2/5-1-78

ANL/AA-6
Vol. 2
(DRAFT)

ASSESSMENT OF THE HEALTH AND ENVIRONMENTAL EFFECTS OF POWER GENERATION IN THE MIDWEST

Vol. II. Ecological Effects

Anthony J. Dvorak
and
Edwin D. Pentecost

(Project Leaders)

DRAFT

April 1977

MASTER

ARGONNE NATIONAL LABORATORY

'repared for the U. S. Energy Research
and Development Administration under
Contract W-31-109-Eng-38

DISCLAIMER

ANL/AA-6
Vol. 2 DRAFT

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

ASSESSMENT OF THE HEALTH AND ENVIRONMENTAL EFFECTS OF POWER GENERATION IN THE MIDWEST

Volume II. Ecological Effects

Anthony J. Dvorak
and
Edwin D. Pentecost
(Project Leaders)

Authors: Anthony J. Dvorak
Robert M. Goldstein
Ray R. Hinchman
Julie D. Jastrow
Charles R. LaFrance
Jon I. Parker
Edwin D. Pentecost
Richard C. Stupka

Other Contributors: W. Kenneth Derickson
Becky B. Green*

April 1977

Division of Environmental Impact Studies

*(*Division of Energy and Environmental Systems)*

Prepared as part of the Regional Studies Program sponsored by the Assistant Administrator for Environment and Safety of ERDA.

ASSESSMENT OF THE HEALTH AND ENVIRONMENTAL EFFECTS
OF COAL UTILIZATION IN THE MIDWEST

Vol. I. Energy Scenarios, Technology Characterizations, Air and Water Resource Impacts, and Health Effects

Vol. II. Ecological Effects

Study Coordinators: L. J. Habbeger* (Vol. I)
A. J. Dvorak** and E. D. Pentecost** (Vol. II)

Regional Studies Program: L. J. Hoover,* Manager

Energy Scenarios*

G. Krohm
J. Cavallo
C. Dux
W. Pelletier

Technology Characterization*

R. Bright
P. Dauzvardis

Air Quality*

K. Brubaker
D. Kellermeyer
M. Snider
R. Sprunger
J. VanKuiken

Health Effects†

R. Lundy

Water Resources*

S. Y. Chiu
S. C. Chay
J. Gasper
J. Hoffman
K. Holub

Siting*

D. Smithyman
C. Comer

Ecological Effects (Volume II)**

A. Dvorak
E. Pentecost
W. Derickson
R. Goldstein
B. Green*
R. Hinchman
J. Jastrow
C. LaFrance
J. Parker
R. Stupka

*Energy and Environmental Systems Division
**Environmental Impact Studies Division
†Biological and Medical Research Division

ASSESSMENT OF THE HEALTH AND ENVIRONMENTAL EFFECTS OF COAL UTILIZATION IN THE MIDWEST

ABSTRACT

This report presents an initial evaluation of the major health and environmental issues associated with increased coal use in the six Midwestern states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. Using an integrated assessment approach, the evaluation proceeds from a base-line scenario of energy demand and facility siting for the period 1975-2020. Emphasis is placed on impacts from coal extraction, land reclamation, coal combustion for electrical generation, and coal gasification. The range of potential impacts and constraints is illustrated by a second scenario that represents an expected upper limit for coal utilization in Illinois.

Volume I of the report includes (1) a characterization of the energy demand and siting scenarios, coal related technologies, and coal resources, and (2) the related impacts on air quality, water quality, and human health. Volume II includes (1) background information on the native ecosystems, climate, soils, and agricultural land use and (2) a description of the ecological impacts expected from coal utilization in southern Illinois, which has ecosystems representative of a large segment of the six-state area.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

FIGURES

TABLES

TABLES (Contd.)

TABLES (Contd.)

ASSESSMENT OF THE HEALTH AND ENVIRONMENTAL EFFECTS OF POWER GENERATION IN THE MIDWEST

Volume II. Ecological Effects

SUMMARY

Volume I presented a description of the coal resources and a forecast of energy demands together with discussions of coal-related technologies, siting problems, and land reclamation as foreseen from now until the year 2020 for a six-state area in the Midwest: Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. It also identified and evaluated the impacts of such coal utilization on air quality, water availability, water quality and human health. Here in Volume II, the ecological impacts are assessed. For better accuracy, a smaller "southern Illinois limited study area" (SILSA) is discussed in detail as a representative region of southern portions of the six-state area.

The discussions in this volume are based upon the scenarios for the years 2000 and 2020 and, because the conventional power plants foreseen outnumber gasification facilities and emit more air pollutants, the impacts identified are mainly those of coal combustion in power generation plants. Such impacts are categorized as relating to mining, combustion, and land reclamation. The coal extraction impacts are further categorized as related to deep mining and surface mining.

In southern Illinois the native ecosystems are typical of the oak-hickory deciduous forest association. The most common agricultural crops are corn, soybeans, wheat, oats and various types of hay. Hogs, beef cattle, dairy cattle and poultry are the most abundant livestock animals produced. A rather detailed narration about the SILSA is given in Section 9 and an analytical account of the impacts in Section 10.

Land Use Impacts

Impacts from deep mines primarily result from the gob and slurry areas created during the coal preparation process. The use of land for the deposition of gob and slurry materials precludes its use for other purposes. Acidic runoff from gob piles results in a complete loss or modification of the vegetation in the immediate vicinity of the pile. The degree to which the vegetation is modified will greatly influence use of the area by wildlife.

Strip mining in contrast to deep mines disrupts large acreages of land. During the period from 1975 to 1985, strip mining to supply a 3000-MW coal-fired power plant will require an average of 441.6 acres of land per

year in seven Illinois counties. The cumulative surface acreage mined to supply a 3000-MW plant will increase from the year 1985 to 2020.

Terrestrial Impacts

In general, wildlife species associated with deciduous forests are expected to be impacted more permanently by future surface mining in southern Illinois than are species that inhabit prairies and pasture lands. Since current reclamation amendments return mine spoils to a grassland, wildlife species typical of prairie are expected to recolonize mined areas, once reclamation is completed. Vegetation and wildlife typical of mature deciduous forests are not expected to become established on mine spoils for 50-100 years. The immediate fate of wildlife species following the onset of mining is a function of their mobility. Relatively mobile vertebrates, such as birds and most mammals, will be displaced into areas adjacent to mine sites. A reduction in the acreage of upland deciduous forest and forest edge will reduce habitat available for game species such as gray fox, red fox, fox squirrel, gray squirrel, eastern cottontail, and white-tailed deer. Songbirds such as thrushes, woodpeckers, the red-eyed vireos and ovenbirds will be displaced from forested areas being mined.

The impacts on agriculture from strip mining in the SILSA are considered temporary in comparison to the impacts on forests. Agricultural land disturbed by strip mining is expected to increase each year. In the year 2020 disturbance of the following amounts of agricultural land in seven counties is anticipated.

	Total Acres in Row Crops	Total Acres Disturbed	Percent Disturbed
Gallatin	133,550	668	0.5
Jackson	128,124	128	0.1
Madison	254,821	255	0.1
Perry	89,262	179	0.2
Randolph	156,987	314	0.2
St. Clair	244,670	245	0.1
Williams	29,975	60	0.2

Under current Illinois reclamation laws most of this land will be returned to some form of agricultural use. Rapid establishment of high income crops, such as corn, soybeans, and oats, will require extensive fertilization. Dut during the first several years after reclamation is completed, reclaimed areas may be most efficiently used as livestock pasture.

Aquatic Impacts

Impacts on specific aquatic ecosystems in the SILSA from coal mines and preparation plant developments depend upon the location of coal reserves nd the types of mining. The impacts of premining activities (e.g., vegeta-ion removal, haul road construction, pit excavation) are expected to be negligible if appropriate measures are taken to control erosion. Operational impacts on aquatic ecosystems, historically, have resulted from the offsite disposal of mineral-laden effluents when water is pumped from sumps in low areas of the pits to local waterways. Certain portions of SILSA, such as Saline County, have experienced an acid mine drainage problem when new strip mines encounter abandoned deep mine tunnels. Currently such discharges are treated chemically to neutralize the acid, and are passed through settling basins to ensure that local water quality and aquatic biota are not damaged. Consequently, acidic mine drainage from future surface mining should not pose a hazard to the biota of any waterways within SILSA; no other impacts on aquatic organisms are foreseen if effluent discharges from new mines continue to meet permissible effluent standards. The development of new surface mines in certain portions of the three river basins studied may not be possible because of the low dilution capacity of headwater streams.

Based on assumptions regarding stream flow rates, discharge effluent standards, and mine effluents discharged into local waterways, the following number of new surface mines are considered feasible within the next 50 years; Kaskaskia River Drainage Basin - 10, Big Muddy River Drainage Basin - 5 to 10, Saline River Drainage Basin - none.

Reclamation Impacts

Agricultural incomes will decline because of the removal of row-crop lands. Initial reclamation will be mostly to grasslands, and the return of strip-mined land to use in row crop agriculture may require 10 years or longer from the time of initial disturbance. The changes in land use and the associated ecological and economic impacts from increased strip mining in southern Illinois are the major issues to be considered prior to future mine development, for land use changes will result in the greatest ecological impacts from increased mining.

The revegetation of reclaimed areas with grasses will provide habitat for wildlife species typical of grasslands. Such areas will then develop into foraging habitat for migrant and resident birds of prey such as the marsh hawk, sparrow hawk and red-tailed hawk. Recreational species such as the bobwhite and eastern cottontail will become established quickly once reclamation is completed. In some areas mined lands are being reclaimed to grasslands interspersed with pines and shrubs. This system will increase the nesting and foraging habitat for many songbirds and small mammals, but it will not serve the species characteristic of deciduous forest because many hardwood tree species are slow growing and are not used in reclamation.

The creation of impoundments and final cut reservoirs on surface-mined land will provide new habitat for fish and wildlife. In the Kaskaskia and Saline River Drainage Basins the amount of aquatic habitat has increased by more than 300% as a result of strip mining. The creation of final cut reser-oirs is not expected to greatly alter the distributional patterns of winter esident waterfowl. The establishment of marshes and submergent vegetation will provide habitat for many fish, marsh birds and mammals, but the extent of these marshes will depend greatly on the bathymmetry of the impoundment. A detailed investigation of the biological productivity and water quality of final cut reservoirs is one aspect of reclamation that warrants further study. The potential long-range uses of these reservoirs can be determined only after considerable social, economic, and environmental data are obtained and analyzed.

Coal Combustion Impacts

The ecological impacts from increased coal combustion are associated with the major gaseous pollutants and particulates. A model 3000-MW coal-fired model plant, sited either singly or in a clustered configuration with 12 plants within a 36-square mile area, was used as a basis for impact assessment.

Analysis indicated that SO_2 is the only primary gaseous pollutant resulting from operation of the model 3000-MW plant that may have measurable ecological impacts. For a single 3000-MW model plant, based on 24-hour maximum emission values, the total area in which acute visible injury to sensitive vegetation may occur is approximately 608 acres. For the clustered plant configuration injury to sensitive vegetation could occur in an area in excess of 22,000 acres. The area in which threshold-to-severe injury to sensitive vegetation may occur would approach 6400 acres. In each of the impacted areas visible injury would be in the form of leaf necrosis or chlorosis. The severity of the impact would be directly related to the percentage of area of a particular plant that is injured. SO_2 sensitive agri-agricultural species grown in the SILSA include alfalfa, barley, oats, rye, wheat and soybeans. On the basis of SO_2 damage to agricultural crops it appears that a 12-plant siting configuration in the SILSA would be environmentally unacceptable.

