Transactions of the Illinois State Academy of Science
(1983), Volume 76, 1 and 2, pp. 321-341

Vascular Flora of a Deep Coal Mine Refuse Reclamation Site in Illinois

J.R. Rastorfer[1],
Department of Biological Sciences,
Chicago State University
Chicago, IL 60628
and
G. Wilhelm[2],
The Morton Arboretum,
Lisle, IL 60532

ABSTRACT

The portions of the site that consisted of abandoned gob and slurry refuse were graded, amended, and seeded during reclamation efforts that were carried out in 1976 and 1977. A post-reclamation vascular plant inventory included the reclaimed areas and other segments of the site that were not directly subjected to the reclamation operations. In addition to the planted species, other floristic elements became established on the improved refuse materials. The flora consisted of about 250 taxa of vascular plants, of which approximately 30 species are considered new county records. Six principal growth forms were represented and consisted of 37 trees, 15 shrubs, 10 woody vines, 52 graminoids, 131 forbs, and 2 ferns.

INTRODUCTION

Overview

Prior to enactment of legislation governing coal mining operations, refuse materials from deep coal mines were generally disposed of above-ground. This was done with little or no attention paid to what might already have occupied the ground on which the materials were deposited. Coarse refuse (gob) was usually dumped adjacent to coal preparation facilities, where it accumulated into huge, steep-sided piles. Effluent materials (slurry) from coal washing facilities were pumped into impoundments near the preparation plants. These impoundments then became slurry ponds in which coal fines and other solids formed thick sediments several meters deep. After the mines were closed, the gob piles and slurry ponds were abandoned. Large areas of unaltered deep-mine refuse therefore re-

[1]Faculty Research Participant: Land Reclamation Program, Argonne National Laboratory, Argonne, IL 60439.
[2]Present Address: Department of Botany, Southern Illinois University, Carbondale, IL 62901.

mained on the landscape. There was little or no concern for the potentially adverse effects on both abiotic and biotic aspects of the environment (Martin, 1974; Zellmer and Carter, 1977).

Abandoned gob and slurry refuse areas in Illinois probably exceed 1800 hectares (ha) collectively. These land surfaces are aesthetically unpleasing and often are used locally as garbage dumps; furthermore, these areas have little real-estate or other potential economic value. Their presence may in fact depress local property assessments. In addition, they have caused numerous adverse ecologic effects on their environments. The refuse materials may become highly acidic and thus unfavorable for the establishment of vegetation. Without the protection of plant cover, consequently, the refuse materials are easily eroded, resulting in sediment outwash into adjacent land areas. Erosion also exposes fresh pyritic rock that is subject to oxidation resulting in acid runoff that adversely affects terrestrial and aquatic communities; furthermore, water with high concentrations of sulfates and heavy metals may enter ground-water systems (Nawrot et al., 1977; Zellmer, 1978; Zellmer and Carter, 1977).

In 1976, the Land Reclamation Program at Argonne National Laboratory, the Illinois Abandoned Mined Lands Reclamation Council, and the Illinois Institute of Natural Resources (now the Illinois Department of Energy and Natural Resources) began a cooperative project, the goals of which were to develop, demonstrate, and evaluate techniques for reclaiming abandoned gob and slurry refuse sites. Additional goals of the reclamation project were to (1) reduce the quantity of pollutants entering the surrounding landscape, (2) increase the economic potential of the affected and adjacent land, (3) improve the aesthetic value of the locality, and (4) assess several abiotic and biotic components (Zellmer, 1978; Zellmer and Carter, 1977; Zellmer and Wilkey, 1979).

Selection and Pre-Reclamation Description of the Site

The site selected was the abandoned Consolidated Coal Company Mine No. 14, which is located in Macoupin County, Illinois, near the village of Staunton (Figure 1). The mine was opened in 1904 and operated until the early 1920s. The coal seam (Herrin No. 6) was mined at approximately 85 m below the surface. The work force of about 500 men extracted up to 4550 metric tons of high-sulfur (5%) coal per day. The site has a total area of 13.8 ha, of which 9.3 ha had been affected directly by the mining operations and required reclamation (Zellmer and Carter, 1977).

The entire site consisted of three distinct parcels (Figures 2, 3A, 4A, and 5A): (Bernard, 1980; Zellmer, 1978 and 1979). The northern parcel featured, near its northern boundary, a dam built across a deep ravine. This dam impounded approximately 4.5 ha of water that was used for the mine's power plant, for the coal washing operations, and for pumping slurry from the coal washer. Most of the site, including the southern parcel, drained into this pond by means of a waterway through the middle parcel. Even after mining ceased, the pond continued to fill with sediments from the gob pile. These sediments consisted of coal fines and other solids that, along with the slurry sediments, accumulated up to 9 m (Figure 3A). After the dam failed in the early 1940s, rapid water runoff caused severe erosion, created gullies of 4 to 5 m in depth, and produced acid runoff and sediment outwash into the stream below the dam. From the time of the mine abandonment, the black deposits remained unvegetated except for the eventual presence of a few cattails (*Typha*) in one of the deep gullies; a few nonvascular plants, such as mosses and lichens, occurred on coal fines along some of the tree line margins. Less affected

segments of the northern parcel consisted of wooded areas, pasture lands, and cultivated fields (Figure 2).

The middle parcel, bounded by roads on the north and south, consisted mostly of about 1 ha of weedy pasture with a small stand of trees (Figure 4A). As mentioned previously, a waterway running through this parcel linked the southern and northern parcels. The adverse effects on vegetation by acid runoff were apparent along this waterway. Refuse sediment from the gob pile accumulated at the northern boundary of this parcel because of water impoundment caused by the culvert beneath Bunker Hill Road. This parcel had also become one of the site's major garbage dumps.

The southern parcel was characterized by a huge gob pile that reached an elevation of about 25 m above the surrounding landscape and covered nearly 1.8 ha (Figure 5A). During the 50 years following the closure of the mining operations, erosion cut deep gullies in the face of this refuse heap. No vegetation grew either on the gob pile or adjacent to it in those areas that had been subjected to severe acid runoff and sediment outwash. Within these affected areas, on the other hand, there were a few small patches of vegetation that escaped destruction because they were 30 to 60 cm above the outwash areas. Power plant and coal cleaning structures were located on the west side of the gob pile; however, only the foundations and the smokestack (55 m high) of these facilities remained. Most of the rails were removed from the railroad spur that had served the mine site; nevertheless, the entire right-of-way was still evident along the west and southwest boundaries of the parcel. Several stands of secondary-growth trees occupied small areas. The southern panhandle portion was disturbed by the mining operations, but apparently was not subjected to acid runoff from the eroded gob pile.

Pre-Reclamation Studies

Before the reclamation efforts began, the site was examined and sampled to assess several environmental factors: (1) quality of ground- and surface-water, (2) physical and chemical properties of the refuse materials and adjacent soils, (3) wildlife populations, (4) microbial populations in refuse materials and adjacent soils, and (5) some biotic aspects of the aquatic ecosystem. In addition, laboratory studies were made to investigate the effects of different soil amendments on the growth of selected plant species (Miller and Cameron, 1978; Schubert, 1979; Zellmer, 1978 and 1979; Zellmer and Wilkey, 1979). A detailed survey of the vascular plants occurring on the site was not made prior to the reclamation efforts, but a preliminary survey of the bryophytes was made by the senior author during a brief visit to the site in 1976.

