 3.6 m (12 ft). The impoundment provides containment of site runoff during light rains and modulates peak runoff flows during or following heavy rains. Retention time, even during peak flows, allows for substantial settling of suspended solids from site runoff before discharge to Cahokia Creek.

The quality of water leaving the site and in the new pond has shown steady improvement since spring 1977 when earthmoving and soil treatments were essentially completed (Table 2). Acidity has decreased from values >1000 to <10, pH has risen from 3-4 to 7-8, sulfate has decreased by a factor of 10, and toxic heavy metals have been reduced by 2-3 orders of magnitude. Although toxic metal concentrations were reduced substantially from prereclamation levels as pH increased, concentrations of cadmium and zinc in the on-site retention pond remained above toxic levels until the pH of the water exceeded 7. This pH-solubility relationship is consistent with research data on thermodynamic equilibria reported in other studies (17,21), and suggests that cadmium and zinc may persist at toxic levels in the pond waters unless a pH of at least 7 is maintained.

By all present indications, the quality of site effluent entering Cahokia Creek has substantially improved since completion of site development. However, it is highly unlikely that the quality of Cahokia Creek has been measurably affected by post-development drainage because of the low flow leaving the site and the influence of the many unreclaimed refuse areas within the watershed.

4 AQUATIC ECOSYSTEMS

4.1 INTRODUCTION

The aquatic ecosystems investigation is being done in conjunction with the water quality study in Cahokia Creek and the on-site ponds. Macroinvertebrate studies were chosen to accompany water quality studies as they can give long-term indications of water quality, whereas water samples only give the conditions present at the time of collection. Additionally, macroinvertebrates are useful as pollution indicators as they are large enough to be easily captured, show wide ranges of tolerance to varying degrees of pollution, are not highly mobile, and have annual (or longer) life cycles so that their presence or absence can provide information on what has taken place during several previous months.

4.2 SCOPE

The first aspect of this subproject is an investigation of the possible impacts that site reclamation will have on the macroinvertebrates of Cahokia Creek. Cahokia Creek receives drainage from the site, particularly during and after periods of precipitation. Investigations of the benthic macroinvertebrates in the creek were performed before and during site construction to determine if improvements in the water quality draining from the site following recontouring have any affects upon the creek's invertebrate community. The second aspect is a study of macroinvertebrate establishment in the newly created pond.

The objectives of this subproject are to: assess the effects of the reclamation effort on the macroinvertebrate communities in Cahokia Creek; determine the biotic colonization, succession patterns, and rates in the new pond; and develop a self-sustaining sport fish community in the new pond for recreational purposes.

These objectives are being met by the seasonal sampling of macroinvertebrates in both ponds and at selected sites in Cahokia Creek (Figure 7). Samples are returned to the laboratory for sorting and identification. These data, used in

Fig. 7. Collecting Macroinvertebrate Samples in the New Pond

conjunction with surface water quality data, will be used to develop recommendations for the establishment of a sport fish community in the new pond.

4.3 RESULTS

The new pond is showing signs of developing a stable and diverse invertebrate community over time. The most conspicuous observation is the occurrence of only a single midge species (Chironomus plumosus) in the new pond. This is not surprising as the initial water quality of the pond was not exceptionally good. Harp and Campbell (6) found C. plumosus to be the only midge in water with a pH < 6.0. As this pond may have initially had a pH below 6.0, it is probable that only C. plumosus was capable of colonizing and that other species of midges will come in when the water quality improves. The lower numbers of C. plumosus in the new pond compared to those of the old pond may be due to a lack of leaf litter in the new pond for the midges to feed on compared to abundant leaf litter in the old pond. Harp and Campbell (6) felt leaf detritus was necessary for C. plumosus to be present.

Sampling indicates that a greater assemblage of organisms was found in the old pond, though an overly diverse condition does not really exist. With water conditions improving in the new pond and observations made upon later collections, preliminary results indicate that it should develop a diverse assemblage of invertebrates similar to that present in the old pond. If so, there is promise that the new pond will be capable of supporting game and forage fish within the next year or two. It should be mentioned, however, that most samples have been collected in the shallower portions of the new pond. These areas often show higher numbers of organisms than deeper portions, at least in regard to midge larvae. Field observations from collections in the deeper areas of the new pond tend to show similar results to those of other studies (1,12,23). Estimates of invertebrate abundance may then actually be overestimates, and knowledge of this fact will be weighed in regard to decisions on the stocking of fish.

Results from Cahokia Creek samples indicate a poor representation of macroinvertebrate groups, with the majority of organisms being midge larvae (Chironomidae). Several individuals from two other Diptera (fly) families, a dragonfly, and aquatic worms were the only other specimens collected. This lack of diversity among invertebrate groups is due to a substrate that consists of sand, fine rock pebbles, and bits of fine coal debris. This substrate is continuously suspended and redeposited due to changes in creek flow. As a result, an unstable substrate is present that is not suitable for colonization by invertebrates, except for those species adapted to burrowing into loose bottom materials. The lack of habitat variety in the creek, along with the siltation, desiccation, and industrial pollution of the small streams in the watershed, has been stated as reasons Cahokia Creek is considered a poor fish habitat (19). These same factors also result in the low faunal diversification of macroinvertebrates observed in the substrate.

The apparent trend is for the creek bottom to support a limited benthic community due to an unstable habitat; because of this, the discharge from the reclamation site does not have a major influence on the creek invertebrates. Preliminary results indicate that water quality improvements of the reclamation site drainage would not improve the benthic community of Cahokia Creek. At present, impacts from the Staunton 1 site drainage are probably too subtle to factor out from the overriding influences of a near-homogeneous and unstable sand substrate.

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5 SITE-WIDE REVEGETATION SUCCESS STUDY

5.1 INTRODUCTION

During the site development phase of the Staunton project, the site was seeded with a mixture of grasses and legumes. Species choice for this site-wide revegetation effort was based on capability to rapidly stabilize the soil surface and tolerance to acidic growth conditions. The suitability of these species for revegetation, under the unique plant growth conditions presented at the reclamation site, is unknown. The intent of this project is to determine the performance of these species under the present field conditions at the reclamation site.

By measuring vegetative cover on selected areas with differing growth conditions, the effects of various microclimates on revegetation success can be determined. Based on the success of individual species grown under specific conditions, recommendations for reseeding the demonstration site and for seeding of future reclamation sites can be made. Application rates of cover material, fertilizer, and lime, as well as methods for seedbed preparation and seeding, can be assessed on the basis of vegetative productivity.

5.2 SCOPE

A measurement of vegetative cover on an individual species basis was chosen to determine the success of site-wide revegetation. Cover, expressed as percentage, is usually defined as the proportion of the ground occupied by a perpendicular projection of the aerial vegetation. Cover measurements have been found to be of greater ecological significance than density or frequency measurements (13). This is due to increased correlation with plant biomass.

Due to differing microclimatic and topographic conditions affecting vegetation establishment at the site, the following five areas, shown in Figure 8, were chosen for segregated study:

Area A. South-facing slope: Approximately 0.2 ha (0.5 ac) was staked out on the south slope (18%) of the recontoured gob pile.

Area B. North-facing slope: Approximately 0.2 ha (0.5 ac) was staked out on the north slope (18%) of the recontoured gob pile.

Area C. Central poorly-drained area: Approximately 0.1 ha (0.25 ac) was staked out along the drainage channel between the recontoured gob pile and the old slurry area.

Area D. Well-drained elevated area: Approximately 0.2 ha (0.5 ac) was staked out on a gently (easterly) sloping location west of the new pond.

