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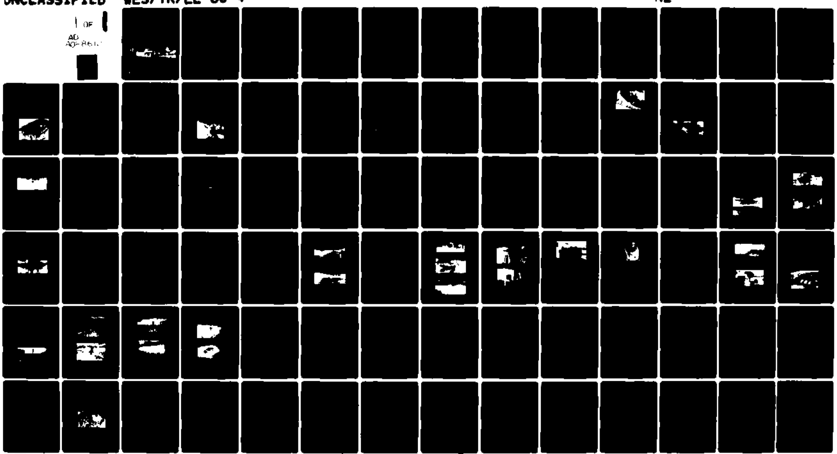

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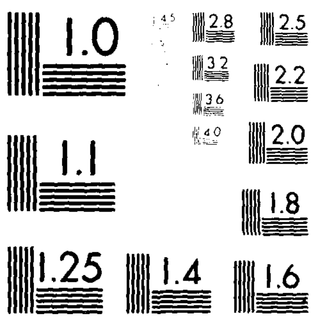

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TECHNICAL REPORT EL-80-4

AREA STRIP MINE RECLAMATION USING DREDGED MATERIAL: A FIELD DEMONSTRATION

by

Eugene R. Perrier, Jose L. Llopis, Patricia A. Spaine

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This report describes the application of dredged material for area strip mine reclamation as a possible alternative to the present practices of dredged material disposal. The purpose of the study was to demonstrate the feasibility of using a cover of dewatered dredged material to reclaim surface mine spoils. The goal of reclamation effort was the prevention and abatement of erosion and acid mine drainage by the use of dredged material as a media for a vegetative cover.

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The demonstration site consisted of four 80- by 180-ft diked test plots treated as follows: (a) control plot of untreated mine spoil, (b) mine spoil with a 3-ft covering of dredged material, (c) 5 tons/acre of crushed limestone incorporated into the top 6 in. of mine spoil and covered by 3 ft of dredged material, and (d) 7.5 tons/acre of crushed limestone incorporated into the top 6 in. of mine spoil and covered by 3 ft of dredged material. A seed mixture of five grasses and a legume was sown for a vegetative cover as well as plant growth analyses.

Samples of the dredged material and the mine spoil were physically and chemically analyzed prior to the field demonstration. The dredged material used in this study was not high in contaminants. The chemical analysis of surface runoff and leachate samples of the dredged material showed no contamination as these samples were well within recommended limits for agricultural irrigation water standards. There was no increase or decrease in the low concentration of contaminants in the groundwater sampled throughout the duration of the reclamation demonstration.

The seed mixture produced a complete vegetative ground cover early in the spring. By midseason, smartweed, which is an invading specie particularly attractive to wildlife, emerged as the primary specie. Chemical analysis of heavy metal uptake by tall fescue showed that the dredged material provided a suitable noncontaminating growth media. In addition, vegetation did not grow on the mine spoil control plot, but on the dredged material plots vegetation was produced that was both environmentally beneficial and aesthetically pleasing.

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PREFACE

This report is the result of a field demonstration concerning the use of dredged material as a cover material to reclaim an area strip mine spoil. The study was performed under Work Unit No. 4C04 of the completed Dredged Material Research Program (DMRP). This report was part of the DMRP Productive Uses Project (PUP), Mr. Thomas R. Patin, Project Manager. MAJ Robert M. Meccia, CE, was manager of PUP during the planning phase of the project.

The project was conducted by the Environmental Engineering Division (EED), of the Environmental Laboratory (EL), at the U. S. Army Engineer Waterways Experiment Station (WES), under the general supervision of Dr. John Harrison, Chief, EL, Dr. Roger T. Saucier, Special Assistant, EL, and Mr. A. J. Green, Chief, EED. The work was under the direct supervision of Dr. Raymond L. Montgomery, Chief, Water Resources Engineering Group (WREG), EED.

This report was written by Dr. Eugene R. Perrier, Mr. Jose L. Llopis, and Ms. Patricia A. Spaine, WREG. Appendix B was written by Mr. Raymond E. Jones, Louisiana Tech University, Ruston, Louisiana. Valuable assistance was provided by Mr. Michael R. Walsh, EED, in developing the study activities. Appreciation is expressed to Dr. C. R. Lee, Dr. B. L. Folsom, Jr., and Mr. Robert Peters, Ecosystems Research and Simulation Division, for technical assistance in the design and implementation phases of the project.

Commanders and Directors of WES during this study were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	0.0254	metres
miles (U. S. statute)	1609.344	metres
pounds (mass) per acre	0.00012085	kilograms per square metre
tons (2000 lb, mass)	907.1847	kilograms
tons (mass) per acre	0.22417	kilograms per square metre

AREA STRIP MINE RECLAMATION USING DREDGED MATERIAL: A FIELD DEMONSTRATION

PART I: INTRODUCTION

1. Strip mining has played a key role in the production of coal used to produce energy in this country. About 2 million acres* of land have been strip mined for coal since 1965.[1] In strip mining for coal, the land is stripped of vegetation, a deep cut is made into the basin or hillside, and the waste overburden is piled or cast down the slope. The unsightly areas created by strip mining have resulted in public pressure for State and Federal laws directing mine owners to submit a reclamation plan when applying for a mine license and/or permit. However, there remain many abandoned strip mines that are sources of acid mine runoff and erosion.[2] The desired result of reclamation on strip mine spoils is the establishment of vegetation for the control of acid runoff and soil erosion.

2. The completed Dredged Material Research Program (DMRP) sought to determine the environmental impacts of dredged material disposal and included the investigation of productive uses of dredged material. The Productive Uses Project (PUP) of the DMRP studied dredged material as a manageable resource. This report describes the results of one productive use of dredged material, that of reclaiming an area strip mine.

Purpose and Scope

3. The purpose of this report is to demonstrate the feasibility of using a cover of dewatered dredged material to reclaim surface mine spoils. Establishment of vegetation and control of soil erosion and acid runoff are primary objectives of the reclamation effort.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) can be found on page 6.

4. The scope of the demonstration project focused on the application of dredged material as a medium to establish and support vegetation. A variety of grasses and legumes native to the region were planted to provide a cover. Invading plant species, windborne species, or species transplanted with the dredged material were allowed to emerge and provide additional cover. In addition, plant samples were taken and analyzed for heavy metal content. Surface runoff, soil water, and groundwater samples were periodically monitored for contaminants. Finally, the experience gained from this demonstration study provided general guidance for the application of dredged material to reclaim surface mine spoil.[3]

Project Development

5. As early as 1974, the PUP was planning the establishment of a demonstration site to exemplify the use of dredged material for the restoration of surface mine areas. In September 1975, a preliminary greenhouse investigation was initiated with the Bureau of Mines at the Morgantown Energy Research Center, West Virginia.[4] In this study, test plots of mine spoil were either covered with dredged material or the dredged material was incorporated with the mine spoil. These plots were limed and fertilized as required by soil chemical analysis and planted with a mixture of Kentucky bluegrass, fescue, and birdsfoot trefoil. The plots with dredged material cover were not successful due to germination difficulties as the fine-textured dredged material crusted. It was concluded that additional testing by use of a field demonstration project would be needed.

6. Efforts to find a suitable field test site were concentrated in the State of Illinois[2] for a number of reasons:

- a. Over 160,000 acres of Illinois land was surface mined prior to legislation requiring mine-land reclamation (Figure 1).
- b. The Illinois River Waterway bisects a number of Illinois counties with prelaw abandoned mine spoil lands and connects these counties to sources of dredged material near Chicago (Figure 2).

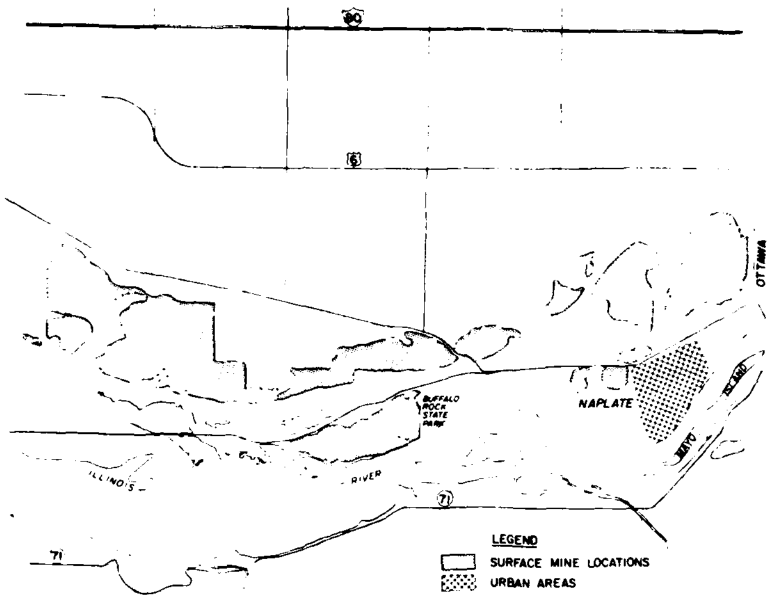


Figure 1. Schematic showing extensive mine spoil areas along the Illinois River west of Ottawa, Illinois

Figure 2. Irregularly shaped parallel ridges of mine spoil at Buffalo State Park, Illinois

c. The cost of confined dredged material disposal in the Great Lakes region has risen dramatically to the point where distant inland disposal could be economically competitive despite transportation costs.

7. During February 1976, the Chicago District of the Corps of Engineers was contacted concerning the possibility of a field demonstration site of 1 to 15 acres in the northern part of the state that would permit the use of dredged material from the Chicago area. By July, the Ottawa Silica Company of Ottawa, Illinois, was contacted and a verbal agreement with company representatives was reached that a few acres of one of their pyritic coal mine spoils could be used for a field demonstration site.

8. A predesign and coordination meeting was held during August 1976 to inform concerned agencies of the PUP's desire to perform a field demonstration and to obtain the agencies endorsement of the proposed project. In addition, the PUP wanted to obtain the agencies' input to a preliminary field design, identify areas of environmental concern, and establish coordinating links with agencies wishing to participate in or be kept informed of project activities. Representatives from the following agencies were involved:

a. Illinois Institute for Environmental Quality, Chicago, Ill.

b. Illinois Environmental Protection Agency, Springfield, Ill.

c. Illinois Division of Water Resources, Springfield, Ill.

d. Illinois Bureau of Mines and Minerals, Urbana, Ill.

e. Metropolitan Sanitary District of Greater Chicago, Chicago, Ill.

f. Region V, Environmental Protection Agency, Chicago, Ill.

g. Ottawa Silica Company, Ottawa, Ill.

h. U. S. Army Engineer District, Chicago, Ill.

i. U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

9. The agencies main concerns were about the following environmental impacts:

a. Pollution of ground and/or surface waters by contaminants leached from the dredged material.

b. Potential impact on the test area and the surrounding environment due to natural flooding.

Site Selection

10. Several large tracts of pyritic mine spoil owned by Ottawa Silica Company in LaSalle County were examined as potential sites for the field demonstration. The site selected, as shown in Figures 3 and 4, covered about 25 acres and was located 1 mile east of the city of Ottawa, Ill. The site was abandoned after coal and clay mining operations were completed in the 1930's. The reasons that led to the selection of the site were:[5]

a. The owner was interested in cooperating with the PUP and the Chicago District on a reclamation demonstration.

b. The site was adjacent to the Illinois River and was within a reasonable distance from the potential source of dredged material near Chicago.

c. The site was extremely degraded and would remain so indefinitely unless subjected to some form of reclamation activity.

11. Dredged material for the project was taken from disposal area MSD-6 owned by the Metropolitan Sanitary District of Greater Chicago. The containment area was located on the north side of the Cal-Sag Channel approximately 72 miles from the selected field demonstration site as shown in Figure 5. The containment area was last used for dredged material disposal in 1973.