Concomitant with the pre-reclamation investigations, the State of Illinois Abandoned Mined Lands Reclamation Council was in the process of obtaining titles to the three parcels discussed previously (Figure 2). Purchases and title transfers from the Consolidated Coal Company to the State of Illinois were completed by late summer of 1976. Legal ownership by the State of Illinois allowed the awarding of contracts for subsequent reclamation work. Marle, Inc., of Springfield, Illinois, was awarded a contract for construction work, and the project was directed by Stanley Zellmer of Argonne's Land Reclamation Program (Zellmer, 1978 and 1979; Zellmer and Carter, 1977).

Reclamation Efforts

Reclamation work began in September 1976. This initially required the removal of the old power plant and coal cleaning facility foundations, and accumulated

junk from the site. A borrow pit was dug to provide a mixture of topsoil, subsoil, and glacial till, which was stockpiled for subsequent use. The gob pile was graded down to an average height of about 8 m (approximately one-third its original height). Grading of the old slurry area was also initiated during this period.

After the grading and recontouring work was completed (Figure 6), refuse-amendment procedures began with the application and incorporation of acid-neutralizing agents into the upper 15 cm of the recontoured refuse surfaces. Several experimental plots on top of the recontoured gob pile area were left untreated. A cover material from the stockpile was placed over the treated refuse to a depth of 30 cm. A seed bed was prepared, including the application of agricultural limestone and fertilizer (N, P, K). Seeds mixed for drill planting consisted of *Festuca arundinacea*, *Lotus corniculatus*, *Phalaris arundinacea*, *Secale cereale*, and *Trifolium repens*. Other reclamation efforts included the installation of culvert pipe and water flow control structures, the excavation of a 0.5-ha retention pond, the construction of a dam, and the erection of new fencing. All of the site development endeavors mentioned above were completed before May 1977 (Zellmer, 1978; Zellmer and Carter, 1977; Zellmer and Wilkey, 1979).

Post-Reclamation Studies on the Site

Evaluation projects were carried out subsequent to the initial reclamation efforts. Projects included studies that concerned ground- and surface-water quality, aquatic ecosystems, revegetation assessments, characterizations of soils, rates of erosion, populations of soil microorganisms, wildlife surveys, and economic benefits (Jastrow et al., 1981; Miller and May, 1981; Sobek and Sullivan, 1981; Vinikour, 1981; Zellmer, 1979). In addition, Bernard (1980) has reported an interesting assessment of the views of local residents concerning the reclamation efforts.

Objectives of This Investigation

One of the objectives of this study is to make a detailed inventory of the vascular plants inhabiting the site, including both affected and non-affected areas (Figures 2 and 6). In addition, the vascular floristic components are characterized in each of the four major survey units discussed in the next section. Although qualitative in nature, the floristic information in this study is important in the establishment of a data base that will be necessary in future years to evaluate floristic changes on reclaimed deep-mine refuse areas.

METHODS FOR THE VEGETATIONAL SURVEYS AND COLLECTIONS

Survey Areas and Collections

Figure 6 shows the four major vegetational units that were surveyed among the three parcels of the site. These units were designated as those areas (1) dominated by trees and shrubs; (2) representing abandoned pastures; (3) altered by the mining operations, but not reclaimed; and (4) affected by the mining operations and subsequently graded, treated, and seeded. The surveys also included the margins of the three ponds on the site. Incidental collections of 17 species were made during 22-25 August 1978. Subsequently, more intensive surveys and collections of vascular plants were made 20-23 June 1979, 22-27 September 1979, and 18-19 May 1980.

Nomenclature and Floristics

The scientific names for the vascular plants follow those of Mohlenbrock (1975).

Species reported as new county records represent those taxa not reported for Macoupin County by Mohlenbrock and Ladd (1978). Mounted voucher specimens for all of the taxa reported were deposited in the herbarium of the Morton Arboretum in Lisle, Illinois.

The taxa, including those representing county records, are cited in a checklist arranged alphabetically by genus under eight categories: trees, shrubs, woody vines, sedges, grasses, rushes, forbs, and ferns. In the following text, the term "graminoid" includes the sedges, grasses, and rushes because of their superficially similar appearance. The term "forb" refers to all nonwoody vascular plants, with the exception of the graminoids and the ferns.

Vegetational Assessments

The characterization of the vegetation for the four major vegetational units are necessarily qualitative in nature owing to the inventory objectives and limitations. In general, the different areas are described with respect to their most conspicuous and apparent vegetational components. The three ponds on the site (Figure 6) are treated individually following the discussions of the four major vegetational units.

Although the forbs and graminoids in the ground cover of woodlands can be considered important in the characterization of plant communities, they have not been considered in detail here because these wooded areas have been greatly disturbed by grazing and other activities. A few noteworthy nonwoody species were found, nevertheless, in some isolated habitats within these areas and are mentioned.

OBSERVATIONS

Woodlands

The tree/shrub stands (Figure 6) within each of the three parcels of the site differed in character and composition because their recent histories were different; thus, they are discussed separately.

The areas dominated by trees and shrubs in the northern parcel were not affected extensively by the mining operations, but apparently were subjected to livestock grazing, at least periodically, before reclamation began. In addition, the perimetrical shapes of most of these stands were altered during the construction work. This can be seen clearly by comparing Figures 2 and 6. These woodland segments consisted mostly of *Carya ovata*, *Carya tomentosa*, *Fraxinus americana*, *Prunus serotina*, *Quercus imbricaria*, and *Quercus velutina* as the major tree taxa, along with *Celtis occidentalis*, *Diospyros virginiana*, *Sassafras albidum*, and other species of *Quercus*. Conspicuous shrubs included *Corylus americana*, *Lonicera maackii*, *Ribes missouriense*, *Rhus aromatica*, and *Rubus pensylvanicus*. A few vines worthy of mention included *Parthenocissus quinquefolia*, *Toxicodendron radicans*, *Rubus flagellaris*, and *Lonicera japonica*.

The middle parcel had only a small strip of woody vegetation. This was dominated by relatively young trees and shrubs, which apparently became established after mining ceased (Figure 6). The trees in this stand included *Juniperus virginiana*, *Prunus serotina*, *Quercus imbricaria*, *Quercus stellata*, *Robinia pseudoacacia*, *Sassafras albidum*, and *Ulmus americana*. Shrubs included *Lonicera maackii*, *Rhus glabra*, *Rubus pensylvanicus*, and *Sambucus canadensis*. Two vines were noted, i.e., *Lonicera japonica* and *Rubus flagellaris*.

The stands dominated by trees and shrubs in the southern parcel had very degraded understories, probably because of damaging effects from mining and

subsequent activities. Moreover, the trees in this parcel were generally younger than those in the northern and middle parcels. This was true especially along the abandoned railroad right-of-way in the southern parcel. The boundaries of the wooded areas in the southern parcel also were altered during the recontouring work (Figures 2 and 6). These wooded areas were different enough to warrant separate considerations.