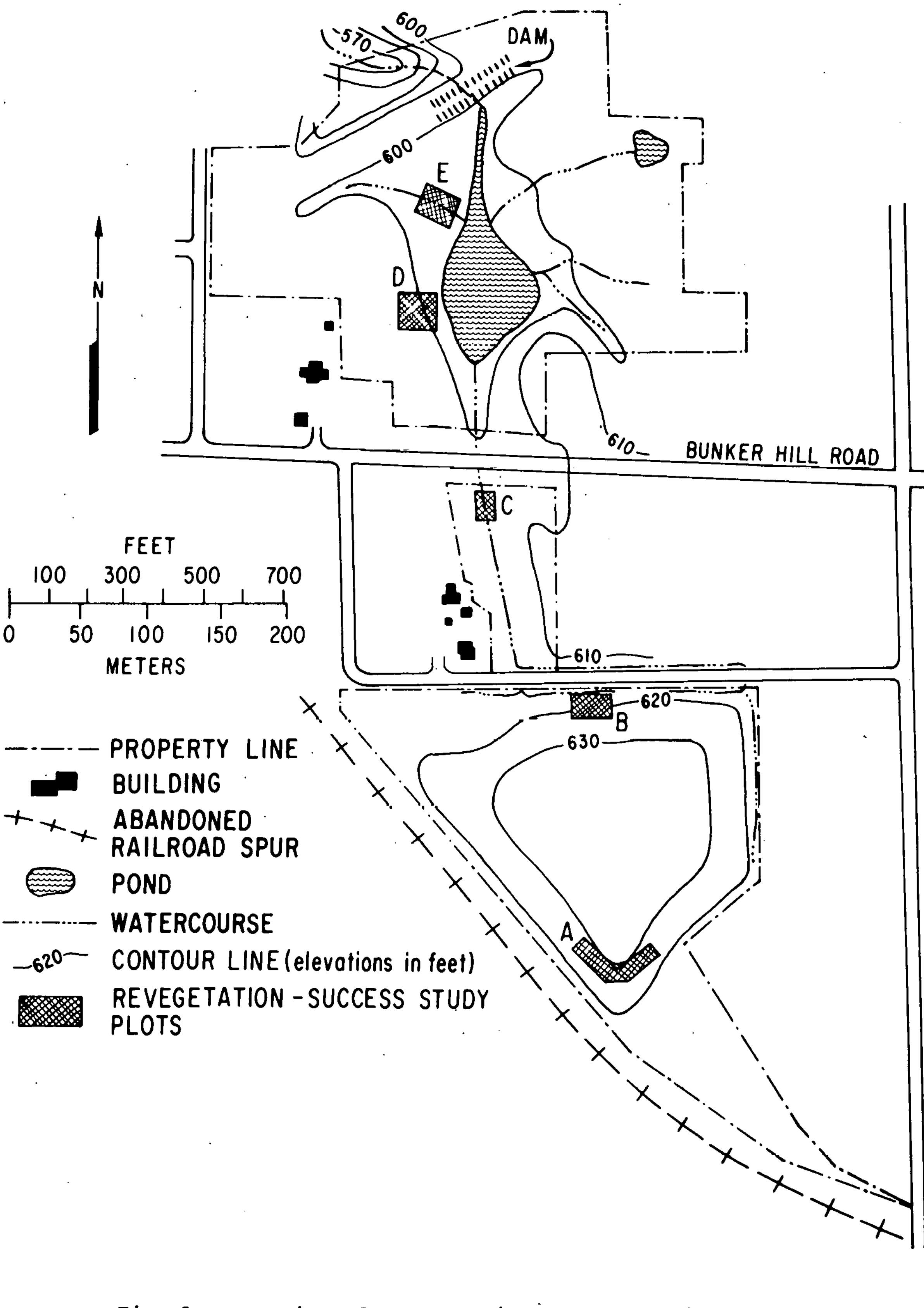

Fig. 8. Location of Revegetation Success Study Areas

Area E. Northern poorly-drained area: Approximately 0.1 ha (0.25 ac) was staked out along a gently sloping drainageway northwest of the new pond.

Permanent quadrats were randomly located within each study area to enable observation of changes in vegetation through time and to compile a photographic record of these changes. In areas A, B, and D, 24 quadrats were randomly placed, while areas C and E contained 12 quadrats each. Each quadrat was 0.6 m x 0.4 m (1.9 ft x 1.3 ft).

Determinations of cover were made using a point-intercept method. A point-frame was constructed (Fig. 9) to enable data collection for up to 150 points within a quadrat. Stainless steel pins were dropped vertically through the frame and contacts with vegetation were recorded. Field data collection proceeded with the recording of 40 randomly-selected intercept points in each quadrat. For each of the 40 pins dropped, all species contacted were recorded on computer code forms.

In addition to collection of cover data within the study areas, a qualitative site-wide survey of vegetation establishment was performed. This enabled identification of locations outside of the study areas which maintained inadequate stands of vegetation. Specimens observed on the site were collectd and pressed for future reference. Photographic records of each quadrat were made using color film. Climatic data were collected from on-site and local weather stations.

5.3 RESULTS

Results from the June and August data collections are presented in Tables 3 and 4. For each quadrat, the median percent cover by species was calculated on the basis of the number of pins out of the 40 dropped which hit an individual species. Additionally, a total percent cover value was calculated by dividing the number of pins dropped. Using the data obtained from the quadrats, mean percent cover values were calculated for each area. Figure 10 presents the June results in the form of a histogram.

A high degree of variability was observed between quadrats within an area. This was likely due to physical and chemical heterogeneity of the cover material and gob substrate. Additionally, variability in the application rates of fertilizer, lime, and seed may have contributed to quadrat differences.

It can clearly be seen that Balbo rye provided the majority of cover in all the areas studied in the first sampling period following seeding. This is consistent with observations that this species is quick to germinate and grows more quickly that most other commonly-grown grasses (5). As a result of this rapid establishment, recently-laid cover material was stabilized against erosion. During the latter part of June, 15 cm (6 in.) of rain fell, but no major signs of erosion were evident. By August, the surviving rye cover had decreased to 20% or less on all the areas. The rapid senescence of this annual species was likely due to the low amounts of rainfall received in July.

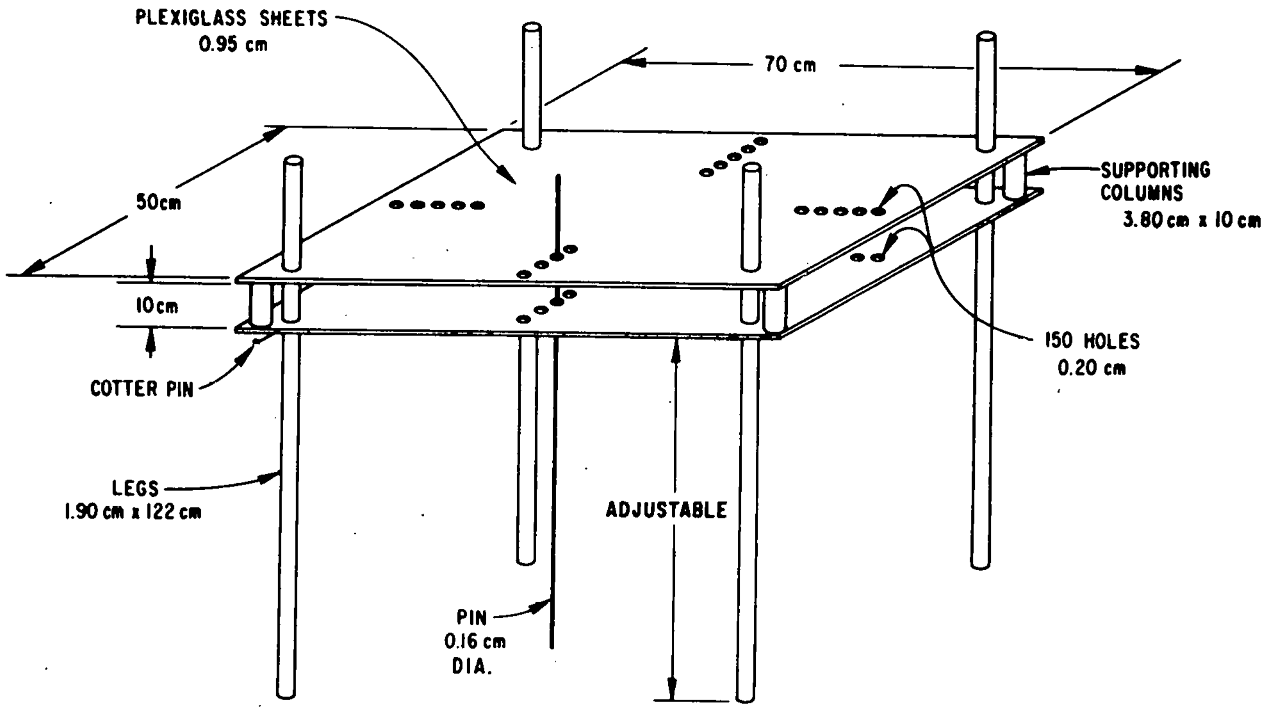

Fig. 9. Point-Intercept Frame Used to Collect Plant Cover Data

As anticipated, perennial species that were seeded provided substantially improved cover in August as compared to June. This was likely due to the additional time required for establishment and development of perennial species. Reed canarygrass was observed with the greatest cover in area C for both June and August. This is consistent with this species' preferences for poorly drained areas. Its lower degree of success in area E, particularly during early establishment in June, is perhaps due to the high siltation rate observed in this poorly drained area. It has been found that reed canarygrass does poorly along slow-running streams where siltation affects establishment (7). If high sedimentation rates in area E are the major cause of poor establishment, the elimination of wide sedimentation bands may be essential for strong vegetative establishment in future reclamation projects. The well-drained slopes (areas A and B) supported poor stands of reed canarygrass, perhaps due to insufficient moisture.