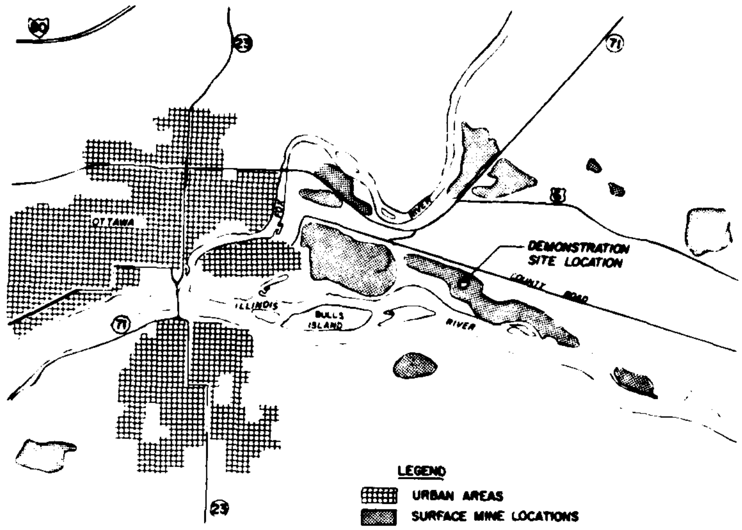


Figure 3. Schematic of the area east of Ottawa, Illinois, showing the location of the site selected for the field demonstration

Figure 4. Photograph showing site prior to establishment of the field demonstration

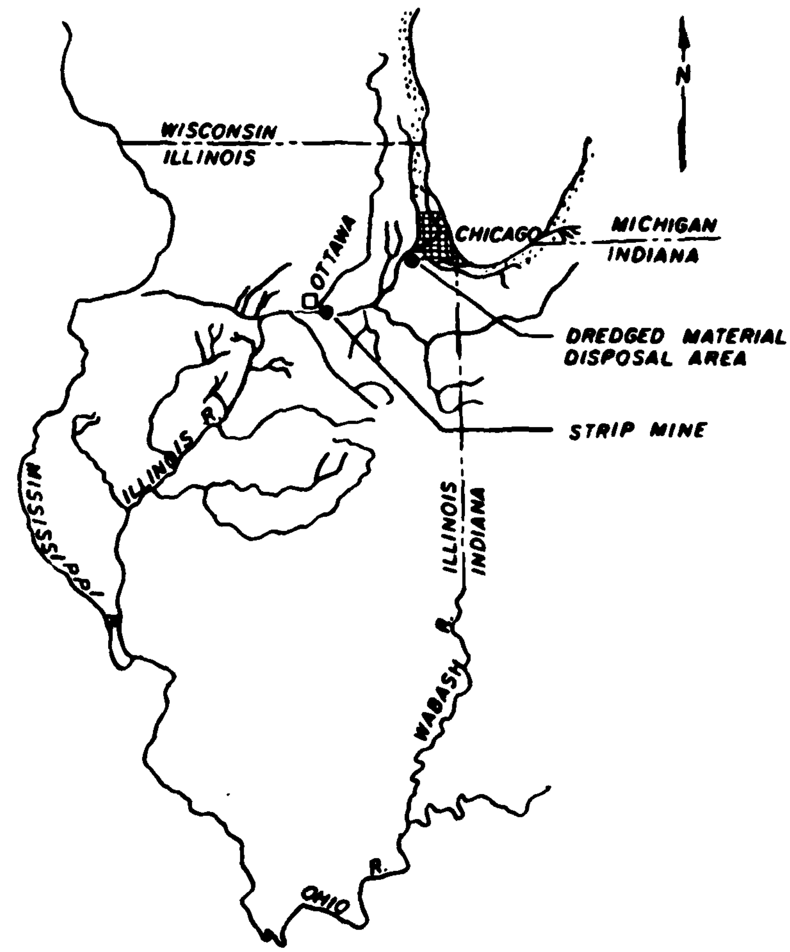


Figure 5. Schematic showing the relative location of the field demonstration site and the dredged material containment area

PART II: SUMMARY OF INFORMATION ON STRIP MINE RECLAMATION

Description of Surface Mines

12. The history of surface mining is essentially that of mining coal, copper, and iron ores, and nonmetallic minerals--clays, gypsum, rock phosphate, sand, gravel, and stone. In this report, surface mining of coal will be examined; however, much of this methodology applies to other minerals. In surface mining, large shovels are able to strip coal seams to great depths, up to 100 ft or more. As this type of mining continues, the ratio of waste to coal increases[6] and requires a greater effort for the restoration of the natural terrain. Nonetheless, because technology has increased surface mining productivity, up to 30 tons per man-day on the average, it has been more economical to produce coal by stripping than by underground methods. The surface mining industry has met the challenge of economic conditions by developing larger shovels, trucks, and bucket-wheel excavators; by initiating the use of explosives; and by improving drilling equipment.[6]

13. Surface mines are located where the coal seam can be economically uncovered and where the product can be utilized competitively with other fuels. Strip mining, which is the method to be examined in this report, is but one method for surface mining, e.g., open pit mining, auger mining, hydraulic mining, and dredging. Strip mining is the process of digging a series of parallel trenches (area mining), or digging around a hillside (contour mining) for coal.[7]

14. Strip mining is usually extensive because of the thin deposits of coal necessitating the removal of large amounts of overburden to recover the ore[8] as shown in Figure 6. The removal of this overburden results in the disruption of the natural terrain exposing soil, subsoil, and pyritic rock strata and creating large areas of steeply sloping land. The creation of fresh spoil banks without protective plant cover permits the moving water to entrain sediment and permits the buildup of acid concentration, both of which discharge into streams.

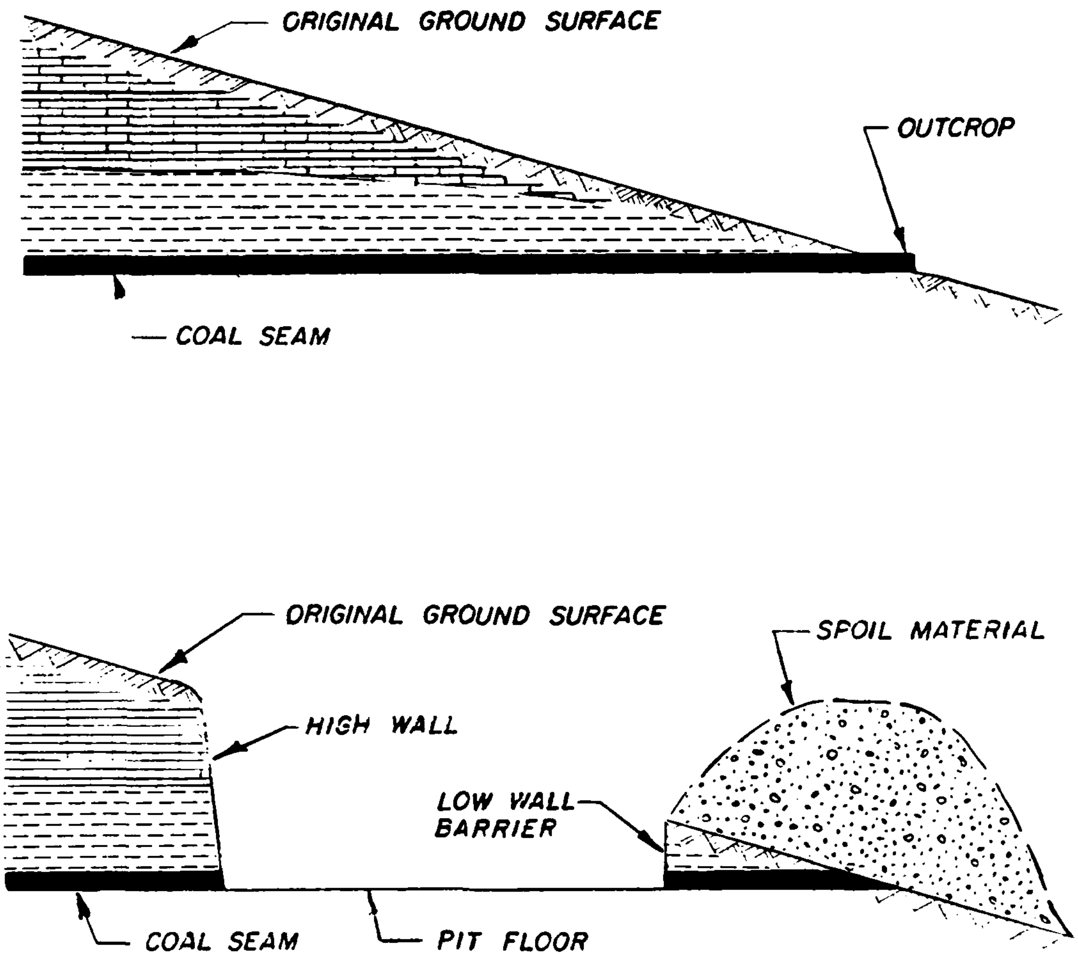


Figure 6. Cross section of a potential strip mine site showing the original land surface, mineral seam, and bedrock before and after contour mining[9]

Acid Drainage from Strip Mining

15. Spoil banks, refuse pits, and access roads often contain acid-forming pyritic materials that prevent ground cover from developing. Most of the refuse materials at strip mine sites have acid soils that affect the solubility and the availability of soil nutrients for plant growth.

16. As water flows over and through a strip mine area, it may come in contact and react with sulfur-bearing minerals that have been exposed to air as a result of mining. When water reacts with these minerals, it becomes acid. The three prerequisites for acid production are water, air, and sulfur-bearing minerals.[7] In coal deposits, the sulfur is present principally as either pyrite or marcasite, which are different crystalline forms of iron disulfide (FeS_2). In this report, any sulfur-bearing material will be referred to generally as pyrite. The amount and type of sulfuric acid production are related to the following:[10]

- a. Length of time water and air are in contact with minerals.
- b. Hydrologic, geologic, and surface configuration of the mine and surrounding terrain.
- c. Type of mining methods employed.
- d. Type of strip mine, active or abandoned.
- e. To some extent, presence or influence of microbial activity.

17. Pyrite on a strip mine site oxidizes in the presence of air and water to form sulfuric acid and acid sulfate compounds.[1] The chemistry of this oxidation is relatively complex and not fully understood but apparently follows the general reaction described by Hill:[11]

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4$$

The pyrite (FeS_2) is oxidized by oxygen in the presence of water, then ferrous sulfate ($FeSO_4$) and sulfuric acid are produced. The reaction continues as follows:

$$4FeSO_4 + 2O_2 + 2H_2SO_4 \rightleftarrows 2Fe_2(SO_4)_3 + 2H_2O$$

The ferrous iron formed is oxidized slowly, depending upon pH, temperature, and the amount of ferrous iron in solution, to give:

$$Fe_2(SO_4)_3 + 6H_2O \rightleftarrows 2Fe(OH)_3 + 3H_2SO_4$$

In some cases the resultant ferric iron ($Fe(OH)_3$) produced can be reduced by the pyrite to release more acid and ferrous iron as follows:

$$FeS_2 + 14Fe^3 + 8H_2O \rightarrow 15Fe^{+2} + 2SO_4^{-2} + 16H^{+1}$$

Thus, the cycle is completed and oxidation continues with the net result that two molecular weights of sulfuric acid are released for each molecular weight of the original pyrite.[11] This production of sulfuric acid is known as the acid mine drainage problem, the main obstacle to revegetation.

18. In addition to this continuous process, erosion on the barren strip spoils constantly exposes additional pyrite. Therefore, both new and old exposed pyrite material produce acid runoff. There is also some evidence that microbial activity may act as a catalytic agent in part of this oxidation process.[1]

19. The geological formations associated with coal seams are a determining factor in acid production. Shale generally is recognized as a source of acid-producing mineral, whereas sandstone associated with shale is a provider of heavy metal contaminants found in the acid runoff.[11] Since the formations associated with coal seams vary greatly, no two acid mine drainage problems are exactly alike.

Types of Strip Mines

Area mining

20. Area mining to depths of 150 ft is generally used in relatively flat terrain where mineral seams are roughly parallel to the land surface as shown in Figure 7. An area mine is usually started with a trench and

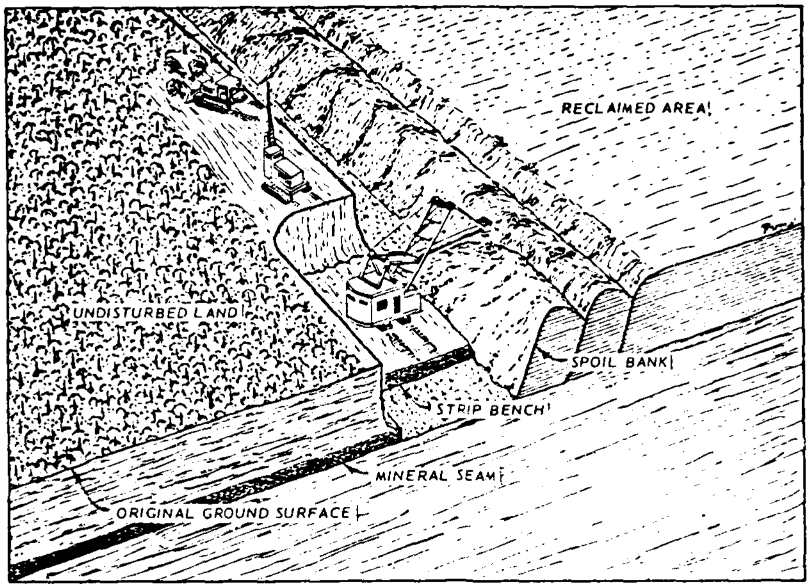


Figure 7. Schematic of the area mining method of strip mining[12]

a concomitant parallel spoil bank extending to the limits of the property or vein deposit. Spoil material from each successive parallel cut or trench is placed in the preceding trench. The last cut or trench is bounded by overburden material on one side and an undisturbed high wall on the other.[12] The open trench remaining from the mining process usually forms a pond and, if the mine spoil is pyritic, the pond may be varying shades of blue or green and quite acid.

21. Many area mines have little or no surface water discharge as most of the acid water and sediment are entrapped within the surface mine area, e.g., the Ottawa demonstration site as shown in Figure 8. Erosion may be heavy within the mine site, but a large portion of the sedimentation and acid runoff occurs within the mine and never reaches external surface flow or river channels.[12] The runoff and eroded material are collected in the trenches and depressions of the mine eliminating any discharge.

Contour mining

22. Contour mining requires removal of the overburden by starting at the outcrop of the coal seam and proceeding along the contour around

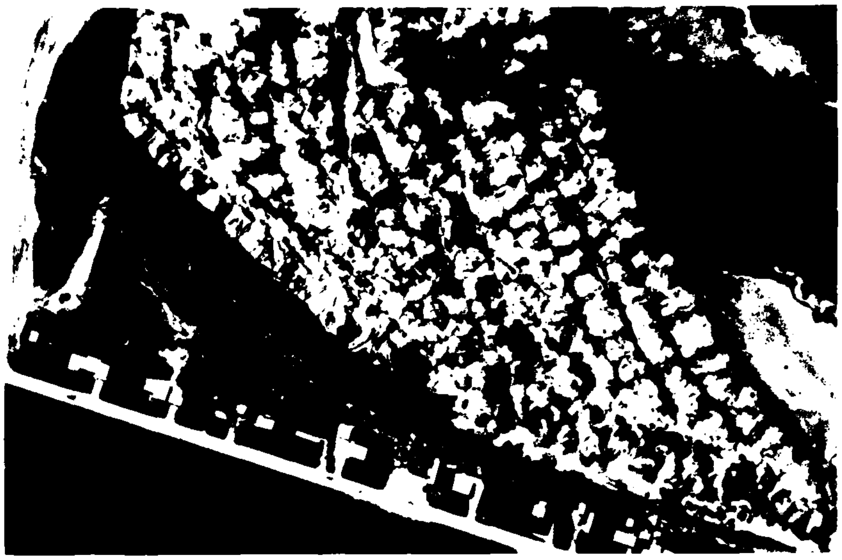


Figure 8. Aerial photograph of the site before the plot layout showing mine spoil ridges that entrap most of the surface acid mine drainage

the hillside (see Figure 6). Digging down to the coal involves excavating the overlying material as deep as 90 ft and spoiling it on the low wall or downslope side away from the coal. The basic function of the low wall barrier is to provide a natural seal along the outcrop. This seal helps to retain the surface and mine water within the mine during the mining operation. The high wall is located to the uphill side of the cut. Since the operation is above the grade of local drainage, the flow of water from the exposed cut is directly into natural waterways.[12]

23. The mineable areas may be large, but the cuts extend in great length and have a narrow width. Many of these mines are operating in the central states, but most of the contour mines are located in the eastern Appalachian coalfield.[6]

Strip Mine Reclamation

24. Reclamation is the corrective action for prevention of adverse effects from strip mining after the extraction of the coal.[10] Spoil segregation, the separation of topsoil from mine spoil, was rarely

practiced by miners in the past because it was less expensive to pile all of the spoil material together. Reclamation of these old abandoned strip mines is difficult because the original topsoil is mixed with underlying shale and acid-forming pyritic materials occurring throughout the spoil. The "striking off" of stripped overburden to create level or gently sloping topography consistent with planned land use is an integral part of reclamation. The amount and method of site preparation needed at an abandoned strip mine consists chiefly of regrading the strip mine to a configuration that will accommodate a topsoil or topsoil substitute such as dredged material at a desired thickness and slope to support vegetation.[13] Basic site preparation techniques for reclaiming area and contour strip mines are discussed below.