The tree/shrub area located along the northwestern boundary of this parcel contained a mixture of trees consisting of *Acer saccharinum*, *Prunus serotina*, *Quercus imbricaria*, *Quercus velutina*, *Robinia pseudoacacia*, and *Sassafras albidum*. Shrubs were represented by *Ribes odoratum*, *Rosa multiflora*, *Rubus allegheniensis*, *Rubus pensylvanicus*, and *Sambucus canadensis*. Vines consisted of *Parthenocissus quinquefolia*, *Rubus flagellaris*, and *Toxicodendron radicans*.

The small circular-shaped tree stand about midway along the west side of the recovered gob pile area consisted of a single tree species, *Robinia pseudoacacia*. This group of trees was essentially without an understory.

The more-or-less oval-shaped stand of trees located in the upper portion of the panhandle was populated mostly with *Ulmus americana*, accompanied by *Celtis occidentalis*, *Crataegus crus-galli*, *Fraxinus pennsylvanica* var. *subintegerrima*, *Prunus serotina*, *Quercus imbricaria*, *Salix amygdaloides*, and *Salix interior*.

The long narrow wooded area along the abandoned railroad right-of-way consisted mostly of scattered seedlings of *Acer saccharinum*, *Crataegus* spp., *Populus deltoides*, and *Robinia pseudoacacia*. Shrubs in this area included *Rhus glabra* and *Sambucus canadensis*.

Abandoned Pastures

Two abandoned pasture segments occurred in the northern parcel (Figure 6). These areas and the adjacent wooded stands were actively pastured until 1976. They have remained abandoned since the site development began, except for periodic invasions by cattle and goats. These pasture segments were essentially the same with respect to species composition. The most abundant plants were *Festuca arundinacea*, *Poa pratensis*, and *Tridens flavus*, with *Asclepias syriaca* and *Rosa multiflora* also present.

Areas Affected by Mining but Not Reclaimed

A highly disturbed strip of land (Figure 6) occurred along the western boundary of the southern parcel, and for the most part corresponded to a portion of the abandoned railroad right-of-way. It was not part of the reclamation effort because of property easement disagreements between the state and the village of Staunton. The western margin of this area included a tree row (not shown in Figure 6) that was composed mostly of *Celtis occidentalis*, *Maclura pomifera*, and *Populus deltoides* intermixed with *Quercus* spp. The graminoids of the affected area consisted of *Carex annectens*, *Panicum virgatum*, *Poa pratensis*, *Sorghastrum nutans*, and *Tridens flavus*. Forbs included *Achillea millefolium*, *Apocynum sibiricum*, *Chenopodium album*, *Helianthus annuus*, *Lotus corniculatus*, *Rumex crispus*, *Trifolium pratense*, *Verbascum thapsus*, and *Vernonia missurica*.

Areas Recontoured, Treated, and Seeded

The largest portions of the site represent those areas of the three parcels that were greatly altered by the mining operations, abandoned for about 50 years, and then recently subjected to intensive reclamation tasks, during which these land surfaces were graded, edaphically amended, and seeded, all in similar fashion.

The subsequent development of vegetation in these three areas differed, however, and thus will be discussed separately below.

The rectified land of the northern parcel had a conspicuously dense coverage of graminoids (Figures 3B and 6) in which the major components were *Festuca arundinacea*, *Phalaris arundinacea*, and *Tridens flavus*, with lesser amounts of *Bromus commutatus*, *Bromus tectorum*, *Hordeum pusillum*, *Juncus tenuis*, and *Poa pratensis*. Numerous forbs were scattered throughout the area, including *Ambrosia artemisiifolia*, *Geranium carolinianum*, *Geum canadense*, *Lotus corniculatus*, *Oxalis dillenii*, *Polygonum lapathifolium*, *Polygonum pensylvanicum* var. *laevigatum*, *Potentilla simplex*, *Pycnanthemum tenuifolium*, *Rumex acetosella*, *Solanum carolinense*, *Specularia perfoliata*, *Trifolium repens*, and *Veronica peregrina*. Invading trees were *Populus deltoides* and *Salix interior*.

The reclaimed land in the middle parcel (Figures 4B and 6) was also characterized by graminoids consisting of *Agrostis alba*, *Festuca arundinacea*, *Dactylis glomerata*, *Phalaris arundinacea*, and *Tridens flavus*. Associated forbs included *Ambrosia trifida*, *Chenopodium album*, *Eupatorium serotinum*, *Lactuca serriola*, *Lotus corniculatus*, *Plantago aristata*, *Plantago lanceolata*, and *Solidago canadensis*.

The constructed land in the southern parcel had a varied distribution of herbaceous vascular plants, especially in the area occupied by the graded gob pile. This area was quite varied topographically and was characterized by a flat-topped hill (the regraded gob pile) that had relatively steep slopes down to level land (Figures 5B and 6). Graminoid components of the vegetation included *Agrostis alba*, *Bromus commutatus*, *Bromus inermis*, *Dactylis glomerata*, *Festuca arundinacea*, *Hordeum pusillum*, *Juncus interior*, *Panicum lanuginosum* var. *implicatum*, *Panicum virgatum*, *Phalaris arundinacea*, *Poa chapmaniana*, *Poa pratensis*, *Schizachyrium scoparium*, and *Setaria viridis*. Numerous forbs were also found in this area, namely, *Ambrosia trifida*, *Arenaria serpyllifolia*, *Aster pilosus*, *Cassia fasciculata*, *Cerastium* sp., *Croton capitatus*, *Erigeron annuus*, *Lepidium densiflorum*, *Lepidium virginicum*, *Lotus corniculatus*, *Melilotus* spp., *Myosotis virginica*, *Plantago virginica*, *Ranunculus abortivus*, *Sibara virginica*, *Silene antirrhina*, *Solidago gigantea*, *Veronica arvensis*, *Veronica peregrina*, *Viola rafinesquii*, and *Xanthium strumarium*.

Pond Margins

There are three ponds on the site, two in the northern parcel, and one in the middle parcel (Figure 6). The floristic elements, if any, associated with these ponds, are discussed below.

The small pond in the northeastern portion of the northern parcel was established prior to the initial site development efforts. Conspicuous marginal species were *Eleocharis obtusa*, *Erechtites hieracifolia*, and *Leersia oryzoides*: *Lemna minor* was a common floating species.

Typha latifolia was the most abundant marginal plant around the pond in the central portion of the northern parcel; however, *Juncus effusus* var. *solutus* also occurred here, and *Phragmites australis* had invaded the northern tip of the pond just below the dam.

The margin of the small pond at the southern boundary of the middle parcel was essentially devoid of vegetation, undoubtedly because of its generally persistent acid conditions.

DISCUSSION

Species Composition Compared to Known Vascular Flora for Macoupin County

Mohlenbrock and Ladd (1978) report 934 species of tracheophytes for Macoupin County: the present list of 247 species thus makes up about 25% of the county's known vascular plant flora. This number of species is appreciable in view of the relatively small area of the reclaimed site and the site's recent history. The list also contains 32 species that, according to Mohlenbrock and Ladd (1978), have been heretofore unknown from Macoupin County. The taxa in this category can be regarded as county records and are marked by an asterisk (*) in the checklist.