Tall fescue did poorly in areas A and B in June, but showed considerable improvement in area B by August. The apparent absence of tall fescue in area B in June was due to the poor cover provided by the seedlings which are very slow to establish (7). The area A cover percentages in August were poor for all of the seeded species. This was likely due to moisture stress and high soil temperatures on this south-facing slope during July. The June data indicate some success in tall fescue establishment for area C, which is consistent with the observation that this species is tolerant of poor drainage and does well on moist soils (7). By August, the area C cover

Table 3. Percent Cover for Revegetation Study Areas in June 1977

Species	Mean Percent Cover				
	Area A	Area B	Area C	Area D	Area E
Balbo 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*	23.5	24.8	70.7	37.8	34.1

*Multiple hits with a single pin were scored as a single hit. Maximum total percent cover equals 100 percent.

Table 4. Percent Cover for Revegetation Study Areas in August 1977

Species	Mean Percent Cover				
	Area A	Area B	Area C	Area D	Area E
Balbo rye	0.2	2.0	0.0	0.7	0.5
Reed canarygrass	0.0	1.8	33.6	4.6	13.0
Tall fescue	0.2	7.9	0.2	20.0	29.1
Birdsfoot trefoil	1.7	41.5	9.1	19.9	24.3
Ladino clover	0.0	0.0	2.3	3.0	12.0
Invading monocot	2.0	2.9	86.6	0.7	3.4
Invading dicot	0.8	0.0	4.1	4.0	6.6
<u>Ambrosia</u> sp.	0.5	0.4	49.1	4.8	0.0
<u>Polygonum</u> sp.	6.7	1.3	20.2	0.5	0.0
<u>Setaria</u> sp.	43.2	8.2	8.9	26.9	1.1
<u>Panicum</u> sp.	31.7	5.2	81.1	6.8	0.0
Total Percent Cover*	69.9	58.1	100.0	59.5	61.6

*Multiple hits with a single pin were scored as a single hit. Maximum total percent cover equals 100 percent.

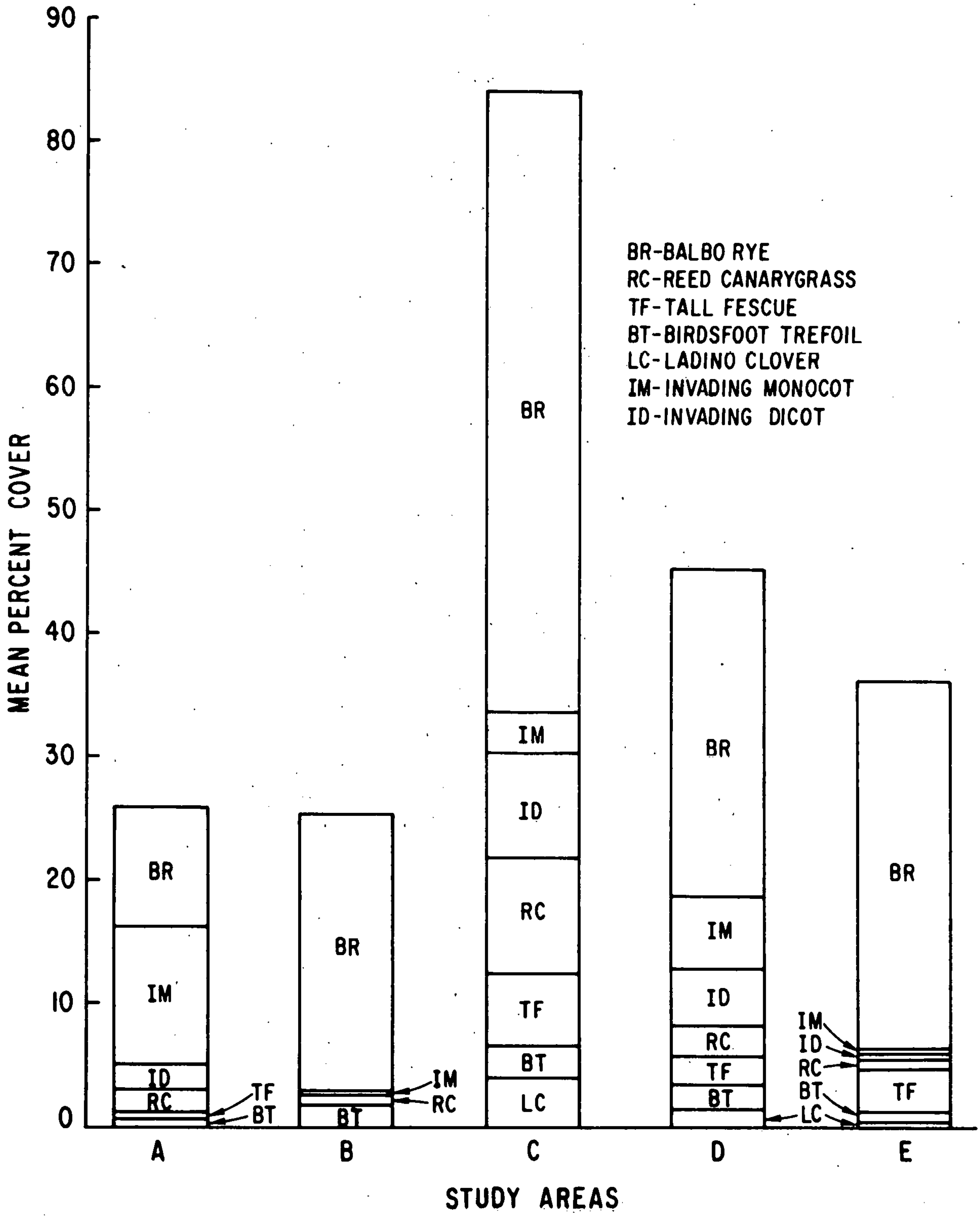

Fig. 10. Mean Percent Cover for June 1977

values for tall fescue were substantially reduced. The intense competition for light and nutrients from invading species may have caused some dieback of the fescue in this area.

The ladino clover did quite poorly on the site, particularly in areas A and B where no specimens were observed on either sampling data. Future observations will be necessary to determine if this was a result of slow establishment or of temporarily inadequate microclimatic conditions. A minimum soil pH of 6 and adequate phosphorus are required for establishment of ladino clover, and these factors may have some bearing on the poor stands observed. Additionally, the heavy application of nitrogen fertilizer, which is good for the development of grasses, may adversely affect ladino clover (7).

Birdsfoot trefoil, although a highly recommended species for disturbed land reclamation, as of June had not provided any substantial cover on the site. This species, like reed canarygrass and tall fescue, has a slow seedling growth rate (7). By August, the birdsfoot trefoil was providing substantial vegetative cover to some areas of the site. Grandt and Lang (5) report that when birdsfoot trefoil is seeded on strip-mined soils, excellent stands have been established although the seedlings were quite weak during the first year of growth. Additionally, any remaining acidic surface conditions on the site may have inhibited establishment. It has been shown that, at a pH of less than 6.5, birdsfoot trefoil seedling growth may be slow and nitrogen fixation may be suppressed (7)

This early assessment of vegetative cover does not provide sufficient information to evaluate the suitability of the species selected for the site revegetation site. To obtain sufficient data, monitoring through a second season will be necessary. Continued research will include physical and chemical analysis of growth medium along with soil moisture and temperature monitoring. This will enable a more thorough interpretation of vegetative cover data. On the basis of the patterns that developed by August, some observations on site reclamation procedures can be made. Some outlying areas on the reclamation site which were wet at the time of seeding were seeded by broadcasting rather than with a seed drill. The establishment of vegetation within these areas was very poor when compared to areas which were drilled. This observation emphasizes the importance of the seed drill in achieving proper planting depth and covering of the seed.

Balbo rye, which was intended as a nurse crop, did provide substantial soil stabilization after seeding. The 50% cover value observed in June on area C, with much lower value in areas A, B, and D, tends to indicate that the rye was moisture-limited in the well-drained areas. The poor success of perennial species in August on the south-facing slope also indicates inadequate moisture. It may be concluded from these factors that some form of moisture conservation, such as mulching, may be necessary to insure rapid establishment of vegetation on a reclamation site.