<u>Area strip mine reclamation</u>

25. The area mining method produces the characteristic topography of a series of parallel ridges or piles of mine spoil. Site preparation consists of leveling mine spoil ridges or piles to a width specified by law and/or final land use. Leveling or "striking off" mine spoil ridges is accomplished by bulldozing the ridges as shown in Figure 9. The mine spoil piles should be leveled to a topography where conventional

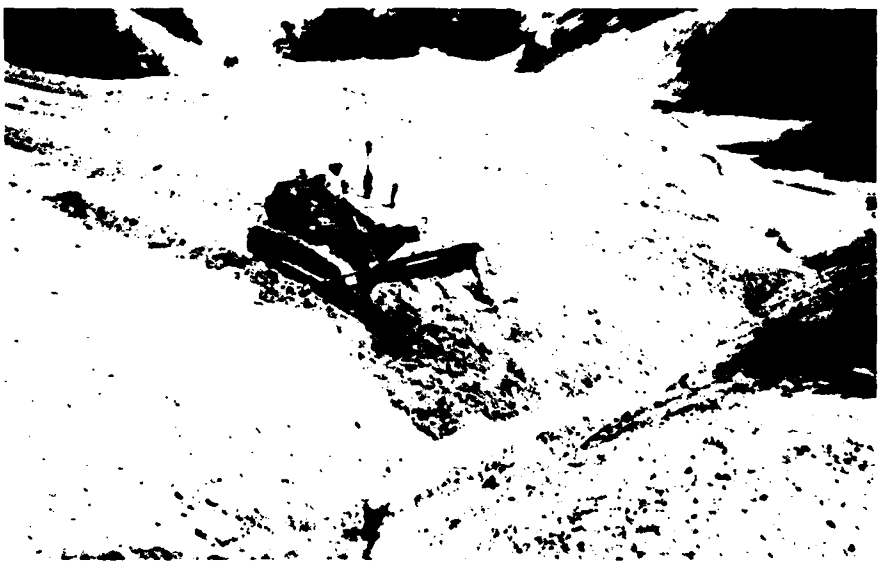


Figure 9. A bulldozer striking off the mine spoil ridges prior to revegetation

earthmoving equipment can spread topsoil such as dewatered dredged material to a desired thickness[3] as shown in Figure 10.

26. Revegetation is a necessary next step in the reclamation of abandoned strip mine spoils.[14] Regraded areas can be seeded or planted with cuttings or seedlings; however, most strip mine areas are not capable of supporting plants without an adequate layer of topsoil or dredged material. Reclaimed strip mines may be used for wildlife, woodland, agriculture, or for recreational uses with the degree of reclamation and type of vegetation varying with the use of this land. In addition, reclaimed sites are used for construction purposes; for example, the large LaSalle County Hospital at Ottawa is built on reclaimed mine spoil. Costs for regrading have been estimated[7,15,16] in 1978 dollars to range from $200 to $7000 per acre, depending on the nature of the mine and amount of regrading required. Revegetation is dependent on the nature of the soils and climate and on planned land use. Cost factors that have been identified are:[7]

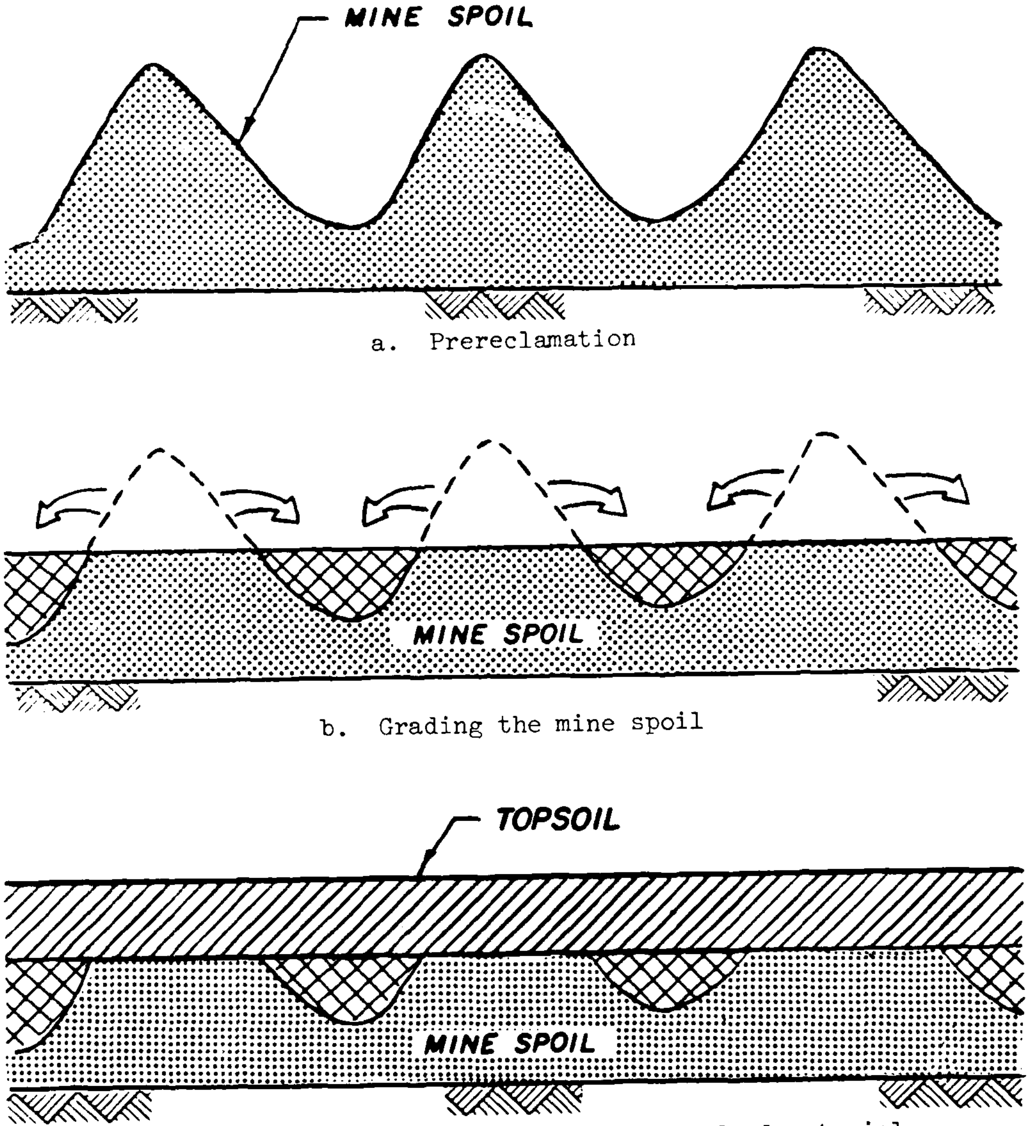
- a. Materials.
- b. Method of planting.
- c. Accessibility.
- d. Seedbed preparation.
- e. Labor costs.
- f. Legislative requirements.
- g. Land use.

Costs of revegetation are estimated in 1978 dollars to range from $100 to $300 per acre with estimates as high as $10,000 per acre for specific land uses.[7,15,16]

Contour strip mine reclamation

27. The reclamation of contour strip mines is more difficult due to the hilly terrain in areas where this type of mining occurs (Figure 11). The problem of preventing slide conditions, spoil erosion, and resultant stream sedimentation is present in any downslope spoil disposal technique.[2] Contour stripping is generally applicable on rolling to moderately steep terrain and may be applied to multiple-seam conditions.

28. Regrading is an essential part of the reclamation of contour



a. Prereclamation

b. Grading the mine spoil

c. Application of topsoil such as dredged material

Figure 10. Schematic showing operational techniques used to reclaim an area of strip mine spoil

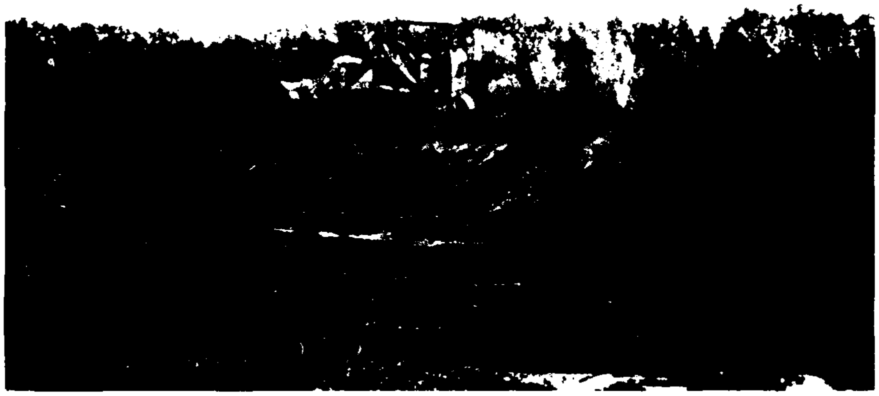


Figure 11. Backfilling of surface mined area

strip mines.[12] This involves backfilling and terracing the disturbed land to the approximate original contour or to a contour compatible to the surrounding terrain as shown in Figure 12. This requires placing a topsoil substitute, such as dredged material, into strip pits and over the spoil that was cast downhill. Establishment of a quick growing vegetative cover is important for effective erosion control.[9]

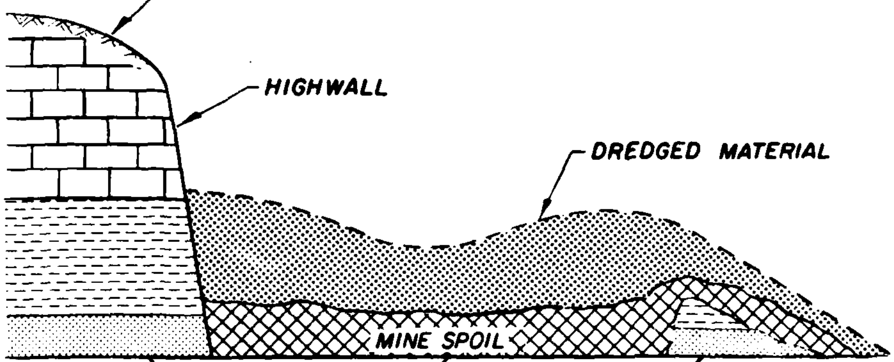


Figure 12. Cross-sectional view of contour backfill technique

PART III: DESCRIPTION OF OTTAWA DEMONSTRATION SITE

Background

29. There is very little specific information available concerning the geology and soils of the Ottawa site. However, an adequate amount of information was provided by the area soil survey[17] and two reports on the geological conditions in the area.[18,19]

Geology and Soils

30. The topography and subsurface conditions of the area are illustrated in Figure 13. The demonstration site is located just north

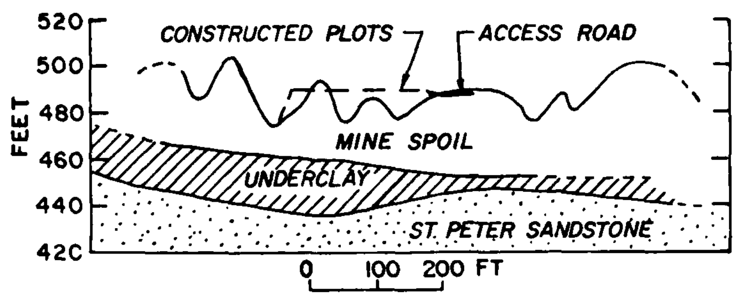


Figure 13. Topographical description of the Ottawa area strip mine field demonstration area[19]

of the Illinois River (750 ft) and south of the Fox River (2300 ft). The area is a part of the Illinois River floodplain and river terrace (460-550 ft mean sea level (msl)). The north side of the study area consists of low ridges with elevation ranges from 480 to 550 ft msl. The strip mine site consists of a series of irregularly shaped parallel ridges of mine spoil covering an area of approximately 25 acres. The ridges are about 600 to 1200 ft in length, 40 to 50 ft in width, and 20 to 30 ft in height. The areas to the north and adjacent to the study site consist of the rugged terrain produced by unreclaimed area strip mines.

Geology

31. The material, as shown in Figure 14, which overlies the bedrock is an alluvium silt and sand soil of the Illinois River.[18] The alluvial soils are thin, varying between 6 and 20 in.[18] These alluvium soils are atop a 14- to 16-ft layer of Francis Creek shale that contains abundant pyrite.