The impact analysis of particulate emissions dealt only with arsenic, beryllium, cadmium, fluoride, lead, and selenium. For all elements analyzed the clustered siting pattern resulted in higher deposition rates. For the clustered siting arrangement arsenic should be considered as an element which potentially may have adverse effects on vegetation of low tolerance (e.g. soybeans). Impacts on vegetation are quite uncertain, however, because of the conservative assumptions and other uncertainties of the analysis. Beryllium deposition is not expected to adversely affect vegetation at either the clustered or single plant. For both siting patterns, cadmium emissions are not expected to have impacts on the vegetation unless endogenous soil levels are just below toxic levels or other sources of cadmium pollution exist within the region. Since cadmium is not readily excreted from mammals possible adverse effects on the food chain should not be ruled out. Flouride emissions are expected to result in some detectable impact on vegetation in the SILSA. Foliar damage to species such as sorghum, fruit trees and conifers may result from the clustered siting plan. Impact on these species is not expected to result in a major economic loss since they are relatively uncommon in the SILSA. Lead accumulation in the soil or deposition on forage vegetation is not expected to reach levels that are hazardous to biota. It is expected that the selenium emitted will be in the form of SeO and SeO_2 and will not be accumulated by most plants. Since the concentrations emitted ill be far below those reported to be harmful to laboratory animals, no dverse impacts are anticipated.

The analysis of airborne combustion emissions on aquatic ecosystems pertained to both gaseous and particulate sources. If acidic precipitation produced by three new 3000-MW plants in the Big Muddy River Drainage Basin falls within the drainage basin, the total surface water acidity may be increased and thus adversely affect the biota in the river. The likelihood of this happening is considered low, however, since gaseous pollutants will be readily dispersed by the atmosphere. Other river drainage basins within the SILSA are even less likely to be adversely affected by acid rain. However, on the basis of the conservative (worst case) estimates for trace element contamination of aquatic ecosystems, it is apparent that smaller drainage basins, such as the Big Muddy and Kaskaskia, may not have sufficient dilution capacity to prevent measurable increase in trace elements.

No adverse impacts on aquatic biota are anticipated from the model plants' cooling water systems. In every location the volume of makeup water required and the size of the intake structure considered with respect to the size of the water body present indicate that impacts from impingement and entrainment should be negligible. Construction of the blowdown discharge structure may cause a temporary adverse affect on some benthic invertebrates. Localized thermal gradients will be established in the vicinity of the discharge structure. These gradients are not expected to be extensive enough in the rivers of the SILSA to result in any adverse impacts on fish populations and most other aquatic biota. No far-field impacts on aquatic biota from trace elements, impingement or entrainment, and thermal additions are anticipated from a single model plant. For power plants sited on reservoirs such impacts are expected to be limited to the reservoirs only.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

9.0 DESCRIPTION OF THE SOUTHERN ILLINOIS LIMITED STUDY AREA (SILSA)

9.1 CLIMATE OF SOUTHERN ILLINOIS

Cold winters, warm summers, and frequent short-period fluctuations in temperature, humidity, cloudiness, and wind direction characterize the continental climate of Illinois. Because the state extends so far in a north-south direction (385 mi), precipitation and temperature, which are principally controlled by latitude, vary greatly from northern to southern portions of the state.[1]

Annual precipitation is approximately one and one-half times as great in the extreme south as in the extreme north; however, the excess in the southern portion falls during winter and early spring. Thirty-two to 34 inches of mean annual precipitation are recorded in the northern regions compared to 46-48 inches in the southern regions (Fig. 9.1). The additional precipitation in the south does not benefit agriculture because it does not occur during the growing season. Precipitation for the six-month period of April to September is uniform, ranging from 21 to 24 inches throughout the state. February is the driest month, contrasted with May and June which are the wettest. Soil erosion in Illinois occurs primarily during the summer, when heavy rains frequently fall during local storms. In southern Illinois, winter precipitation is an additional cause of erosion.

July and August rainfall normally is insufficient to meet the demands of rapidly growing crops so that moisture demand must be met by subsoil moisture accumulated from the previous fall-through-spring season. There is an increased tendency toward midsummer drought in the extreme south because soil there commonly has a lower water-holding capacity due to an impermeable clay layer (claypan) in subsoils.

Snows occur frequently and the temperature drops to below zero several times each winter in the extreme north. The soil freezes to a depth of about three feet and may remain snow-covered for weeks at a time. In the extreme south, the soil freezes to a depth of only 8-12 inches; snow falls infrequently and usually melts winin a few days. The growing season, or freeze-free period*, ranges through the state from 155-230 days (Fig. 9.2). Serious freeze damage to major crops is not common.

Because prevailing winds are westerly, the influence of Lake Michigan on the climate of Illinois, specifically the Chicago area, is limited. However, when winds are easterly, the result is a moderating effect.

9.2 SOILS OF SOUTHERN ILLINOIS

9.2.1 Description of Soil Associations

The soil associations of the Southern Illinois Limited Study Area (Fig. 9.3) are described in the initial part of this section according to the

**A freeze is defined as the occurrence of a temperature 32°F or lower recorded five feet above the ground in a standard instrument shelter.*

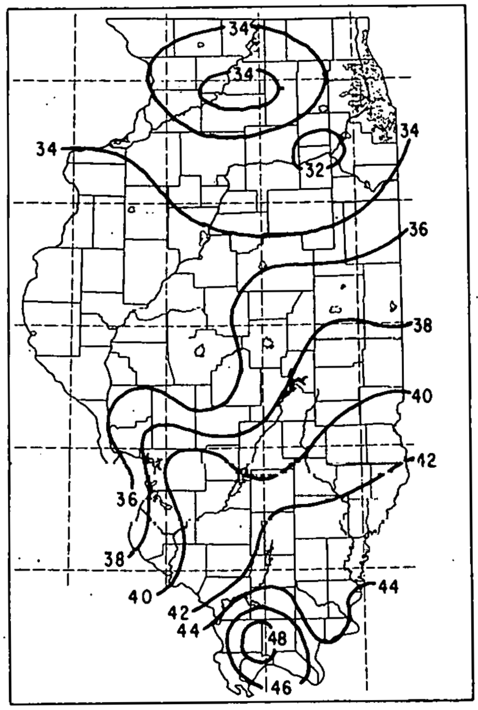
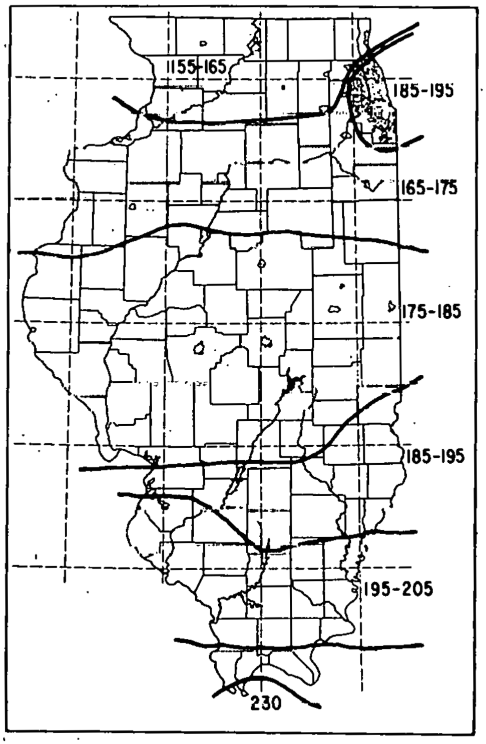


Fig. 9.1. Mean Annual Precipitation (in.) in Illinois Based on Period 1931-1960.* Modified from Ref. 1.

Fig. 9.2. Mean Annual Growing Season (days) in Illinois Based on Period 1931-1960 (or portions of that period for which data are available). Data from Ref. 1.



*Isolines are drawn through points of approximately equal value. The data for the isoline maps in this section are general and the use of site-specific data is recommended for interpolations.

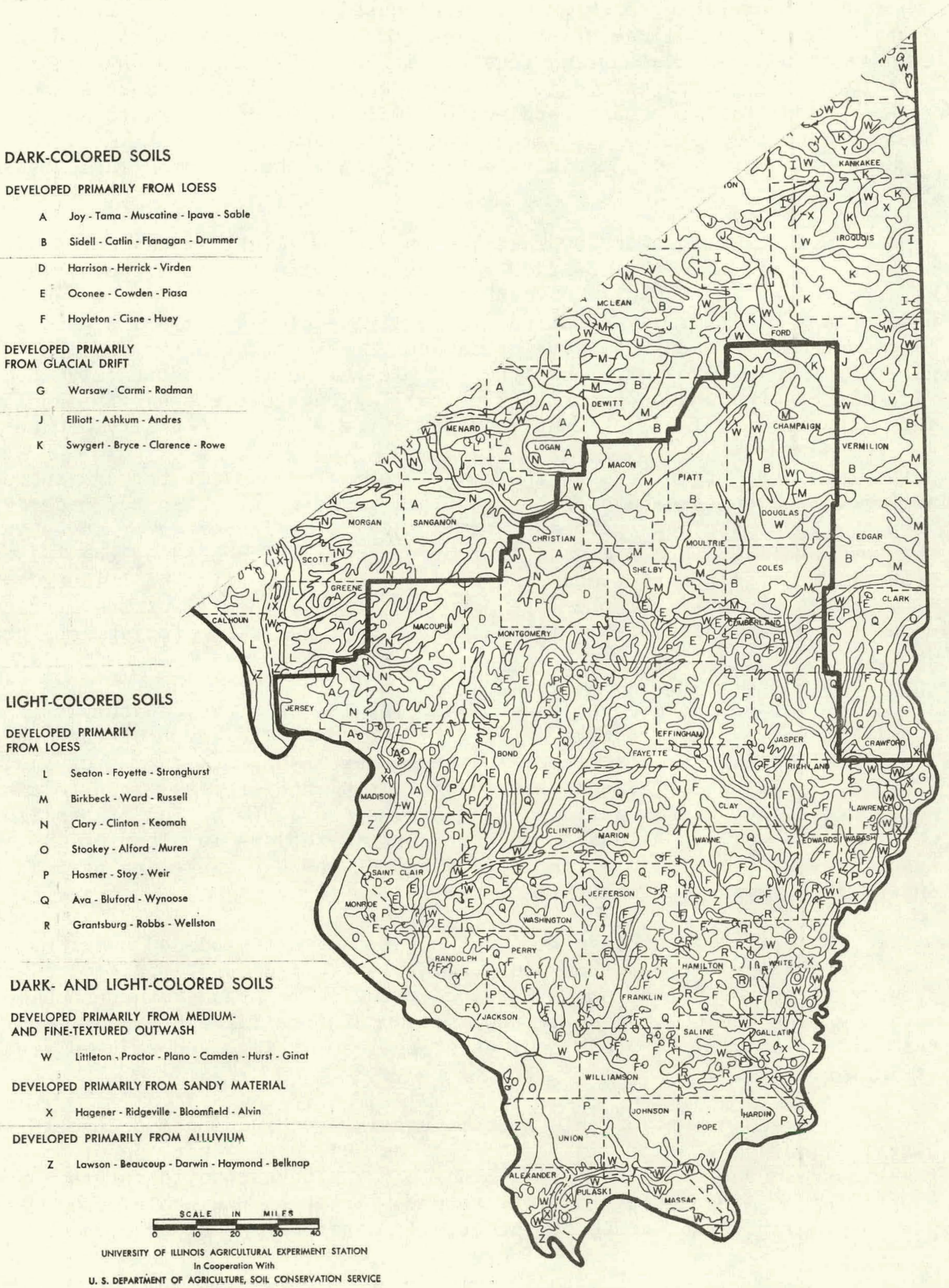


Fig. 9.3. Soil Associations and Major Soils of the Study Area

major soils comprising each association, based on Agricultural Experiment Station Data.[2] A soil association consists of a group of defined and named taxonomic soil units occurring together in an individual and characteristic pattern over a geographic region.[3] As presented, the soil associations are grouped or differentiated according to similarities or contrasts in the following: surface soil color, parent material, subsoil permeability, resistance to drought, texture, productivity estimates and, where appropriate, management practices.

