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STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT

Aquatic Ecosystems
Final Report

LAND RECLAMATION PROGRAM

ARGONNE NATIONAL LABORATORY

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Aquatic Ecosystems Final Report

by

William S. Vinikour

Land Reclamation Program

February 1981

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PREFACE

This study was performed as part of the Argonne National Laboratory Land Reclamation Program, which is sponsored by the U.S. Department of Energy (DOE), 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 the Division of Environmental Impact Studies.

The Land Reclamation Program, as the lead DOE program for reclamation research, conducts basic and applied research into the physical, environmental, and economic problems of land reclamation related to the mining of coal. The work is aimed at developing energy-efficient and cost-effective techniques for reclaiming and rehabilitating mined land to productive end uses. To achieve this goal, the Program has established integrated research and development projects focused on near- and long-term reclamation problems in all major U.S. coal resource regions. These research sites have been established to address both regional and site-specific problems. 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. At five of its research sites, the Program has developed cooperative working arrangements with the operating coal companies. Close cooperation with related research projects at academic institutions and other agencies, in order to transfer pertinent information and avoid duplication of effort, has been a primary goal of the Program.

Coordinated by Stanley D. Zellmer of Argonne's Land Reclamation Program, the Staunton 1 Reclamation Demonstration Project is a multidisciplinary approach to reclamation of an abandoned deep coal mine refuse site in the Midwest. Current investigations are concerned with groundwater and surface water quality, aquatic ecosystems, revegetation, soil characteristics, erosion and runoff, wildlife, soil microbial populations, and economic benefits of the reclamation effort. This report, one in a series of final reports on the project, deals with the aquatic ecosystems investigation.

Ralph P. Carter, Director
Land Reclamation Program

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STAUNTON 1 RECLAMATION DEMONSTRATION PROJECT -- AQUATIC ECOSYSTEMS

Final Report

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ABSTRACT

To provide long-term indications of the potential water quality improvements following reclamation efforts at the Staunton 1 Reclamation Demonstration Project, macroinvertebrates were collected from three on-site ponds and from the receiving stream (Cahokia Creek) for site drainage. Implications for potential benthic community differences resulting from site runoff were disclosed, but macroinvertebrate diversity throughout Cahokia Creek was limited due to an unstable, sandy substrate. The three ponds sampled were the New Pond, which was created as part of the reclamation activities; the Shed Pond, which received drainage from the gob pile and displayed conditions of severe acid mine drainage; and the Old Pond, which, because it was an existing, nonimpacted pond free of site runoff, served as a control. Comparisons of macroinvertebrates from the ponds indicated the potential for the New Pond to develop into a productive ecosystem. Macroinvertebrates in the New Pond were generally species more tolerant of acid mine drainage conditions. However, due to the present limited faunal densities and the undesirable physical and chemical characteristics of the New Pond, the pond should not be stocked with fish at this time.

1 BACKGROUND

In the past, the methods and sites for disposal of coal-mine refuse were usually determined by convenience and economic considerations. Coarse refuse (gob) was usually dumped near the preparation plant, which often created large, steep-sided piles. Effluent (slurry) from the coal washers was pumped into a nearby impoundment where solids were allowed to settle out. Little or no thought was given to the long-term environmental consequences of such indiscriminate actions. While present day mines are required by law to use disposal methods and sites that minimize environmental damage, many abandoned (pre-regulation era) refuse-disposal sites remain today as serious environmental, economic, and aesthetic problems.

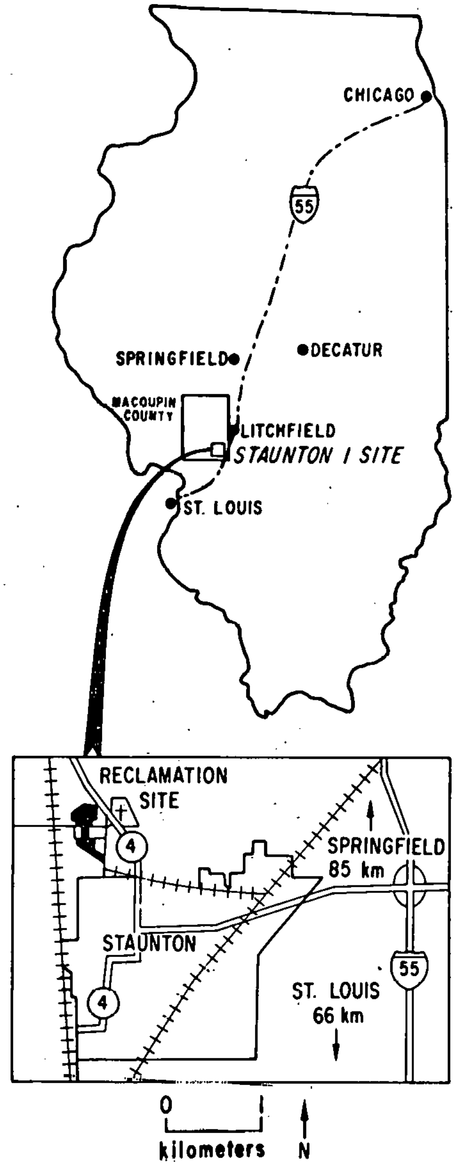

Fig. 1.1 Location of the Staunton 1 Site

The U.S. Department of Energy, through the Land Reclamation Program at Argonne National Laboratory, and two Illinois agencies -- the Abandoned Mined Land Reclamation Council and the Institute of Natural Resources -- developed a cooperative project to address the problems associated with reclaiming an abandoned deep mine refuse site. A major objective of the cooperative project was to demonstrate and evaluate new and cost-effective methods for reclaiming abandoned coal refuse sites in order to provide greater benefits at lower costs. Additional objectives of the project were common to all reclamation efforts. They were to: (a) reduce the quantity of pollutants entering the environment, (b) increase the economic potential of the area, and (c) improve the aesthetic value of the locality.

1.1 THE STAUNTON 1 SITE

The site selected for the reclamation demonstration project was the abandoned Consolidated Coal Company's Mine No. 14 near Staunton, Illinois (Figure 1.1). The mine was opened in 1904 and operated for approximately 19 years, extracting the Herrin (No. 6) coal through an 85-m-deep vertical shaft. The total site included 13.8 ha, of which 9.3 ha had been affected by the past mining operation and required reclamation. Dramatic evidence of the past mining and cleaning operation existed in the form of the gob pile, a steep-sided refuse heap that rose about 25 m above the natural landscape and covered almost 2 ha (Figure 1.2). In the 50-odd years the mine had been closed, erosion had cut deep gullies into the face of the gob pile; no vegetation had become established on the gob or in adjacent areas affected by the acid runoff and sediment. 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 impoundment created by the dam provided water for the mine's power plant and coal washing operation, and also 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 from the gob pile. In the early 1940s the dam was breached, resulting in erosion of the slurry area and gullies as deep as 4.5 m. Acid runoff and sediment from the site were carried down a small stream about 0.8 km to Cahokia Creek. The site had been used as a general dump for many years and was littered with trash and debris. There was evidence that small game used the remaining 4.5 ha of the site that was covered with volunteer shrubs, grasses, and trees.

1.2 PRE-RECLAMATION WORK

Before reclamation work could begin, the project 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 physical and chemical instability of the refuse material. Further investigation determined that the community had a need for additional recreational areas and that this use would be compatible with the conditions at the site. With these considerations in mind, a final land use as a recreational area, wildlife habitat, and ecological education area was selected. Detailed engineering plans and specifications were developed by the Land Reclamation Program to meet the requirements for this final land use. The planning and design phase was jointly funded by the Illinois Institute of Natural Resources (INR) and the U.S. Department of Energy (DOE).

During the first phase of the project, baseline monitoring was instituted to assess the prereclamation environmental conditions of the area. Monitoring included: (a) determination of groundwater and surface water quality; (b) detailed sampling and testing of surface materials to determine

Fig. 1.2 Gob Pile before the Start of Reclamation Work

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 site's watershed; and (e) a survey of soil microbial populations that are indicative of the fertility of the refuse material and site soils. 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. The second phase of the project (actual site development) also was jointly funded by INR and DOE.