Interesting and Noteworthy Species

The trees *Amelanchier arborea* and *Cercis canadensis*, the forbs *Arisaema triphyllum* and *Trillium recurvatum*, and the ferns *Asplenium platyneuron* and *Botrychium virginianum* were confined to the slopes of the woodland in the northwestern portion of the northern parcel. These plants and the local prevalence of species of *Quercus* and *Carya* indicate that the site probably represents a remnant oak-hickory community.

Many specimens of *Quercus velutina* were atypical, their leaves and buds suggesting that hybridization may have occurred with *Quercus rubra*. Also, numerous individuals of *Ulmus americana* were somewhat atypical, particularly with respect to leaf size and general growth habit. The atypical forms were especially apparent in the woodlot in the upper panhandle of the southern parcel. The irregular morphological features of the elm trees in this location may have been caused, at least in part, by the adverse environmental conditions associated with the mining operations. Ashby and his co-workers, on the other hand, have shown that many species of trees can grow normally on some unamended minesoils (Ashby, 1964; Ashby et al. 1978).

Concluding Remarks

As mentioned previously, the originally exposed gob and slurry sediments (pre-reclaimed surface materials) of the site were essentially devoid of vegetation (Figures 3A, 4A, and 5A). The few cattails in a gully in the slurry sediment area of the northern parcel were exceptions. On the other hand, Nawrot et al. (1977) report the occurrence elsewhere in Illinois of numerous plant taxa on some abandoned deep-mine refuse lands consisting of gob, slurry sediments, and tipple waste. Certainly, seeds of numerous forbs, graminoids, and trees from adjacent areas of the site (Figure 2) were readily available to the pre-reclaimed substrata. Among the different environmental parameters, however, high temperatures were probably as effective as any other factor in preventing the establishment of seedlings (Deely and Borden, 1973; Schramm, 1966). High acidity, poor water retention capacity, and other edaphic conditions also may have been critical factors in preventing the establishment of plants on the abandoned gob material.

In contrast, the reworked and edaphically treated minesoil of the site is currently supporting vegetation (Figures 3B, 4B, and 5B). In addition, most of the plant taxa now present apparently were not in the seed mixture used on the treated minesoils, but arrived as disseminules from surrounding areas. Besides forbs and graminoids, these formerly unvegetated areas support invading trees such as *Populus deltoides*, *Robinia pseudoacacia*, and *Salix* spp.

In addition to the aesthetic benefits that the new vegetational cover has brought

to the site, other environmental improvements are apparently developing. The grasses and forbs, which are currently the dominant plants on the constructed minesoil, provide additional food and shelter for wildlife. Furthermore, this vegetational cover, along with the previously established tree stands, will very likely enhance habitat conditions for wildlife, because now there is a much greater plant species diversity than existed on the site prior to the initial reclamation effort (Holland, 1973; Zellmer, 1979).

Edaphic factors such as fertility and organic content undoubtedly will increase with each succeeding growing season. The legumes, such as *Desmanthus*, *Desmodium*, *Lespedeza*, *Lotus*, *Medicago*, *Melilotus*, and *Trifolium* are particularly important because they bear nitrogen-fixing bacteria. The prevalence of graminoids should contribute considerably to an accumulation of litter. This organic matter should foster greater populations of heterotrophic microorganisms that play a significant role in decomposition and nutritent cycling (Miller and May, 1981).

The establishment of a vegetational cover stabilizes the soil surface and thus is instrumental in reducing erosion. A reduction in soil erosion in turn improves surface water quality by reducing acidity and sediment outwash. Eventually, the aquatic communities of the site will benefit from better surface water conditions (Vinikour, 1981).

It is apparent that many of the earlier adverse environmental aspects of the site have been rectified as a result of the reclamation recovery effort; however, many processes in edaphic and biotic development require long periods of time. The complete reclamation of the site, therefore, cannot be realized until the planned objectives have been achieved.

ACKNOWLEDGEMENTS

We gratefully acknowledge, for their support in this investigation, the Land Reclamation Program at Argonne National Laboratory and the Morton Arboretum. We also thank Judith Rastorfer, Floyd Swink, and George Ware for their help in the identification of certain specimens. Thanks are due also to Antonios Antonopoulos, David Curnock, and Charles Malefyt for their suggestions concerning the manuscript, and to Barbara Rogowski and Audrey Salzbrunn for their expert typing. Special thanks are due to Stanley Zellmer for his support, encouragement, and resourceful comments throughout the study.

LITERATURE CITED

Ashby, W.C., 1964. Vegetation development on a strip-mined area in southern Illinois. Transactions of the Illinois State Academy of Science 57:78-83.

Ashby, W.C., C. Kolar, M.L. Guerke, C.F. Pursell, and J. Ashby, 1978. Our reclamation future with trees. Coal Extraction and Utilization Research Center, Southern Illinois University, Carbondale. 99 p.

Bernard, J.R., 1980. Public views of reclaiming an abandoned coal mine: the Macoupin County project. Argonne National Laboratory Report ANL/LPR-7, Argonne, Illinois. 74 p.

Deely, D.J. and E.Y. Borden, 1973. High surface temperatures on strip-mine spoils. pp. 69-79, *In* R.J. Hutnik and G. Davis, eds. Ecology and reclamation of devastated land, Volume 1. Gordon and Breach, New York.

Holland, F.R., 1973. Wildlife benefits from strip-mine reclamation. pp. 377-388. *In* R.J. Hutnik and G. Davis, eds. Ecology and reclamation of devastated land, Volume 1. Gordon and Breach, New York.

Jastrow, J.D., A.J. Dvorak, M.J. Knight, and B.K. Mueller, 1981. Revegetation of acidic coal refuse: effects of soil cover material depth and liming rate on initial establishment. Argonne National Laboratory Report ANL/LRP-17, Argonne, Illinois. 79 p.