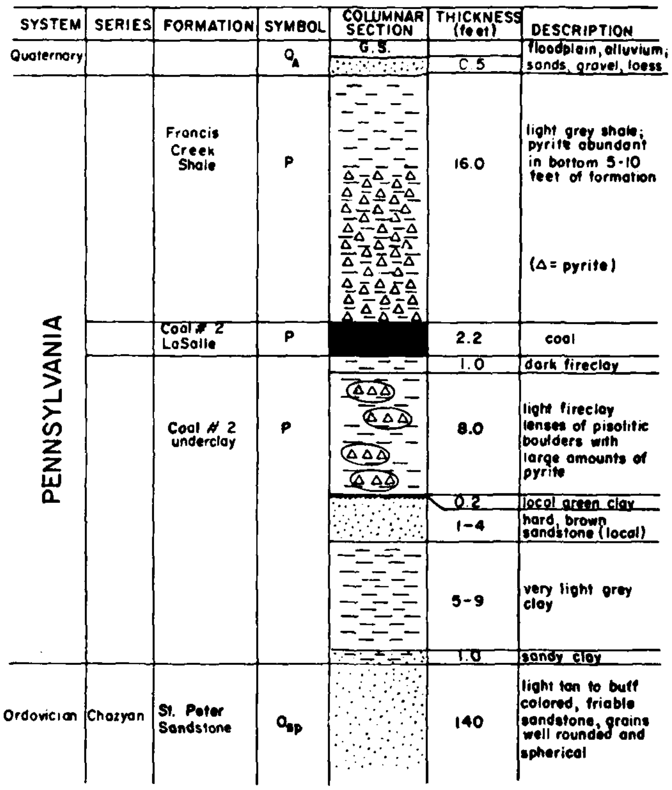


Figure 14. Stratigraphic section of the strip mine demonstration site[17]

32. The coal seam lies upon the lower bedrock of Pennsylvanian age, which is composed mainly of underclay and some sandstone. Directly under the Pennsylvanian bedrock at a depth ranging from 35 to 60 ft is the top of the St. Peter Sandstone of Ordovician age. This sandstone unit is approximately 140 ft thick. The Shakopee Dolomite of Ordovician age lies beneath the St. Peter Sandstone and ranges in thickness from 150 to 200 ft. Beneath the Shakopee Dolomite lies the New Richmond

Sandstone, also of Ordovician age. The New Richmond Sandstone layer ranges in thickness from 140 to 190 ft thick.[18]

Soils

33. The soils of the demonstration site before strip mining operations were Loran and Lawson silt loams,[17] which are dark colored, somewhat poorly drained, and developed in 20 to 30 in. of alluvial silty material over acid shales of Pennsylvania age and under prairie native vegetation. These soils occur on very gently sloping areas along both small and large streams primarily east of Ottawa along the Illinois River.

After Mining

34. The strip mining in this area was abandoned in the early 1930's.[3] The coal seam (No. 2, lignite) in this area was 20 to 30 in. thick and was reached after removing 14 to 18 ft of overburden. The underlying fireclay, 15 to 20 ft thick, was also mined at this time.[19] The unconsolidated material in the strip mine area is composed of the pyritic shale overburden that was overlying the coal and clay that was strip mined.

35. The spoil material consists of reworked soils and pyritic shale from the Pennsylvanian bedrock in which the coal and clay occur. The surface material is covered with a crust due to the release of sulfuric acid from the interaction of surface water, air, and pyrite present in the shale. The high pyrite content of the shales that were removed during stripping is the main cause of acid mine drainage in the area.

Physical and Chemical Characteristics

36. Prior to actual project design, a series of field investigations were made by the U. S. Army Engineer District, Chicago, and the Environmental Laboratory at the U. S. Army Engineer Waterways Experiment Station (WES), to provide needed input concerning both the area strip mine site and the dredged material disposal area. At the proposed

strip mine site, two observation wells were installed to determine the elevation and fluctuation of the water table as well as to permit sampling to determine the chemical characteristics of the groundwater.[20] Cores of the mine spoil and composite samples of the dredged material were taken and tested to determine the soil classification and permeability of the materials. Chemical analyses were determined on material samples from the containment area and composite samples from the material as placed at the demonstration site.

Physical characteristics

37. Strip mine spoil. Grain-size and plasticity analyses and permeability tests were determined from eight core samples taken at the site and their mean values are shown in Table 1. The Unified Soil Classification System (USCS) group symbol[21] for the mine spoil material was CH, i.e., an inorganic clay of high plasticity (fat clays), and, in addition, it contained clay shale with intermixed lignite and pyritic fragments. The U. S. Department of Agriculture (USDA) classification[22] was a silty clay soil with 1.5 percent sand, 57.0 percent silt, and 41.5 percent clay. The very low permeability of the material is typical of inorganic clays;[23] nonetheless, the surface material is somewhat

Table 1

Physical Measurements of Mine Spoil from the Demonstration Site

Depth of Sample ft	Unified Soil Classification Group Symbol	Liquid Limit	Plastic Limit	Plasticity Index	Permeability ($K \times 10^{-8}$ cm/sec)
0.0-2.0	CH	53	28	25	7.4
2.0-3.0	CH	56	30	26	5.8
3.0-5.0	CH	75	31	44	2.1
10.0-12.0	CH	60	27	33	3.3
20.0-22.0	CH	53	25	28	2.2

more permeable than at the lower depths. The potential for contaminating the groundwater with dredged material leachate is negligible because of the very low permeability of the lower layers of mine spoil above the water table at the 30-ft depth.

38. Dredged material. The grain-size distribution for the means of six dredged material samples taken from the plots at the demonstration site (Table 2) showed the group symbol to be MH, i.e., inorganic silt, slightly plastic, small percentage of fine sand. The USDA classification was a silt loam soil that is highly suited as an agronomic crop growth media. The permeability of the dredged material was not determined because it was disturbed when transported.

Table 2

Physical Characteristics of Dredged Material from the Demonstration Site

Unified Soil Classification Group Symbol	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing U. S. Standard Sieve #400 (0.4 mm)
MH	54.0	31.0	23.0	80
MH	54.0	30.0	24.0	80
MH	51.0	28.0	23.0	95
MH	50.0	29.0	21.0	95
MH	53.0	31.0	22.0	90
MH	57.0	31.0	26.0	90

Chemical analysis

39. Strip mine spoil. The procedures used for the chemical analyses of the strip mine spoil and the dredged material are presented in Table 3 along with the units, detection limit, and references. The results of the chemical analysis of the strip mine spoil are shown in Table 4. The pH, ranging from 3.6 to 4.1, was very low as a result of acid generation from the pyrite as discussed in Part II. The salt content as measured by the electrical conductivity (CONDUC) was variable, but at a level that would restrict only the growth of salt-sensitive

Table 3

Procedures Used in Chemical Analyses of Dredged Material and Mine Spoil

Parameter	Description	Units	Detection Limit	Reference
pH	Determined with a glass electrode pH meter on a 1:1 soil to water suspension	—	0.01	Bear, 1964[25]
Chloride	Potentiometric determination of chloride using a titration assembly	mg/kg	10	Black, 1965[26]
Electrical conductivity	Measured with a conductivity bridge using a 2:1 water to soil solution	μmho/cm	7.0	Bear, 1964[25]
Mercury	Manual cold vapor technique	mg/kg	0.025	Environmental Protection Agency (EPA), 1974[27]
Metals	Nitric, perchloric, and hydrofluoric acid digest and analyzed on an atomic absorption spectrophotometer	mg/kg	0.002	Lee et al., 1978[28] Black, 1965[26]
Sulfate	Oxidation of organic sulfur to sulfate and retained upon ignition of a mixture of soil and sodium bicarbonate	mg/kg	0.1	Black, 1965[26]
Cyanide	Conversion to sodium salts and adsorbance measured at 620 mμ	mg/kg	0.02	EPA, 1969[29]
Sulfide	Distillation under acidic conditions to form zinc sulfides and methylene blue and determine concentration with spectrophotometer	mg/kg	1.0	EPA, 1969[29]
Total nitrogen	Determination by titration of ammonia released by distillation from samples previously digested with sulfuric acid	mg/kg	0.02	EPA, 1969[29]
Total phosphorus	Determined colorimetrically with vandomolybdate on a soil-acid (HNO_3-$HCPO_4$) digest	mg/kg	5.0	EPA, 1969[29]
Nitrate-nitrite	Ultraviolet colorimetric determination	mg/kg	0.01	EPA, 1969[29]

Table 4

Chemical Analysis of Mine Spoil from the Demonstration Site

Parameter	Plot No. 1	2	3	4	Average
Calcium (Ca), mg/kg	1,160	1,200	2,390	1,450	1,550
Cadmium (Cd), mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010
Chromium (Cr), mg/kg	9.14	90.0	86.2	84.3	88.0
Copper (Cu), mg/kg	28.2	27.0	28.2	26.8	27.8
Iron (Fe), mg/kg	35,800	38,600	36,500	37,100	37,000
Lead (Pb), mg/kg	41.8	38.2	42.8	42.8	41.4
Magnesium (Mg), mg/kg	4,640	4,110	5,970	4,890	4,903
Nickel (Ni), mg/kg	43.4	44.0	50.9	42.0	45.1
Potassium (K), mg/kg	29,400	31,100	33,800	31,900	31,550
Sodium (Na), mg/kg	6,790	6,810	6,770	6,590	6,740
Zinc (Zn), mg/kg	83.3	78.8	100.0	86.9	88.5
Manganese (Mn), mg/kg	212	266	272	232	246
Organic nitrogen (TKN*), mg/kg	570	670	670	670	645
Total phosphorus (TP), mg/kg	582	630	629	598	610
Ammonia (NH_3-N), mg/kg	<10	18	18	<10	<14
Sulfate (SO_4), mg/kg	18,500	16,800	18,700	15,400	17,350
Chloride (Cl), mg/kg	20	<10	<10	<10	<12
Cyanide (CN), mg/kg	<0.4	<0.4	<0.4	<0.4	<0.4
Mercury, (Hg), mg/kg	<0.025	<0.025	0.028	0.116	<0.049
pH	3.6	3.6	4.1	3.8	3.8
Total nitrogen (NO_3NO_2), mg/kg	10.60	6.40	3.24	7.58	6.96
Sulfide ($S^=$), mg/kg	<10	<10	<10	<10	<10
Conductivity (CONDUC), μmhos/cm	3,370	3,060	4,810	2,970	3,553

* TKN = total Kjeldahl nitrogen.

plants.[24] The capacity of the soil particles to adsorb nutrients was high for the mine spoil with a cation exchange capacity of about 55 meq/ 100 g. Also, the content of organic carbon was low at 0.65 percent.

40. Dredged material. The analyses of the chemical data of the freshwater dredged material (Table 5) show that chromium, iron, zinc, manganese, and lead are near or slightly exceed the upper range of constituents that can be expected in dredged material as shown in Table 6 by the ranges of chemical characteristics found in selected samples of dredged material from west coast brackish waters by Chen et al.[30] and discussed by SCS Engineers.[31] However, the dredged material has concentrations of metals far below that suggested by Chaney[32] (Table 7) as recommended maximum limits on the metal content of sludge for application to agricultural lands. Only cadmium approached anywhere near the suggested toxic level for sludge.

Vegetative Cover

41. As noted previously, the dredged material for the project was obtained from a disposal site near Alsip, Ill., as shown in Figure 15. The disposal site is about 400 ft wide by 1250 ft long. The vegetation on the dredged material generally reflected poor drainage, and there was evidence that water remains in troughs of about 50 ft in width (mudflats) along the western and southern margins of the site during the wet times of the year.

42. A survey revealed 42 species of plants growing on the surface of the containment area. The dredged material disposal site is dominated regularly throughout by smartweed, common beggar's tick, sandbar willow, tall goldenrod, common reed, hairy aster, common evening primrose, and the sweet clovers as shown in Figures 16 and 17. This assemblage gives way gradually in the higher elevations, primarily in the eastern end, to cinquefoil, hairy aster, garden sunflower, knee grass, barnyard grass, common orach, green foxtail, giant foxtail, horseweed, and reed canary grass as shown in Figures 18 and 19. The southern and western margins of very wet troughs are dominated by smartweed, common beggar's tick,

Table 5

Concentrations of Chemical Constituents and Characteristics from Selected Samples of Dredged Material

Parameter	Plot No. 2	Plot No. 3	Plot No. 4	Average
Calcium (Ca), mg/kg	49,500	58,900	52,100	53,500
Cadmium (Cd), mg/kg	12.5	13.6	12.9	13.0
Chromium (Cr), mg/kg	169	168	160	166
Copper (Cu), mg/kg	108	128	103	113
Iron (Fe), mg/kg	42,400	42,400	40,800	41,867
Lead (Pb), mg/kg	507	514	500	507
Magnesium (Mg), mg/kg	25,800	30,100	26,100	27,333
Nickel (Ni), mg/kg	57.3	51.4	51.0	53.2
Potassium (K), mg/kg	17,900	18,100	17,900	17,967
Sodium (Na), mg/kg	4,970	4,470	2,690	4,043
Zinc (Zn), mg/kg	1,190	1,120	1,060	1,123
Manganese (Mn), mg/kg	538	532	536	535
Organic nitrogen (TKN*), mg/kg	1,620	1,610	1,740	1,657
Total phosphorus (TP), mg/kg	4,730	5,180	5,060	4,990
Ammonia (NH_3-N), mg/kg	65	20	20	35
Sulfate (SO_4), mg/kg	3,610	3,770	3,940	3,773
Chloride (Cl), mg/kg	720	140	140	333
Cyanide (CN), mg/kg	2.3	1.9	2.2	2.1
Mercury, (Hg), mg/kg	0.786	1.38	0.621	0.929
pH	7.0	7.1	7.1	7.1
Total nitrogen (NO_3NO_2), mg/kg	23.2	18.8	18.2	20.1
Sulfide ($S^=$), mg/kg	<10	<10	<10	<10
Conductivity (CONDUC), µmhos/cm	2,530	2,530	2,530	2,530

Table 6

Concentrations of Chemical Constituents and Characteristics from Selected Samples of Dredged Material from West Coast Brackish Water[30]

Parameter	Range Expected mg/kg*
Calcium (Ca)	600-17,000
Cadmium (Cd)	0.05-70
Chromium (Cr)	1-200
Copper (Cu)	0.05-600
Iron (Fe)	1,000-50,000
Lead (Pb)	1-400
Magnesium (Mg)	4,000-13,000
Nickel (Ni)	15-150
Potassium (K)	17,000-24,000
Sodium (Na)	12,000-40,000
Zinc (Zn)	30-500
Manganese (Mn)	24-550
Organic nitrogen (TKN)	100-2,000
Total phosphorus (TP)	500-2,000
Ammonia (NH_3-N)	100-2,000
Chloride (Cl)	40-20,000
Mercury (Hg)	0.2-2.0
pH	6-9
Total nitrogen (NO_3NO_2)	200-4,000
Total sulfides (acid soluble)	100-3,000

* Except for pH which is expressed in standard units.