In the late summer of 1976, the State of Illinois Abandoned Mined Land Reclamation Council (AMLRC) purchased the site, and on 15 September 1976 awarded the construction contract to Marle, Inc., of Springfield, Illinois. AMLRC also contracted to have the Land Reclamation Program staff act as resident engineers for the project during the site development phase.

1.3 SITE DEVELOPMENT

Site development began with the removal of the old mine structures and the disposal of accumulated debris. A borrow pit was opened, and cover material removed and stockpiled. The borrow pit was filled with gob, and extensive recontouring reduced the gob pile to approximately one-fifth its original height. The slurry area was recontoured and a retention pond excavated. Neutralizing/stabilizing agents were applied at a rate of 168 t/ha $CaCO_3$ equivalent and incorporated to a minimum depth of 15 cm into the recontoured refuse materials using an industrial disk harrow. Cover material from the borrow pit was then placed on the recontoured and limed refuse material in a layer 30 cm deep. An application of 11.2 t/ha of agricultural limestone, and 135 kg/ha each of nitrogen, phosphorus, and potassium plant nutrients was made to the recontoured area. These amendments were disked to a minimum depth of 10 cm during seedbed preparation. The area was then planted using an agricultural grain drill with a mixture of reed canary-grass, tall fescue, birdsfoot trefoil, ladino clover, and cereal rye. Seeding, fencing of the site perimeter, and final cleanup were completed by the end of April.

During site development, the following tasks were accomplished: (a) all slopes were reduced to 5:1 or less; (b) approximately 180,000 m^3 of refuse material was relocated; (c) an on-site borrow pit providing nearly 30,500 m^3 of cover material was dug; (d) about 1275 t of neutralizing/stabilizing agents was applied at the refuse/cover-material interface; (e) all exposed refuse material was covered with 30 cm of cover material; (f) roughly 103 t of soil amendments (fertilizer and limestone) was incorporated into the surface of the 8.9 ha that was seeded with the mixture of grasses and legumes; (g) placement of about 100 m of culvert pipe and three concrete water flow control structures; (h) excavation of a 0.5-ha retention pond; (i) rebuilding of the old dam; and (j) installation of approximately 2240 m of new fencing around the property. The cost of accomplishing these tasks was $575,906.45; funds were provided by AMLRC through the Illinois Capital Development Board.

1.4 POST-CONSTRUCTION EVALUATION

The end of the project's development phase coincided with the beginning of the postconstruction evaluation phase. Objectives of this final phase were to: (a) demonstrate and evaluate needed technologies for future reclamation efforts at other, similar sites; (b) provide an overall assessment of the reclamation effort in order to determine its environmental effectiveness; (c) ameliorate potential environmental problems that developed at the site; and (d) provide the economic assessment necessary to transfer the most cost-effective reclamation techniques to future projects. These objectives have been met by the establishment and maintenance of a number of interrelated subprojects. The subprojects are: (a) groundwater quality; (b) surface water quality; (c) aquatic ecosystems; (d) site-wide revegetation success; (e) revegetation research plots; (f) soil characteristics; (g) slope angle and erosion rate; (h) soil microbiological investigation; (i) wildlife investigations; and (j) economic benefits. Each subproject covers a specific portion of the reclamation effort, and data gathered by each subproject contributed to an overall assessment of the project. Funding for the final phase of the project was provided jointly by DOE, INR, and AMLRC. The remainder of this report is a description of and final report for the aquatic ecosystems subproject.

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2 INTRODUCTION

Deleterious impacts to aquatic systems stemming from coal mine drainage in eastern and midwestern states are well known. In these areas, the primary effects on water quality in a receiving stream are due to acid mine drainage. These include reduced pH, increased dissolved and suspended solids, decreased alkalinity (with a corresponding increase in acidity), and the introduction of highly toxic heavy metals (Herricks and Cairns, 1975). With the advent of pollution control and abatement regulations, impacts to aquatic systems are now being curtailed. However, many orphaned mine spoils release uncontrolled amounts of acid mine drainage that enter receiving streams and affect aquatic systems. The Staunton 1 Reclamation Demonstration Project site was a typical orphaned mine site. Acidic runoff from the gob and slurry areas flowed through an intermittent discharge channel, eventually emptying into Cahokia Creek.

One goal of the aquatic ecosystems subproject was to evaluate the effects of site reclamation on the quality of effluent entering the creek. Drainage from the Staunton 1 site occurred mainly during periods of precipitation; thus, a survey of the macroinvertebrates was used as a primary means of evaluating the reclamation activities. Intermittent pollution is not always discernible by chemical and physical tests; however, it continues to affect aquatic biota. Macroinvertebrates can provide long-term indications of water quality conditions, whereas water samples only reveal the conditions present at the time of their collections. In addition, macroinvertebrates: (a) are large enough to be captured readily; (b) show a wide range of tolerance to varying degrees of pollution; (c) are not highly mobile; and (d) have annual (or longer) life cycles. Thus, their presence or absence can provide information on conditions that have existed over previous months (Goodnight, 1973).

The relative success of reclamation at the site was assessed by comparing macroinvertebrate fauna upstream and downstream from the entrance of site drainage into the creek. Many studies, e.g., Roback and Richardson (1969), Parsons (1968), Katz (1969), Oliff (1963), Oliff et al. (1965), Kemp (1967), and Harrison (1958), have reported the effects of acid mine drainage in decreasing or eliminating benthic fauna. It was expected that continued observations of macroinvertebrate fauna in Cahokia Creek would demonstrate whether the reclamation project had made an improvement in the quality of water discharged from the site.

Development of a stable and diverse pond fauna as part of the reclamation effort was considered to be beneficial, especially since one of the ultimate goals of the project was to create a wildlife habitat. Benthic macroinvertebrates not only serve to indicate water quality, but also provide food for fish, mammals, birds, reptiles, and amphibians. Therefore, a productive benthic fauna would also contribute to the establishment of a stable and diverse terrestrial wildlife community on the site. The second aspect of the aquatic ecosystems subproject was to evaluate whether the pond that was created as part of the reclamation effort was developing diverse and stable benthic fauna.

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3 MATERIALS AND METHODS

Quantitative macroinvertebrate collections from Cahokia Creek were made in May 1976. Triplicate Ponar grab samples were taken from each of three station locations. Each sample collected a 0.023-m^2 section of creek bottom. Collection stations were: (a) upstream from the entrance of the Staunton 1 site drainage (C-1); (b) immediately downstream of the site drainage entrance (C-2); and (c) approximately 0.8 km downstream from the point of site drainage (C-3). These locations represent areas unaffected by, potentially affected by, and potentially recovering from Staunton 1 drainage, respectively. Collected samples were washed through a #30 mesh sieve with the unsieved portion, including organisms, preserved in 70% ethyl alcohol. In the laboratory, organisms were separated from the remaining sediments in a white enamel tray.

In addition to the quantitative samples taken from Cahokia Creek, qualitative samples were collected in order to compile an inventory of the macroinvertebrates that would not be encountered in Ponar grabs. The qualitative samples emphasized species associated with rocks and leaf litter packs. These collections were made during May, June, and November 1976. Organisms were collected with forceps from rocks or plant matter and preserved in 70% ethyl alcohol.

In June 1976, a qualitative survey was made for macroinvertebrates in standing bodies of water in the unreclaimed slurry area. Only a cursory search of the slurry area was conducted, and the observed aquatic or semiaquatic specimens were collected by hand.

During 1977 and 1978, benthic macroinvertebrates were collected from the three on-site ponds (called the Old Pond, New Pond, and Shed Pond). The location of these ponds is shown in Figure 2.1. Major sampling emphasis was placed on the New Pond, which was sampled on all collection dates and had the greatest number of samples collected per sample date. Since the Old Pond was unrelated to and unaffected by the refuse or the reclamation work, it served as a control for benthic community comparisons with the New Pond. It was assumed that the Old Pond would indicate the potential community that could develop in the New Pond. The Old Pond was also one of several ponds in the area that could serve as a source of colonizing organisms for the New Pond. The Shed Pond was sampled because its extremely poor water quality typified acid mine drainage conditions. Knowledge of the invertebrates that inhabited this pond could indicate those organisms capable of inhabiting degraded water. By comparing the organisms in the three ponds, it could be determined whether only tolerant organisms were colonizing the New Pond or whether more sensitive species were becoming established.