Martin, J.F., 1974. Coal refuse disposal in the eastern United States. News of Environmental Research in Cincinnati (December 27), United States Environmental Protection Agency, National Environmental Research Center, Cincinnati, Ohio. 4 p.
Miller, R.M. and R.E. Cameron, 1978. Microbial ecology studies at two coal mine refuse sites in Illinois. Argonne National Laboratory Report ANL/LRP-3, Argonne, Illinois. 44 p.
Miller, R.M. and S.W. May, 1981. Staunton 1 Reclamation demonstration project: soil microbial structure and function. Argonne National Laboratory Report ANL/LRP-11, Argonne, Illinois. 29 p.
Mohlenbrack, R.H., 1975. Guide to the vascular flora of Illinois. Southern Illinois University Press, Carbondale. 494 p.
Mohlenbrock, R.H. and D.M. Ladd, 1978. Distribution of Illinois vascular plants. Southern Illinois Press, Carbondale. 282 p.
Nawrot, J.R., R.J. Haynes, P.L. Pursell, J.R. D'Antuono, R.L. Sullivan, and W.D. Klimstra, 1977. Illinois lands affected by underground mining for coal. Illinois Institute for Environmental Quality, Chicago. 137 p.
Schramm, J.R., 1966. Plant colonization studies on black wastes from anthracite mining in Pennsylvania. Transactions of the American Philosophical Society, New Series 56:1-194.
Schubert, J.P., 1979. Groundwater contamination problems resulting from coal refuse disposal. Proceedings of the First International Mine Drainage Symposium, Denver, Colorado, May 1979. Miller Freeman Publications, Inc., San Francisco, California. 24 p.
Sobek, A.A. and P.J. Sullivan, 1981. Staunton 1 reclamation demonstration project: minesoil characterizations. Argonne National Laboratory Report ANL/LRP-15, Argonne, Illinois. 31 p.
Vinikour, W.S., 1981. Staunton 1 reclamation demonstration project: aquatic ecosystems. Argonne National Laboratory Report ANL/LRP-9, Argonne, Illinois. 51 p.
Zellmer, S.D., 1978. Staunton 1 reclamation demonstration project progress report for 1977. Argonne National Laboratory Report ANL/LRP-TM-14, Argonne, Illinois. 59 p.
Zellmer, S.D., 1979. Staunton 1 reclamation demonstration project progress report II. Argonne National Laboratory Report ANL/LRP-4, Argonne, Illinois. 110 p.
Zellmer, S.D. and R.P. Carter, 1977. Abandoned coal mine refuse areas: their reclamation and use. Paper presented at the 1977 winter meeting of the American Society of Agricultural Engineers held in Chicago, Illinois, December 13-16. 17 p.
Zellmer, S.D. and M.L. Wilkey, 1979. A reclamation demonstration project at an abandoned deep mine. Minerals and the Environment 1:57-63.

CHECKLIST OF VASCULAR PLANTS[1]

TREES

Acer (Aceraceae)
A. negundo L.
A. saccharinum L.

Amelanchier (Rosaceae)
A. arborea (Michx. f.) Fern.

Carya (Juglandaceae)
C. ovata (Mill.) K. Koch
C. tomentosa (Poir.) Nutt.

Celtis (Ulmaceae)
C. occidentalis L.

Cercis (Leguminosae)
C. canadensis L.

Corylus (Betulaceae)
C. americana Walt.

Crataegus (Rosaceae)
C. crus-galli L.
C. pruinosa (Wendl.) K. Koch

Diospyros (Ebenaceae)
D. virginiana L.

Fraxinus (Oleaceae)
F. americana L.
F. pennsylvanica var. *subintegerrima* (Vahl) Fern.

Gleditsia (Leguminosae)
G. triacanthos L.

Juniperus (Cupressaceae)
J. virginiana L.

Maclura (Moraceae)
M. pomifera (Raf.) Schneider

Morus (Moraceae)
**M. alba* L.
M. rubra L.

Populus (Salicaceae)
P. deltoides Marsh.

[1]Asterisk (*) indicates new county record.

Prunus (Rosaceae)
P. serotina Ehrh.

Quercus (Fagaceae)
Q. alba L.
Q. imbricaria Michx.
Q. marilandica Muenchh.
Q. muhlenbergii Engelm.
Q. rubra L.
Q. stellata Wangh.
Q. velutina Lam.

Robinia (Leguminosae)
R. pseudoacacia L.

Salix (Salicaceae)
S. amygdaloides Anderss.
S. discolor Muhl.
S. fragilis L.
S. interior Rowlee
S. nigra Marsh.
S. rigida Muhl.

Sassafras (Lauraceae)
S. albidum (Nutt.) Nees

Ulmus (Ulmaceae)
U. americana L.
U. rubra Muhl.

SHRUBS

Berberis (Berberidaceae)
B. thunbergii DC.

Cornus (Cornaceae)
C. racemosa Lam.

Lonicera (Caprifoliaceae)
L. maackii Maxim.

Malus (Rosaceae)
M. ioensis (Wood) Britt.

Rhus (Anacardiaceae)
R. aromatica Ait.
R. glabra L.

Ribes (Saxifragaceae)
R. ordoratum Wendl.
R. missouriense Nutt.

Rosa (Rosaceae)
R. carolina L.
R. multiflora Thunb.
R. setigera Michx.

Rubus (Rosaceae)
R. allegheniensis Porter
R. occidentalis L.
R. pensylvanicus Poir.

Sambucus (Caprifoliaceae)
S. canadensis L.

WOODY VINES

Campsis (Bignoniaceae)
C. radicans (L.) Seem.

Cocculus (Menispermaceae)
C. carolinus (L.) DC.

Lonicera (Caprifoliaceae)
L. japonica Thunb.

Parthenocissus (Vitaceae)
P. quinquefolia (L.) Planch.
P. vitacea (Knerr) Hitchc.

Rubus (Rosaceae)
R. flagellaris Willd.

Smilax (Smilacaceae)
S. hispida Muhl.

Toxicodendron (Anacardiaceae)
T. radicans (L.) Kuntze

Vitis (Vitaceae)
V. cinerea Engelm.
V. riparia Michx.

SEDGES (Cyperaceae)

Carex
- **C. annectens* Bickn.
- *C. artitecta* Mack.
- *C. blanda* Dewey
- *C. brevior* (Dewey) Mack.
- *C. bushii* Mack.
- **C. cephalophora* Muhl.
- *C. cristatella* Britt.
- **C. muhlenbergii* var. *enervis* Boott
- **C. umbellata* Schk.

Cyperus
- **C. ferruginescens* Boeckl.

Eleocharis
- *E. erythropoda* Steud.
- **E. obtusa* (Willd.) Schult.
- *E. obtusa* var. *detonsa* (Gray) Drap. & Mohlenbr.

GRASSES (Gramineae)

Agrostis
- *A. alba* L.

Alopecurus
- *A. carolinianus* Walt.

Andropogon
- *A. virginicus* L.

Bromus
- *B. commutatus* Schrad.
- *B. inermis* Leyss.
- *B. tectorum* L.

Danthonia
- *D. spicata* (L.) Beauv.

Dactylis
- *D. glomerata* L.

Echinochloa
- *E. pungens* (Poir.) Rydb.

Elymus
- *E. canadensis* L.
- *E. hystrix* L.
- *E. villosus* Muhl.
- *E. virginicus* L.

Festuca
- *F. arundinacea* Schreb.

Hordeum
- *H. jubatum* L.
- *H. pusillum* Nutt.

Leersia
- *L. oryzoides* (L.) Swartz

Panicum
- *P. dichotomiflorum* Michx.
- *P. lanuginosum* var. *implicatum* (Scribn.) Fern.
- *P. virgatum* L.

Phalaris
- **P. arundinacea* L.

Phleum
- *P. pratense* L.

Phragmites
- **P. australis* Trin.

Poa
- *P. chapmaniana* Scribn.
- *P. compressa* L.
- *P. pratensis* L.

Schizachyrium
- *S. scoparium* (Michx.) Nash.

Secale
- **S. cereale* L.

Setaria
- *S. lutescens* (Weigel) Hubb.
- *S. viridis* (L.) Beauv.

Sorghastrum
- *S. nutans* (L.) Nash

Sphenopholis
- *S. obtusata* var. *major* (Torr.) Erdman

Tridens
- *T. flavus* (L.) Hitchcock

Tripsacum
- *T. dactyloides* L.