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6 REVEGETATION RESEARCH PLOTS

6.1 INTRODUCTION

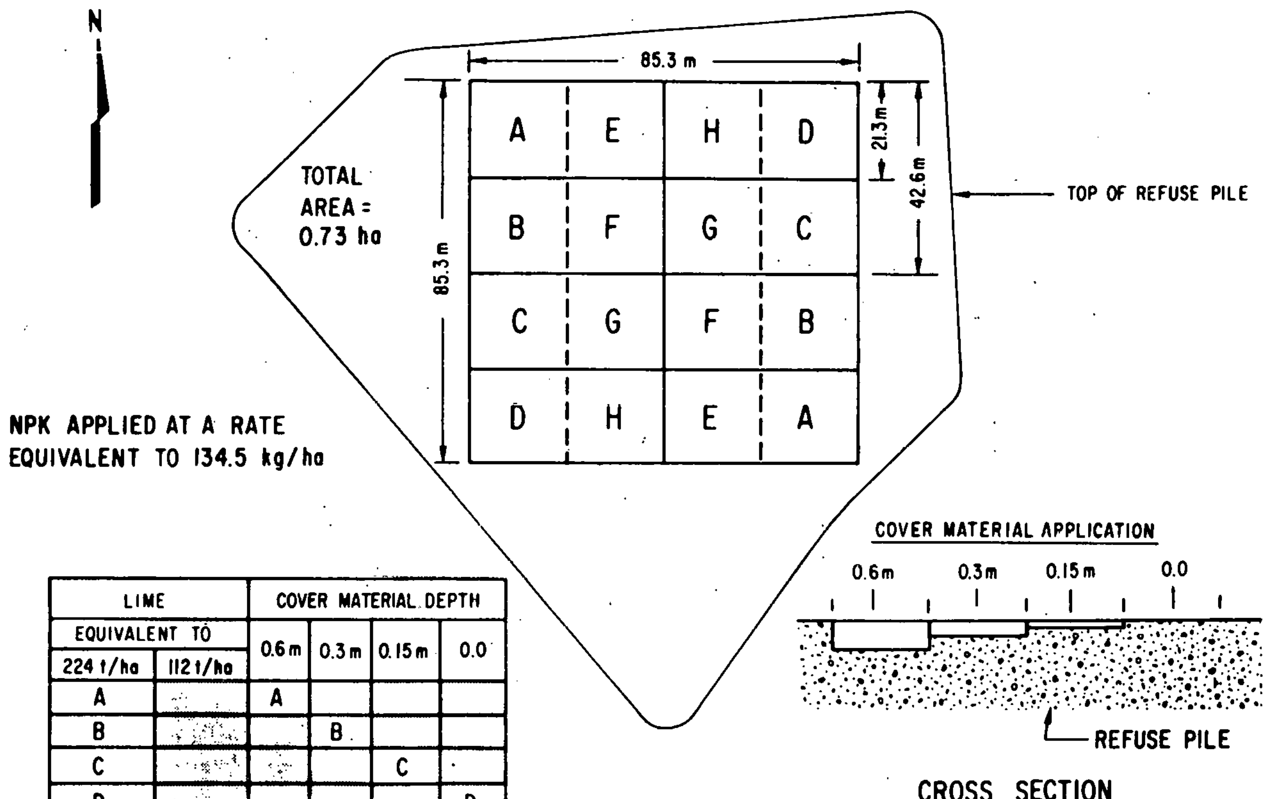
An important aspect of most reclamation efforts is the establishment of a self-sustaining vegetative cover. This protective cover reduces runoff rates and controls erosion, thereby improving surface water quality. A mixture of grasses and legumes improves the physical and chemical properties of the soil and also reduces long-term site maintenance costs. Food and cover for wildlife is an additional benefit from a planned vegetative cover. Since the growth media of most reclamation sites are less than ideal, a method for revegetating these sites must be field tested.

6.2 SCOPE

Revegetation research plots at the Staunton 1 site were established to aid in determining the most cost-effective means of achieving long-term revegetation success on highly acid (pH ~ 2.2) gob material. The objectives of this subproject are to: evaluate various liming rates and cover depths (soil) in the establishment of vegetation; evaluate the success of several candidate plant species for revegetation; and field-test species and treatments for long-term success. The three major parameters being evaluated in this study are the minimum depth of cover material required, minimum amount of lime required, and approporiate plant species to seed. Figure 11 displays the various liming and cover material depths applied to each 21.3 m x 21.3 m (70 ft x 70 ft) revegetation research plot. Lime was applied to the gob and mixed to a depth of about 0.15 m (0.5 ft) prior to the placement of the cover material. The cover material was limed at a rate of 11.2 t/ha (5 tons/ac), fertilized, and disked after placement. All treatments were seeded on 27 April 1977 with the seed mixture and application rates listed in Table 5. Camper little bluestem was broadcast-seeded and the remaining species were seeded as a mixture with an agricultural drill. Permanent 0.25 m^2 (0.21 yd^2) quadrats, two replicates per species, were constructed at the edge of the B plots and hand seeded with 100 seeds to establish monocultures of each seed mixture species. The quadrats were used to determine field germination rates and to aid in identifying seed mixture components. Several abiotic and biotic parameters were sampled during the 1977 growing season. The soil abiotic parameters include bulk density, pH, samples for initial physical and chemical analyses, and soil moisture. Biotic parameters were limited to vegetation and included germination, density, plant cover, and biomass.

6.3 RESULTS

Table 6 presents the germination results from both the field monoculture plots and the tests conducted in the laboratory. Blackwell switchgrass was the only species to achieve comparable germination percentages in both the field and laboratory tests. The remaining species had much lower field germination percentages than under the ideal conditions of the laboratory. Also, more seeds may have germinated and perished during the dry spell that



LIME EQUIVALENT TO 224 t/ha	LIME EQUIVALENT TO 112 t/ha	COVER MATERIAL DEPTH 0.6 m	0.3 m	0.15 m	0.0
A		A			
B			B		
C				C	
D					D
	E	E			
	F		F		
	G			G	
	H				H

Fig. 11. Revegetative Research Plots: Liming and Cover Material Depths

occurred between the time of planting and the first counting, thus contributing to the low germination percentages. Germination counts were not continued beyond 5 July because of the difficulty in distinguishing individual plant species due to numerous tillers or rhizomes produced by individual plants. However, during the course of other vegetation sampling, it was apparent that the planted seeds were germinating throughout the growing season.

Density counts of individual plant species were made on all replicates by random sampling with a 0.1 m^2 (0.12 yd^2) circular quadrat. The treatments with the lowest plant densities are D and H, the gob plots without cover material. Blackwell switchgrass and Camper little bluestem exhibited the greatest potential of the planted species to revegetate the gob plots, but this is only a preliminary observation based on an early stage of growth. The remaining data are quite variable and range from a high of 352 plants/m^2 (293/yd^2) to a low of 100 plants/m^2 (83/yd^2).

Cover data were collected towards the end of the growing season when many of the invader species such as foxtail, crabgrass, and barnyard grass had flowered and were just beginning senescence. Plant cover was estimated for the plots with a surface application of "suitable" plant growth material using a randomly placed point-frame with ten pins, each spaced 10 cm (4 in) apart. Ten frames, or 100 pins, were dropped on each replicate. The treatments lacking cover material - the gob plots - required a different sampling method due to the very sparse cover. Line-transects were run at 1 m (3.3 ft) intervals to obtain cover data on the gob plots.

The interpretations of preliminary results for the first growing season indicate that the percent of ground area having plant cover for those treatments with a surface application of suitable plant growth material ranged from a low of 89% to a high of 99%. This is excellent plant cover for one growing season. Unfortunately, the major contributors to plant cover were annual weeds such as foxtails (Setaria spp.), smooth crabgrass (Digitaria ischaemum), hairy crabgrass (D. sanguinalis), and fall panicum (Panicum dichotomiflorum). The eight perennial species that were planted in the late spring exhibited slower growth compared to the robust life cycle of the annual weeds and therefore contributed very little to the first year's total plant cover. The total plant cover in the gob plots ranged from 0.52% to 2.35%; not even the weeds are becoming established there.