Surface soil color is described as dark or light. The degree of darkness is, in general, positively correlated with the amount of organic matter present in the soil. A dark color indicates that the soil developed under grass or prairie vegetation, while light-colored soils are generally low in organic matter and have developed under trees or forest vegetation. In general, the level of organic matter in mineral soils is positively correlated with the development and stability of soil aggregates; the supply, availability, and recycling of plant nutrients, and the water-holding capacity of the soil.

Permeability refers to the passage of water and air through the soil profile. The surface layer is generally more permeable than the underlying strata. Thus, the more permeable the subsoil, the faster water moves through the soil profile. The downward flow of water is influenced by the relative proportions of clay, silt and sand in the most restrictive soil layer. The finer the texture (i.e., the more clay particles), the slower the movement. A moderately permeable subsoil is considered most desirable for agricultural soils.

Resistance to drought is a measure of the relative capacity of soil to supply water for plant uptake during dry periods. The depth of root penetration into the soil also influences water uptake by plants during dry periods. Normally, shallow-rooted, drought-intolerant plants are the first to exhibit water stress during dry periods. The amount and distribution of available water in the soil profile are important considerations in planning land-use practices, especially in areas where frequent and/or severe dry periods occur during the growing season.

The estimated average yield of selected crops produced under high levels of management, as shown in Table 9.1, are indicative of the relative productivities of soil associations occurring in the study area. A high level of management includes adequate application of fertilizers, proper control of soil water, control of weeds and pests, and use of improved adapted crop varieties.

The second part of this section consists of information concerning the distribution and characteristics of various soil units which occur in eighteen counties selected from the entire study area. These counties are of special concern because of their proximity to major waterways suitable for power plant sitings and/or the presence of potentially strippable coal reserves.

Table 9.1. Soil Water Characteristics and Estimated Crop Yields of Major Soils in the SILSA[a]

Soil Associations[b] Occurring in the Study Area	Subsoil Permeability	Resistance to Drought	Estimated Average Yields Under High Level of Management[c,d] Corn, bu/a	Soybeans, bu/a	Wheat, bu/a
A	Moderate	Very good	105	36	43
B	Moderate	Very good	101	37	44
D	Moderate	Good-very good	94	36	43
E	Slow	Good	83	31	40
F	Slow	Good	81	29	39
G	Moderate	Fair	84	32	37
J	Moderate-moderately slow	Good-very good	90	33	38
K	Slow	Good-fair	83	32	37
L	Moderate	Good-very good	89	29	35
M	Moderate	Good-very good	93	34	41
N	Moderately slow	Good-very good	85	29	34
O	Moderate	Good-very good	88	29	36
P	Slow	Good-fair	76	28	35
Q	Slow-moderately slow	Fair-good	67	25	34
R	Slow-very slow	Fair	63	24	31
W	Moderate-slow	Very good-fair	112-60	40-22	40-26
X	Moderately rapid-rapid	Fair-poor	85-40	33-23	36-18
Z	Rapid to very slow	Very good-poor	106-45	38-20	43-20

[a]Modified from J. B. Ferenbacher, G. O. Walker, and H. L. Wascher, *Soils of Illinois*, Arig. Exp. Sta. Bull. 725, University of Illinois, Urbana (1967).

[b]For the period 1956-1965.

[c]See Fig. 9.3 for key to soil associations.

[d]A high level of management includes adequate application of fertilizers, proper control of soil water, weeds, and pests, and use of improved adapted crop varieties.

9.2.1.1 Dark-Colored Soil Associations Developed Primarily from Loess

Soil Associations A, B, and D

All of the soils which comprise these three associations are dark-colored, indicating development under prairie vegetation. The soils occur on nearly level to strongly sloping upland areas. Subsoil permeability is moderate and resistance to drought is classified as very good to good in the major soils because of high available-water storage capacities. Indigenous fertility is high for Associations A and B, but generally low for D. Crops grown on these soils respond favorably to lime, nitrogen, and phosphorus applications. Crop yields are high, particularly if soils are intensively managed. The major crops are corn, soybeans, wheat, and mixed hay. Oats is a major crop only on soils of Association A. Erosion control is necessary on the more sloping areas and can be effected by contouring or terracing, reducing the frequency of planting crops that require intensive cultivation, and expanding the time between crop rotations.

Soil Associations E and F

Component soil units are moderately dark-colored, occur on nearly level to moderately sloping uplands and have developed under grass vegetation. Fragipans or siltpans occur in the lower strata of some soil units. A pan is a dense layer of fine soil particles (silt and/or clay) which is slowly permeable and restricts root penetration. Subsoil permeability is slow but resistance to drought is good. Low fertility, erosion hazards, and, in some cases, poor drainage are the major management problems. Large applications of fertilizer and limestone are necessary to improve fertility and ameliorate soil acidity. Crop yields are moderately high under high levels of management. The soils are commonly used for combined livestock and grain production. The major field crops are corn, soybeans, mixed hay, and wheat.

9.2.1.2 Dark-Colored Soil Associations Developed Primarily from Glacial Drift

Soil Association G

The distribution of this association within the study area is limited to the northeast portion of Lawrence County. Soils are dark-colored and occur on level to moderately sloping uplands and on stream terraces. The presence of gravel close to the surface causes these soils to be thin, with limited capacities for holding moisture and plant nutrients. Yields of late summer crops such as corn and soybeans are reduced when moisture is insufficient. Crop yields can be increased by irrigation and frequent lime, nitrogen, potash, and phosphorus application. Wheat is the major crop. Some of the more shallow gravelly soils support trees or are left idle.

Soil Associations J and K

These two associations are comprised of dark-colored soils developed on glacial till and underlain by a silty clay loam layer at an average depth of three feet. The topography is generally undulating but variously interrupted with short, choppy slopes intermingled with potholes or depressions. Permeability of the soil profile is moderate in the upper portions but moderately slow in the lower strata. Resistance to drought is better for soils of Association J than those of K. Primary crops are corn, soybeans, wheat, hay, and pasture, and yields are moderately high under a high level of management. Because the topography is irregular, most erosion control methods are difficult to implement; therefore, areas of high surface drainage may be left in a natural state (grass waterways).

9.2.1.3 Light-Colored Soil Associations Developed Primarily from Loess

Soil Associations L, M, and N

The soils which constitute these soil associations occur on uplands and are either light colored or moderately dark colored, having developed under vegetation characteristic of a prairie-forest transition zone. Subsoil permeability is moderate and resistance to drought ranges from good to very good. Moderately sloping areas can be successfully managed by implementing erosion controls, but the steepest slopes are not amenable to cultivation; many are forested and produce excellent timber. Crop yields are generally high and productivity can be increased by additonal lime and fertilizer applications. Soils of Association N are acid and low in organic matter content. Soils of these three associations are commonly used for mixed livestock and grain production, with corn, soybeans, wheat, oats, hay, and pasture grown as major field crops.

Soil Associations O and P

Soil Associations O and P occur in uplands ranging from nearly level to very steep. Subsoil permeability is moderate and moisture-holding capacities high for soils of Association O. Hosmer and Stoy, two of three major soils comprising Association P, have a fragipan or siltpan in the lower part of the soil profile. Drought resistance for P soils is good to fair. Soils of both associations occur on many steep areas which are forested and exhibit good timber production. Reforestation with pine species is suggested on steep, eroded areas. Indigenous fertility of all major soils is low. Corn, wheat, hay, pasture, and soybeans are the major crops grown. Apples and peaches are grown in many areas and production could be expanded. A mixture of livestock and grain production is characteristic for most soils of these two associations.

Soil Associations Q and R

Soils constituting Association Q occur on uplands ranging from nearly level to steep terrain, while soils of Association R occur on gently sloping to very steep topography, often on narrow ridges bordered by deep ravines. Subsoil permeability is slow to very slow in all the major soils because of the presence of a fragipan, siltpan, or claypan. These pans within the profile hinder root penetration unless the plants are grown under high fertility. Low fertility and erosion hazards are the main problems in utilizing these soils for crop production. Areas with steep slopes should remain forested; steep eroded areas should be reforested. Corn, wheat, soybeans, and hay are the main crops produced on soils of Association Q. Yields are moderate under a high level of management. Some corn, wheat, and soybeans are grown on some soils in Association R. Crop yields are only moderate to low under a high level of management; therefore, substantial acreages are idle. Pasture improvement programs for moderately sloping areas and reforestation on the steeper slopes are recommended for the soils of Association R.

9.2.1.4 Dark- and Light-Colored Soils Developed Primarily from Medium- and Fine-Textured Outwash

Soil Association W

Both dark- and light-colored soils are included in this association, because in most areas soil distribution patterns are mixed and complex. Forty-three major soils and 18 associated soils comprise this association. Subsoil permeability, resistance to drought, and crop yields are quite variable from one soil to another; therefore, only the ranges for these parameters are given in Table 9.1. These soils occur on upland and stream terrace areas where slopes range from nearly level to very steep. The soils which occur on terraces along major waterways such as the Mississippi, Illinois, and Wabash Rivers are underlain by shallow aquifers that can be tapped for irrigation. Many of the well-drained, permeable, silty and loamy soils are excellent for the production of vegetables and truck crops. More information concerning this diverse association is presented by Fehrenbacker et al.[2]

9.2.1.5 Dark- and Light-Colored Soils Developed Primarily from Sandy Material

Soil Association X

The soils of this association are sandy (large particle size) and occur on level to strongly sloping topography within many of the river valleys. Because sand is predominant and clay content low, these soils are moderately rapid to rapid in permeability and capacities for holding water and plant nutrients are limited. Therefore, the main problems these soils present are drought, fertility, and wind and water erosion. Small grains, melons, alfalfa, pine plantations, and fruit trees produce fairly well on soils comprising this association. In very sandy areas, wind erosion is more of a problem than water erosion. Active wind erosion can totally eliminate plant cover and cause a depression or "blowout". Reforestation with pines is suggested as the best method to control active wind erosion. Irrigation is possible for most soils of Association X because of the presence of good aquifers. Large amounts of water have to be applied because of the rapid permeability of the sandy soils.