Vulpia
- *V. octoflora* (Walt.) Rydb.

RUSHES (Juncaceae)

Juncus
J. brachycarpus Engelm.
**J. effusus* var. *solutus* Fern. & Wieg
J. interior Wieg
J. tenuis Willd.

FORBS

Achillea (Compositae)
A. millefolium L.

Agrimonia (Rosaceae)
A. pubescens Wallr.

Allium (Liliaceae)
A. canadense L.

Amaranthus (Amaranthaceae)
**A. ambigens* Standl.

Ambrosia (Compositae)
A. artemisiifolia L.
A. trifida L.

Antennaria (Compositae)
A. plantaginifolia (L.) Richards.

Apocynum (Apocynaceae)
A. sibiricum Jacq.

Arctium (Compositae)
A. minus (Hill) Bernh.

Arenaria (Caryophyllaceae)
**A. serpyllifolia* L.

Arisaema (Araceae)
A. triphyllum (L.) Schott

Asclepias (Asclepiadaceae)
A. hirtella (Pennell) Woodson
A. incarnata L.
A. syriaca L.

Aster (Compositae)
A. novae-angliae L.
A. pilosus Willd.

Barbarea (Cruciferae)
**B. vulgaris* var. *arcuata* (Opiz) Fries

Bidens (Compositae)
B. aristosa L.
B. aristosa var. *retrorsa* (Sherff) Wunderlin
B. comosa (Gray) Wieg.

Capsella (Cruciferae)
C. bursa-pastoris (L.) Medic.

Cardamine (Cruciferae)
C. pensylvanica Muhl.

Carduus (Compositae)
**C. nutans* L.

Cassia (Leguminosae)
C. fasciculata Michx.

Cerastium (Caryophyllaceae)
C. sp.
**C. vulgatum* L.

Chaerophyllum (Umbelliferae)
C. procumbens (L.) Crantz

Chamaesyce (Euphorbiaceae)
C. maculata (L.) Small.

Chenopodium (Chenopodiaceae)
C. album L.

Cichorium (Compositae)
C. intybus L.

Cirsium (Compositae)
C. vulgare (Savi) Tenore

Claytonia (Portulacaceae)
C. virginica L.

Commelina (Commelinaceae)
C. communis L.

Croton (Euphorbiaceae)
C. capitatus Michx.

Desmanthus (Leguminosae)
D. illinoensis (Michx.) MacM.

Desmodium (Leguminosae)
D. dillenii Darl.

Ellisia (Hydrophyllaceae)
E. nyctelea L.

Erechtites (Compositae)
E. hieracifolia (L.) Raf.

FORBS (Cont'd)

Erigeron (Compositae)
E. annuus (L.) Pers.
E. canadensis L.
E. philadelphicus L.

Erythronium (Liliaceae)
E. albidum Nutt.

Eupatorium (Compositae)
E. altissimum L.
E. rugosum Houtt.
E. serotinum Michx.

Fragaria (Rosaceae)
F. virginiana Duchesne

Galium (Rubiaceae)
G. aparine L.
G. circaezans Michx.

Geranium (Geraniaceae)
G. carolinianum L.

Geum (Rosaceae)
G. canadense Jacq.

Helianthus (Compositae)
H. annuus L.
H. grosseserratus Martens
H. strumosus L.

Hieracium (Compositae)
**H. gronovii* L.

Holosteum (Caryophyllaceae)
H. umbellatum L.

Hypericum (Hypericaceae)
H. punctatum Lam.

Ipomoea (Convolvulaceae)
I. hederacea (L.) Jacq.

Lactuca (Compositae)
L. canadensis L.
L. serriola L.

Lamium (Labiatae)
**L. amplexicaule* L.

Lemna (Lemnaceae)
L. minor L.

Lepidium (Cruciferae)
L. campestre (L.) R. Br.
**L. densiflorum* Schrad.
L. virginicum L.

Lespedeza (Leguminosae)
L. virginica (L.) Britt.

Liatris (Compositae)
L. aspera Michx.

Lippia (Verbenaceae)
L. lanceolata Michx.

Lotus (Leguminosae)
**L. corniculatus* L.

Medicago (Leguminosae)
M. sativa L.

Melilotus (Leguminosae)
M. alba Desr.
M. officinalis (L.) Lam.

Monarda (Labiatae)
M. bradburiana Beck.

Myosotis (Boraginaceae)
M. virginica (L.) BSP.

Myosurus (Ranunculaceae)
M. minimus L.

Ornithogalum (Liliaceae)
**O. umbellatum* L.

Osmorhiza (Umbelliferae)
O. longistylis var. *villicaulis* Fern.

Oxalis (Oxalidaceae)
O. dillenii Jacq.
O. violacea L.

Parietaria (Urticaceae)
P. pensylvanica Muhl.

Pastinaca (Umbelliferae)
P. sativa L.

Penstemon (Scrophulariaceae)
P. digitalis Nutt.
P. pallidus Small

Phytolacca (Phytolaccaceae)
P. americana L.

Plantago (Plantaginaceae)
P. aristata Michx.
P. lanceolata L.
P. rugelii Dene.
P. virginica L.

Podophyllum (Berberidaceae)
P. peltatum L.

FORBS (Cont'd)

Polygala (Polygalaceae)
P. sanguinea L.

Polygonatum (Liliaceae)
P. commutatum (Schult.) A. Dietr.

Polygonum (Polygonaceae)
P. convolvulus L.
P. lapathifolium L.
P. pensylvanicum var. *laevigatum* Fern.
P. punctatum Ell.
P. virginianum L.

Potentilla (Rosaceae)
P. simplex Michx.

Pycnanthemum (Labiatae)
P. tenuifolium Schrad.

Ranunculus (Ranunculaceae)
R. abortivus L.

Rorippa (Cruciferae)
**R. islandica* var. *fernaldiana* Butt. & Abbe.

Rumex (Polygonaceae)
R. acetosella L.
R. crispus L.

Sanicula (Umbelliferae)
S. canadensis L.

Sibara (Cruciferae)
S. virginica (L.) Rollins

Sida (Malvaceae)
S. spinosa L.

Silene (Caryophyllaceae)
S. antirrhina L.

Smilacina (Liliaceae)
S. racemosa (L.) Desf.

Solanum (Solanaceae)
S. carolinense L.

Solidago (Compositae)
S. canadensis L.
S. gigantea Ait.
S. nemoralis Ait.
S. missouriensis Nutt.
S. speciosa Nutt.

Specularia (Campanulaceae)
S. perfoliata (L.) A. DC.

Staphylea (Staphyleaceae)
S. trifolia L.

Taraxacum (Compositae)
T. officinale Weber

Thlaspi (Cruciferae)
T. arvense L.

Tradescantia (Commelinaceae)
T. ohiensis Raf.

Tragopogon (Compositae)
**T. dubius* Scop.

Trifolium (Leguminosae)
T. hybridum L.
T. pratense L.
T. repens L.

Trillium (Liliaceae)
T. recurvatum Beck

Typha (Typhaceae)
T. latifolia L.

Valerianella (Valerianaceae)
V. radiata (L.) Dufr.