Pond benthic samples were taken with a Ponar grab in 1977 and with an Ekman grab in 1978. Each device collected a 0.023-m^2 area of pond bottom per sample. Most sampling was done along the shoreline in depths of 0.3 to 1.0 m. Shallower areas of ponds (and lakes) tend to have more organisms per unit area than do deeper areas, particularly as regards midge larvae (Thut, 1969; McLachlan, 1970; Ali and Mulla, 1969). Therefore, the densities reported may be overestimates of the overall densities occurring

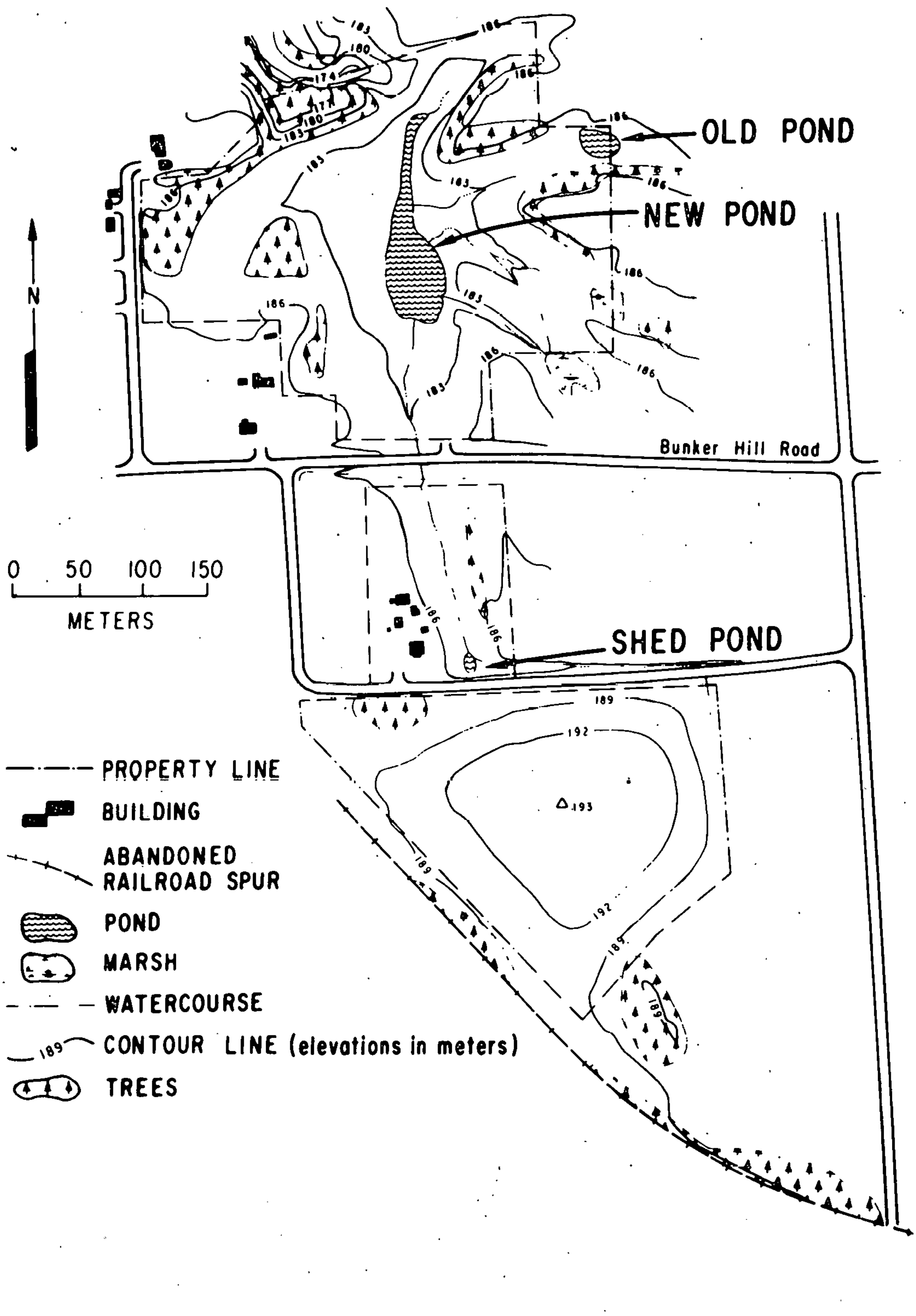

Fig. 2.1 Aquatic Ecosystem Sampling Locations

in the ponds; however, collections from similar areas of the three ponds allow the density values to be used for comparison among the ponds. The pond samples were washed, preserved, and sorted in the same manner as the samples from Cahokia Creek.

The invertebrates were identified to the lowest possible taxonomic level. This was usually to genus, especially for the Diptera (true flies). For many immature aquatic insects, associations with adults are needed for species determination.

Information from the species lists was used to calculate Shannon diversity indices. Diversity indices are often used to compare invertebrate communities based on both the number of species and the distribution of individuals among the species. Generally, the higher the diversity value, the more complex, developed, and stable a community is thought to be. The formula used (following that in Brower and Zar, 1977) was:

$$H = (N \log N - \Sigma n_i \log n_i)/N$$

where:

H = Shannon diversity index,

N = total number of individuals for all species, and

n_i = number of individuals of species i.

The macroinvertebrate communities were further compared using Morisita's index of community similarity (Horn, 1956; Morisita, 1959). The value obtained for this index relates to the probability that two individuals collected from a given location (in this case, a specific Cahokia Creek sampling station or one of the on-site ponds) will be of the same species relative to drawing individuals from the same species from two locations (e.g., New Pond and Old Pond) (Brower and Zar, 1977). Index values range from 0.0 (when no species similarity exists) to 1.0 (when species composition and abundance are the same between sites). Community similarity values were calculated for the quantitative benthic samples collected from Cahokia Creek using the cumulative number of individuals and species for each sampling station. On-site ponds were compared for April, May, and June 1978 collections based upon mean number of individuals per species per square meter. The formula used to calculate the index was:

$$I_M = \frac{2\Sigma X_i Y_i}{(\lambda_1 + \lambda_2) n_1 n_2}$$

where:

I_M = Morisita's index of community similarity,

X_i = number of individuals in species i from community 1,

Y_i = number of individuals in species i from community 2,

n_1 = total number of individuals from community 1,

n_2 = total number of individuals from community 2,

$$\lambda_1 = \frac{\Sigma X_i(X_i-1)}{n_1(n_1-1)} \text{ , and}$$

$$\lambda_2 = \frac{\Sigma Y_i(Y_i-1)}{n_2(n_2-1)} \ .$$

Comparisons of the data for each pond, accompanied by supporting literature on the life histories and pollution tolerances of the prominent species collected, allowed conclusions to be drawn about benthic community development, and hence long-term water quality, in the New Pond. From this information, the potential for a productive biological system in the New Pond could be determined.

4 RESULTS AND DISCUSSION

4.1 CAHOKIA CREEK

Species lists for macroinvertebrates collected in Ponar samples from Cahokia Creek in May 1976 are presented in Table 4.1. There is a poor representation of macroinvertebrate orders; of those invertebrates collected, the majority of organisms are midge larvae (Diptera: Chironomidae). Several individuals from two other dipteran families, as well as a dragonfly (Odonata: Anisoptera) species and a worm (Oligochaeta) species, composed the remainder of the collected invertebrates. This low variability of invertebrate groups was related to a loose substrate that consisted of sand, pebbles, and, occasionally, fine coal debris. The loose substrate is continuously resuspended and deposited because of changes in creek flows (e.g., from precipitation events). The unstable nature of the sand, pebbles, and coal fines makes colonization by invertebrates, other than those adapted to burrowing into porous sediments, most unsuitable. In addition to substrate limitations, Smith (1971) rated Cahokia Creek as a poor fish habitat due to extensive industrial pollution, siltation, and dessication of the small streams in the watershed. These factors have resulted in the low diversification of macroinvertebrates. Similar decreases in benthic diversity due to sand substrates have been observed elsewhere. For example, Duda (1979) found that erosion from mica, feldspar, and kaolin mining activities changed the bottom of the North Toe River in North Carolina from exposed cobble and gravel to a sand-bed bottom. Accompanying this alteration was an 84 to 90% reduction in the number of macroinvertebrates.