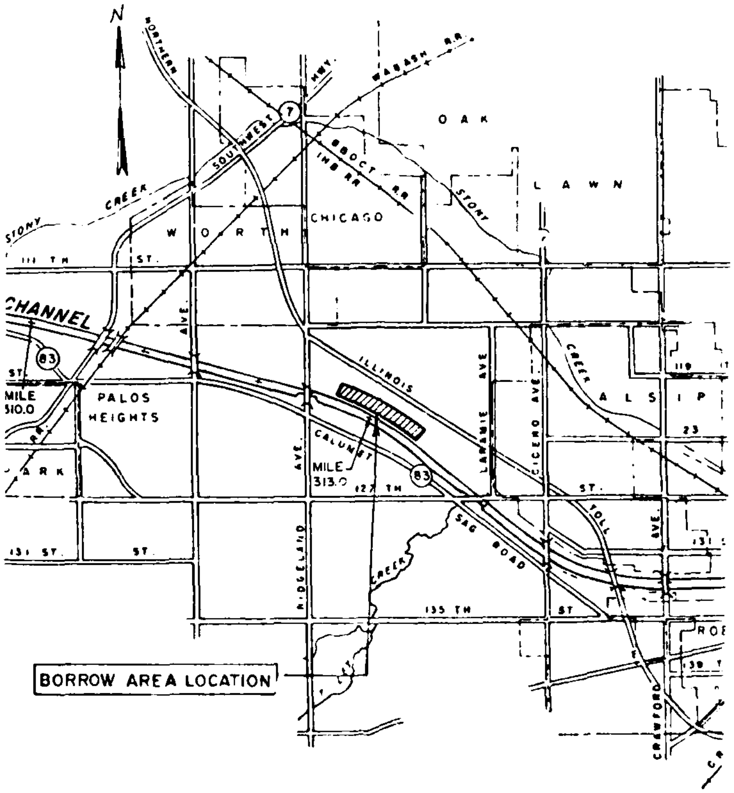


Figure 15. Schematic showing the location of the dredged material borrow site for the strip mine reclamation demonstration

Figure 16. Photograph taken from the northwest corner of the site. A portion of a wet trough can be seen in the foreground

Figure 17. Photograph taken from the southern dike; in the foreground is a very wet trough area. Note smartweed in the foreground

Figure 18. Photograph taken down in the fill area along the edge of a wet trough. Giant foxtail visible in the foreground and cottonwoods in the background

Figure 19. Photograph taken from the south dike. Cottonwoods are visible along the extreme foreground

Table 7

Allowable Metal Contents in Digested Sewage Sludges* for Agricultural Use[32]

Element	Domestic Sludge Concentration, ppm
Zinc (Zn)	2000
Copper (Cu)	1000
Nickel (Ni)	200
Cadmium (Cd)	15 or 1.0% of Zn
Boron (B)	100
Lead (Pb)	1000
Mercury (Hg)	10
Chromium (Cr)	1000

* Typical sludge from communities without excessive industrial waste inputs, or with adequate abatment.

purple-stemmed tickweed, rice cut grass, barnyard grass, and nodding burr marigold.

43. All the plants are ubiquitous in their Chicago region distribution; i.e., they have a very broad ecological amplitude with respect to their autecology. However, at least 40 percent of the species are not native to the Chicago area, a percentage that is rather high for a wet soil community. A more complete description of the vegetation at the dredged material disposal site is given in Appendix A.

44. No vegetation description was done for the strip mine site as very little vegetation is present on pyritic strip mine spoils.[3] In addition, the spoil site was leveled to accommodate the reclamation demonstration and no vegetation was present on the site area.

PART IV: DESIGN OF FIELD DEMONSTRATION

45. The design of the strip mine demonstration was consistent with the project objective and included the input of the various agencies concerned (Part I) to the preliminary field plan including their identification of environmental concerns and technical review, together with their recommendations. The demonstration project involved five parts: project design; site preparation; runoff, leachate, and groundwater monitoring; vegetative cover; and operation and maintenance.

Project Design

46. The site plan and profile views are shown in Figure 20. The site consisted of four diked plots, each approximately 80 by 180 ft. The four test plots are described below:

Plot I - Control plot, untreated mine spoil.

Plot II - Mine spoil with a 3-ft dredged material cover.

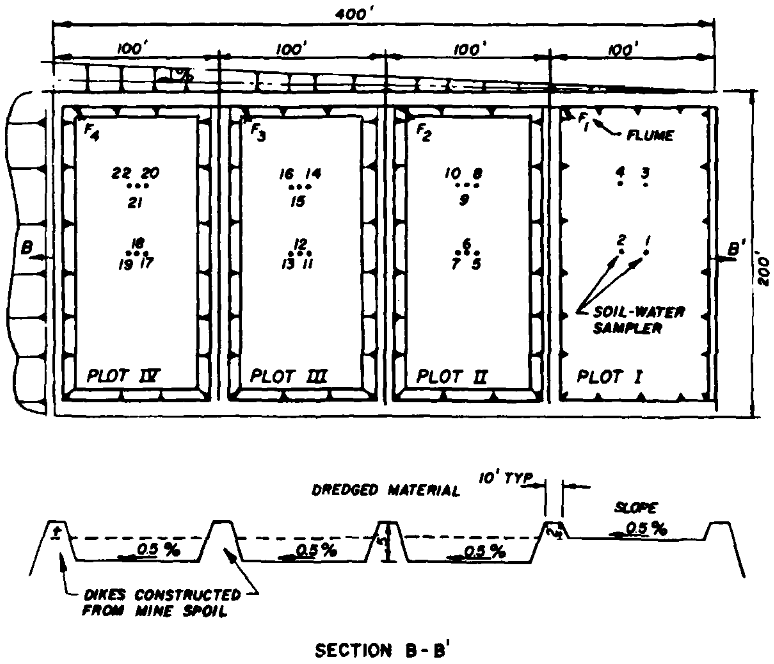


Figure 20. Site plan and profile views of test plots

Plot III - Five tons/acre of crushed agricultural limestone incorporated into the top 6 in. of mine spoil overlaid by a 3-ft cover of dredged material.

Plot IV - Seven and a half tons/acre of crushed agricultural limestone incorporated into the top 6 in. of mine spoil overlaid by a 3-ft cover of dredged material.

These treatments were selected to evaluate the incorporation of crushed agricultural limestone (5 and 7.5 tons/acre) at the interface of the mine spoil and dredged material. Both pretreatments should effectively neutralize the acid conditions of the mine spoil surface thereby: (a) preventing acid injury to plants whose root systems penetrate the dredged material-mine spoil interfaces, and (b) fixing heavy metal contaminants that might leach from the dredged material to the interface with the mine spoil (heavy metal solubility decreases as pH increases).

Site Preparation

47. The demonstration site consisted of a series of northwest-southeast trending parallel ridges as shown in Figure 21. The site was constructed as shown in Figure 22 by leveling a section of the center two ridges with dozers and forming a raised plateau. The 5-ft-high dikes were constructed from mine spoil and covered with heavy-duty polyvinyl chloride (PVC) plastic. The purpose of the dikes was to separate the plots and segregate the surface runoff from each plot for monitoring activities (Figure 20).

48. Prior to the transportation of dredged material, the borrow area (dredged material disposal area at Alsip, Ill.) was cleared, stripped, and excavated. Clearing consisted of the complete removal from the borrow area of objectionable materials such as trees, timbers, logs, brush, and debris. Stripping of the site to the 6-in. depth below the ground surface consisted of the removal of all plant material for weed control. After the 6-in. layer of top material had been removed, the next 18-in. depth of material was stockpiled as a source of material for placement on the test plots. The material was excavated with a front-end loader and stockpiled, as shown in Figure 23, in the center of the borrow area.

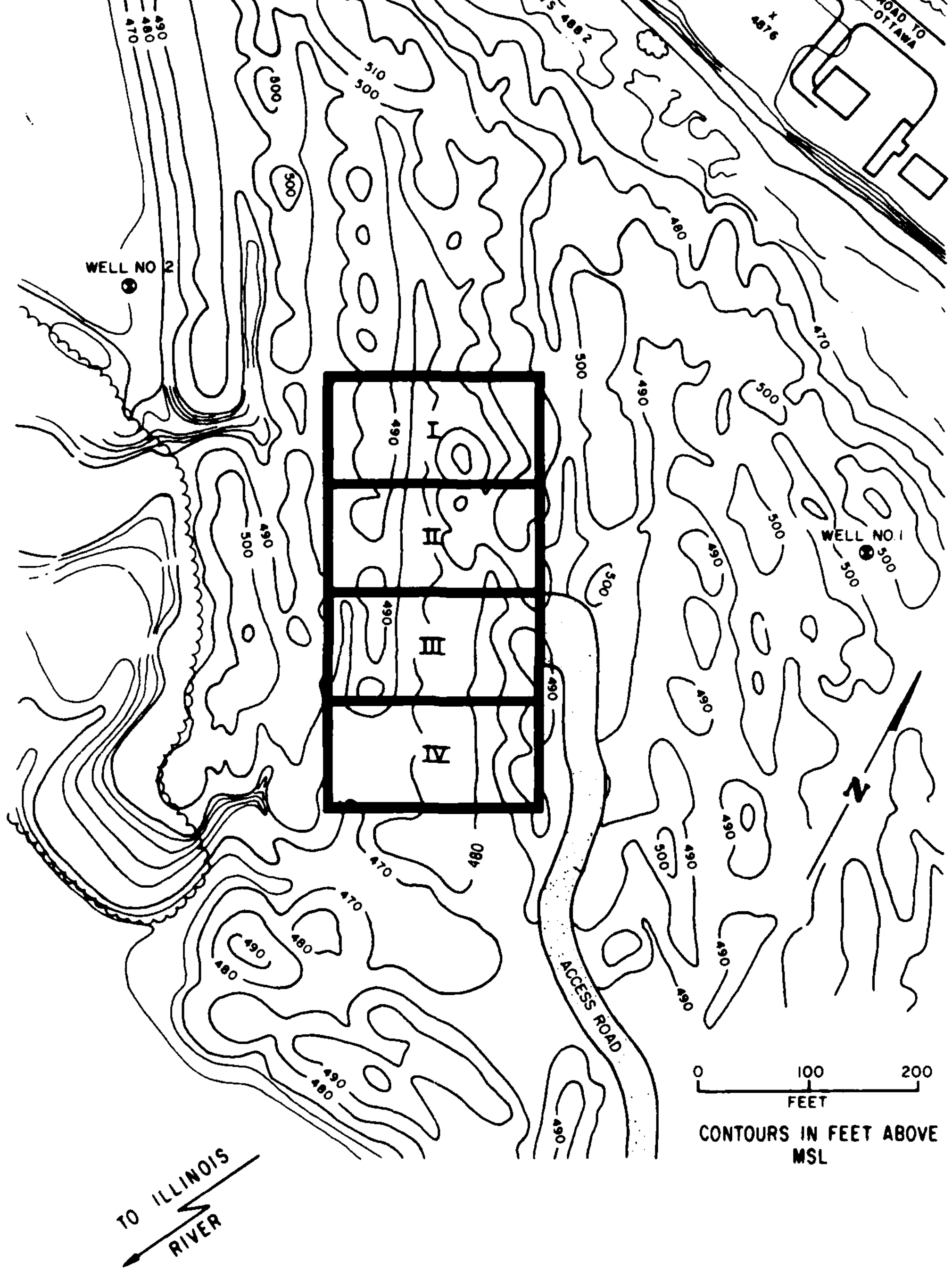


Figure 21. Initial site topography, groundwater observation wells, and test plots (superimposed)

Figure 22. Leveling mine spoil ridges

Figure 23. Stockpiling dredged material in borrow area

49. The stockpiled dredged material was loaded by a front-end loader onto trucks, whose capacity was approximately 15 yd^3, and hauled to the test site (Figure 24). The Corps used the truck haul method for transporting the dredged material in preference to the seemingly more economical barge haul method because of simplicity and timeliness.[3] Crushed agricultural limestone was spread, as shown in Figure 25, and then disked into the mine spoil in plots III and IV. The dredged material was placed in plots II, III, and IV to the 3-ft depth. A dozer then spread the material to the specified depth of 3 ft (Figure 26) and the finished surface was graded with a front-end loader to the southwest corner of each plot at a grade of approximately 0.5 percent.

50. The finished surface was scarified (Figure 27) to a depth of 3 in. with the teeth of the bucket of a front-end loader in preparation for broadcast seeding.

Runoff, Leachate, and Groundwater Monitoring

Objective

51. The objective of the surface runoff, leachate, and groundwater monitoring portion of the project was to monitor the migration of chemical compounds and metals present in the dredged material and mine spoil. This was accomplished by the Energy and Environmental Systems Division of the Argonne National Laboratory.[20] The chemical parameters analyzed included pH, acidity, alkalinity, total phosphorus, orthophosphate, total Kjeldahl nitrogen, ammonia-nitrogen, nitrate-nitrite, chloride, cyanide, sulfate, sulfide, silica, calcium, magnesium, sodium, potassium, strontium, aluminum, cadmium, chromium, copper, iron, mercury, manganese, nickel, lead, and zinc.

Monitoring devices

52. The amount of runoff from each plot was gaged by a Parshall flume made of fiberglass-reinforced polyester and a water stage recorder as shown in Figure 28. Each prefabricated flume (9-in. throat width) was carefully leveled when placed in the corner of a plot and inlet wing walls were used to train the runoff into the flume as shown in Figure 29.