First year plant production was estimated from biomass data obtained by clipping five 0.5 m^2 (0.6 yd^2) quadrats from each replicate with surface cover material. Each quadrat was clipped and hand-sorted by species in the field, bagged, and brought back to ANL where dry weight/species was obtained. Table 7 contains the mean biomass/0.5 m^2 replicate for all species and for the planted species. The final column in Table 7, percent composition, gives an indication of the contributions that the planted species are providing to the total mean biomass of the replicate. This contribution ranges from a low of 0.8% to a high of 17.95%.

Table 5. Seed Mixture for Revegetation Research Plots

	kg/ha	lb/acre
Kentucky 31 tall fescue (Festuca arundinacea)	12.2	10.9
Blackwell switchgrass (Panicum virgatum)	11.1	9.9
Lincoln smooth brome (Bromus inermis)	8.3	7.4
Orchardgrass (Dactylis glomerata)	8.3	7.4
Reed canarygrass (Phalaris arundinacea)	6.6	5.9
Camper little bluestem (Andropogon scoparius)	6.3	5.6
Tioga deertongue grass (Panicum clandestinum)	4.4	3.9
Empire birdsfoot trefoil (Lotus corniculatus)	8.3	7.4
TOTAL	65.6	58.4

Table 6. Germination Percentages of Seed Mixture Components as Measured by Field Plots and Laboratory Tests

	Percent Germination	
	Laboratory	Field[a]
Kentucky 31 tall fescue	88	20.3
Blackwell switchgrass	16	15.3
Lincoln smooth brome	91	35.3
Orchardgrass	89	15.8
Reed canarygrass	57	3.0
Camper little bluestem	54	13.3
Tioga deertongue	28	5.3
Empire birdsfoot trefoil	64	18.5

[a]Average of four replicates.

Table 7. Mean Dry Weight/Area and Standard Error (SE) for All Species (Total Biomass) and for Planted Species by Treatment with Cover Material

		Total Biomass		Biomass of Planted Species		
Treatment	Replicate	Mean $g/0.5m^2$ [a]	SE[b]	Mean $g/0.5m^2$	SE	Percent Composition[c]
A	I	333.78	37.72	5.79	1.72	1.73
A	II	226.36	51.27	1.81	0.31	0.80
B	I	142.92	29.34	12.45	1.67	8.71
B	II	75.25	29.66	13.51	3.92	17.95
C	I	167.26	24.40	11.41	4.44	6.82
C	II	159.95	34.48	17.70	2.36	11.06
E	I	222.07	41.95	11.19	2.21	5.04
E	II	109.42	12.65	7.21	1.97	6.59
F	I	132.80	13.88	14.42	3.70	10.86
F	II	206.76	34.37	7.91	2.09	3.83
G	I	152.68	29.55	6.36	2.42	4.16
G	II	122.79	35.17	14.10	3.88	11.48

[a] $1\ m^2 = 1.1960\ yd^2$

[b] $SE = \frac{s}{n}$

[c] $\text{Percent composition} = \frac{\text{Biomass of planted species}}{\text{Total biomass}} \times 100$

Analyses of the data collected to date are insufficient to allow a thorough discussion in regard to the revegetation research plots. The species that were planted seem to occur throughout the plots with the exception of perhaps two that are more sparse: reed canarygrass and Tioga deertongue. The first year's plant production and cover were dominated by annual weeds with only minor contributions from the planted species. Time will tell if the planted perennials will continue to grow and drastically reduce the populations of the annual weed species.

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7 SOIL CHARACTERISTICS

7.1 INTRODUCTION

The establishment of a stable and self-sustaining vegetative cover on the reclamation site is directly related to soil characteristics. Productivity and fertility are dependent on the soil's physical and chemical properties. Surface and groundwater quality, vegetative cover, and wildlife are all linked directly or indirectly to soil properties. The changes that occur in the surface material within the first few years of its placement will affect the long-term success of the reclamation effort.

7.2 SCOPE

In order to better evaluate the success of individual reclamation techniques, a characterization of the newly created soil profile is underway. The objectives of this subproject are to: determine if significant changes occur, over a period of time, in the physical properties and chemical characteristics of the root zone materials; and determine if available soil moisture and/or soil temperature levels are outside the established requirements for vegetation.

During 1977 a sampling program was initiated to determine the physical and chemical properties of the new soil being developed at the site. Six sampling sites were selected and replicated samples were taken from the soil profile at 0.15 m (0.5 ft) intervals. Soil bulk density measurements were also taken in the field.

A soil psychrometer system was purchased and will be used in the field to monitor soil water potential and soil temperature at various points within the root zone.

7.3 RESULTS

Results from this first year's effort will be used as baseline data to measure changes which occur over a period of time. While this first year's data can be reported, trends cannot be established until additional information from later sampling periods is available.

Bulk density determinations were made of the surface soil at the site. These tests indicate the oven-dry bulk density of surface material ranged from 1.4 g/cc to 1.9 g/cc. The expected bulk density of the plow layer of a silt loam soil which has been in cultivation ranges from 1.2 g/cc to 1.5 g/cc. The high compaction of surface soils at the site is a result of low organic matter content and the placement of the soil by heavy construction equipment. This compaction results in lower than normal water infiltration (higher runoff rates) and reduced plant root development. Natural processes, temperature changes, precipitation, and root growth will reduce compaction over a period of time.

Table 8. Typical Soil Analysis[a]

Depth[b] ft	pH	Ca ppm	Mg ppm	Zn ppm	Electrical Conductance mmhos/cm	Neutralization Potential[c]
0 -0.5	7.7	347	23	0.3	4.1	142
0.5-1.0	7.4	417	20	2.7	3.5	198
1.0-1.5	5.4	642	10	14.0	2.8	13
1.5-2.0	2.4	147	5	92.0	13.6	-22

[a]Sample collected June 1977

[b]One ft = 0.3048 m

[c]Tons $CaCO_3$/1000 tons material

Chemical analyses of soils are underway in the laboratory. The analysis of a typical soil sample from the recontoured area is shown in Table 8. The effect of the neutralizing material at the refuse/cover material interface (0.30-0.45 m or 1-1.5 ft depth) should be noted. These data also indicate that favorable chemical conditions exist for plant root establishment and growth in the 0.30-0.45 m (1.0-1.5 ft) layer. Additional sampling and analyses in the coming year will determine if significant change occurs.

Data from the soil moisture and soil temperature studies indicate that soil moisture is adequate and soil temperature within established limits on most areas of the site. Exceptions are slopes with west and south aspects, and refuse material that received no application of cover material. Temperatures as high as 56°C (133°F) have been recorded just below the surface on bare refuse. These temperatures are well outside limits for plant establishment. The soil psychrometer system will provide needed data in the coming year. An experiment is planned to monitor differences in soil moisture and soil temperatures beneath cover material and beneath mulched and unmulched refuse material.

8 SLOPE ANGLE AND EROSION RATE

8.1 INTRODUCTION

In this subproject, an examination is made of the effect of various slopes (3:1, 5:1, and 7:1) on erosion rates and on runoff water quality and quantity.

8.2 SCOPE

During the site development phase, three research areas were located where nominal slopes of 3:1, 5:1, and 7:1 were cut into regraded refuse material. On each of these slopes, plots were established on bare refuse and on cover material that had been applied in thicknesses of 0.15 m and 0.30 m (0.5 ft and 1.0 ft) over the regraded refuse. Three replicated runoff collection devices were installed on each of these research plots (3 slopes times 3 cover thicknesses; see Figures 12 and 13). The sheet metal sides of each device enclose 4.05 m^2 (43.56 ft^2). The runoff collects at a weir at the bottom of each device and runs through a plastic hose into