9.2.1.6 Dark- and Light-Colored Soils Developed Primarily from Alluvium

Soil Association Z

Bottomland soils along the streams throughout the study area make up Soil Assocation Z. The topography of these soils is usually level to gently sloping. The soils of this association may be either calcareous (alkaline), neutral to slightly acid, or acid. The acid soils are confined to southern Illinois. Soil textures range from sandy to clayey, permeability from rapid to very slow, and drought resistance from very good to poor. Low fertility, flooding, and weed control are the main problems associated with these soils. Levees, diversion ditches, and cleared stream channels are suggested measures to reduce flooding. Weeds are a persistent problem in areas subject to flooding because water transports and deposits weed seeds with the rise and fall of stream volume. Corn and soybeans are the major crops. Cotton is grown in extreme southern Illinois. Low-lying areas commonly support native bottomland hardwood forests and produce very high yields of timber and pulpwood. Pastures are also prevalent on many of the smaller bottomland areas.

9.2.2 Soils in Eighteen Selected Counties

The counties included in the following discussion were selected on the basis of their proximity to major waterways suitable for power plant sitings and/or the presence of strippable coal reserves lying beneath the surface. The major waterways include the Mississippi and Ohio, and to a lesser extent, the Wabash, Big Muddy, and Kaskaskia Rivers. The areas within the study area where strippable Herrin (No. 6) Coal and Harrisburg--Springfield (No. 5) coal deposits occur at less than 150 feet below the surface, have been identified from Smith and Stall.[4] These two coals constitute approximately 85% of the mapped coal reserves that occur in seams 42 or more inches thick. The eighteen counties selected according to the above criteria are depicted in Figure 9.4. The only selected counties lacking strippable coal are Lawrence, Wabash, and White, all of which lie adjacent to the Ohio River.

All but four of the soil associations previously discussed occur in the 18-county area. The exceptions are Soil Associations B, J, K, and M. The relative extent to which the various associations occur within each of the selected counties is given in Table 9.2. Soil Association P occurs in 15 counties and in nine of those occupies the most extensive area. Soil Associations G, L, and N occur in only one, two, and three counties, respectively. However, L and N occupy 82.5% of Jersey County. The highest percentage of distribution for one association within a county is 65.9% for Soil Association R in Pope County.

9.2.2.1 Soil Types

Runge et al.[5] have summarized the areal extent of each soil type as a percentage of the total acreage within the county in which the type occurs. The authors point out that the accuracy of the percentages increases with the amount of acreage occupied by the soil type. Therefore, only the five most abundant soil types for each county were chosen for inclusion in Table 9.3.

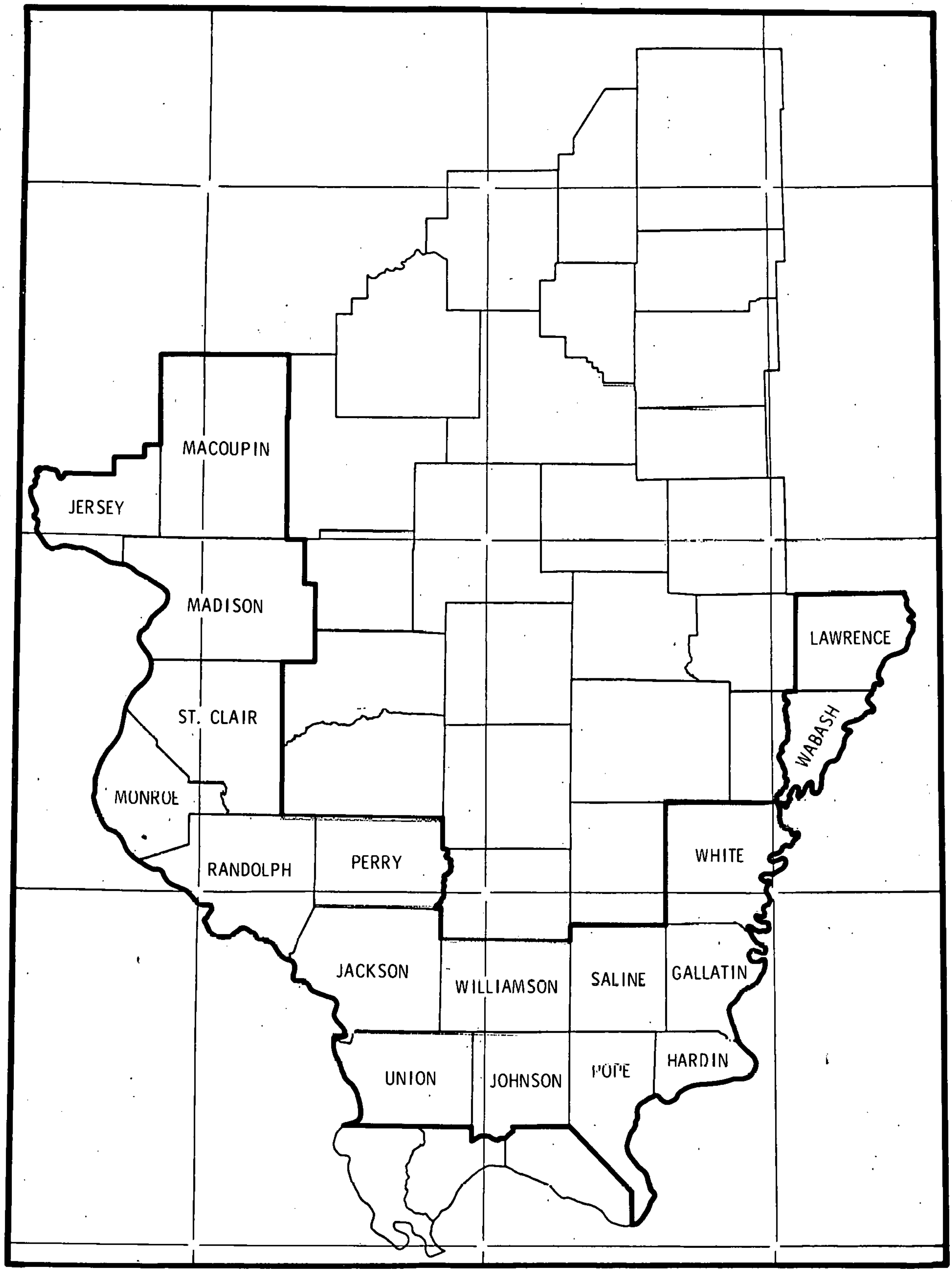


Fig. 9.4. Eighteen Selected Counties in the SILSA.

.e 9.2. Relative Percentage Distribution of Soil Associations within Selected Counties in the SIL:

County	Soil Associations													
	A	D	E	F	G	L	N	O	P	Q	R	W	X	Z
Gallatin								10.2	10.6	3.8		54.7	7.8	12.9
Hardin								16.3	42.0		41.7			
Jackson								12.5	43.2	5.1		28.8		10.5
Jersey	5.6	6.6				43.1	39.4							5.3
Johnson									53.8		39.1			7.1
Lawrence				1.7	12.0			4.8	8.3	38.2	15.2		8.2	11.6
Macoupin	8.6	42.6					20.0		28.8					
Madison	9.0	12.4	15.6			8.8	4.7	11.9	23.3					12.4
Monroe			4.8					31.6	34.9					28.7
Perry				30.6					9.4	58.6		1.4		
Pope									21.1		65.9	4.7		8.3
Randolph			10.1	2.0				20.8	30.6	20.2				16.2
Saline										40.7	13.6	45.8		
St. Clair	3.5	9.9	6.2					22.6	37.3	2.1		4.1		14.3
Union								17.8	62.0					20.2
Wabash				12.6				16.8	17.6	7.6		14.9	5.0	25.6
White								6.2	29.1	21.8	2.3	17.3	7.3	15.9
Williamson				5.2										
No. of counties in which soil association occurs	4	4	4	5	1	2	3	11	15	9	6	8	4	13

[a]From P. W. Mausel, E. C. A. Runge, and S. G. Carmer, *Soil Productivity Indexes for Illinois Counties and Soil Associations*, Agric. Exp. Sta. Bull. 752, University of Illinois, Urbana (1975).

Table 9.3. Percentage of Total Acreage of the Five Most Abundant Soil Types within Eighteen Selected Counties in the SILSA[a]

Soil Types	Gallatin	Hardin	Jackson	Jersey	Johnson	Lawrence	Macoupin	Madison	Monroe	Perry	Pope	Randolph	Saline	St. Clair	Union	Wabash	White	Williamson
Reeseville silt loam	9.96																	
Allison silty clay loam	7.74															10.10		
Patton silty clay loam	7.16					7.56							10.68			9.94	5.49	
Alford silt loam	6.25	9.88	9.06					8.70	21.78			11.45		13.00		8.18		
Uniontown silt loam	5.75																	
Wartrace silt loam		18.84													18.98			
Muskingum stony silt loam		15.45									12.25							
Grantsburg silt loam		12.16			12.51						35.15		12.09					
Baylis silt loam		6.11																
Hosmer silt loam			24.92		29.32			6.22	11.11		12.57	11.01		13.04	25.73		9.35	8.20
Okaw silt loam			6.52															
Hickory loam			5.77	10.10			16.40		6.25	8.26								
Hurst silt loam			4.64															
Fayette silt loam				12.17														
Clinton silt loam				8.45			7.56											
Keomah silt loam				7.77														
Rozetta silt loam				7.43														
Wellston-Muskingum complex					13.99													
Zanesville silt loam					12.93						7.99							7.85
Sandstone rock land					9.62													
Herrick silt loam							27.92											
Virden silty clay loam							5.77											
Sicily silt loam							4.96	6.51										
Herrick-Piasa complex								8.45										
Lawson silt loam								7.71						5.21				
Stoy silt loam									8.83					10.79				
Riley silty clay loam									4.98									
Cisne silt loam										22.3								
Wynoose silt loam										15.77		7.94						
Bluford silt loam						13.05				14.40			10.18					6.46
Bonnie silt loam										7.80						8.34		
Wellston silt loam											4.07							
Ava silt loam						11.51						6.7[illegible]						25.46
Stoy silt loam												6.1[illegible]					5.19	
Belknap silt loam						5.88							12.63		6.05	9.63	7.72	
Blair silt loam													7.48					
Birds silt loam														6.25				
Mixed alluvial land															6.97			
Wakeland silt loam															5.87			
Hickory-Ave complex																		9.28
Carmi loam						6.62												
Robi silt loam																	6.18	
Totals	36.86	62.44	50.91	45.92	78.37	44.62	62.61	37.59	52.95	68.53	72.03	43.27	53.06	48.29	63.90	46.19	33.93	56.25

[a]From E. C. A. Runge, L. E. Taylor and S. C. Carmer, Soil Type Acreages for Illinois--Statewide and County Summaries, Agric. Exp. Sta. Bull. 735, University of Illinois, Urbana (1969).

hese soil types occur on approximately 53% of the area within the 18 counties; ercentages range from only 33.9 for White County to 78.4 for Johnson County.