Verbascum (Scrophulariaceae)
V. thapsus L.

Vernonia (Compositae)
V. missurica Raf.

Veronica (Scrophulariaceae)
V. arvensis L.
V. peregrina L.

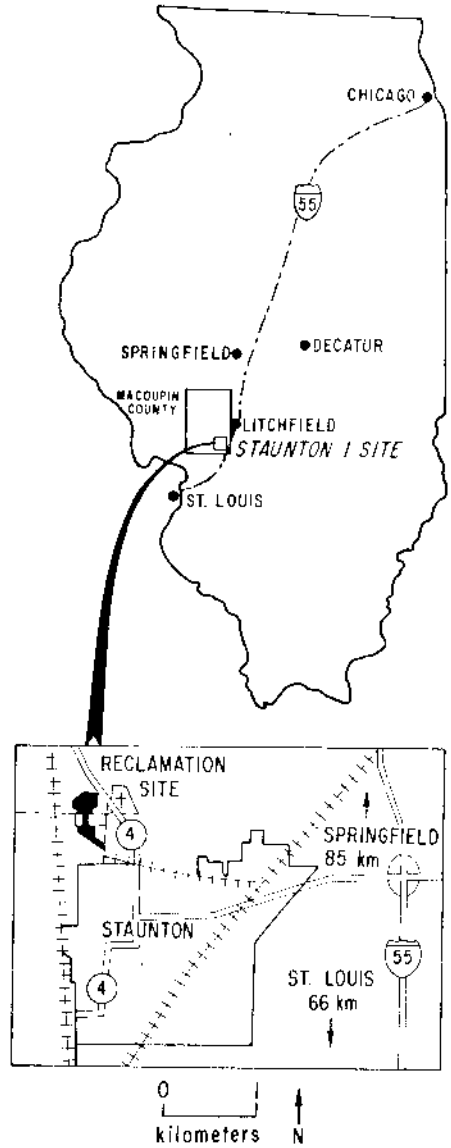
Viola (Violaceae)
V. rafinesquii Greene
V. sororia Willd.

Xanthium (Compositae)
X. strumarium L.