Fig. 12. Runoff/Sedimentation Research Plots at the Staunton 1 Site

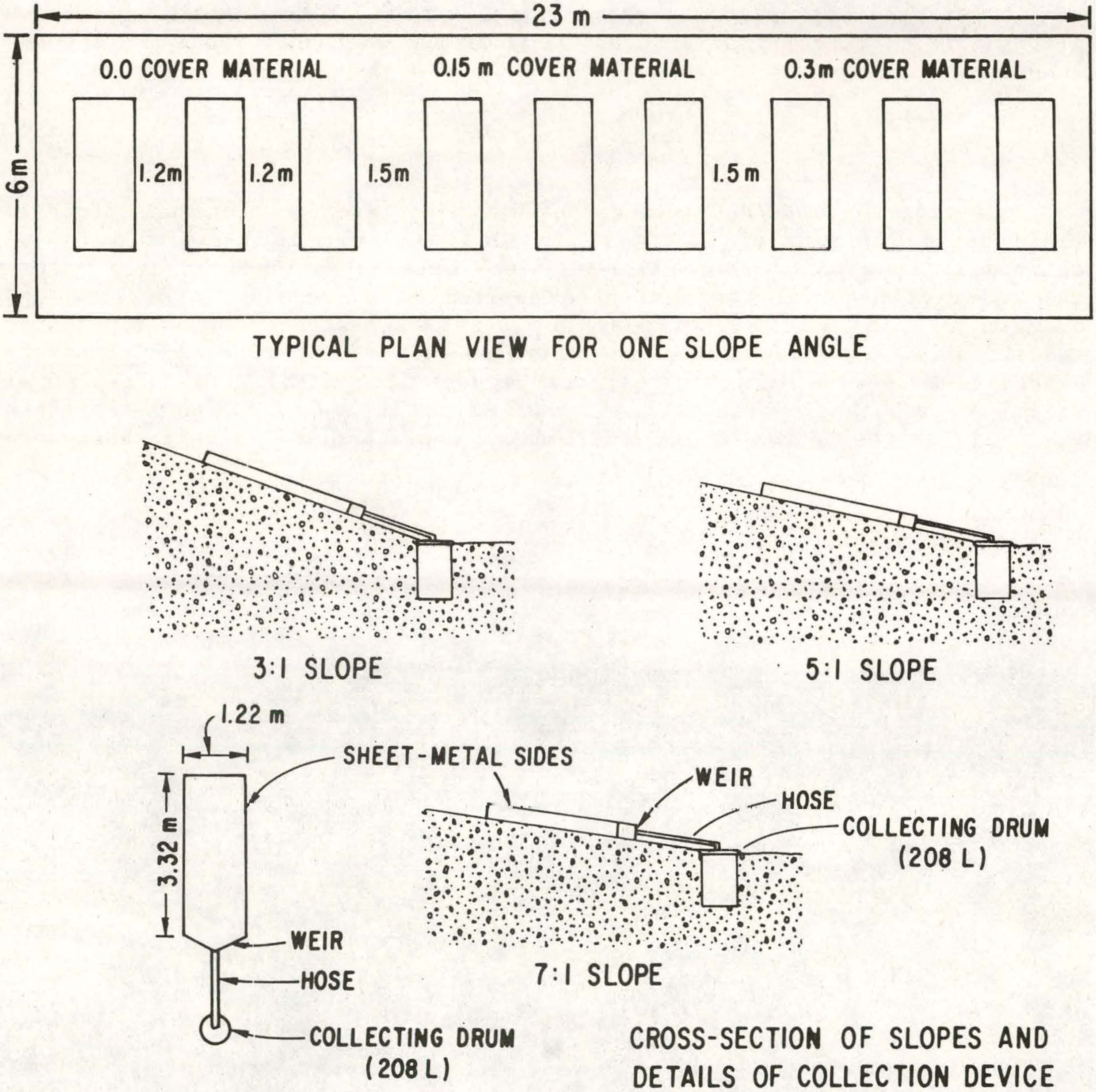

Fig. 13. Diagram and Arrangement of Runoff/Sedimentation Devices

Table 9. Analysis of 4.6 cm (1.8 in.) Rainfall on Nominal 3:1 Slopes

% Slope	Cover Depth (m)	pH	Zn ppm	Fe ppm	Acidity ppm	Sulfate ppm	% Runoff
27.1	0	3.3	8.9	103.2	837.5	1454	42.99
25.9	0.15	5.9	1.2	1.3	30.15	179	24.23
27.6	0.30	5.8	0.4	0.5	8.04	56	22.26

a drum buried in the ground. After each storm event the depth of runoff water is measured, and water and sediment samples are taken. These runoff/sedimentation measurement devices enable the objectives of this subproject to be met. These objectives include: development of the relationship between slope angle and amounts of surface cover to erosion rates and runoff water quality and quantity; establishment of the effect of various physical and chemical properties and their relationship to runoff water; and determination of the economic and environmental feasibility of various treatments tested.

Sampling began in June 1977. In addition to a quantity measurement, a laboratory sample is taken from each drum. This sample is later analyzed for pH, acidity, alkalinity, HCO_3, chloride, phosphate, nitrogen, nitrate, sulfate, calcium, potassium, magnesium, manganese, sodium, cadmium, copper, iron, zinc, and aluminum. A sediment sample is also taken by resuspending the sediment into the runoff water in the drum. This sample is then analyzed for settlable solids and suspended solids. The rainfall amount associated with each of these sampling parameters is provided by the on-site weather station which continuously monitors temperature, humidity, and precipitation.

8.3 RESULTS

Table 9 shows a typical set of results for a 4.6 cm (1.8 in.) rainfall on the nominal 3:1 slope. Results collected to date indicate no dramatic differences for the three slopes. The major differences are between the plots on which cover material was applied and those plots which were left bare. As indicated in this table, the percent runoff, and the concentrations of sulfate, acidity, iron, and zinc all dropped significantly when going from bare refuse to a cover depth of 0.15 m (0.5 ft). The pH increased two units when comparing 0 to 0.15 m of cover depth. The improvements noted in going from 0.15 m to 0.30 m (1.0 ft) of cover depth are not as pronounced as those associated with going from 0 to 0.15 m. If this can be further substantiated, it will mean a cost savings for future projects since the amount of cover material could be reduced from 0.30 m to 0.15 m.

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9 SOIL MICROBIAL INVESTIGATION

9.1 INTRODUCTION

Significant factors that affect the ability of land to support vegetation and undergo rehabilitation are: amount and periodicity of precipitation; soil productivity and fertility; and suitability and availability of plant materials for rehabilitation. The major effort of this subproject concerns the effect of reclamation on below-ground processes, which in turn influences soil productivity and fertility. Thus, a soil ecosystems approach is necessary to assess, as well as to identify, techniques that are successful in restoring below-ground processes needed for stability and prevention of particle transport during reclamation. The soil microflora constitute an essential element of these processes and are intimately associated with nutrient cycling, as well as acting as symbionts necessary to the stability of the ecosystem being established.

9.2 SCOPE

In order to better evaluate the success of particular reclamation techniques, an evaluation of the below-ground processes associated with the resultant newly-formed soil profiles has been undertaken. The experimental design is such that information collected within this subproject can be related to other aspects of the project. The objectives of the soil microbial investigation are to: determine and relate shifts in the microbial populations associated with the characteristics of the site; determine which environmental characteristics govern microbial diversity and abundance; and develop reclamation procedures which will favorably affect soil microbial population.

During 1977, sampling sites were established within the revegetation group's experimental plots. Thus, both above- and below-ground ecosystems may be assessed as a unit. Though many tasks are associated with this project, the approach can be simplified into four main parts: an assessment of the microbial community which includes an evaluation of both bacterial and fungal abundances, kinds, and functional groups; an assessment of the biogeochemical and enzymatic processes associated with the reestablishment of the below-ground ecosystem; an evaluation of carbon and nitrogen cycling within the newly formed soil profiles; and an assessment of the reestablishment of below-ground symbionts necessary for a stable plant community to develop, e.g., mycorrhizae and nitrogen-fixers.

9.3 RESULTS

Soil samples are currently being characterized as to their microbial composition in conjunction with both physical and chemical analyses. Preliminary enzymatic studies have been undertaken for soil urease, dehydrogenase, cellulase, and proteolytic activity (Table 10). Activity levels encountered will act as a baseline to assess the recovery process. Dehydrogenase activity should reflect the amount of respiratory activity of the

Table 10. Some Biochemical Characteristics of Gob and Soil

	Enzyme Activities			
	Ur.[a]	Deh.	Prot.	Cell.
Field Soil	1.77	16.0	18.3	741
Gob	0.21	3.1	0	0
Cover Material	0.16	1.4	3.0	0

[a]Ur = Urease (ppm NH_4 + formed);
Deh. = Dehydrogenase (µg product formed $100g^{-1}$ dry soil);
Prot. = Proteolytic activity (% hydrolysis);
Cell. = Cellulase (µg glucose formed $100g^{-1}$).

soil microflora, whereas proteolytic activity is usually related to the total soil microbial activity (respiration, growth, and maintenance). Urease activity is proportional to the total microbial activity, but is also greater in soils with high C/N ratios. Many microorganisms synthesize large amounts of urease under conditions of nitrogen starvation. Cellulase activity is associated with the ability to utilize cellulose, and is thus a major component of the carbon cycle.