Figure 24. Loading dredged material at borrow area

Figure 25. Spreading agricultural ground limestone on the dredged material in plot III

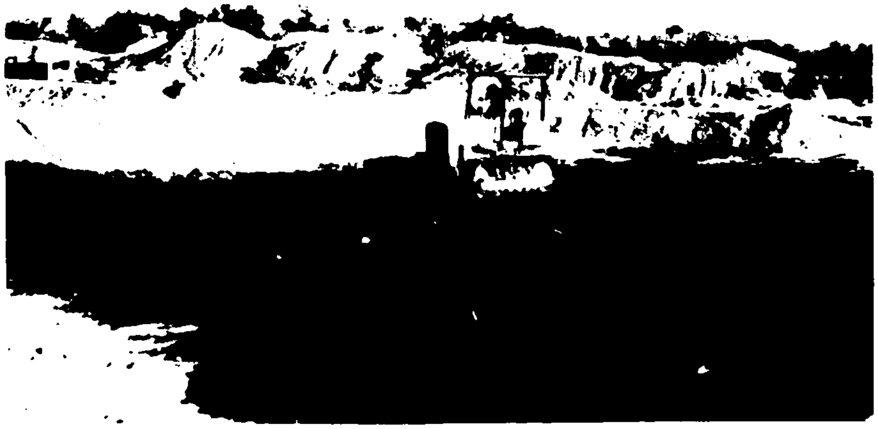


Figure 26. Spreading dredged material on plots

Figure 27. Plot IV scarified and prepared for seeding

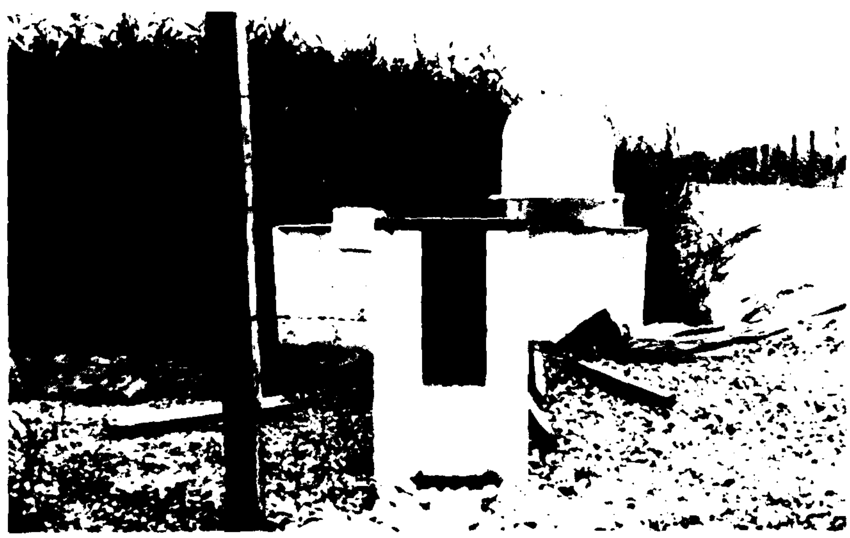


Figure 28. Outflow end of a Parshall flume showing installation and water stage recorder. Note white crushed rock in foreground used to reduce erosion

Figure 29. Inflow to a Parshall flume showing the inlet wing walls to train the runoff into the flume

During periods of rainfall, samples of runoff were collected manually for chemical analysis.

53. To determine the chemical constituents in the leachate, pressure-vacuum soil-water samplers were installed as shown in Figure 30. The soil-water samplers were chosen over groundwater removal pits and pan collectors because of the ease of installation and operation of soil-water samplers and their inherent safety compared to open pits. Duplicate sets of soil-water samplers (22 in all, see Figure 20) were installed at three depths: in the dredged material and mine spoil at the 2-ft depth, at the dredged material mine spoil interface at the 3-ft depth (lime layer), and in the mine spoil at the 5-ft depth.

54. Groundwater was sampled monthly at the two observation wells, shown in Figure 21, to assess possible contamination of the local groundwater by leachate from the dredged material.[20] The wells were blown out with compressed air and allowed to refill before being sampled with a thief sampler.

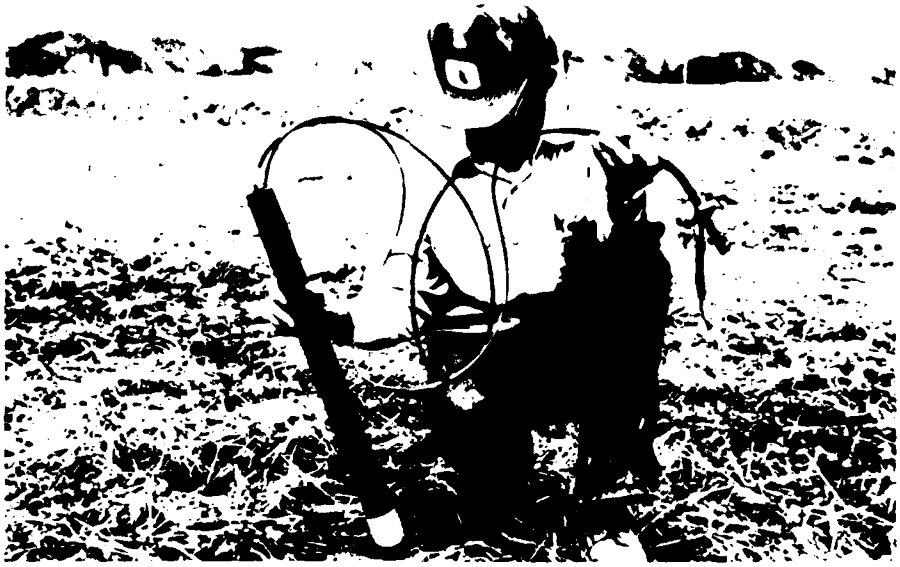


Figure 30. Installing a pressure-vacuum soil-water sampler

Vegetative Cover

55. The seed mixture and application rate shown in the tabulation below was applied to each plot:

Seed Mixture	Application rate lb/acre
Kentucky bluegrass (*Poa pratensis*)	15
Tall fescue (*Festuca arundinacea*)	20
Smooth brome (*Bromus interimis*)	15
Blackwell switchgrass (*Panicum virgatum*)	20
Birdsfoot trefoil (Empire) (*Lotus corniculatus*)	15
Perennial ryegrass (*Lolium perenne*)	15
	100

After seeding, wheat straw mulch was placed on each plot at a rate of 2 tons/acre and sprayed with a fine asphalt emulsion as a binder. When the stand was established, samples of fescue were taken for analysis to measure uptake of contaminants. At this time, and near the end of the growing season, the ring-toss technique was applied to measure yield. Height measurements were also determined.

Operation and Maintenance

56. The plots were surrounded by a barbed wire fence (grounded for protection from overhead powerlines and lightning storms) to restrict traffic. Also, 2- by 12-in. planks were laid in each plot to permit ready access to the soil-water samplers.

57. The monitoring plan for the soil-water samplers called for sampling 2 to 3 days after a significant rainfall (>0.5 in.) or once every 4 weeks. Groundwater was sampled once monthly at the two observation wells.

58. Vegetative samples were collected twice during the growing season and a plant specie description was made after the plants had matured.

59. Continuous maintenance was required on the PVC plastic as holes continued to develop due to climatic effects. Also, erosion of the southeastern corner outside of the plots (Figure 31) required constant inspection and maintenance.

60. As the material in the demonstration plots continued to settle, correction of the grade by adding thin layers of material to the surface required constant attendance to ensure that all the water ran off the plots and that puddling and stagnation did not persist (Figure 32).

61. The major disadvantage of the pressure-vacuum soil-water samplers was their unexpectedly low volume of water extracted from the soil material. In addition, damage from climate and human traffic to hoses and stopper equipment required that the soil-water samplers be under constant maintenance.

Figure 31. Recurring erosion of the southeastern corner of the demonstration site

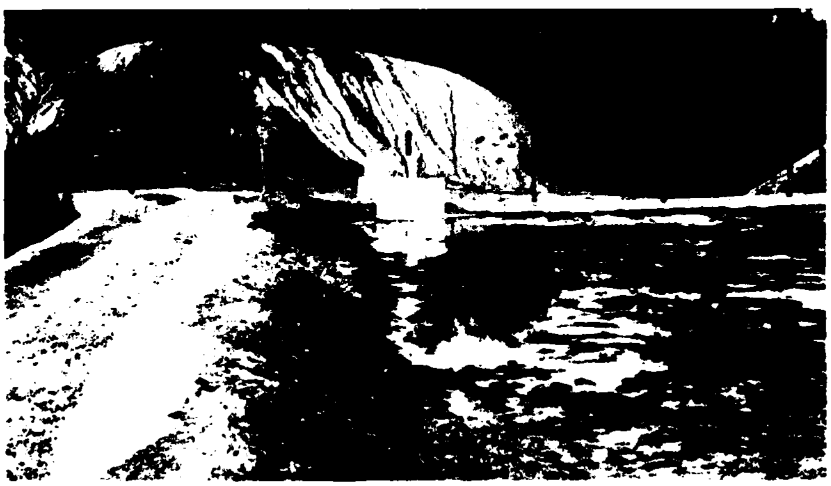


Figure 32. Photograph of plot I looking south showing ponded water following a rain. Note mine spoil hills in background

PART V: RESULTS AND DISCUSSION

62. In general, the field demonstration fulfilled the objectives of the study and was highly successful in reclaiming the strip mine area using dredged material as a cover. Leveling the plots and covering three of them with dewatered dredged material stopped erosion, reduced oxygen diffusion, and limited water contact with pyritic materials, which eliminated the production of sulfuric acid. Although vegetation did not grow on the strip mine spoil, it did thrive bountifully on the reclaimed test plots.

Vegetative Production

63. The winter of 1977-78 was rather severe in north-central Illinois; however, the fall-applied seed mixture germinated on the three dredged material plots and by June of 1978 provided a complete vegetative cover as shown in Figure 33. In addition, the aerial photograph shows the adjacent strip mine spoil ridges as well as the ponded water remaining from the last pass of the coal mining shovel.

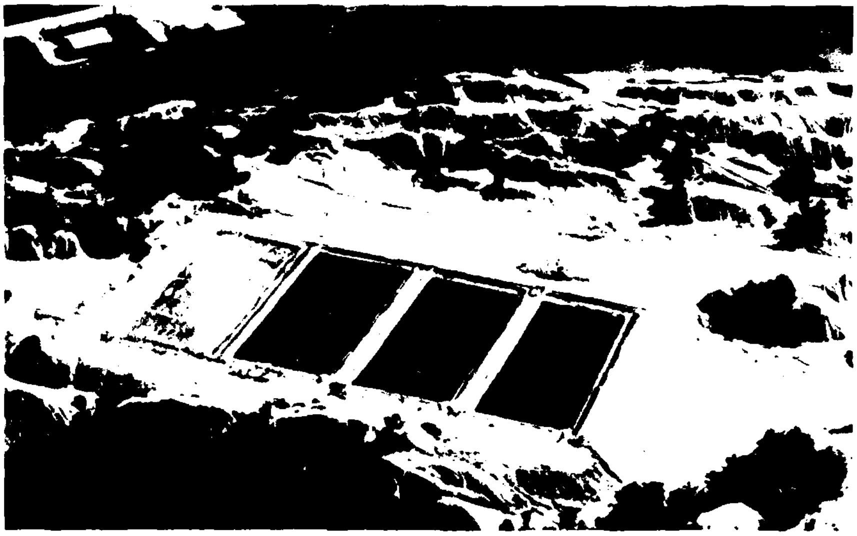


Figure 33. Aerial photograph of demonstration plots. Dark shades on plots II, III, and IV are vegetative cover. No growth on plot I

64. The height of the plants as of 8 June 1978 is shown in Figures 34-37. In control plot I, the seed mixture did not germinate and only an occasional grass or weed appeared to be growing in the plot. Plots II, III, and IV produced an excellent cover that was about 8 in. in height as of 8 June 1978. Some of the broad leaves present in the plots were smartweed (Polygonum lapathifolium), an invading species particularly attractive to wildlife, and an occasional head of wheat (the seed was carried in the straw mulch).

65. As no weed control practices were initiated at the study site, smartweed, which germinates from rhizomes and seed, was transported with the dredged material and eventually took over the plots as shown in Figure 38. The rank growth of smartweed dominated all other species by the end of June and eventually reached 7 to 8 ft in height as shown in Figure 39. By 9 July 1978, the plant species associated with the fall-planted seed mixture had died and only those species of plants carried by the dredged material survived.

66. A species identification study (Figure 40) was completed on 11 July 1978 and complete details are presented in Appendix B. The control plot was essentially barren with only scanty vegetation in one corner. However, prolific growth of native species brought into the

Figure 34. Photograph of plot I (control) showing that none of the seed mixture germinated on the plot as of 8 June 78

Figure 35. Photograph of vegetative growth of seed mixture plus additional specie on plot II as of 8 June 78

Figure 36. Photograph of vegetative growth of seed mixture on plot III as of 8 June 78

Figure 37. Photograph of vegetative growth of seed mixture on plot IV as of 8 June 78

Figure 38. Photograph taken on 22 August 1978 showing how smartweed dominated the plots

Figure 39. Photograph of the plots showing the rank growth of smartweed which was 7 to 8 ft in height

Figure 40. Plant identification of vegetation at the area strip mine site

basin with the dredged material appeared to be identical in the three dredged material treatments. The planting of the seed mixture, shown in the tabulation in paragraph 55, resulted in germination and growth of only four species: perennial ryegrass, smooth brome, tall fescue, and birdsfoot trefoil. Only the perennial ryegrass reached populations considered to be significant. No specimens of the remaining two planted species, Kentucky bluegrass and blackwell switchgrass, were found. The rich growth of the native species was made up primarily of five species: smartweed, black mustard, common ragweed, common beggar's tick, and giant beggar's tick. Smartweed contributed the greatest proportion of the biomass within each of the dredged material treatments.

67. The yield as dry matter production of the plant material is tabulated below for the sampling periods of 8 June and 22 August 1978. In both instances, the area within a 14-in.-diam. ring was sampled at two locations within each dredged material plot to determine yield. The ring was tossed at each end of the plot to select a random location for

Sampling		Plot Yield (lb/acre)		
Date	Location	II	III	IV
8 Jun	North	932	637	1,015
	South	726	844	1,178
22 Aug	North	17,913	17,699	17,070
	South	20,822	20,822	10,698
8 Jun	Mean	829	740	1,096
22 Aug	Mean	19,367	19,260	13,885

the 8 June 1978 sampling. However, this technique would not work for the 22 August sampling (smartweed about 8 ft in height) and the ring was placed around the area to be sampled.

68. In general, the plots produced nearly 0.5 ton/acre of dry matter by 8 June and nearly 10 tons/acre of dry matter by 22 August. The variation in the yield taken at the latter date was attributed to the lack of randomness in the sample collection technique.

69. Clippings of the leaves of tall fescue (*Festuca arundinacea*) were obtained for chemical analysis of heavy metal uptake on 9 June when the plants were approximately 8 in. in height. The samples, about 5 g

of oven-dried plant material, were collected in the same vicinity as the yield samples. The chemical method of analysis is shown in Table 3 and the results of these analyses are tabulated below.

70. Comparing these results with the suggested tolerance levels of heavy metals presented by Gupta et al.[33] shows that the heavy metal content of tall fescue was low and well within the suggested tolerance levels for heavy metal content of agronomic crops.