Diversity values were calculated for the cumulative total numbers of organisms collected from each site. The values were: 2.21 upstream of the discharge (C-1), 2.58 at the discharge (C-2), and 2.57 at the downstream station (C-3). The small variation in these values reflects the differences in the number of midges among the collected genera. This could have resulted from variations in the natural clumping of individuals as much as from water quality influence. Morisita's index of community similarity values were: 0.09 (between C-1 and C-2), 0.62 (between C-1 and C-3), and 0.45 (between C-2 and C-3). These index values imply that drainage from the Staunton site had an influence on the creek invertebrates, i.e., the benthic community immediately downstream of site drainage (C-2) was quite dissimilar to the upstream control station. The intermediate values comparing stations C-1 to C-3 and C-2 to C-3 imply that water quality and substrate conditions at station C-3 are improving over those at C-2, but that recovery has not occurred at C-1.

Data from the quantitative collections made before reclamation showed that the creek bottom supported a limited benthic community because of habitat restrictions. Qualitative samples from leaf litter packs and rocks along the shoreline further demonstrated that the creek's sand substrate was limiting the benthic community. Data from these collections (Table 4.2) reveal that there is a greater assemblage of organisms at all the sampling stations located in the more stable and organically (food supply) enriched portions of the creek. Thus, it can be concluded that Cahokia Creek would support a greater diversity of organisms if the substrate were more complex and stable than sand. Therefore, it was concluded

Table 4.1 Macroinvertebrates from Cahokia Creek (Quantitative Samples, May 1976)

Taxa	Sample Number										
	1	2	3	4	5	6	7	8	9	10	11
Diptera											
Chironomidae											
Ablabesmyia sp.				1			2	1			
Clinotanypus pinguis				1							
Procladius sp.		3	1		1		7	5			
Tanypus punctipennis	1							2			
Cryptochironomus sp.			1								
Endochironomus sp.				1							
Clyptotendipes sp.							1				
Limnochironomus (Dicrotendipes) sp.			1				1				
Polypendilum sp.								2			
Cladotanytarsus sp.	7	9	13	6	1	2	6	14			
Tanytarsus sp.	3	3	3		2		8	1	1		
Ceratopogonidae											
Probezzia complex	2	1		1		1	2	2			
Chaoboridae											
Chaoborus punctipennis									5	4	32
Coleoptera											
Dytiscidae											
Laccophilus maculosus							1				
Ephemeroptera											
Baetidae											
Callibaetis fluctuans		1							1		
Caenidae											
Caenis sp.										1	
Odonata											
Coenagrionidae											
Enallagma sp.					1	3	3				
Libellulidae											
Libellula luctuosa						1					
Pachydiplax longipennis							1				

Table 4.2 Macroinvertebrates from Cahokia Creek (Qualitative Samples, May, June, and November 1976)

Taxa	Taxa
Nematomorpha	Ephemeroptera
Gordiidae	Heptageniidae
Gordius sp.	*Heptagenia diabasia*
	Stenacron interpunctatum
Oligochaeta	Caenidae
Tubificidae	*Caenis simulans* (?)
Limnodrilus sp.	
	Coleoptera
Isopoda	Elmidae
Asellidae	*Stenelmis* sp.
Asellus intermedius	Dryopidae
	Helichus sp.
Amphipoda	
Talitridae	Diptera
Hyalella azteca	Ceratopogonidae
	Palpomyia complex
Decapoda	Chironomidae
Astacidae	*Ablabesmyia* sp.
	Chironomus sp.
Plecoptera	*Stictochironomus* sp.
Perlidae	*Polypedilum* sp.
Perlesta placida	*Tanytarsus* sp.
	Paratanytarsus sp.
Trichoptera	*Orthocladius* sp.
Hydropsychidae	*Cricotopus* sp.
Cheumatopsyche analis (?)	*Corynoneura* sp.
Odonata	
Calopterygidae	
Calopteryx aequabilis	
Coenagrionidae	
Argia sp.	

that the potential water quality improvements relating to reclamation activities of the Staunton 1 site would not significantly alter the benthic community in Cahokia Creek. It was decided that further sampling of the creek was unwarranted; therefore, the remaining sampling efforts focused on the on-site ponds.

4.2 PRE-RECLAMATION SITE SURVEY

A cursory survey of the unreclaimed slurry area revealed few aquatic species inhabiting the standing water bodies of the area. The only truly aquatic species found was a water strider, *Gerris* sp. (Hemiptera: Gerridae).

This discovery was not unexpected; because gerrids live on the water surface and derive oxygen from the atmosphere, they are thus more tolerant of environmental extremes than most aquatic insects (Roback, 1974). However, Roback (1974) pointed out that hemipterans (true bugs) are more responsive to chemical extremes than one would expect. Water quality conditions for Gerris species reported by Roback did not approach the extreme conditions found in the Staunton slurry area. This is probably because of a lack of collection efforts under conditions of degraded water quality, rather than because water striders do not normally inhabit such areas.

The only other species encountered in the pre-reclamation site survey was the variegated mud-loving beetle Lanternarius brunneus (Coleoptera: Heteroceridae). This semiaquatic beetle was collected from its galleries surrounding many of the water bodies in the slurry area. Species of this beetle family previously have not been reported to inhabit coal slurry and/or such extreme chemical conditions; a short report summarizing this finding was published (Vinikour, 1979).

4.3 ON-SITE POND SURVEY

Macroinvertebrates collected from the on-site ponds for each sampling date are listed in the Appendix. The mean percent composition for the major taxa summarized for each pond and sampling date is presented in Table 4.3. Table 4.4 lists the mean number of individuals and percent composition per square meter for the 1978 pond samples. The tables indicate dominance of Diptera in the ponds. Dipterans were the only organisms collected from the Shed Pond, were the most abundant organisms in the New Pond, and were numerically dominant on all but one sampling occasion in the Old Pond. Chironomidae were the most prevalent family of Diptera. Eighteen species of midges were collected from the ponds, with the major species being Chironomus plumosus, Procladius sp., and Tanypus punctipennis. Chironomus plumosus was the only species collected in abundance from the Shed Pond and was often the dominant species collected from the New Pond. This was no surprise, considering the degraded water quality in the Shed Pond (e.g., pH was < 4.5, alkalinity was 0.0 mg/L, and acidity ranged from 72 to 29,520 mg/L) and the poor-to-fair water quality of the New Pond (e.g., pH ranged from 4.0 to 8.4, alkalinity from 0.0 to 46.0 mg/L, and acidity from 0.0 to 28.0 mg/L). Zellmer (1979) contains a more detailed account of the pond chemistry. Harp and Campbell (1962) observed C. plumosus to be the only midge species in water with a pH of < 6.0.

Other dipterans regularly collected were species of Ceratopogonidae (biting midges) and Chaoboridae (phantom midge). Species of these families were common in both the Old and New Ponds. Mosquito larvae were observed regularly in the New Pond, but were collected in the samples on only one occasion. The species was identified as Aedes vexans, one of the most common mosquitoes in North America and one of the most annoying pests and fierce biters to be found (Gerhardt, 1966; Nielsen and Rees, 1961; Rempel, 1953).