Because only one growing season has passed, none of the treatments has approached the activity levels of the field-soil control site. During the coming growing season, dramatic changes are expected for each of the treatments. Since the microbial community is in a very transient state and is in the process of reestablishing itself and its associated cycles, any activity levels measured at this time can be of only a baseline nature.

Cylinders necessary for the measurement of total soil respiration, an indicator of total soil productivity, have been established on each of the revegetation plots. Major changes in microbial and faunal populations are anticipated and should be exemplified by changes in respiration rates.

Mesh litter bags were made from nylon gauze, filled with straw or filter paper, and placed 6 cm (2.3 in.) below ground surface. Enough bags were placed within each treatment for sampling three times a year for the next three years. The first sampling period was 1 October 1977. By following litter decomposition, an assessment of the nutrient cycling capacities of these newly formed soils can be measured. This will help in gauging the success of a particular treatment.

10 SOIL FAUNA STUDIES

10.1 INTRODUCTION

Soil fauna make up the second part of the below-ground ecosystem. The long-term success of vegetation establishment at the reclamation site is largely dependent upon the physical structure and chemical properties of the topsoil and underlying materials. While certain aspects of the physical structure of topsoil are correlated closely with soil particle size and composition, other aspects such as porosity and organic matter content are affected by the actions of soil fauna and microorganisms. Earthworms probably represent the single most important group of organisms affecting the soil's physical structure, particularly in temperate ecosystems.

10.2 SCOPE

Laboratory and field studies are underway to determine the survival of the earthworm, Lumbricus terrestris, on limed gob. Additional laboratory studies are determining the uptake of various trace elements (As, Cd, Cr, Fe, Hg, Ni, Pb, Zn) of earthworms maintained on limed gob compared with worms maintained on limed topsoil. In the field, three window-screen enclosures were set up on the recontoured refuse. Each enclosure was approximately 1 m (3 ft) in diameter and buried to a depth of approximately 0.45 m (1.5 ft). A known number of worms was placed in each enclosure to determine survival rates in field conditions. The objectives of these studies are to: determine the survival rates of earthworms in various refuse/topsoil mixtures; determine the reaction of earthworms to layered and lime mixtures as used at the site; and determine the uptake of various trace elements by earthworms maintained on refuse material.

10.3 RESULTS

In the laboratory experiment, approximately 60% survival occurred over the 45-day period for earthworms maintained in containers of limed gob under laboratory conditions. Temperature was maintained at 12.2°C (54°F) with 12 hours of light. Tissue analyses for trace elements have not been completed.

In the field experiment, twelve adult L. terrestris were placed in each enclosure in late July. Approximately 60 days later, the enclosures were excavated, but attempts to locate the worms were unsuccessful.

Since survival was so low in both the field and laboratory, the future of this experimental approach is uncertain until the plant and animal tissue analyses are complete. If, as the preliminary analysis seems to indicate, subsoil fauna have difficulty establishing themselves in reclaimed areas, then research specifically aimed at detecting and mitigating the responsible factors must be undertaken.

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11 WILDLIFE INVENTORY

11.1 INTRODUCTION

Reclamation implies a stable and self-sustaining ecosystem when the site ultimately reaches its proposed land use. One of the land uses of the Staunton 1 site is as a wildlife habitat. To date, very little research has been conducted on the responses of fauna to various reclamation techniques. A definite need exists to correlate vegetation establishment and water quality with wildlife species use of reclaimed areas.

11.2 SCOPE

Field studies are being conducted to characterize the vertebrate fauna of the site and adjacent habitats. Birds are inventoried by the transect method, and small mammals are sampled using Sherman live traps. Amphibians and reptiles observed on the site are recorded as to habitat type and location. Wildlife inventories have been made at the site since mid-May of 1977. The objectives of the wildlife inventory are to: determine the wildlife composition of habitats adjacent to the site; determine if wildlife is utilizing the recontoured site; and evaluate the quality of the site as a wildlife habitat.

11.3 RESULTS

Sampling was conducted in May, June, July, and September at the Staunton 1 site. Observations of reptiles and amphibians was limited to miscellaneous field observations and drift fence trapping. A list of

Table 11. Reptiles and Amphibians Observed, May-September 1977

Ornate Box Turtle	*Terrapene ornata*
Eastern Box Turtle	*Terrapene carolina*
Six-Lined Racerunner	*Cnemidophorus sexlineatus*
Northern Water Snake	*Natrix sipedon*
Green Snake	*Opheodrys vernalis*
Cricket Frog	*Acris crepitans*
Leopard Frog	*Rana pipiens*
Bull Frog	*Rana catesbeiana*
American Toad	*Bufo americanus*

Table 12. Birds Observed, May-September 1977

American goldfinch	House wren
Barn swallow	Indigo bunting
Black-capped chickadee	Least flycatcher
Blue jay	Mockingbird
Bobwhite	Mourning dove
Brown thrasher	Purple martin
Cardinal	Red-headed woodpecker
Catbird	Red-winged blackbird
Chimney swift	Robin
Common grackle	Rough-winged swallow
Crow	Rufous-sided towhee
Downy woodpecker	Song sparrow
Eastern kingbird	Sparrow hawk
Eastern meadowlark	Starling
Eastern wood pewee	Tree swallow
Field sparrow	Tufted titmouse
Flicker	Yellow-billed cuckoo
Golden-eyed duck	Yellow warbler
Great crested flycatcher	

herpetofaunal species observed appears in Table 11. A population of six-lined racerunners is present along the abandoned railroad spur adjacent to the recontoured gob pile. Ornate box turtles are present in sufficient numbers to repopulate the site as wooded habitat becomes available. Most important, however, is the rapid influx of cricket frogs, leopard frogs, and American toads observed in the north area between the ponds during the first week of May. Populations remain very high, with 125 frogs counted in a circumference survey of the new pond in July.

Thirty-seven species of birds were recorded during three surveys conducted in May, July, and September (Table 12). Of these, most were passerine species. One raptor and one shorebird were observed. Insectivorous birds were most abundant, and adapted most easily to the reclamation site once insect-supporting vegetation became established. The site has abundant supporting woodland, and sitings of thrushes, buntings, mockingbirds, chickadees, and woodpeckers were common. Such a diverse avifauna will recolonize the site as suitable habitat becomes available; succession, however, must be carefully controlled to prevent the establishment of a monotypic oldfield community that is suitable to only a few species. Such habitat management techniques will be a part of the future effort of this subproject.

Tables 13 and 14 summarized the trapping data and miscellaneous field observations of mammals at the reclamation site. The qualitative pattern of repopulation followed a typical pattern. Early in the sampling, the relative abundance of <u>Peromyscus leucopus</u>, a pioneer species, was high, and <u>Mus musculus</u> was also present. As the trapping season progressed and the monotypic vegetation characteristic of a first-year oldfield became well established, M. musculus dominated in the sampling. Only late in the season was the first evidence obtained of a mammalian fauna characteristic of an oldfield community; a pregnant female Microtus pennsylvanicus was trapped and recaptured on the north side of the reclaimed refuse pile. It is expected that, as the plant diversity increases and an understory becomes well established, capture of this and related species will become commonplace and detailed population studies can begin.

Trapping at the north area was less fruitful, probably because little habitat was available adjacent to the reclaimed area that would facilitate inward migration of small mammals. None of the areas yet have small mammal populations large enough or with sufficient structure to undertake an analysis of density or diversity.

Table 13. Mammals Trapped, May-September 1977

White-footed mouse	Peromyscus leucopus
House mouse	Mus musculus
Meadow vole	Microtus pennsylvanicus
Eastern chipmunk	Tamias striatus
Norway rat	Rattus norvegicus

Table 14. Miscellaneous Field Observations of Mammals, May-September 1977

White-tailed deer	Odocoileus virginianus
Raccoon	Procyon lotor
Opossum	Didelphis virginianus
Muskrat	Ondatra zibethicus
Eastern cottontail	Sylvilagus floridanus

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12 ECONOMIC EVALUATION

12.1 INTRODUCTION

The economic aspects of any reclamation project are often considered before the environmental benefits. It is, therefore, of prime importance that the cost-effectiveness of each new reclamation technique be established. This evaluation of reclamation efforts is 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, such as area reclaimed or volume of refuse disposed of, 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 is often calculated to provide missing factors. This, too, can be misleading because of unknown or untested data. Other economic evaluations can be made by comparing prereclamation property values, tax rates, or economic growth of the area with post-reclamation values.