Hosmer silt loam is the most extensively distributed of soil types, occurring as one of the five most prevalent soil types in ten of the 18 counties. Hosmer is one of three major soil series constituting Soil Association P. Hosmer soils are characterized by a silt loam A horizon and a silty clay loam B horizon. (The A horizon is the upper part of the soil profile which is commonly differentiated into surface and subsurface soil. The B horizon underlies the A horizon and is referred to as the subsoil.) The B horizon of Hosmer is slowly permeable and includes fragipans or siltpans in the lower part.

Alford silt loam, a major soil type of Association O, occurs in eight of the selected counties, predominantly in the Mississippi and Ohio River Valleys. Alford has the same textural A and B horizons as Hosmer but has not developed pans in the lower portions of subsoil. Hickory loam, Patton silty clay loam, and Balknap silt loam each occur in five counties. Hickory and Patton series are soils included in Soil Association Q. Belknap is one of the major soils comprising Soil Association Z--soils developed primarily from alluvium. Belknap occurs primarily in those counties which lie within the Mississippi and Ohio River Valleys.

9.2.2.2 Slope and Erosion Characteristics

Slope and erosion classes were developed for Illinois soils as a part of the Conservation Needs Inventory (CNI). The CNI study was conducted by the Soil Conservation Service in cooperation with the University of Illinois. The slope class and erosion data presented for the eighteen counties in Table 9.4 are based on a randomized two-percent sample. The key, identifying slop classes, is presented in a footnote to Table 9.4.

Erosion classes are based on the assumption that the thickness of the topsoil is indicative of the degree to which a given soil has been eroded. The key to classes of topsoil thickness is also presented as a footnote in Table 9.4. Numbers (0-3) corresponding with topsoil classes indicate erosion classes or a relative index of erosion intensity.

Erosion Classes 0 and 1 jointly indicate "none-to-slight" erosion, Class 2 is "moderate", and Class 3 indicates "severe" erosion. Accordingly, data presented in Table 9.4 indicate that about 63% of the 18-county area is in the none-to-slight erosion class, 23% in the moderate, and 14% is severely eroded. Most of Macoupin County is in the 0-2% slope class and the none-to-slight erosion class. Large acreages in Jackson, Johnson, Randolph, and Williamson Counties are designated in Class 3, severe erosion.

Table 9.5 shows qualitative and relative distribution of county acreages apportioned according to slope and erosion classes. Seventy percent or more of the acreage in Gallatin, Lawrence, Macoupin, Madison, Perry, Saline, Wabash, and White Counties is in the none-to-slight erosion class. Over 20% of the tal surface area in Hardin, Johnson, Pope, Union, and Williamson Counties is verly eroded (Class 3). The latter counties are located in the southernmost part of the study area.

Table 9.4. Composite Acreage of All Soil Types According to Slope and Erosion for the Eighteen Selected Counties[a]

County	Slope/Erosion Mapping Units, hundreds of acres																	Total County Area, hundreds of acres
	A[b]	B1[c]	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3	F2	F3	G2	G3	
Gallatin	1239	227	52	3	30	114	38	2	50	48	43	24	52	31	3	1	3	1960
Hardin	96	38	2	-	19	97	2	13	70	87	20	42	160	186	28	79	-	939
Jackson	1065	586	3	-	69	284	30	7	158	282	76	126	271	389	60	24	3	3433
Jersey	625	534	13	-	33	181	61	10	58	115	5	43	103	143	73	250	5	2252
Johnson	404	176	4	-	25	151	24	6	80	324	-	117	298	275	27	164	-	2075
Lawrence	1304	551	16	1	28	179	47	7	22	96	-	9	21	11	1	3	-	2296
Macoupin	3010	782	22	-	5	254	5	6	372	45	2	116	40	618	7	143	-	5427
Madison	1940	676	36	7	81	249	43	14	195	180	84	129	108	153	39	29	-	3963
Monroe	814	457	25	8	83	100	57	18	41	143	12	41	128	219	82	148	3	2379
Perry	1436	467	15	-	34	184	20	22	45	176	46	30	88	50	25	12	2	2652
Pope	237	176	12	-	23	254	9	18	109	245	52	83	115	175	4	87	-	1599
Randolph	990	875	45	1	132	377	18	18	164	341	33	90	219	123	35	58	12	3532
Saline	1267	363	37	2	34	174	25	7	94	114	4	6	26	12	-	2	-	2168
St. Clair	1751	631	53	-	77	243	106	43	60	319	17	12	120	69	74	87	-	3662
Union	764	144	2	-	22	243	1	19	103	155	58	83	213	206	71	102	-	2266
Wabash	872	185	37	2	33	79	25	4	8	53	8	4	18	2	15	-	-	1346
White	1532	572	42	8	53	210	75	18	86	188	12	58	101	58	6	28	1	3048
Williamson	546	530	9	-	102	157	90	10	57	332	-	141	186	57	3	-	1	2221
TOTAL	19892	7970	426	32	1214	3530	677	242	1772	3243	472	1154	2347	2777	553	1217	30	47218
% of Total	42.1	16.9	1.0	0.1	2.6	7.5	1.4	0.5	3.7	6.9	1.0	2.4	5.0	5.9	1.2	2.6	0.1	100.9

[a] From E. C. A. Runge, L. E. Tyler, and S. G. Carmer, Soil Type Acreages for Illinois--Statewide and County Summaries, Agric. Exp. Sta. Bull. 735, University of Illinois, Urbana (1969).

[b] A = 0-2% slope
B = 2-4% slope
C = 4-7% slope
D = 7-12% slope
E = 12-18% slope
F = 18-30% slope
G = greater than 30% slope

[c] 0 = more than 14 in. of topsoil
1 = 7-14 in. of topsoil
3 = 3-7 in. of topsoil
4 = 0-3 in. of topsoil

Table 9.5. Relative Acreage of All Soil Types by Slope and Erosion for the Eighteen Selected Counties[a]

	Slope Group														Erosion Groups					
	0-2		2-4		4-7		7-12		12-18		18-30		> 30		None to Slight		Moderate		Severe	
County	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Gallatin	1239	63.2	282	14.4	182	9.3	100	5.1	119	6.1	34	1.7	4	0.2	1541	78.6	272	13.9	147	7.5
Hardin	96	10.2	40	4.3	118	12.6	170	18.1	222	23.6	214	22.8	79	8.4	186	19.8	476	50.7	277	29.5
Jackson	1065	31.0	589	17.2	383	11.2	447	13.0	473	13.8	449	13.1	27	0.8	1803	52.5	984	28.7	646	18.8
Jersey	625	27.8	547	24.3	275	12.2	183	8.1	151	6.7	216	9.6	255	11.3	1207	53.6	688	30.6	357	15.8
Johnson	404	19.5	180	8.7	200	9.6	410	19.8	415	20.0	302	14.6	164	7.9	611	29.4	791	38.1	673	32.4
Lawrence	1304	56.8	568	24.7	254	11.1	125	5.4	30	1.3	12	0.5	3	0.1	1890	82.3	240	10.4	166	7.2
Macoupin	3010	55.5	804	14.8	264	4.9	423	7.8	158	2.9	625	11.5	143	2.6	3805	70.1	1525	28.1	97	1.8
Madison	1940	48.9	719	18.1	373	9.4	389	9.8	321	8.1	192	4.8	29	0.7	2795	70.5	791	20.0	377	9.5
Monroe	814	34.2	490	20.6	240	10.1	202	8.5	181	7.6	301	12.6	151	6.4	1384	58.2	574	24.1	421	17.7
Perry	1436	54.2	482	18.2	238	8.9	243	9.2	164	6.2	75	2.8	14	0.5	2005	75.6	336	12.7	311	11.7
Pope	237	14.8	188	11.8	286	17.9	372	23.3	250	15.6	179	11.2	87	5.4	506	31.6	720	45.0	373	23.3
Randolph	990	28.0	922	26.1	527	14.9	523	14.8	342	9.7	158	4.5	70	2.0	2048	58.0	858	24.3	626	17.7
Saline	1267	58.4	402	18.6	233	10.8	215	9.9	36	1.7	12	0.6	2	0.1	1676	77.3	325	14.9	167	7.7
St. Clair	1751	47.8	684	18.7	426	11.6	422	11.5	149	4.1	143	3.9	87	2.4	2519	68.8	524	14.3	619	16.9
Union	764	33.7	146	6.4	266	11.7	277	12.2	434	19.2	277	12.2	102	4.5	1007	44.4	739	32.6	520	22.9
Wabash	872	64.8	224	16.6	138	10.6	65	4.8	30	2.2	17	1.3	0	0	1102	81.9	130	9.7	114	8.5
White	1532	50.3	622	20.4	338	11.1	292	9.6	171	5.6	64	2.1	29	1.0	2187	71.7	482	15.8	379	12.4
Williamson	546	24.6	539	24.3	349	15.7	399	18.0	327	14.7	60	2.7	1	0.05	1188	53.5	421	19.0	612	27.6

[a]From E. C. A. Runge, L. E. Tyler, and S. G. Carmer, Soil Type Acreage for Illinois--Statewide and County Summaries, Agric. Exp. Sta. Bull. 735, University of Illinois, Urbana (1969).

9.3 VEGETATION OF SOUTHERN ILLINOIS

The presettlement vegetation of Illinois[6] (Fig. 9.5) includes three community types: Western Mesophytic Forest, Ozark Oak-Hickory Forest,[7] and Prairie Peninsula[8,9] (Prairie Formation). Basically, the geographic distribution of these community types coincides with the limits of Pleistocene glaciation[10] (Fig. 9.6). The Western Mesophytic Forest is confined to the unglaciated southern tip of the state while the Ozark Oak-Hickory Forest and the Prairie Peninsula form a mosaic of communities[8] on the till plains of glacial origin. The exact environmental conditions controlling the distributions of forest and prairie within this mosaic are not known, but are apparently quite complex.[8]

9.3.1 Western Mesophytic Forest[6,7,10]

The Western Mesophytic Forest (Fig. 9.5) of Illinois occurs in the Coastal Plain, Wabash Lowland, and Shawnee Hills physiographic sections (Fig. 9.4). The Coastal Plain is a low, flat region subject to frequent flooding. The soils of this region are often saturated with water all year and may even be permanently inundated. The Wabash Lowland is the level floodplain and terraces of the Wabash River south of the maximum advance of the Wisconsin glacier.[11] The Shawnee Hills are an east-west ridge with hilltops as much as 850 feet above the ravine bottoms. In this region, the effective moisture regime is strongly influenced by elevation and slope exposure (that is, which direction the slope faces relative to the warm afternoon sun). In addition, the Shawnee Hills are variously topped with rocky to gravelly soils, sandy soils, or loess (airborne dust of extremely fine particle size) deposits.

On the Coastal Plain where soils are usually heavily saturated with water all year, various swamp forest associations dominate the regional landscape. In permanent standing water, a bald cypress-tupelo gum association develops.[10] This association is also the most characteristic association of the Coastal Plain in Illinois.

The Wabash Lowlands are subject to frequent flooding, but the soil moisture drops below saturation levels during dry periods. Here, a zonal vegetation is produced by the successively higher levels of floods with longer return periods. Pure stands of black willow or cottonwood occur on the lowest zone, which is subjected to annual flooding. There appears to be an element of chance in determining which species will occupy the river's edge, but black willow is the more common species. Continuing back from the one-year flood frequency zone, the associations are cottonwood, river birch, river birch-silver maple, pin oak, sycamore, and Spanish oak-pin oak-shagbark hickory. The latter is transitional to upland forests and can be expected to occur just below the 50-year return period flood level.