In the Old Pond, the fingernail clam Musculium transversum and the snail Physa gyrina were commonly collected. They were absent or rare in the New Pond because of inadequate water quality, substrate limitations,

Table 4.3 Mean Percent Composition of Major Taxonomic Groups Collected from the Ponds

	May 10, 1977		June 28/29, 1977	Aug. 16, 1977		Oct. 3, 1977		April 23/24, 1978			May 23, 1978			June 26, 1978		
	New Pond	Old Pond	New Pond	New Pond	Old Pond	New Pond	Shed Pond	New Pond	Old Pond	Shed Pond	New Pond	Old Pond	Shed Pond	New Pond	Old Pond	Shed Pond
Number of samples	5	3	20	11	5	8	3	16	5	3	7	4	3	6	4	3
INSECTA																
Diptera	100.0	96.70	99.90	92.11	31.52	79.10	100.0	96.61	57.48	100.0	96.30	68.66	100.0	99.57	21.16	100.0
Odonata	—	—	0.04	5.60	15.54	11.18	—	2.50	1.41	—	3.70	1.25	—	0.27	0.47	—
Ephemeroptera	—	0.35	—	1.72	25.04	9.26	—	0.88	4.93	—	—	1.52	—	—	1.98	—
Coleoptera	—	0.34	0.02	0.57	0.54	0.46	—	—	0.18	—	—	0.14	—	0.16	—	—
MOLLUSCA	—	1.90	0.04	—	26.84	—	—	—	29.99	—	—	26.77	—	—	73.06	—
OLIGOCHAETA	—	0.35	—	—	0.27	—	—	—	6.00	—	—	1.66	—	—	1.22	—
OTHER	—	0.34	—	—	0.51	—	—	—	—	—	—	—	—	—	—	—

Table 4.4 Mean Number and Percent Composition of Benthic Macroinvertebrates/m^2 from the Staunton 1 On-Site Ponds, 1978

	April 23, 1978			May 23, 1978			June 26, 1978		
	Shed Pond	New Pond	Old Pond	Shed Pond	New Pond	Old Pond	Shed Pond	New Pond	Old Pond
Taxa	X (%)	X (%)	X (%)	X (%)	X (%)	X (%)	X (%)	X (%)	X (%)
INSECTA									
Diptera									
Chironomidae									
Ablabesmyia			148 (3.0)		6 (1.9)	33 (0.4)			11 (0.2)
Clinotanypus pinguis		8 (1.6)	9 (0.2)						
Procladius		171 (34.7)	9 (0.2)		19 (5.8)			406 (3.1)	
Tanypus punctipennis		212 (43.0)	991 (20.3)		106 (32.7)	2272 (25.7)		116 (0.9)	402 (5.8)
Chironomus plumosus	87 (66.9)		965 (19.8)	188 (93.1)	19 (5.8)	511 (5.8)	43 (59.7)	12029 (92.0)	500 (7.2)
Endochironomus					6 (1.9)	239 (2.7)			
Glyptotendipes			417 (8.5)		12 (3.8)	1576 (17.3)			228 (3.3)
Kiefferulus			26 (0.5)						
Lauterborniella			130 (2.7)		6 (1.9)	141 (1.6)			22 (0.3)
Parachironomus			35 (0.7)						
Polypedilum		14 (2.8)	9 (0.2)		6 (1.9)	22 (0.2)			
Ceratopogonidae									
Probezzia complex	44 (33.1)	35 (7.1)	43 (0.9)		130 (40.4)	152 (1.7)		457 (3.5)	315 (4.5)
Chaoboridae									
Chaoborus americanus			17 (0.4)			435 (4.9)			33 (0.5)
C. punctipennis		8 (1.6)							
Tabanidae									
Chrysops		19 (3.9)						7 (<0.1)	
Tipulidae									
Erioptera		3 (0.6)	9 (0.2)	14 (6.9)			29 (40.3)	7 (<0.1)	
Odonata									
Coenagrionidae									
Enallagma		3 (0.6)	17 (0.4)			11 (0.1)		14 (0.1)	
Libellulidae									
Erythemis simplicicollis									
Ladona julia		3 (0.6)						14 (0.1)	
Libellula luctuosa		5 (1.0)			6 (1.9)	33 (0.4)		7 (<0.1)	11 (0.2)
Pachydiplax longipennis			26 (0.5)			54 (0.6)			22 (0.3)
Plathemis lydia		3 (0.6)			6 (1.9)				
Sympetrum corruptum			9 (0.2)						
Tramea lacerata									
Aeshnidae									
Aeshna		3 (0.6)							

Table 4.4 (contd.)

	April 23, 1978						May 23, 1978						June 26, 1978					
	Shed Pond		New Pond		Old Pond		Shed Pond		New Pond		Old Pond		Shed Pond		New Pond		Old Pond	
Taxa	X	(%)	X	(%)	X	(%)	X	(%)	X	(%)	X	(%)	X	(%)	X	(%)	X	(%)
Ephemeroptera																		
Baetidae																		
Callibaetis fluctuans					9	(0.2)											11	(0.2)
Caenidae																		
Caenis			3	(0.6)	235	(4.8)							120	(1.4)			130	(1.9)
Ephemoridae																		
Hexagenia limbata			3	(0.6)														
Coleoptera																		
Dytiscidae																		
Agabus																		
Hydroporus					9	(0.2)												
Laccophilus maculosus															14	(0.1)		
Gyrinidae																		
Gyrinus															7	(<0.1)		
Haliplidae																		
Peltodytes edentulus											11	(0.1)						
Hydrophilidae																		
Berosus																		
Helophorus																		
Bryozoa																		
Phylactolaemata																		
Plumatellidae																		
Plumatella																		
Oligochaeta																		
Haplotaxida																		
Tubificidae																		
Limnodrilus hoffmeisteri					296	(6.0)					130	(1.5)					87	(1.2)
Mollusca																		
Pelecypoda																		
Sphaeriidae																		
Musculium transversum					1148	(23.5)					2957	(33.5)					5152	(73.7)
Gastropoda																		
Ancylidae																		
Ferrissia fragilis					9	(0.2)					76	(0.9)						
Physidae																		
Physa gyrina					322	(6.6)					65	(0.7)					65	(0.9)
TOTALS	130	(100)	493	(99.9)	4888	(100.2)	202	(100)	322	(99.9)	8838	(99.5)	72	(100)	13078	(99.8)	6989	(100.2)

and/or physical constraints in colonizing the pond. The aquatic worm Limnodrilus hoffmeisteri was also common in the Old Pond, but absent in the New Pond. This was apparently related to the lack of organic matter and mud in the New Pond sediments. Several dragonfly (Odonata), mayfly (Ephemeroptera), and beetle (Coleoptera) species were frequently collected, but in low numbers, from both the Old and New Ponds. The occurrence of a moderate number of species in the insect orders Diptera, Odonata, and Coleoptera in the New Pond does not necessarily indicate that a productive and "healthy" biotic community has developed in the pond. These orders contain species that are tolerant to extremes of water quality and/or that are so highly mobile that they may enter or leave a body of water at will (Roback, 1974). The mayfly genera present in the New Pond (Caenis, Callibaetis, and Hexagenia) are also more resistant to pollution (Edmunds et al., 1976). The limited benthic community composition in the New Pond currently resembles that in some of the acid strip-mine lakes found in Grundy County, Illinois (Master, 1979). The composition is especially similar in the prevalence of Diptera (mainly Chironomus), with most other non-fly species in the orders Coleoptera, Ephemeroptera, and Odonata. Severely degraded water quality indicative of acid mine drainage in the Shed Pond limited its benthic fauna to low densities of C. plumosus and to sporadic occurrences of a few other tolerant Diptera larvae, e.g., Erioptera (Tipulidae).

Densities of organisms were generally greater in the Old Pond than in the other ponds, while the lowest densities always occurred in the Shed Pond. Also, diversity values were always highest in the Old Pond, while the Shed Pond usually had the lowest values (Table 4.5). The high diversities or later successional development in the Old Pond were due to better water quality, developed macrophyte flora, and an abundance of allochtonous leaf litter. Living plant matter (excluding cattails) and detrital plant matter were sparse in the other ponds. Macrophytes and leaf litter provide diverse habitat and food resources for macroinvertebrates, allowing development of a fauna that encompasses a variety of functional feeding and habit groups (Cummins, 1978). Although an abundant stand of cattail (Typha latifolia) was present in the New Pond, and although some insects (e.g., Chironomus, mosquitoes, and beetles) thrive near cattails, this plant often prevents higher orders of plants from growing in shallow areas and is not considered a good "fertilizing" plant (Lackey, 1939).