12.2 SCOPE

This subproject consists of collecting the data necessary to provide two types of economic evaluation related to the project. First, the cost-effectiveness will be determined for each of the subprojects. Second, the overall cost-effectiveness of the project will also be established by a review of the economic and environmental data collected for the entire project.

The subproject is directly dependent upon the environmental evaluation of other subprojects; therefore, results are limited to one year's environmental evaluation and all results are preliminary. Economic data to meet both stated objectives are being assembled and will be combined with environmental data as they become available.

12.3 RESULTS

The cost-effectiveness of various reclamation techniques is available in preliminary form. Data from the revegetation research plots and the slope erosion studies indicate that refuse material must be covered with established plant growth. Construction costs for covering 0.4 ha (1 ac) with 0.3 m (1 ft) of soil totaled about \$5000.00. The cost is calculated by the volume of material necessary to cover an area times the unit cost paid to move the material. The contract cost for cover material was \$4.05 per m^3 (\$3.10/yd^3).

$$3000\ m^3/ha \times \$4.05/m^3 = \$12,150.00/ha$$

$$1613\ yd^3/ac \times \$3.10/yd^3 = \$5000.30/ac$$

Additional data from revegetation research plots indicate little difference in vegetation establishment between 0.3 m (1.0 ft) and 0.15 m (0.5 ft) of cover material. Therefore, the data indicated a minimum of \$6075 per hectare (\$2500.15/ac) is required to establish some type of vegetative cover.

These findings are confirmed by runoff water quality data from the slope erosion studies. Definite differences in runoff water quality occur between plots with cover material and those with no cover material. The data indicate 0.15 m of cover material is sufficient to maintain runoff water quality. In both cases, these are preliminary data and 0.15 m may not provide adequate protection to maintain environmental quality.

Other data from the revegetation research plots indicate only small differences exist between 224 t/ha (100 tons/ac) and 112 t/ha (50 tons/ac) of agricultural limestone applied at the refuse/cover material interface. Construction costs for limestone are \$13.23 per metric ton (\$12.00/U.S. ton). With this cost of agricultural limestone and an application rate of 224 t/ha, total limestone cost per unit area is \$2963.53/ha (\$1200.00/ac). If one-half the application rate is successful in maintaining a vegetative cover, overall costs could be reduced by \$1481.76/ha (\$600.00/ac). These calulations are based on one year's vegetation data. Additional vegetation data are needed to evaluate long-term effects of each treatment.

Observations from the slope erosion study indicate little difference in water quality from the various slope angles as long as the slope has cover material on it. The overall cost of the project would have been lowered because less relocation of refuse material would be required.

Prior to reclamation, the State of Illinois had the Staunton 1 site and a second abandoned mine site (Staunton 2 site) appraised. In May 1978, ANL engaged the same firm to reappraise both sites. Table 15 shows both the

Fig. 14. Home Under Construction Near the Staunton 1 Site

Table 15. Comparison of Appraised Values for Two Abandoned Mined Sites

STAUNTON 1 SITE

Parcel	Hectares	Acres	Appraised Market Value 1976	Appraised Market Value 1978[a]
1	4.61	11.39	$1,700.00	$ 5,685.00
2	0.88	2.17	55.00	1,000.00
3	0.86	2.13	550.00	1,065.00
4	7.39	18.26	1,825.00	18,250.00
TOTAL	13.74	33.95	$4,130.00	$26,000.00

STAUNTON 2 SITE

Parcel	Hectares	Acres	Appraised Market Value 1976	Appraised Market Value 1978
1	5.73	14.16	$ 3,900.00	$ 3,900.00
2	6.10	15.07	4,150.00	4,150.00
3	4.39	10.85	3,250.00	3,250.00
4	4.20	10.38	260.00	260.00
TOTAL	20.42	50.46	$11,560.00	$11,560.00

SOURCE: Reference No. 15

[a]After reclamation

1976 and 1978 appraisals. As indicated by the 1978 figures, the Staunton 1 site after reclamation has shown a change in market value of $21,870, or an increase of 529.5 percent over its 1976 appraised value. This is an increase of 1,699.3 percent over the purchase price ($1530) paid by the state in September 1976. The market value of the Staunton 2 site shows no change between 1976 and 1978 due to the lack of improvement at this site.

The economic effect of the reclamation effort reaches beyond the site property lines. A property about 0.4 km (0.25 mi) west of the site was owned by the City of Staunton from 1938 to 1977, when the city sold this 0.88 ha (2.17 ac) property for $2600. The owner is presently building a home (Fig. 14) valued at $60,000 on the property (3). The owner indicated that he would not have considered purchasing the property nor building his home on this parcel if the unsightly gob pile had not been leveled and the reclamation of the site undertaken (20).

Results from the economic evaluation indicate improvements have been made in the economic potential of the area, but additional environmental data must be collected and evaluated to determine the cost-effectiveness of the entire project.

The economic aspects of the site development phase at Staunton 1 will be the subject of a forthcoming report.

13 SITE MANAGEMENT AND MAINTENANCE

13.1 INTRODUCTION

Reclamation of any site is a process which may require years to complete. At the Staunton 1 site, reclamation will be complete when a stable, self-sustaining ecosystem has been established that meets the needs of the planned land use. The recontouring, seeding, and other site development activities are only the first steps in the reclamation process. The site must be managed in a manner that encourages the development of the intended ecosystem. Maintenance is required to ameliorate environmental problems that develop at the site. These additional efforts are necessary if the reclamation process is to be completed successfully.

13.2 SCOPE

The objectives of this subproject are to: provide an environmental and economic evaluation of the reclamation effort; ameliorate environmental problems which may develop on the site; and provide a completely reclaimed site to the public at some future date.

The first objective involves coordination of the research efforts of the various subprojects. Data collected by one researcher at the site can be of value to another researcher working on a different subproject. By pooling information, a better understanding of the reclamation process can be achieved. Duplication of effort is eliminated by the sharing of basic data with other subprojects working at the site. The basic need for on-site day-to-day observations are accomplished by employing an on-site consultant.

One of the major objectives of the project's fourth phase (post-construction evaluation) is to investigate and ameliorate potential environmental problems which may develop on the reclamation site. This objective is being met as individual investigators report potential problems and corrective action is taken.

13.3 RESULTS

During 1977, erosion control was the major problem reported. Approximately 20 t (22 tons) of rip rap were placed just downstream from the dam to control erosion. About 0.2 ha (0.25 ac) on the downstream side of the dam was reseeded and mulched with straw to control runoff and erosion. Small gullies in drainage channels were filled and reseeded. On areas where vegetative cover was sparse, fall reseeding was done.

An automatic recording climatological station was installed to collect basic information useful to many investigators. Mr. Barry Deist, biology instructor at Staunton High School, serves as a consultant for on-site day-to-day observations and sample collection. All subprojects have used his services at various times. Mr. Deist also acts as ANL's local representative and is invaluable in his public relations role connected with the project.

In the coming year, a mowing program will be instituted to better control unwanted vegetation. Results of the site-wide revegetation study and soils investigations will be used for site maintenance. Recommendations from the wildlife habitat inventory and the aquatic ecosystems research will be used to better achieve the ultimate land use of the site. These activities will be undertaken to prepare the site for future public use.

14 SUMMARY

The total reclamation of any site requires physical control of the site, favorable natural conditions, considerable capital investment, as well as years of time. It must be realized that processes involving biological systems require time to become established and self-sustaining. Assessment of the entire reclamation effort also requires years. The Staunton 1 project has been designed to provide data on many aspects of the reclamation process. Information collected to date indicates that a significant improvement has been made in the overall environmental quality of the site, and that there is a general reduction in the quantity of acid mine drainage, heavy metals, sediment, and other pollutants entering the environment. Data from the economic evaluation portion of the project suggest a substantial increase in the economic potential of the site and adjacent properties. The reaction of visitors and local residents to the site implies a genuine enhancement of the entire area's aesthetic value. The Staunton 1 Reclamation Demonstration Project, while serving to reclaim this one site, will also provide a much broader benefit by furnishing the necessary design data for future reclamation efforts of this type.

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Program Summary

The Land Reclamation Program is addressing the need for coordinated applied and basic research into the physical and ecological problems of land reclamation, and advancing the development of cost-effective techniques for reclaiming land mined for coal. This program is conducting integrated research and development projects focused on near- and long-term reclamation problems in all major U.S. coal resource regions, and is evaluating and disseminating the results of related studies conducted at other research institutions. These activities involve close cooperation with the mining industry. Regional and site-specific reclamation problems are being addressed at research demonstration sites throughout the country, and through laboratory and greenhouse experiments.

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