Plot and Area	Cadmium mg/kg	Chromium mg/kg	Copper mg/kg	Lead mg/kg	Manganese mg/kg	Zinc mg/kg
II, North	0.43	1.2	18.5	5.4	146.7	135.0
II, South	0.40	1.2	19.8	4.7	181.7	168.2
III, North	0.40	1.3	20.5	6.3	161.5	154.5
III, South	0.43	1.3	24.0	5.8	172.7	223.5
IV, North	0.45	1.2	21.7	4.8	189.0	172.7
IV, South	0.50	1.2	21.9	8.6	160.7	163.2
Mean	0.44	1.2	21.0	5.9	168.7	169.5
Suggested tolerance level, mg/kg	3	2	150	10	300	300

Runoff, Leachate, and Groundwater

71. Data collection and chemical analysis of the runoff, leachate, and groundwater samples are currently being performed by the Energy and Environmental Systems Division of Argonne National Laboratory, Argonne, Ill.[20] Only a partial summary of their data will be presented here. Table 8 presents water quality characteristics for the runoff waters collected for the 10 April 1978 storm. The precipitation for this storm was 1.40 in. of which 0.89 in. fell over a 3-hr period allowing the collection of three well-separated samples. An examination of the initial, peak, and final runoff samples reveals, with few exceptions, the initial peaking and subsequent tapering of parameter loading that is characteristic of the runoff process. The results showed that runoff water from the dredged material was well within the water quality standards set for irrigation water. The range of pH from plots II, III, and IV was 7.15 to

Table 8

Selected Water Quality Data for Runoff Samples from the Plots for the 10 April 1978 Storm with Respect to Initial Runoff (I), Peak Flow of Runoff (P), and Final Runoff (F)[20]

Parameter	(I)				(P)				(F)			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Calcium (Ca), mg/kg	203.0	174.0	146.0	115.0	86.8	87.4	65.0	47.7	57.6	62.7	64.0	49.0
Copper (Cu), mg/kg	0.27	---	---	---	0.03	---	---	---	0.02	---	---	---
Iron (Fe), mg/kg	3.66	0.02	1.05	0.40	0.02	0.60	0.64	0.02	0.02	0.50	1.34	0.02
Magnesium (Mg), mg/kg	242.0	43.9	31.7	17.7	72.3	17.3	9.63	8.10	41.8	12.2	9.63	7.45
Nickel (Ni), mg/kg	1.34	---	---	---	0.32	---	---	---	0.17	---	---	---
Potassium (K), mg/kg	1.15	4.45	2.64	2.74	0.58	1.64	0.99	0.60	0.50	1.28	1.12	1.07
Sodium (Na), mg/kg	1.73	4.60	3.89	2.20	0.98	1.64	1.44	0.98	0.72	1.23	1.34	0.98
Zinc (Zn), mg/kg	1.64	---	---	---	0.39	---	---	---	0.26	---	---	---
Sulfate (SO_4), mg/kg	2000	550	500	350	650	300	200	150	400	200	200	150
Chlorine (Cl), mg/kg	1	6.0	0.5	0.5	1	5.0	0.5	0.5	1	0.5	0.5	0.5
pH	3.34	7.28	7.41	7.42	3.72	7.20	7.30	7.15	3.50	7.15	7.17	7.32
CONDUC, μmhos/cm	2450	1050	870	640	1050	480	370	320	820	400	390	320
Orthophosphate (PO_4), mg/kg	0.03	0.02	0.03	0.05	0.01	0.04	0.06	0.05	0.05	0.05	0.05	0.07
Aluminum (Al), mg/kg	102.0	0.3	0.1	0.1	24.7	0.1	0.1	0.1	16.2	0.1	0.1	0.1
Strontium (Sr), mg/kg	0.5	---	---	---	0.5	---	---	---	0.5	---	---	---
Acidity, mg/kg	1340	19.7	11.8	11.8	236	19.7	15.8	17.7	169	15.8	7.9	19.7
Alkalinity, mg/kg	---	47.1	37.7	37.7	---	23.0	21.3	19.7	---	23.0	23.0	23.0

7.42, with a mean of 7.2, and from the mine spoil plot I the pH ranged from 3.34 to 3.72 with a mean of 3.5. Also, the specific conductivity for the runoff from plot I was relatively high ranging from 1050 to 2450 μmhos/cm, whereas the runoff from the dredged material plots ranged very low from 320 to 1050 μmhos/cm. The concentrations of nitrogen and phosphorus as well as the metals in the surface runoff were very low for the dredged material plots and only somewhat higher for the mine spoil plots. For the runoff samples from plot I (untreated plot) aluminum, copper, iron, manganese, nickel, and zinc concentrations exceeded criteria for irrigation water. Thus, surface runoff from the dredged material demonstration plots showed no high levels of contaminants or trend from the data collected.

72. The objective of sampling the soil water was to determine the effect of the dredged material treatments on soil solutions with respect to migration of chemical constituents from dredged material into the mine spoil. The leachate collected from the soil-water samplers showed a similar result to the runoff data, in that the soil water of the dredged material plots did not contain toxic levels of nutrients and metals. The pH of the leachate at the 2-ft depth in plot I ranged from 3.4 to 5.4 and, in general, became more acid with time. In plots II, III, and IV, the pH of the leachate at the 2- and 3-ft depths ranged from 5.7 to 8.0 and did not change with time. The mean values of pH for each of the treatment plots are shown in the tabulation below. The control plot shows

Plot	Depth, ft 2	3	5
I	4.27		6.84
II	7.21	7.20	2.77
III	7.25	6.95	5.48
IV	7.33	6.58	4.05

acid leachate in the top 2 ft of material, whereas the dredged material plots have near neutral pH values.[20] At the 5-ft depth, the dredged material plots show the effect of the lime treatments, whereas the mine spoil plot I shows the effect of the mine spoil not being exposed to air. These plots were sampled from November 1977 through November 1978.[20]

73. The groundwater quality as measured from samples collected at the two observation wells had a moderate pH ranging from 6.3 to 7.7. However, the groundwater had a rather high specific conductance ranging from a mean of 2910 μmhos/cm at well No. 1 to a mean of 2460 μmhos/cm at well No. 2. The concentration of total Kjeldahl nitrogen was moderate, ranging from 1.5 to 8.2 mg/kg; however, total phosphorus was very low, <0.08 mg/kg. Most metals, including heavy metals, were in very low concentration in the groundwater, but were at least greater than those concentrations found in the surface water runoff. The groundwater samples showed no buildup or trend with time from the data collected.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

74. Dredged material can be used beneficially as a cover to reclaim surface mine areas. The field demonstration reclamation of an area strip mine fulfilled the objectives of the study and was highly successful. The application of dewatered dredged material to the leveled plots abated erosion and acid mine drainage from the area.

75. The dredged material provided a rooting media for vegetation, and the fall-applied seed mixture provided a complete vegetative cover. The mixture produced nearly 0.5 ton/acre of dry matter and grew to 8 in. in height. Chemical analysis of the heavy metal uptake by tall fescue showed that uptake was low and well within the suggested tolerance levels for heavy metal uptake in agronomic crops.

76. Smartweed (Polygonum lapathifolium) transported with the dredged material invaded the dredged material plots and was the dominant specie by midseason providing an attractive cover and forage for wildlife. Smartweed produced nearly 10 tons/acre of dry matter and grew to nearly 8 ft in height.

77. The dredged material used in this study was low in contaminants. The chemical analysis demonstrated that it did not contain excessive amounts of contaminants so as to restrict plant growth or contaminate the harvested plant material. The water quality of the runoff from the dredged material plots was adequate for agricultural irrigation water standards. In all cases, the water quality of the dredged material plots as measured in the surface runoff, leachate, and groundwater was better than that of the mine spoil. There was no buildup or trend with time in the concentration of contaminants measured in the runoff, leachate, and groundwater of the dredged material plots.

78. The dredged material provided a suitable noncontaminated growing medium for vegetation that made the demonstration site environmentally beneficial and aesthetically pleasing.

Recommendations

79. To have a complete overview for applying dredged material to surface mine spoil, the planner should first identify the purpose for which the area will be used. Then consideration of the chemical and physical characteristics, possible salinity problems, and potential weed infestation must be made before deciding upon the suitability of a particular dredged material as a media for plant growth. If the reclaimed area is to be considered for construction as a final land use, then tests for consolidation, shear strength, and permeability should be performed on the dredged material as well as the strip mine spoil.

80. There are four major cost areas for strip mine reclamation: (a) site preparation, which consists of leveling mine spoil ridges or piles with a bulldozer; (b) transportation of a suitable dredged material to the mine spoil site; (c) leveling the dredged material for seedbed preparation and planting; and (d) weed control measures for specific land uses.

81. Before reclamation activities of strip mine spoil can commence, the planners must familiarize themselves with State reclamation laws, which include the final grade of the area, cover requirements, and vegetation requirements. Assistance for various aspects of surface mine reclamation can be obtained from State reclamation departments, county agricultural extension offices, the USDA Soil Conservation Service, and other local, State, and Federal agencies.

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APPENDIX A: VEGETATION OF THE ALSIP DREDGED MATERIAL DISPOSAL SITE[34]*

1. The Alsip dredged material disposal site is located about 0.25 mile east of Ridgeland Road along the north side of the frontage road which parallels the Calumet-Sag Channel in western Alsip, Cook County, Illinois: N1/2, NW1/4 Sec. 29, T37N, 413E.

2. Measurements are rough (based on pacing and odometer readings), but the site is very close to 400 ft wide at the west end and about 1250 ft long on the south end. The northern and eastern borders are difficult to discern from the surrounding terrain. At the east end a dike runs north and south, separating the site from a similar area to the east. This latter area has most of the same species, but its borders, except for the southern and western portion, are amorphous and nebulous as far as existing topography and blend of vegetation with the surrounding landscape.

3. The determination of species present, and their relative importance, was done during an initial visit to the site on 25 September 1976. The nomenclature follows Fernald.[35] Common names used are those given by Swink.[36]

4. The dredged material is contained on the east, south, and west by dikes, while on the north side it is contained apparently as a result of a sloping substrate, at elevations above the level of the fill. At the extreme west end of the site, through the south dike, is a culvert that drains the site. Nevertheless, the vegetation on the dredged material generally reflects poor drainage; there is evidence that water stands in troughs (about 50 ft wide) along the western and southern margins of the site during wet times of the year. Mudflats appear in these areas by late summer.

5. The disposal site area is dominated fairly regularly throughout by smartweed, common beggar's tick, sandbar willow, tall goldenrod, common reed, hairy aster, common evening primrose, and sweet clover (Figures 15 and 16 in the main text). This assemblage gives way gradually in the

* References can be found at the end of the main text.

higher elevations, primarily in the eastern end, to domination by cottonwood, common evening primrose, field thistle, Norway cinquefoil, hairy aster, garden sunflower, knee grass, barnyard grass, common orach, green foxtail, giant foxtail, horseweed, and reed canary grass (Figures 17 and 18 in the main text).

6. As mentioned earlier, the southern and western margins are characterized by very wet troughs about 50 ft wide; these are dominated by smartweed, common beggar's tick, purple-stemmed tickweed, rice cut grass, barnyard grass, and nodding burr marigold (Figures 15, 16, and 18 in the main text). The open mudflat areas are inhabited almost solely by red rooted sedge, sprangletop, oak-leaved goosefoot, and knee grass (Figure A1).

Figure A1. Photograph taken at the southwest corner of the site near the culvert showing the fall aspect of the open mudflat areas that occur along the 50-ft-wide troughs that extend along the southern and western borders of the spoil site. Pictured are oak-leaved goosefoot and red rooted sedge. Other species abundant in these areas include sprangletop and barnyard grass

7. The total 42 species surveyed as growing on the fill are enumerated as follows:

BARNYARD GRASS *Echinochloa crusgalli*

BITTERSWEET NIGHTSHADE *Solanum dulcamara*

BLACK MUSTARD *Brassica nigra*

BLUE VERVAIN *Verbena hastata*

BOX ELDER *Acer negundo*

BROAD-LEAVED CATTAIL *Typha latifolia*

BURR MARIGOLD *Bidens polylepis*

BURNING BUSH *Kochia scoparia*

COMMON BEGGAR'S TICK *Bidens frondosa*

COMMON EVENING PRIMROSE *Oenothera biennis*

COMMON ORACH *Atriplex patula*

COMMON REED *Phragmites communis berlandieri*

COTTONWOOD *Populus deltoides*

CURLY DOCK *Rumex crispus*

CURSED BUTTERCUP *Ranunculus sceleratus*

DOGBANE *Apocynum sibiricum*

FIELD THISTLE *Cirsium arvense*

GARDEN SUNFLOWER *Helianthus annuus*

GIANT FOXTAIL *Setaria faberi*

GREAT BULRUSH *Scirpus validus creber*

HAIRY ASTER *Aster pilosus*

HORSEWEED *Erigeron canadensis*

KNEE GRASS *Panicum dichotomiflorum*

LADY'S THUMB *Polygonum persicaria*

LATE BONESET *Eupatorium serotinum*

MARSH CRESS *Rorippa islandica fernaldiana*

NARROW-LEAVED CATTAIL *Typha angustifolia*

NODDING BURR MARIGOLD *Bidens cernua*

OAK-LEAVED GOOSEFOOT *Chenopidium glaucum*

OLD WITCH GRASS *Panicum capillare*

PENNSYLVANNIA KNOTWEED *Polygonum pensylvanicum laevigatum*

PURPLE-STEMMED TICKWEED *Bidens connata*

PUSSY WILLOW *Salix discolor*

RED ROOTED SEDGE *Cyperus erythrorhizos*

RED TOP *Agrostis alba*

RICE CUT GRASS *Leersia oryzoides*

RIVER BULRUSH *Scirpus fluviatilis*

SANDBAR WILLOW *Salix interior*

SMARTWEED *Polygonum lapathifolium*

SPRANGLETOP *Leptochloa fascicularis*

SQUIRREL TAIL *Hordeum jubatum*

SWEET CLOVER *Melilotus spp.*

TALL GOLDENROD *Solidago altissima*

TREE OF HEAVEN *Ailanthus altissima* (one plant)

WATER HEMP *Acnida altissima*

8. Just about all of the species recorded are more or less common on the dredged material containment area in one place or another. All the species are plants that are ubiquitous in their Chicago region distribution, as they have a very broad ecological amplitude with respect to their autecology. At least 40 percent of them are species that are not native to the Chicago area, a percentage that is rather high for a wet soil community. Those which are native are usually invaders in moist open soil, though the mudflat populations are, in particular, low in diversity with only red rooted sedge native in such situations locally.