Values for Morisita's index of community similarity (comparing the ponds) are provided in Table 4.6. The degree of similarity between ponds for the April and May 1978 collections follow expected patterns, with the New Pond and Old Pond being most similar. The higher diversity of the Old Pond, accompanied by the abundance of species not encountered in the New Pond (e.g., Musculium transversum), accounts for the community similarity indices only being of intermediate values. For the June 1978 samples, high similarity occurred between the Shed Pond and New Pond (0.81), while both the New Pond and Shed Pond had low similarity with the Old Pond (0.10 and 0.08, respectively). The high similarity between the New Pond and Shed Pond in June was largely due to the high density (and thus dominance) of Chironomus plumosus in the New Pond (12,029/m^2). This also explains why the New Pond had the lowest diversity of the three ponds in June (Table 4.5). The high density of Chironomus plumosus in June 1978 is undoubtedly connected with the species life cycle, as it was also very abundant in the June

Table 4.5 Shannon Diversity Values[a] Based on Mean Number/m^2 of Benthic Macroinvertebrates Collected from the Staunton 1 On-Site Ponds

Collection Date	New Pond	Old Pond	Shed Pond
May 10, 1977	0.06	0.36	--
June 28 & 29, 1977	0.02	--	--
August 16, 1977	0.90	1.06	--
October 3, 1977	1.15	--	0.04
April 23 & 24, 1978	0.57	0.95	0.28
May 23, 1978	0.75	0.85	0.11
June 26, 1978	0.17	0.56	0.29

[a]Logarithmic base 10.

1977 samples. New Pond diversity was also low that month (0.02). However, decreasing water quality and undesirable physical conditions in the New Pond would, in part, account for the occurrence of large numbers of Chironomus plumosus in the pond and for the limited composition and abundance of other species. With continued degradation of water quality in the New Pond during 1979 and 1980, e.g., pH $\leq$ 4.2 throughout both years (Prodan, 1981), the New Pond would be expected to maintain a low diversity and a high similarity to the Shed Pond; the benthic community would thus consist mostly of species tolerant to acid mine drainage conditions.

Table 4.6 Morisita's Index of Community Similarity Based on Mean Number/m^2 of Benthic Macroinvertebrates Collected from the Staunton 1 On-Site Ponds

Collection Date	Shed Pond and New Pond	Shed Pond and Old Pond	New Pond and Old Pond
April 23, 1978	0.06	0.38	0.52
May 23, 1978	0.10	0.10	0.41
June 26, 1978	0.81	0.08	0.10

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5 CONCLUSIONS

Findings from the macroinvertebrate investigations, coupled with water quality data (Prodan, 1981), imply that stabilized conditions do not currently exist in the New Pond. After two years of study, the results indicate that slight-to-moderate acid mine drainage conditions are present. These conditions have contributed to the limited diversity and density of macroinvertebrates in the pond. Also contributing to the low diversity is the lack of allochtonous organic matter, macrophytes, and less mobile organisms such as molluscs.

Reclamation activities have created a better aquatic habitat than existed in the slurry area prior to site development. If the water quality were to remain at the levels observed in 1978, then the New Pond could become a viable aquatic habitat. However, water samples collected in 1979 revealed that the pH in the New Pond had dropped to < 4.0. Persistence of such conditions will limit the biota of the New Pond to those species that can tolerate acid mine drainage conditions; i.e., the few dipteran species that are able to inhabit the Shed Pond. In an acidic lake in Sweden (pH of 3.9 to 4.6), the bottom fauna were low in abundance, only a few taxa were present, and only the midge species were minimally affected (Wiederholm and Eriksson, 1977).

A good supply of fish food (e.g., <u>Chironomus</u>) can potentially thrive in the low pH, high acidity, and high ferrous concentrations of acid mine drainage. However, fish cannot tolerate such conditions in order to utilize the food supply (Koryak et al., 1972). Therefore, it is doubtful that the New Pond could be productive for fish as long as the water quality remains low. Even if the biota and water quality conditions warranted stocking the New Pond, its small size would necessitate an intense management program. Because of the limited public fishing that could be supported by the pond, the cost of such a program could not be justified. Due to the present low abundance and sporadic occurrence of benthic invertebrates, together with the poor water quality, stocking the New Pond would result in a stressed and stunted fish community.

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6 RECOMMENDATIONS

The pond could have been constructed in a manner more desirable for stocking with fish; i.e., with greater acreage and steeper banks. If stocking is viewed as a desirable part of future reclamation endeavors, information from state conservation or natural resource departments related to construction and maintenance of fish ponds should be incorporated into the reclamation design. Planting trees near the pond would improve conditions by providing allochtonous organic matter (from leaf fall) and shading. Riprap or sod placed along the waterline of the pond would help prevent bank erosion and thus reduce sedimentation into the pond. It is recommended that the initial planning efforts include methods to ensure good water quality in the pond for more than the first few years. The suggestion in the final report on surface water quality (Prodan, 1981) for placing limestone boulders in the pond could help maintain adequate water quality. No amount of correct physical design, however, can overcome poor water quality in developing a desirable pond ecosystem.

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REFERENCES

Ali, A., and M. S. Mulla, Chironomid Larval Density at Various Depths in a Southern California Water-Percolation Reservoir, Environ. Ent. 5(6):1071-1074 (1976).

Brower, J. E., and J. H. Zar, Field and Laboratory Methods for General Ecology, Wm. C. Brown Company, Dubuque, Iowa (1977).

Cummins, K. W., Chapter 4, Ecology and Distribution of Aquatic Insects, In R. W. Merritt and K. W. Cummins (eds.), An Introduction to the Aquatic Insects of North America, pp. 29-31, Kendall/Hunt Publishing Company, Dubuque, Iowa (1978).

Duda, A. M., Water Quality Degradation from Industrial Minerals Mining in Appalachia, In S. B. Carpenter (ed.) Proceedings of the Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, pp. 235-242 (1979).

Edmunds, G. F., Jr., S. L. Jensen, and L. Berner, The Mayflies of North and Central America, University of Minnesota Press, Minneapolis (1976).

Gerhardt, R. W., South Dakota Mosquitoes and Their Control, South Dakota State University, Agr. Exptl. Sta., Bull. 531 (1966).

Goodnight, C. J., The Use of Aquatic Macroinvertebrates as Indicators of Stream Pollution, Trans. Amer. Microscop. Soc. 92(1):1-13 (1973).

Harp, G. L., and R. S. Campbell, The Distribution of Tendipes plumosus (Linne) in Mineral Acid Water, Limnol. Oceanogr. 12(2):260-263 (1962).

Harrison, A. D., The Effect of Sulfuric Acid Pollution on the Biology of Streams in Transvaal, South Africa, Verb. Internat. Ver. Limnol. 13:603-610 (1958).

Herricks, E. E., and J. Cairns, Jr., Rehabilitation of Streams Receiving Acid Mine Drainage, Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, Blacksburg, Bull. 66 (1975).

Horn, H. S., Measurement of "Overlap" in Comparative Ecological Studies, Amer. Natur. 100:419-424 (1966).

Katz, M., The Biological and Ecological Effects of Acid Mine Drainage with Particular Emphasis to the Waters of the Appalachian Region, Appalachian Regional Commission, Washington, D.C. (1969).

Kemp, P. H., Hydrobiological Studies on the Tugela River System, Part VI, Acid Drainage From Mines in Natal Coal Fields, Hydrobiol. 29(3-4):393-425 (1967).

Koryak, M., M. A. Shapiro, and J. L. Sykora, Riffle Zoo Benthos in Streams Receiving Acid Mine Drainage, Water Res. 6:1239-1247 (1972).

Lackey, J. B., Aquatic Life in Waters Polluted by Acid Mine Waste, Public Health Reports 54:740-746 (1939).

Master, W. A., Characterization of Three Acid Strip Mine Lakes in Grundy County, Illinois, Argonne National Laboratory Report ANL/LRP-TM-15 (1979).

McLachlan, A. J., Some Effects of Annual Fluctuations in Water Levels on the Larval Chironomid Communities in Lake Kariba, J. Anim. Ecol. 39:79-90 (1970).

Morisita, M., Measuring of Interspecific Association and Similarity between Communities, Mem. Fac. Sci. Kyushu Univ., Ser. E (Biol.) 3:65-80 (1959).