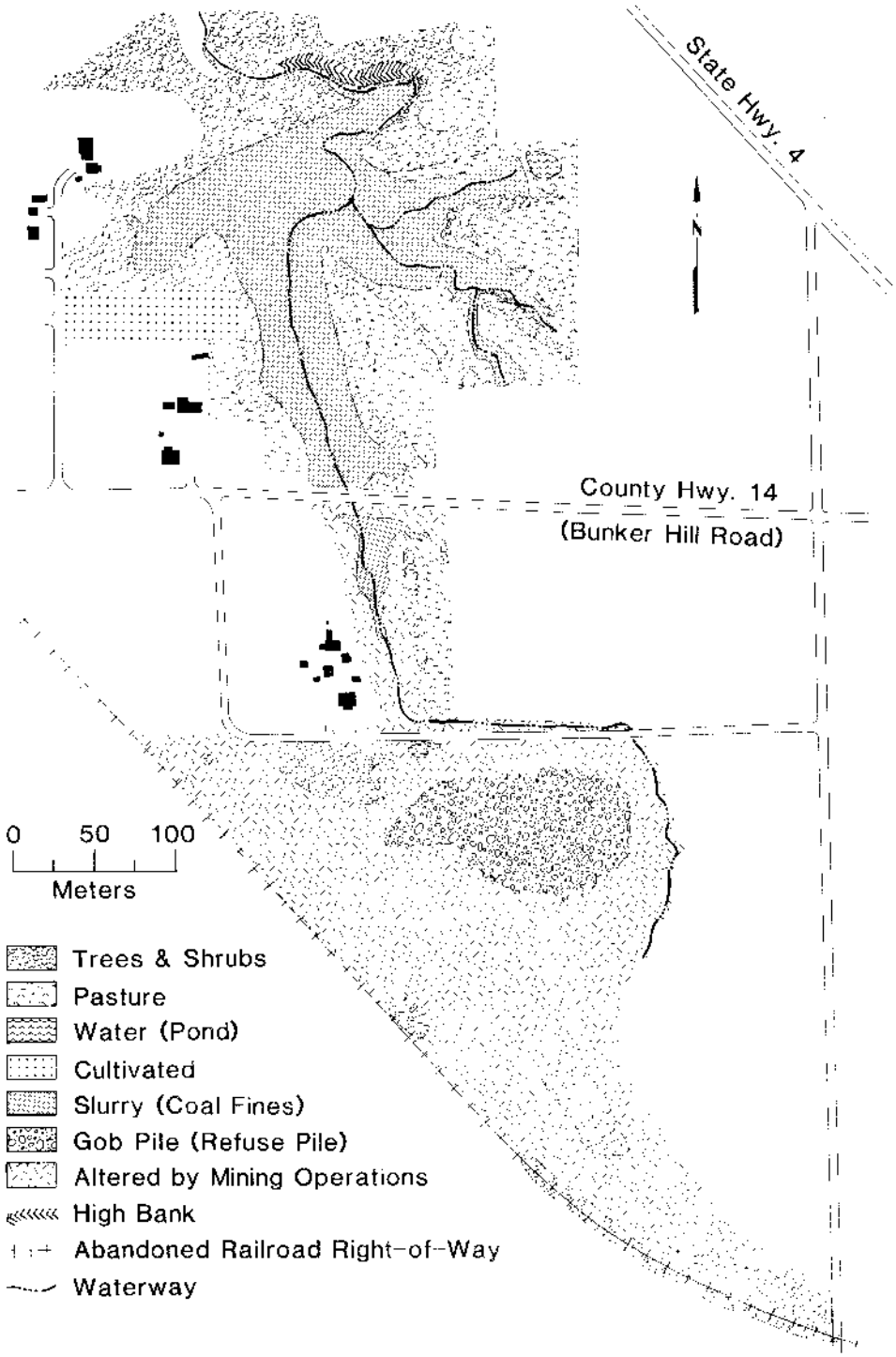
FERNS

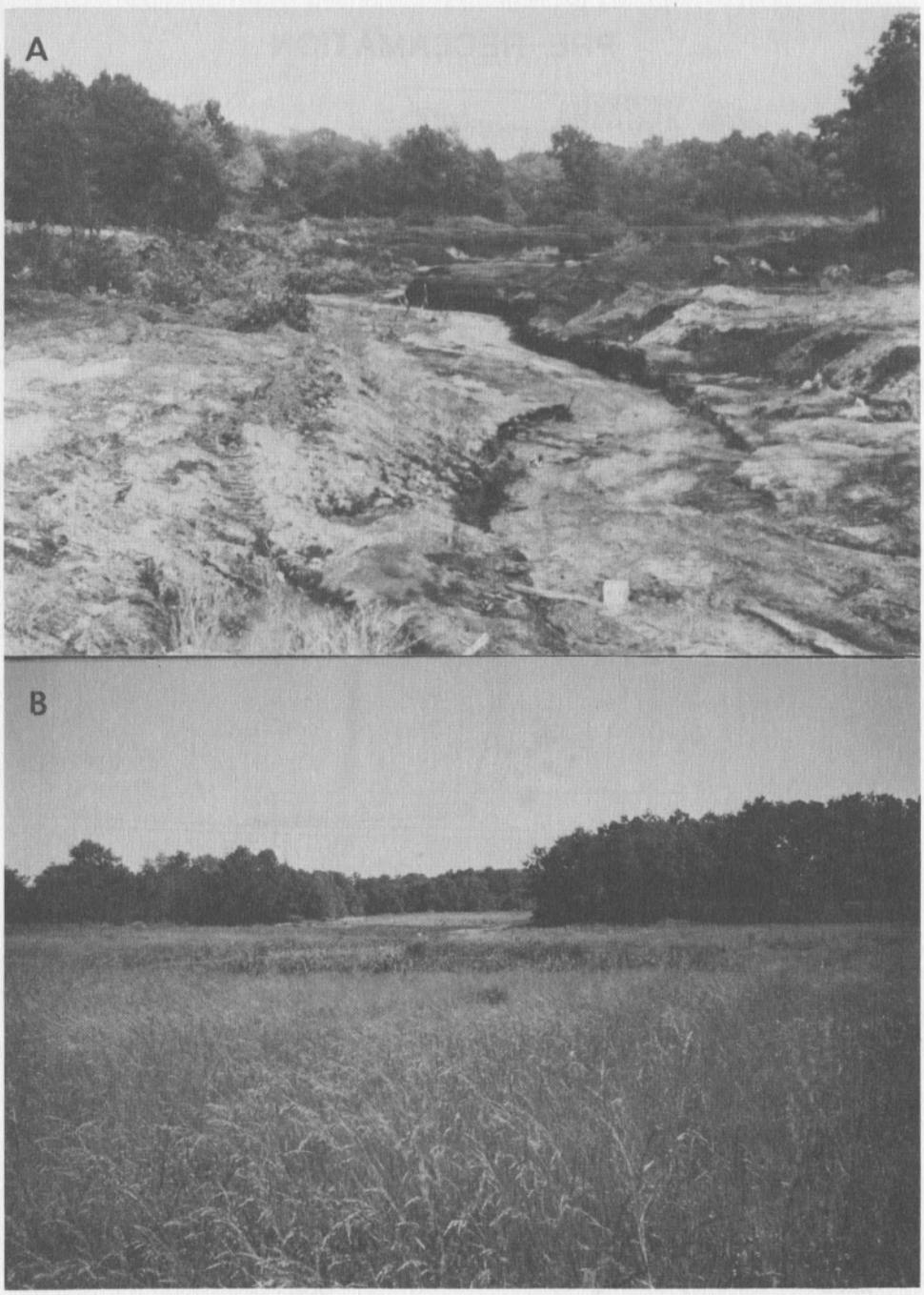
Asplenium (Polypodiaceae)
A. platyneuron (L.) Oakes

Botrychium (Ophioglossaceae)
B. virginianum (L.) Sw.


CHICAGO
55
SPRINGFIELD
DECATUR
MACOUPIN COUNTY
LITCHFIELD
STAUNTON I SITE
ST. LOUIS
RECLAMATION SITE
4
SPRINGFIELD
85 km
STAUNTON
4
55
ST. LOUIS
66 km
0
kilometers
N

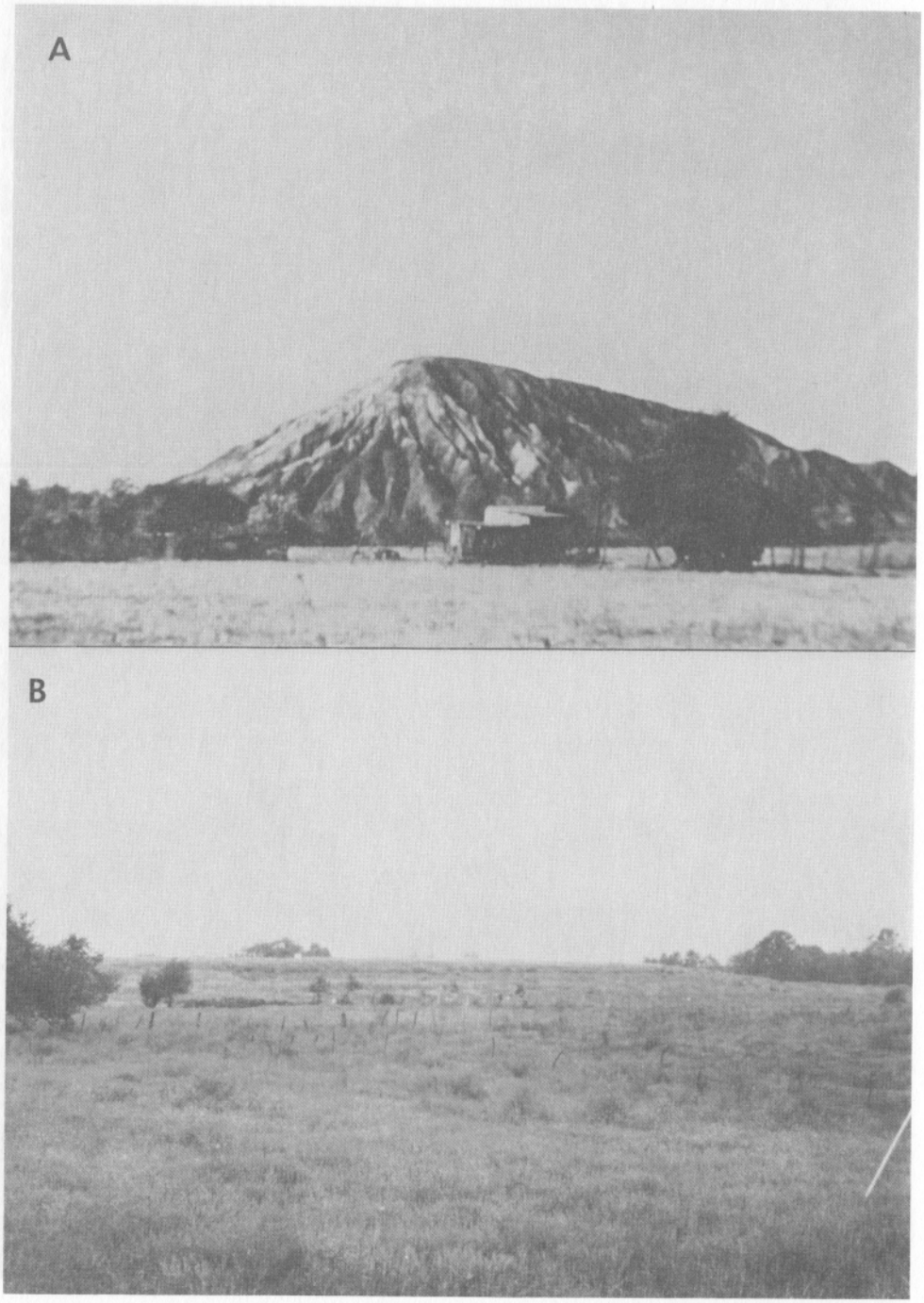
PRE-RECLAMATION




A
B


A


B


A
B

POST-RECLAMATION