9. If the site is allowed to continue its succession, it will probably disclimax eventually in box elder, cottonwood, green ash *Fraxinus pennsylvanica subintegerrima* (though none is evident at this time), and common buckthorn, with lingering colonies of sandbar and pussy willow. Tree of heaven is represented by only one specimen on the entire site. This plant is not expected to be a significant component in the future synecology of this site because, for one, it is dioecious and, secondly, it generally grows better in more upland, urban areas, particularly in alleys and vacant lots where competition with other woody vegetation is minimal.

10. The dredged material from this site is to be removed to a location near Ottawa, Illinois, where it will rest atop overburden from past strip mining. It is true that the material will be laden with the

seeds of those species enumerated above, but whether or not these same species will be manifest similarly at the new site is questionable. Intuition suggests that the soil water retention abilities of the fill may be altered. This possibility should be considered when attempting to predict what species will become manifest at the new site. Without knowing what the substrate/retention scenario will be, it would be difficult to predict what will happen vegetatively.

11. Whatever the case, the above species, now firmly on a successional itinerary, will have to start again on a new site with added competition from species in the area surrounding the new site plus species going to seed in abundance on the dikes retaining the fill. Depending upon the water regime and perhaps other factors, species from the dike area could be more manifest at the new area, at the expense of many of the more moisture-loving species.

12. The following is a list of species currently common along the dikes:

BIENNIAL GAURA *Gaura biennis*
BLACK MUSTARD *Brassica nigra*
BOX ELDER *Acer negundo*
BULL THISTLE *Cirsium vulgare*
BURNING BUSH *Kochia scoparia*
CANADA WILD RYE *Elymus canadensis*
CATNIP *Nepeta cataria*
CLIMBING FALSE BUCKWHEAT *Polygonum scandens*
COMMON BUCKTHORN *Rhamnus cathartica*
COMMON BURDOCK *Arctium minus*
COMMON FESCUE *Festuca elatior* (*sensu lato*; probably planted originally for erosion control along the dikes)
COMMON KNOTWEED *Polygonum aviculare*
COMMON ORACH *Atriplex patula*
COMMON RAGWEED *Ambrosia artemissifolia elatior*
COMMON SOW THISTLE *Sonchus uliginosus*
CURLY DOCK *Rumex crispus*
ENGLISH RYE GRASS *Lolium perenne*

FIELD THISTLE *Cirsium*

GIANT RAGWEED *Ambrosia trifida*

GARDEN SUNFLOWER *Helianthus annuus*

GRASS-LEAVED GOLDENROD *Solidago graminifolia nuttallii*

GREEN FOXTAIL *Setaria viridis*

HEDGE BINDWEED *Convolvulus sepium*

JAPANESE CHESS *Bromus japonicus*

LAMB'S QUARTERS *Chenopodium album*

LATE BONESET *Eupatorium serotinum*

NEW ENGLAND ASTER *Aster novae-angliae*

NORWAY CINQUEFOIL *Potentilla norvegica*

PETIOLED SUNFLOWER *Helianthus petiolaris*

PLAINS THREE-AWN GRASS *Aristida oligantha*

PRICKLEY LETTUCE *Lactuca scariola*

QUACK GRASS *Agropyron repens*

RED TOP *Agrostis alba*

REED CANARY GRASS *Phalaris arundinacea*

SQUIRREL TAIL *Hordeum jubatum*

SWEET CLOVER *Melilotus spp.*

TALL BONESET *Eupatorium altissimum*

TALL GOLDENROD *Solidago altissima*

TALL GROUND CHERRY *Physalis subglabrata*

WHITE CAMPION *Lychnis alba*

WILD CARROT *Daucus carota*

13. The species growing on the dike area are, as one would expect, dominated by cosmopolitan Old World weeds. Of the 42 species listed, 70 percent are not native in the Chicago region. Those that are highly aggressive species are ubiquitous in their distribution. Also, none of them are faithful to any stabile native communities.

14. The general synergism of association at the new site is extremely difficult to contemplate, particularly when most of the species have such complex autecological features. Even the final state is difficult to foresee, though the alternative combinations are potentially fewer than the several intermediate association possibilities.

15. The following is a list of species seen at the site, including those on the dike, i.e., those which, among others, have the potential to establish themselves at the new site.

TYPHACEAE

BROAD-LEAVED CATTAIL *Typha latifolia*

NARROW-LEAVED CATTAIL *Typha angustifolia*

GRAMINEAE (POACEAE)

JAPANESE CHESS *Bromus japonicus*

COMMON FESCUE *Festuca elatior* (including *F. arundinacea* which is often planted for erosion control)

SPRANGLETOP *Leptochloa fascicularis* (this follows Hitchcock's manual of the grasses of the United States which lumps *Diplachne acuminata* with *D. fascicularis* of Fernald (1950)[35] and assigns the complex to the genus Leptochloa)

COMMON REED *Phragmites communis berlandieri*

QUACK GRASS *Agropyron repens*

ENGLISH RYE GRASS *Lolium perenne*

SQUIRREL TAIL *Hordeum jubatum*

CANADA WILD RYE *Elymus canadensis*

RED TOP *Agrostis alba*

PLANIS THREE-AWN GRASS *Aristida oligantha*

REED CANARY GRASS *Phalaris arundinacea*

RICE CUT GRASS *Leersia oryzoides*

KNEE GRASS *Panicum dichotomiflorum*

OLD WITCH GRASS *Panicum capillare*

BARNYARD GRASS *Echnochloa crusgalli*

GREEN FOXTAIL *Setaria viridis*

GIANT FOXTAIL *Setaria faberi*

CYPERACEAE

RED-FOOTED SEDGE *Cyperus erythrorhizos*

GREAT BULRUSH *Scirpus validus creber*

RIVER BULRUSH *Scirpus fluviatilis*

SALICACEAE

SANDBAR WILLOW *Salix interior*

PUSSY WILLOW *Salix discolor*

COTTONWOOD *Populus deltoides*

POLYGONACEAE

CURLY DOCK *Rumex crispus*

COMMON KNOTWEED *Polygonum aviculare*

PENNSYLVANIA SMARTWEED *Polygonum pensylvanicum laevigatum*

NODDING SMARTWEED *Polygonum lapathifolium*

LADY'S THUMB *Polygonum persicaria*

CLIMBING FALSE BUCKWHEAT *Polygonum scandens*

CHENOPODIACEAE

BURNING BUSH *Kochia scoparia*

LAMB'S QUARTERS *Chenopidium album*

OAK-LEAVED GOOSEFOOT *Chenopodium glaucum*

COMMON ORACH *Atriplex patula* (including vars. *patula*, *littoralis*, and *hastata*--all three varieties are common)

AMARANTHACEAE

WATER HEMP *Acnida altissima*

CARYOPHYLLACEAE

WHITE CAMPION *Lynchnis alba*

RANUNCULACEAE

CURSED BUTTERCUT *Rannuculus sceleratus*

CRUCIFERAE (BRASSICACEAE)

BLACK MUSTARD *Brassica nigra* (it is almost a certainty that *B. kaber pinnatifida* was also present earlier in the year)

MARSH CRESS *Rorippa islandica fernaldiana*

ROSACEAE

NORWAY CINQUEFOIL *Potentilla norvegica*

LUGUMINOSAE (FABACEAE)

SWEET CLOVER *Melilotus* spp. (the two ubiquitous elements in this area are *M. alba* and *M. officinalis*)

SIMAROUBACEAE

TREE OF HEAVEN *Ailanthus altissima*

ACERACEAE

BOX ELDER *Acer negundo*

RHAMNACEAE

COMMON BUCKTHORN *Rhamnus cathartica*

ONAGRACEAE

COMMON EVENING PRIMROSE *Oenothera biennis*

BIENNIAL GAURA *Baura biennis*

UMBELLIFERAE (APIACEAE)

WILD CARROT *Dacus carota*

APOCYNACEAE

DOGBANE *Apocynum sibiricum*

CONVOLVULACEAE

HEDGE BINDWEED *Convolvulus sepium*

VERBENACEAE

BLUE VERVAIN *Verbena hastata*

LABIATAE (LAMINACEAE)

CATNIP *Nepta cataria*

SOLANACEAE

BITTERSWEET NIGHTSHADE *Solanum dulcamara*

TALL GROUND CHERRY *Physalis subglabrata*

COMPOSITATE (ASTERACEAE)

TALL BONESET *Eupatorium altissimum*

LATE BONESET *Eupatorium serotinum*

TALL GOLDENROD *Solidago altissima*

GRASS-LEAVED GOLDENROD *Solidago graminiflolia nuttallii*

NEW ENGLAND ASTER *Aster novae-angliae*

HAIRY ASTER *Aster pilosus*

HORSEWEED *Erigeron canadensis*

GIANT RAGWEED *Ambrosia trifida*

COMMON RAGWEED *Ambrosia artemisiifolia elatior*

GARDEN SUNFLOWER *Helianthus periolaris*

NODDING BURR MARIGOLD *Bidens cernua*

PURPLE-STEMMED TICKWEED *Bidens connata*

COMMON BEGGAR'S TICK *Bidens frondosa*

BURR MARIGOLD *Bidens polylepis*

COMMON BURDOCK *Arctium minus*

BULL THISTLE *Cirsium vulgare*

FIELD THISTLE *Cirsium arvense*

COMMON SOW THISTLE   Sonchus uliginosus

PRICKLY LETTUCE   Lactuca scariola

APPENDIX B: VEGETATION OF THE STRIP MINE RECLAMATION PROJECT*

1. The strip mine reclamation project at Ottawa, Ill., is located on the banks of the Illinois River approximately 6 miles southeast of Ottawa. All portions of the site were dry at the time of the visit.

2. The site is composed of four leveed basins of identical size, but with varying treatments. The basins are rectangular and are elongated east-west. Wheat straw was strewn upon the basin floors, and some viable wheat seeds germinated and later matured. These wheat plants, however, were not a major element in the vegetation of the basins.

3. The northernmost basin (control plot) was essentially barren except for very scanty vegetation in its southeastern corner. This sparse vegetation consisted principally of Lolium perenne (planted) and Polygonum aviculare (volunteer). Other plants of much lesser importance were Ambrosia artemisifolia, Brassica nigra, Bromus inerimis, Lotus corniculatus, Polygonum lapathifolium, and Triticum vulgare. Triticum vulgare was confined to higher positions near bases of levees.

4. There were no significant vegetational differences among the remaining three basins. Even total primary production appeared to be identical among these basins. Most vegetational variation occurred within the basins and was apparently due to variations in drainage.

5. Because no significant variation existed among the three basins, their floras are treated as one. This flora is simple because the habitat is recent, having only had time for invasion by the most aggressive species. The fact that this cumulative flora is simple in terms of numbers or species present (i.e., as compared to the vegetational list for the dredged material disposal site) does not detract from its surprising lushness. The prolific growth was provided largely by native species presumably brought into the basins in the dredged material. All native plants present and collected on this trip were listed as occurring

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* Raymond E. Jones, Louisiana Tech University, Ruston, La., trip report from Ottawa. Ill., 8-11 July 1978.

at the dredged material disposal site with the exceptions of Phleum pratense (timothy) and Rubus spp.

6. The planting of a mixture of six species by the contractor resulted in germination from at least four of these species: Bromus inerimis, Festuca anindinacea, Lolium perenee, and Lotus corniculatus. No specimens of the remaining two planted species, Panicum virgatum and Poa annua, were found. Of those species planted, only Lolium perenne reached populations considered to be significant. Lotus corniculatus produced numerous germlings which were quickly overgrown by native species.

7. The rich growth of the treated basins was made up largely of five species: Ambrosia artemisifolia, Bidens frondosa, Bidens spp., Brassica nigra, and Polygonum lapathifolium. The combined biomass of the above species was truly impressive. Polygonum lapathifolium appeared to have contributed most to primary production within each of the treated basins. Brassica nigra was prolific and extremely showy with its tall stalks of yellow flowers. Brassica nigra was the only broad-leaved species readily flowering; only a few specimens of Polygonum lapathifolium had begun flower production. All specimens of Ambrosia and Bidens were sterile.

8. Except for the five species mentioned above, all other species, with the possible exception of Lolium perenne, must be ascribed secondary importance in the floras of the basins. Lolium merits special consideration because of its predominance in grassy borders around each basin at the bases of the levees.

9. A vegetation list is as follows:

GRAMINEAE

BROMEGRASS Bromus inerimis

BARNYARD GRASS Echinochloa crisgulli

TALL FESCUE Festuca arundinacea

SPRANGLETOP Leptochloa fascicularis

RYE GRASS Lolium perenne

TIMOTHY Phleum pratense

WHEAT Triticum vulgare

POLYGONACEAE

COMMON KNOTWEED *Polygonum aviculare*

SMARTWEED *Polygonum lapathifolium*

CHENOPODIACEAE

LAMB'S QUARTERS *Chenopodium album*

CRUCIFERAE

BLACK MUSTARD *Brassica nigra*

LEGUMINOSAE

BIRDSFOOT TREFOIL *Lotus corniculatus*

WHITE SWEET CLOVER *Melilotus alba*

ROSACEAE

Rubus spp.

COMPOSITAE

COMMON RAGWEED *Ambrosia artemisifolia*

COMMON BEGGAR'S TICK *Bidens frondosa*

GIANT BEGGAR'S TICK *Bidens* spp.

GARDEN SUNFLOWER *Helianthus annus*

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Perrier, Eugene R
  Area strip mine reclamation using dredged material: a field demonstration / by Eugene R. Perrier, Jose L. Llopis, Patricia A. Spaine. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1980.
  64, 10, 3 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; EL-80-4)
  Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Dredging Operations Technical Support Program (Formerly DMRP Work Unit No. 4C04)
  References: p. 62-64.

1. Dredged material. 2. Dredged material disposal. 3. Erosion control by vegetation. 4. Mine wastes. 5. Reclamation. 6. Strip mining. 7. Vegetative cover. I. Llopis, Jose L., joint author. II. Spaine, Patricia A., joint author. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; EL-80-4.
TA7.W34 no.EL-80-4