Nielsen, L. T., and D. M. Rees, An Identification Guide to the Mosquitoes of Utah, Univ. Utah Biol. Ser. Vol. XXII, No. 3 (1961).

Oliff, W. D., Hydrobiological Studies on the Tugela River System, Part III, The Buffalo River, Hydrobiol. 21:355-379 (1963).

Oliff, W. D., P. H. Kemp, and J. L. King, Hydrobiological Studies on the Tugela River System, Part IV, The Sundays River, Hydrobiol. 26(1-2):189-202 (1965).

Parsons, J. D., The Effects of Acid Strip Mine Effluents on the Ecology of a Stream, Arch. fur Hydrobiol. 65:25-50 (1968).

Prodan, P., unpublished information, Argonne National Laboratory (1981).

Rempel, J. G., The Mosquitoes of Saskatchewan, Can. J. Zool. 31:433-509 (1953).

Roback, S. S., Chapter 10, Insects (Arthropoda: Insecta), In C. W. Hart, Jr. and S. L. H. Fuller (eds.), Pollution Ecology of Freshwater Invertebrates, pp. 313-376, Academic Press, Inc., New York (1974).

Roback, S. S., and J. W. Richardson, The Effects of Acid Mine Drainage on Aquatic Insects, Proc. Acad. Nat. Sci. Phila. 121:81-107 (1969).

Smith, P. W., Illinois Streams: A Classification Based on Their Native Fishes and an Analysis of Factors Responsible for Disappearance of Native Species, Ill. Nat. Hist. Surv., Biol. Notes No. 76 (1971).

Thut, R. N., A Study of the Profundal Bottom Fauna of Lake Washington, Ecol. Monogr. 39(1):79-100 (1969).

Vinikour, W. S., Coal Slurry Observed as Habitat for Semiaquatic Beetle Lanternarius Brunneus (Coleoptera: Heteroceridae), With Notes on Water Quality Conditions, Entomol. News 90(4):203-204 (1979).

Wiederholm, T., and L. Eriksson, Benthos of an Acid Lake, Oikos 29:261-267 (1977).

Zellmer, S. D. (site coordinator), Staunton 1 Reclamation Demonstration Project: Progress Report II, Argonne National Laboratory Report ANL/LRP-4 (1979).

APPENDIX

SPECIES LIST FOR MACROINVERTEBRATES COLLECTED FROM ON-SITE PONDS

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Table A-1 Macroinvertebrates Collected from the New Pond, May 10, 1977

Taxa	Sample Number 1	2	3	4	5
INSECTA					
Diptera					
Chironomidae					
Tanypus punctipennis	1				
Chironomus plumosus	12	28	42	39	49
Tipulidae					
Erioptera sp.	1		3		

Table A-2 Macroinvertebrates Collected from the Old Pond, May 10, 1977

Taxa	Sample Number 1	2	3
INSECTA			
Diptera			
Chironomidae			
Tanypus punctipennis		4	
Chironomus plumosus	143	263	78
Glyptotendipes sp.	18	4	15
Goeldichironomus sp.			6
Kiefferulus sp.	9		
Ceratopogonidae			
Probezzia complex		6	
Chaoboridae			
Chaoborus americanus	6	1	5
Dolichopodidae			
Coleoptera			
Dytiscidae			
Agabus sp.		1	
Hydrophilidae			
Helophorus sp.		1	
Ephemeroptera			
Caenidae			
Caenis sp.		2	
MOLLUSCA			
Gastropoda			
Physidae			
Physa gyrina	2		2
Pelecypoda			
Sphaeriidae			
Musculium transversum	3	1	3
BRYOZOA			
Phylactolaemata			
Plumatellidae			
Plumatella sp.		1	
OLIGOCHAETA			
Haplotaxida			
Tubificidae			
Limnodrilus hoffmeisteri		2	
CRUSTACEA			
Isopoda			
Asellidae			
Asellus intermedius		1	

Table A-3 Macroinvertebrates Collected from the New Pond, June 28 and 29, 1977

Taxa	Sample Number, June 28, 1977								Sample Number, June 29, 1977											
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	9	10	11	12
Diptera																				
Chironomidae																				
Chironomus plumosus	1	9	8	138	90	169	263	341	422	168	428	25	228	418	472	244	226	372	353	285
Ceratopogonidae																				
Probezzia complex					1	7			1								1	1	1	
Culicidae																				
Aedes vexans					10	3	1													1
Coleoptera																				
Dytiscidae																				
Laccophilus maculosus																				1
Odonata																				
Aeschnidae																				
Aeschna sp.					2															
Gastropoda																				
Physidae																				
Physa gyrina												2								

Table A-4 Macroinvertebrates Collected from the New Pond, August 16, 1977

Taxa	C-1-1	C-1-2	C-1-3	Total	C-2-1	C-2-2	C-2-3	Total	C-3-1	C-3-2	C-3-3	Total
Oligochaeta												
Tubificidae												
Limnodrilus sp.									2			2
Odonata												
Gomphidae												
Progomphus obscurus			2	2					1	1		2
Ephemeroptera												
Baetidae												
Pseudocloeon nr. _dubium_	1			1								
Diptera												
Ephydridae							1	1				
Ceratopogonidae												
Palpomyia complex			2	2	2	1		3	2			2
Chironomidae												
Ablabesmyia sp.	1		1	2								
Procladius sp.					1			1				
Chironomus sp.	1			1	2	4	6	12	1		2	3
Stictochironomus sp.		2	3	5	4	15	14	33	8	3	6	17
Polypedilum sp.	2	2	2	6	2	3	1	6	4	2	2	8
Cryptochironomus fulvus			1	1								
Paratendipes sp.		1		1								
Tanytarsus sp.						1		1				
Paratanytarsus sp.	1		3	4			1	1				
Microspectra sp.									1			1
Orthocladius sp.	24	1	50	75	2	2		4	4	4	16	24
Corynoneura sp.	7	3		10	1			1	9	21	14	44
Cricotopus sp.	17		16	33	4	1	3	8	2	2	8	12
Heterotrissocladius sp.						1	1	2				
Psectrocladius sp.									1			1
Totals:												
Number of species	8	5	9	13	8	8	7	12	11	6	6	11
Number of individuals	54	9	80	143	18	28	27	73	35	23	48	106

Table A-5 Macroinvertebrates Collected from the Old Pond, August 16, 1977

Taxa	Sample Number 1	2	3	4	5
INSECTA					
Diptera					
Chironomidae					
Ablabesmyia sp.	11	1	12	8	8
Tanypus punctipennis	4				
Chironomus plumosus	10	2	3	1	3
Glyptotendipes sp.					1
Lauterborniella sp.		1			
Limnochironomus (*Dicrotendipes*) sp.			1		
Polypendilum sp.		1	1		
Pseudochironomus sp.				5	2
Cladotanytarsus sp.					3
Tanytarsus sp.					1
Ceratopogonidae					
Probezzia complex	14		9	1	9
Chaoboridae					
Chaoborus americanus	10				
Coleoptera					
Haliplidae					
Peltodytes edentulus?	1				
Hydrophilidae					
Berosus sp.			1		
Ephemeroptera					
Baetidae					
Callibaetis fluctuans	1		6		1
Caenidae					
Caenis sp.	2	1	49	14	23
Odonata					
Coenagrionidae					
Enallagma sp.			2	10	4
Libellulidae					
Erythemis simplicicollis			2	1	
Ladona julia		1			
Libellula luctuosa	4	2	8	2	13
Pachydiplax longipennis				3	
Tramea lacerata	1		1	3	3
MOLLUSCA					
Gastropoda					
Physidae					
Physa gyrina	7		7	5	12
Pelecypoda					
Sphaeriidae					
Musculium transversum	10	29	5	2	2
BRYOZOA					
Phylactolaemata					
Plumatellidae					
Plumatella sp.	2				
OLIGOCHAETA					
Haplotaxida					
Tubificidae					
Limnodrilus hoffmeisteri		1			