In the uplands of the Shawnee Hills, the soils of ravine bottoms and the sheltered north-facing slopes remain permanently moist. These sites support highly diverse American beech-sugar maple-tulip tree associations which are characteristic of the Western Mesophytic Forest community type. The mid-slopes support various oak-hickory associations depending on exposure. The dominant oaks in these associations exhibit the following gradient response, from moist (sheltered) to dry (exposed) sites: red oak, white oak,

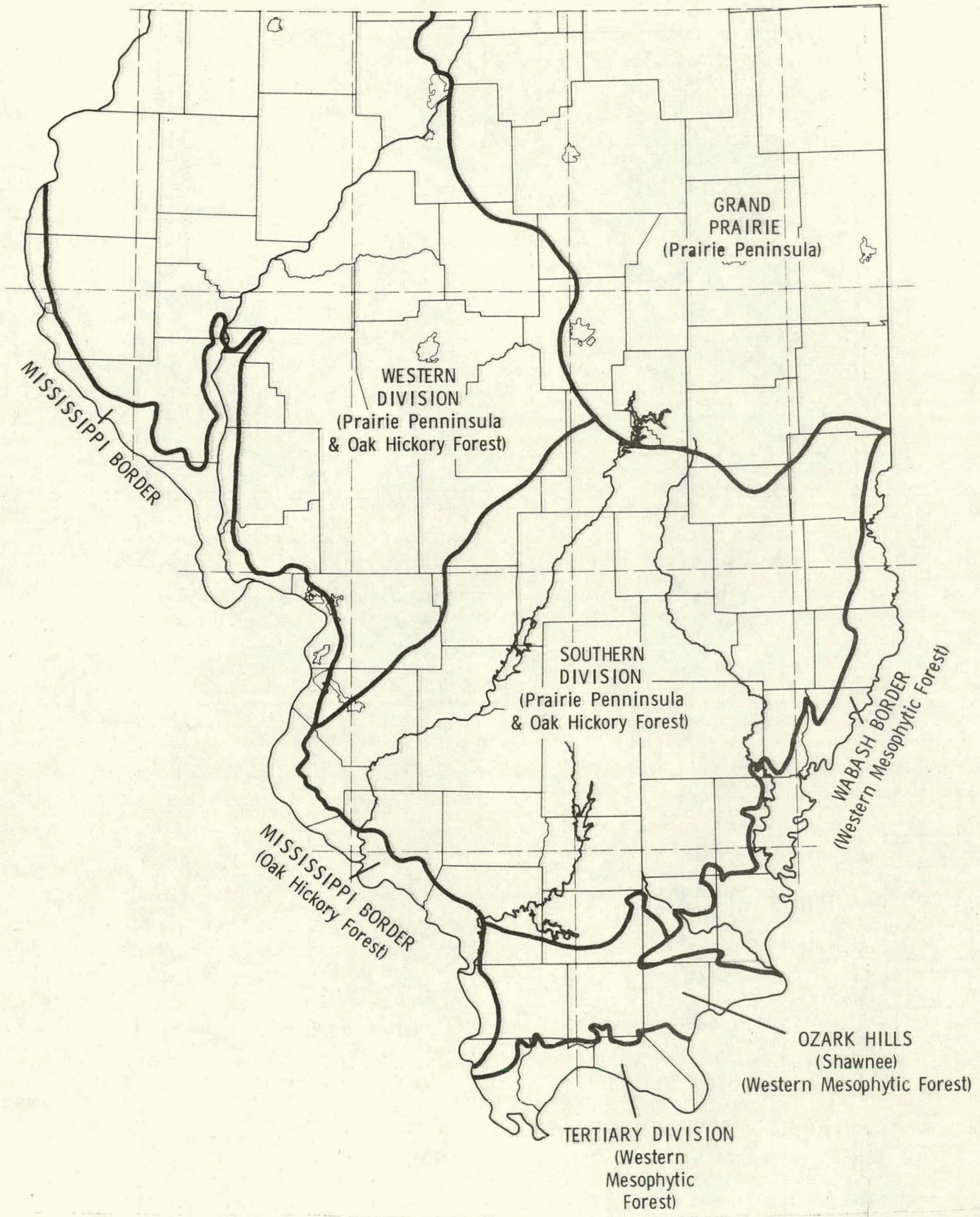


Fig. 9.5. Biogeographic Divisions of Southern Illinois.

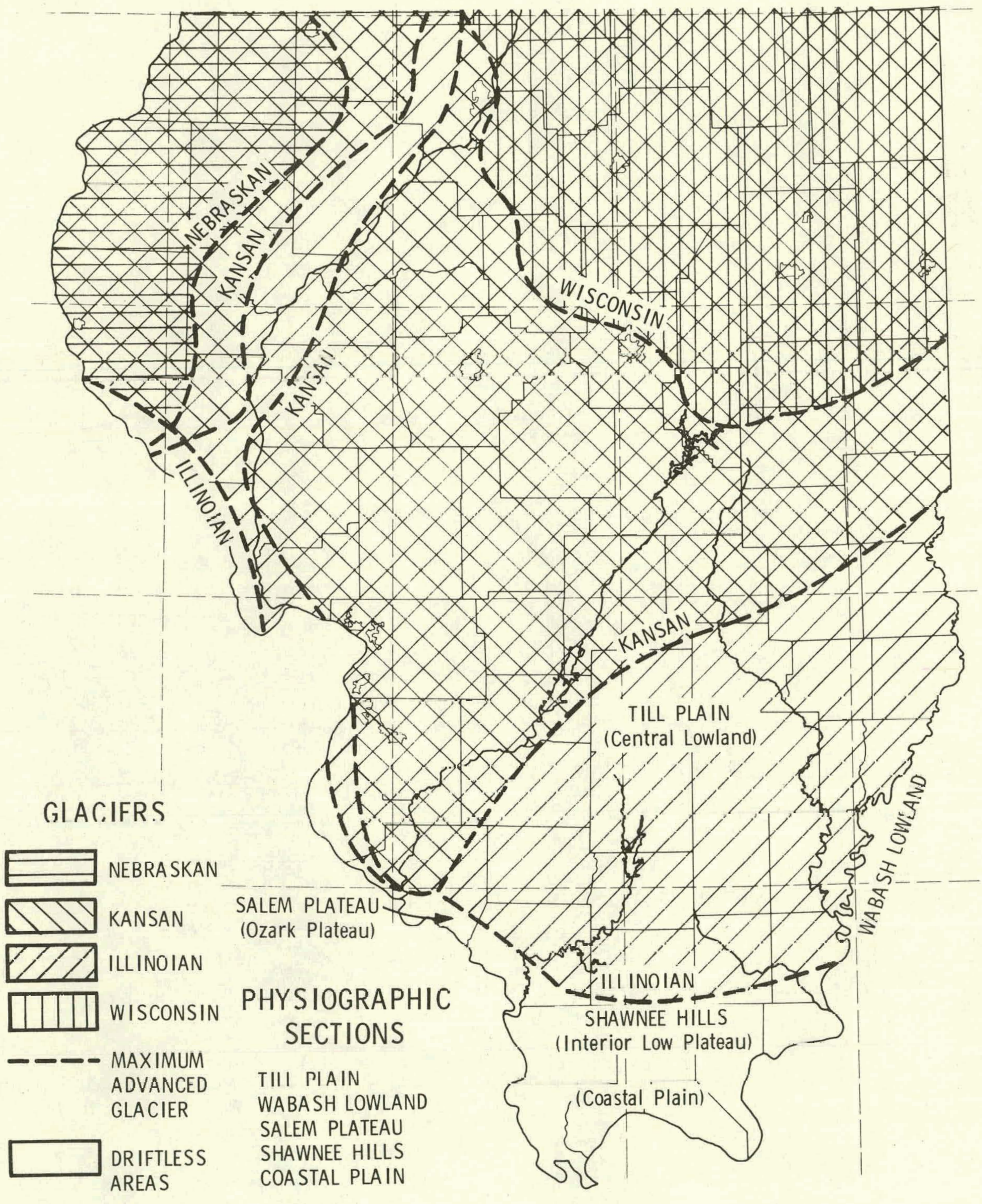


Fig. 9.6. Physiographic Sections in Southern Illinois (Divisions Shown in Parentheses).

lack oak, post oak, and blackjack oak. Of these species only the latter two can be found on hilltops or other excessively drained or exposed sites. These oak-hickory forests are apparently transitional between the true Western Mesophytic forests occurring in the ravines and the true Ozark Oak-Hickory forests occurring on the till plains (see Sec. 9.3.2).

On the hilltops in the Shawnee Hills, there is a strong edaphic (in this case, soil particle size) influence. "Hill prairies" develop on the loess-covered hills. These are bunch grass prairies (little bluestem-June grass-side oats grama) which are a montane variant of the Prairie Peninsula (see Sec. 9.3.3). Species diversity is very high (390 species compared to 265 species in the Prairie Peninsula, 237 in the true prairie of Nebraska).[10] Sandy soils on the hilltops typically support a post oak-blackjack oak association. This is basically an Ozark Oak-Hickory community type, but where it occurs on the Shawnee Hills, it can be expected to include several Coastal Plain species. Rocky to gravelly hilltop soils support a yellow pine-Buckley's hickory-post oak association. This association is typical of barren sites of the Coastal Plain.

9.3.2 Ozark Oak-Hickory Forest[6,12,13]

The Ozark Oak-Hickory Forest and Prairie Peninsula (Sec. 9.3.1) formations include a mosaic of communities (Fig. 9.5) on the till plains (Fig. 9.6) of Illinois. This complex consists of three biogeographic divisions based on the relative frequencies of the two community types.[6] In the Western Division, the presettlement vegetation was divided nearly equally between forest and prairie. The Grand Prairie Division supported more prairie than forest; and in the Southern Division, the forest occupied more area than did the prairie. However, there are no consistent distribution patterns of the forests or prairies of this region.[8] Riverine forests and prairie sloughs occur along river courses; upland forests and upland prairies occur on sandy as well as clay and loess soils; both vegetation types occur over clay subsoils; etc.

Within the forests of the till plains there is clear evidence of vegetation response to moisture gradients. From the river edges to the dry uplands, the sequence of associations is silver maple-black willow, red ash, cottonwood-sycamore, black walnut-hackberry, red oak-slippery elm, white oak-black oak, and black oak. The compositions of the associations are typically less diverse than counterparts in the unglaciated southern tip of the state. On dry sites, the black oak tree layer is often sparsely populated (less than 60% cover) and the ground flora is composed of prairie species. This association, an oak savanna (locally called "oak openings"), is transitional between Ozark Oak-Hickory Forest and Prairie Peninsula.

9.3.3 Prairie Peninsula[6,8-10]

Numerous explanations have been proposed to account for the eastward extension of prairie into Illinois, but none is capable of fully explaining the distribution of prairies.[8] A common theme in many discussions of the Illinois prairies is that they are "subclimax" and would be replaced by Ozark Oak-Hickory Forests if successfully protected from disturbances such as natural prairie fire and grazing. However, Transeau[8] presents strong evidence that the Prairie Peninsula is a climax community type. Among the more convincing arguments are: (1) some sites have apparently been occupied continuously by prairie for as much as 5000 years, (2) most forest sites within the peninsula do not have evidence of prairie soils under the present forest soils, (3) where prairie soils occur under forest sites (eastern Ohio, western Pennsylvania), there is evidence in pollen profiles of a climatic shift sufficient to account for a shift from prairie to forest vegetation. Therefore, the Illinois prairies can be categorized as a true climax community type.

Unlike the bunch grass character of the hill prairies (Sec. 9.3.1), the vegetation of the Prairie Peninsula is predominantly composed of sod-forming species. A moisture gradient is sometimes apparent within the Prairie Peninsula. In general, the sequence of dominants from wet to dry areas is cordgrass, wild rye, switchgrass, big bluestem, Indian grass, little bluestem, and side oats grama. Kentucky bluegrass may be subdominant with any of these except cordgrass or side-oats grama.

9.4 AGRICULTURE IN SOUTHERN ILLINOIS

The major crops produced in southern Illinois (Fig. 9.7) are corn and soybeans; together they contribute 65% of the area's total annual income. Hogs are the third most important commodity, contributing 15% of the total income. Beef and wheat production are fourth, each contributing about 7% of the income. Dairy products, although they are important in some counties, contribute only 3% of the total annual income, and hay and egg production 2% and 1%, respectively. Oats and sheep and lambs contribute less than 1%.

In the northern counties, corn is the leading crop. Champaign County was the leading producer of corn in 1975 (277,100 acres) followed by Christian (161,400 ac), Douglas (131,300 ac) and Moultrie (91,900 ac) Counties (Table 9.6).

Soybeans become the major crop as one moves south through the study area. Although Champaign remains the major producer, the southern counties in general, are high in soybean production (Table 9.6). Johnson and Hardin Counties are notable exceptions; both these counties rely heavily on beef cattle and hogs for their income (Table 9.7).

Macoupin County is the leading hog producer in the study area with 129,400 head on farms in 1974. Hogs are an important source of revenue for the southern counties and are the leading source of agricultural income for Johnson, Williamson, Massac, and Edwards Counties. These counties and Pope, Bond, Monroe, and Jersey Counties derive at least 25% of their agricultural income from hog production (Table 9.7).

Beef and wheat production are variable throughout the study area. Wheat production contributes the highest income percentage in the southwestern and central counties (Table 9.6). Madison County leads in wheat production with 2.94 million bushels in 1975. Average yield per acre in 1975 was 38.0 bu in the study area. The statewide average was 39 bu/ac. Income from beef is important to the southern counties (Table 9.7). In Hardin County, for example, beef production accounts for 46% of the total annual income. Cattle are also an important income source for Johnson (30%), Massac (25%), and Pope (25%) Counties.

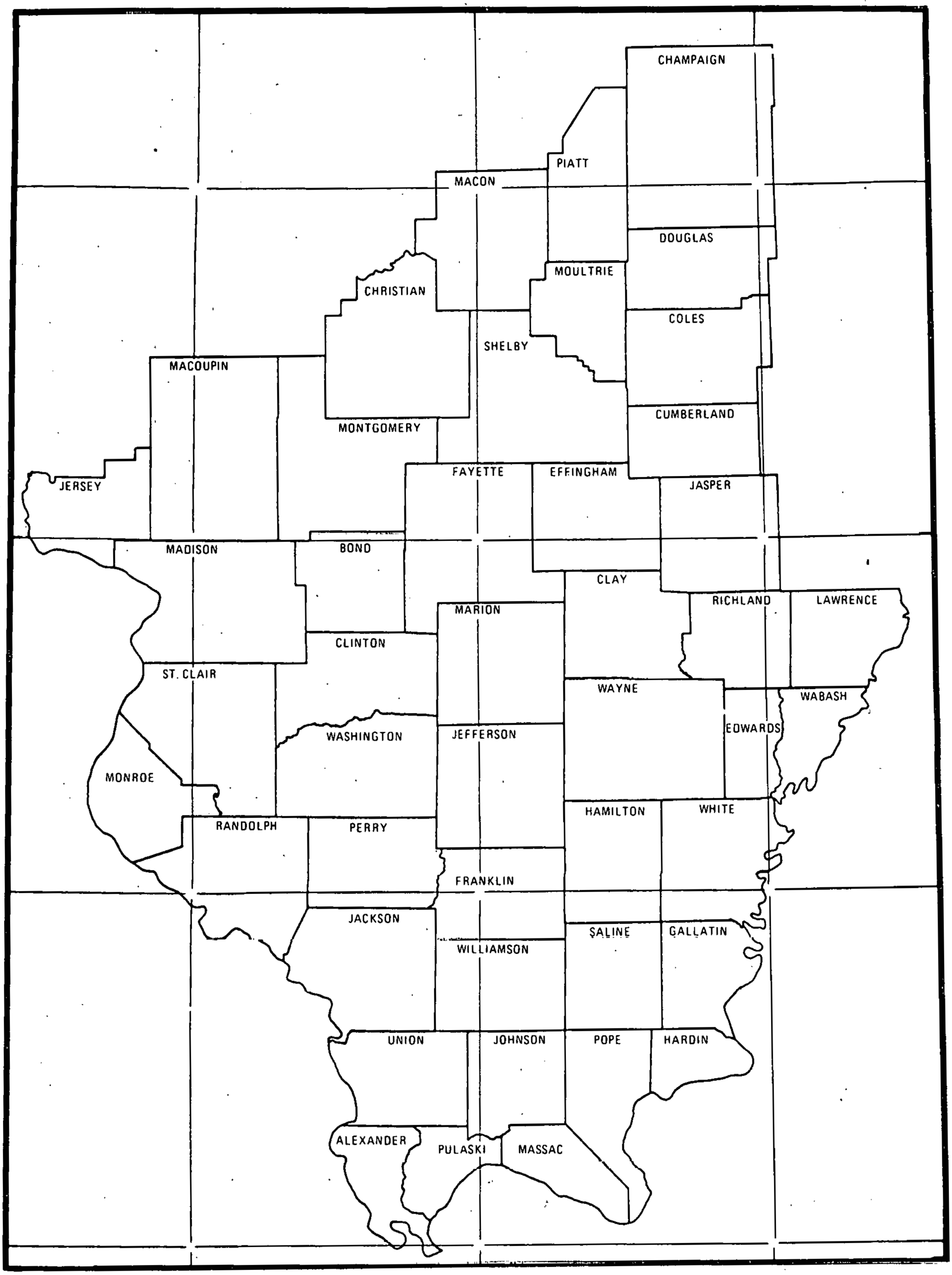


Fig. 9.7. Southern Illinois Limited Study Area

Table 9.6. Crop Acreage, Income, and Yield Statistics for the SILSA (1975)

County	Corn				Soybeans				Wheat			
	Acreage, 1000 ac	% of County Acreage	% of Total County Income	Yield, bu/ac	Acreage, 1000 ac	% of County Acreage	% of Total County Income	Yield, bu/ac	Acreage, 1000 ac	% of County Acreage	% of Total County Income	Yield, bu/ac
Alexander	10.4	07.1 (39)[a,b]	20	70.4 (43)[b]	26.5	18.1 (32)	20	24.4 (42)	14.0	9.6 (18)	18	33.6 (33)
Bond	53.2	22.0 (20)	11	92.7 (17)[b]	68.0	28.1 (16)	32	28.9 (28)	34.3	14.2 (6)	13	37.4 (21)[b]
Champaign	277.1	43.3 (5)	53	136.1 (4)	224.6	35.1 (7)	38	40.7 (1)	23.1	3.6 (36)	10	49.8 (4)
Christian	161.4	35.6 (8)	47	134.0 (5)	171.9	37.9 (2)[b]	35	37.9 (6)	24.7	5.4 (33)	3	46.5 (7)
Clay	43.8	14.7 (32)	13	93.0 (16)	108.7	36.6 (4)	42	25.1 (37)[b]	23.2	7.8 (24)	10	31.9 (39)
Clinton	55.9	20.1 (21)	9	84.5 (29)[b]	75.9	27.3 (18)	23	31.6 (19)[b]	45.1	16.2 (3)	8	35.1 (25)
Coles	144.8	44.7 (3)	50	121.6 (3)	93.5	28.9 (13)[b]	34	37.1 (8)	16.1	5.0 (34)	3	49.5 (5)
Cumberland	42.4	19.1 (22)	27	100.2 (13)	60.1	27.1 (20)[b]	37	32.1 (16)[b]	15.3	7.1 (26)[b]	6	36.1 (26)[b]
Douglas	131.3	48.8 (2)	54	135.9 (5)	86.8	32.3 (8)	33	39.1 (3)[b]	7.3	2.9 (39)[b]	2	53.6 (2)
Edwards	45.2	31.4 (9)	13	91.3 (21)[b]	36.4	25.3 (25)	27	33.2 (13)	15.9	11.0 (8)[b]	7	34.0 (29)[b]
Effingham	77.0	25.0 (17)	17	107.3 (10)	86.9	28.2 (15)	31	32.1 (16)[b]	23.8	11.0 (8)[b]	8	42.2 (9)
Fayette	75.3	16.7 (25)	19	92.0 (20)	105.3	23.4 (28)	36	26.1 (36)	48.0	10.7 (12)	11	40.2 (16)
Franklin	32.0	11.5 (34)[b]	9	89.3 (25)	67.4	24.3 (27)	48	27.1 (30)[b]	20.0	7.2 (28)	13	34.0 (29)[b]
Gallatin	60.8	29.0 (11)	29	99.3 (14)	56.0	26.7 (22)	40	29.2 (25)[b]	16.8	8.0 (23)	9	38.0 (18)[b]
Hamilton	41.0	14.7 (31)	12	90.3 (24)	99.3	35.7 (6)	46	29.2 (25)[b]	25.0	9.0 (20)	10	32.5 (36)[b]
Hardin	5.2	4.4 (44)	14	74.3 (42)	0.8	0.7 (45)	3	25.1 (37)[b]	0.1	0.1 (45)	<1	36.0 (28)
Jackson	27.4	7.1 (39)[b]	12	79.5 (35)	68.4	17.7 (33)	34	30.5 (21)[b]	22.5	8.4 (22)	12	30.0 (43)
Jasper	77.0	24.3 (18)	20	95.6 (15)	120.2	37.9 (2)[b]	38	30.1 (24)	21.2	9.8 (17)	12	34.0 (29)[b]
Jefferson	42.1	11.5 (34)[b]	10	76.3 (37)[b]	96.5	26.3 (23)	41	25.1 (37)[b]	36.3	9.9 (16)	11	32.5 (36)[b]
Jersey	62.3	25.9 (16)	17	102.7 (12)	52.2	21.7 (30)	32	32.9 (14)	20.4	8.5 (21)	9	40.4 (15)
Johnson	18.4	8.3 (38)	16	74.4 (40)[b]	7.7	3.5 (43)	9	23.4 (45)	2.6	1.2 (44)	2	27.7 (44)[b]
Lawrence	68.4	28.6 (12)	40	81.8 (33)	50.3	21.0 (31)	26	24.0 (44)	25.8	11.2 (7)	14	36.1 (26)[b]
Macon	154.5	41.8 (6)	55	138.3 (3)	136.5	36.9 (5)	38	39.1 (3)[b]	12.7	3.4 (37)[b]	2	47.8 (6)
Macoupin	148.7	26.6 (13)	24	110.8 (9)	151.8	27.2 (19)	35	34.9 (10)	41.2	7.4 (25)	7	43.5 (8)
Madison	71.2	15.2 (28)	17	92.7 (17)[b]	105.2	22.4 (29)	35	33.9 (11)	73.6	15.8 (2)	14	37.4 (21)[b]
Marion	54.8	14.8 (30)	16	88.9 (26)	96.6	26.1 (24)	40	27.1 (30)[b]	38.6	10.4 (13)	14	41.2 (11)[b]
Massac	18.1	11.5 (34)[b]	10	91.3 (21)[b]	17.6	11.2 (40)	22	27.1 (30)[b]	5.0	3.8 (35)	4	30.5 (42)
Monroe	31.4	12.8 (33)	13	90.5 (23)	40.9	16.7 (34)	23	31.6 (19)[b]	44.6	13.2 (1)	17	40.5 (13)[b]
Montgomery	117.9	26.1 (14)	30	103.7 (11)	137.6	30.5 (12)	36	31.9 (18)	45.3	10.3 (14)[b]	6	38.4 (17)
Moultrie	91.9	44.0 (4)	52	139.0 (2)	67.1	32.2 (9)	35	39.1 (3)[b]	7.0	3.4 (37)[b]	3	54.6 (1)
Perry	30.5	10.9 (37)	13	77.5 (36)	40.6	14.5 (38)	37	32.6 (15)	13.4	6.5 (32)	13	33.1 (34)
Piatt	160.4	57.4 (1)	56	145.0 (1)	107.5	38.4 (1)	35	39.7 (2)	4.0	1.4 (43)	<1	51.9 (3)
Pope	13.4	5.5 (43)	15	70.2 (45)	6.4	2.6 (44)	20	25.1 (37)[b]	4.0	1.6 (42)	9	32.0 (38)
Pulaski	9.0	6.9 (41)	8	70.4 (43)[b]	20.0	15.3 (37)	38	26.5 (35)	9.1	7.0 (29)[b]	9	30.6 (40)[b]
Randolph	56.5	14.9 (29)	10	84.5 (29)[b]	59.7	15.7 (36)	27	33.6 (12)	41.2	10.8 (11)	13	40.5 (13)
Richland	54.8	14.8 (30)	16	84.8 (27)[b]	67.4	28.9 (13)[b]	46	27.1 (30)[b]	15.5	6.7 (31)	9	37.1 (23)
St. Clair	73.1	17.0 (24)	17	92.5 (19)	106.7	24.8 (26)	40	37.7 (7)	65.2	15.1 (5)	12	41.5 (10)
Saline	43.8	17.9 (23)	32	76.3 (37)[b]	28.0	11.4 (39)	35	27.1 (30)[b]	17.3	7.1 (26)[b]	8	34.0 (29)[b]
Shelby	146.7	30.5 (10)	45	129.8 (7)	130.3	27.1 (20)[b]	30	35.1 (9)	33.5	7.0 (29)[b]	6	41.2 (11)[b]
Union	18.0	6.8 (42)	11	74.4 (40)[b]	21.5	8.1 (41)	21	28.5 (29)	7.6	2.9 (39)[b]	4	27.7 (44)[b]
Wabash	51.1	36.0 (7)	38	84.3 (31)	22.6	15.9 (35)	20	29.2 (25)[b]	13.0	9.1 (19)	10	37.0 (24)
Washington	56.9	15.8 (26)	12	82.5 (32)	113.3	31.4 (10)	35	30.5 (21)[b]	55.2	15.3 (4)	11	37.6 (20)
Wayne	70.0	15.3 (27)	13	80.8 (34)	126.1	27.6 (17)	38	25.1 (37)[b]	47.0	10.3 (14)[b]	9	38.0 (18)[b]
White	83.5	26.0 (15)	28	84.8 (27)[b]	99.3	30.9 (11)	36	30.2 (23)	35.5	11.0 (8)[b]	11	33.0 (35)
Williamson	11.0	4.0 (45)	11	75.4 (39)	14.3	5.2 (42)	23	24.4 (42)[b]	4.7	1.7 (41)	4	30.6 (40)[b]