Table A-6 Macroinvertebrates Collected from the New Pond, October 13, 1977

Taxa	Sample Number 1	2	3	4	5	6	7	8
Diptera								
Chironomidae								
Clinotanypus pinguis	1						1	
Procladius sp.		1	1	1	7	5	3	2
Tanypus punctipennis	4					2	14	4
Chironomus plumosus	8	1						
Endochironomus sp.	2	3						
Glyptotendipes sp.	13	5	4					
Goeldichironomus sp.	18	4	1					
Parachironomus sp.		1					2	
Polypedilum sp.		1	1			2		
Cladotanytarsus sp.	4	2	4	3	4	14	1	
Rheotanytarsus sp.		1				1	1	
Tanytarsus sp.						1		
Ceratopogonidae								
Probezzia complex					1	2		
Chaoboridae								
Chaoborus punctipennis				1				
Tabanidae								
Chrysops sp.		2			1		3	1
Tipulidae								
Erioptera sp.							2	
Coleoptera								
Hydrophilidae								
Hydrobius sp.							1	
Ephemeroptera								
Baetidae								
Callibaetis fluctuans	1				1			
Caenidae								
Caenis sp.								1
Ephemeridae								
Hexagenia limbata					4	16	1	
Odonata								
Coenagrionidae								
Enallagma sp.		3					1	
Libellulidae								
Libellula luctuosa		4		4	2		1	
Pachydiplax longipennis	3	5						

Table A-7 Macroinvertebrates Collected from the New Pond, April 23 and 24, 1978

Taxa	Sample Number, April 23, 1978										Sample Number, April 24, 1978					
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6
Diptera																
Chironomidae																
Clinotanypus pinguis							1						1	1		
Procladius sp.		1	1	1	2	4	2		2	11	2	7	12	3	7	8
Tanypus punctipennis			2				1			65	1			1	8	
Polypedilum sp.							4		1							
Ceratopogonidae																
Probezzia complex			1			1				5					3	3
Chaoboridae																
Chaoborus punctipennis				1										1	1	
Tabanidae																
Chrysops sp.	1					1	3	1							1	
Tipulidae																
Erioptera sp.												1				
Odonata																
Coenagrionidae																
Enallagma sp.														1		
Libellulidae																
Ladona julia												1				
Libellula luctuosa	1			1												
Plathemis lydia													1			
Aeschnidae																
Aeschna sp.		1														
Ephemeroptera																
Caenidae																
Caenis sp.													1			
Ephemeridae																
Hexagenia limbata											1					

Table A-8 Macroinvertebrates Collected from the Old Pond, April 23, 1978

Taxa	Sample Number 1	2	3	4	5
INSECTA					
Diptera					
Chironomidae					
Ablabesmyia sp.		8	4	3	2
Clinotanypus pinguis	1				
Procladius sp.	1				
Tanypus punctipennis	8	31	45	21	9
Chironomus plumosus	7	33	7	36	28
Endochironomus sp.					
Glyptotendipes sp.	20	12	4	12	
Kiefferulus sp.		3			
Lauterborniella sp.			8	5	2
Parachironomus sp.		3			1
Polypedilum sp.					1
Ceratopogonidae					
Probezzia complex		1		4	
Chaoboridae					
Chaoborus americanus	1		1		
Tipulidae					
Erioptera sp.	1				
Coleoptera					
Dytiscidae					
Hydroporus sp.			1		
Ephemeroptera					
Baetidae					
Callibaetis fluctuans	1				
Caenidae					
Caenis sp.	9	1	4	9	4
Odonata					
Coenagrionidae					
Enallagma sp.	1				1
Libellulidae					
Pacvhydiplax longipennis	3				
Sympetrum (= Tarnetrum) corruptum		1			
MOLLUSCA					
Gastropoda					
Ancylidae					
Ferrissia fragilis	1				
Physidae					
Physa gyrina	18	13		1	5
Pelecypoda					
Sphaeriidae					
Musculium transversum	18	16	34	48	16
OLIGOCHAETA					
Haplotaxida					
Tubificidae					
Limnodrilus hoffmeisteri		16	6	4	8

Table A-9 Macroinvertebrates Collected from the New Pond, May 23, 1978

Taxa	Sample Number 1	2	3	4	5	6	7
Diptera							
Chironomidae							
Ablabesmyia sp.			1				
Procladius sp.							3
Tanypus punctipennis						2	15
Chironomus plumosus				2		1	
Endochironomus sp.						1	
Glyptotendipes sp.						2	
Lauterborniella sp.						1	
Polypedilum sp.						1	
Ceratopogonidae							
Probezzia complex	1	2		3	1	8	6
Odonata							
Libellulidae							
Libellula luctuosa						1	
Plathemis lydia							1

Table A-10 Macroinvertebrates Collected from the Old Pond, May 23, 1978

Taxa	Sample Number 1	2	3	4
INSECTA				
Diptera				
Chironomidae				
Procladius sp.		3		
Tanypus punctipennis	69	42	13	85
Chironomus plumosus	30		8	9
Endochironomus sp.	20		2	
Glyptotendipes sp.	128	10	2	5
Lauterborniella sp.		5	8	
Parachironomus sp.			2	
Ceratopogonidae				
Probezzia complex	3	5	4	2
Chaoboridae				
Chaoborus americanus	8	20	9	3
Coleoptera				
Haliplidae				
Peltodytes edentulus?			1	
Ephemeroptera				
Caenidae				
Caenis sp.	7	2		2
Odonata				
Coenagrionidae				
Enallagma sp.	1			
Libellulidae				
Libellula luctuosa			2	1
Pachydiplax longipennis	2	1	2	
MOLLUSCA				
Gastropoda				
Ancylidae				
Ferrissia fragilis	6	1		
Physidae				
Physa gyrina	3	1	1	1
Pelecypoda				
Sphaeriidae				
Musculium transversum	54	23	126	69
OLIGOCHAETA				
Haplotaxida				
Tubificidae				
Limnodrilus hoffmeisteri			3	9

Table A-11 Macroinvertebrates Collected from the New Pond, June 26, 1978

Taxa	Sample Number 1	2	3	4	5	6
Diptera						
Chironomidae						
Procladius sp.	4	52				
Tanypus punctipennis						16
Chironomus plumosus	34	1094	315	38	158	21
Polypedilum sp.				3		
Ceratopogonidae						
Probezzia complex	4	15	24	9	5	6
Tabanidae						
Chrysops sp.			1			
Tipulidae						
Erioptera sp.			1			
Coleoptera						
Dytiscidae						
Laccophilus maculosus			1			1
Gyrinidae						
Gyrinus sp.			1			
Odonata						
Coenagrionidae						
Enallagma sp.		1				1
Libellulidae						
Ladona julia	1			1		
Libellula luctuosa			1			

Table A-12 Macroinvertebrates Collected from the Old Pond, June 26, 1978

Taxa	Sample Number 1	2	3	4
INSECTA				
Diptera				
Chironomidae				
Ablabesmyia sp.	1			
Tanypus punctipennis	2	15	7	13
Chironomus plumosus	6	20	3	17
Glyptotendipes sp.	3	5		13
Lauterborniella sp.	1		1	
Ceratopogonidae				
Probezzia complex	6	5	17	1
Chaoboridae				
Chaoborus americanus		2	1	
Ephemeroptera				
Baetidae				
Callibaetis fluctuans			1	
Caenidae				
Caenis sp.	7		3	2
Odonata				
Libellulidae				
Libellula luctuosa	1			
Pachydiplax longipennis	1			1
MOLLUSCA				
Gastropoda				
Physidae				
Physa gyrina		1	5	
Pelecypoda				
Sphaeriidae				
Musculium transversum	93	98	202	81
OLIGOCHAETA				
Haplotaxida				
Tubificidae				
Limnodrilus hoffmeisteri	2	1	5	

Table A-13 Macroinvertebrates Collected from the Shed Pond

	October 4, 1977			April 23, 1978			May 23, 1978			June 26, 1978		
	Sample Number											
Taxa	1	2	3	1	2	3	1	2	3	1	2	3
Diptera												
Chironomidae												
Chironomus plumosus	40	13	6			6	4	4	5	3		
Parachironomus sp.	1											
Ceratopogonidae												
Probezzia complex				1	2							
Tipulidae												
Erioptera sp.							1			1		1

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