[a]Rankings of percent of county acreage and yield appear in parentheses in the appropriate column, with 1 the highest rank.

[b]Ranks with one or more other counties.

Table 9.7. Livestock on Farms and Their Percent Contribution to County Income in the SILSA (1975)

County	Hogs: No. of Head (1000 Head)	Hogs: % of Total County Income	Beef: No. of Head (1000 Head)	Beef: % of Total County Income	Dairy: Production (1000 lbs)	Dairy: % of Total County Income
Alexander	6.1 (44)	8	1.7 (45)	3	1,000 (41)	1
Bond	44.7 (18)[a,b]	27	4.5 (33)	6	34,900 (6)	9
Champaign	42.1 (21)	4	5.6 (29)	2	7,800 (23)	<1
Christian	44.7 (18)[b]	6	9.3 (8)	3	4,600 (31)	<1
Clay	50.5 (13)	23	7.6 (17)[b]	8	4,800 (28)[b]	1
Clinton	56.0 (11)	14	4.2 (35)[b]	12	138,500 (1)	23
Coles	43.6 (20)	9	4.4 (34)	2	5,700 (26)	1
Cumberland	46.4 (16)	18	4.2 (35)[b]	18	12,400 (16)	3
Douglas	28.6 (29)	6	2.8 (43)	3	10,500 (19)[b]	1
Edwards	49.6 (14)	38	6.7 (23)[b]	13	4,800 (28)[b]	2
Effingham	66.2 (4)[b]	18	7.4 (20)	10	76,300 (3)	13
Fayette	49.1 (15)	14	10.7 (5)	9	25,800 (8)	5
Franklin	21.9 (35)	18	6.7 (23)[b]	9	4,000 (32)	1
Gallatin	23.0 (34)	12	3.4 (40)[b]	6	800 (42)[b]	<1
Hamilton	40.8 (22)	21	6.7 (23)[b]	9	3,200 (34)[b]	1
Hardin	4.7 (45)	31	3.4 (40)[b]	46	800 (42)[b]	2
Jackson	37.6 (25)	22	10.0 (6)	7	14,700 (14)	5
Jasper	66.2 (4)[b]	20	6.6 (26)	7	16,700 (12)	3
Jefferson	39.7 (23)	21	7.6 (17)[b]	8	10,400 (21)	3
Jersey	58.8 (10)	25	8.1 (14)	10	10,100 (22)	2
Johnson	27.4 (30)	36	9.6 (7)	30	3,900 (33)	3
Lawrence	20.4 (37)	11	3.7 (37)[b]	5	4,800 (30)	2
Macon	19.5 (38)	3	4.7 (32)	2	2,900 (36)[b]	3
Macoupin	129.4 (1)	20	17.4 (1)	12	21,600 (11)	2
Madison	65.9 (6)	14	9.0 (9)[b]	6	60,100 (4)	8
Marion	38.9 (24)	17	7.2 (21)[b]	8	11,900 (18)	3
Massac	29.9 (28)	36	8.8 (11)	25	3,200 (34)[b]	2
Monroe	44.9 (17)	27	3.7 (37)[b]	7	13,200 (15)	4
Montgomery	88.2 (2)	16	11.0 (4)	9	22,100 (9)	2
Moultrie	21.1 (36)	6	2.7 (44)	2	6,700 (25)	1
Perry	23.7 (32)	19	7.9 (16)	9	16,600 (13)	7
Piatt	23.4 (33)	5	3.6 (39)	2	2,900 (36)[b]	4
Pope	12.0 (41)	27	8.0 (15)	25	800 (42)[b]	1
Pulaski	10.2 (42)	18	5.4 (30)	12	2,900 (36)[b]	2
Randolph	59.3 (8)[b]	23	12.5 (3)	14	44,500 (5)	10
Richland	25.2 (31)	17	4.9 (31)	8	10,500 (19)[b]	3
St. Clair	52.3 (12)	4	6.2 (28)	5	28,400 (7)	4
Saline	9.8 (43)	8	7.2 (21)[b]	14	800 (42)[b]	<1
Shelby	62.7 (7)	10	9.0 (9)[b]	6	21,900 (10)	2
Union	17.2 (39)	21	7.5 (19)	13	7,300 (24)	4
Wabash	31.7 (27)	21	3.4 (40)[b]	7	5,200 (27)	2
Washington	59.3 (8)[b]	16	6.3 (27)	9	85,100 (2)	13
Wayne	67.0 (3)	24	13.9 (2)	13	12,000 (17)	2
White	33.9 (26)	14	8.4 (12)	8	2,000 (40)	<1
Williamson	15.5 (40)	30	8.3 (13)	22	2,900 (36)[b]	3

[a] Rankings of number of head and production appear in parentheses in the appropriate column, with 1 the highest rank.

iks with one or more other counties.

Dairy products are important sources of income in some counties (Table 9.7). Clinton, Washington, and Effingham Counties all derive greater than 10% of their agricultural income from dairy products. The highest levels of dairy production are in the central counties, with Clinton County producing 138.5 million pounds of milk in 1974.

The production of eggs, oats, hay, and sheep and lambs also contribute to the agricultural income of the study area, accounting for less than 10% of the income for any one county.

The agricultural commodities discussed above account for at least 95% of the income of most counties in the study area. Union County is the exception. Only 74.4% of the county's income can be accounted for from these products. It is probable that the majority of the fruit produced in Illinois is grown in Union and the surrounding counties. This industry, which consists primarily of apples and peaches, contributed 130 thousand dollars to the state agricultural income in 1974.

9.5 AQUATIC ECOSYSTEMS OF THE MAJOR RIVERS AND TRIBUTARIES IN SOUTHERN ILLINOIS

General features of the waterways of SILSA are summarized in this section. The major rivers bordering the study area, and the tributary streams that drain it are shown in Figure 9.8.[14]

9.5.1 Major Rivers

Portions of the Mississippi, Ohio and Wabash Rivers form the boundaries of SILSA. Discharge information for each of these rivers is shown in Table 9.8, with information on the smaller Kaskaskia and Big Muddy Rivers presented for comparison. Values of discharge rate per unit of drainage area are about one cubic foot per second per square mile of drainage area.[15] This figure is typical for streams where the mean annual rainfall is about 35-40 inches per year.[15] Seasonal maximum discharge in these rivers usually occurs in March or April, while minimum flow occurs between September and November.[16]

The Mississippi River, between St. Louis, Missouri and Cairo, Illinois, is the western boundary of the study area. There are no locks or dams on this section of the river and it is free-flowing. A navigable channel (9 ft deep by 300 ft wide) is maintained throughout this section by dredging. The river meanders through a wide alluvial valley in this section, forming numerous sloughs, marshes, and shoal areas that provide essential habitat for aquatic biota. However, flooding during the spring, dessication during dry periods, and scouring action by ice gorges often alter the habitat in this section of the river.[17]

Biotic assemblages in this section of the river are influenced by two physical factors, (1) upstream impoundments, and (2) dredging to maintain the barge-traffic channel. The upstream impoundments encourage development of planktonic organisms that are commonly found in lakes and reservoirs.[8] These organisms are transported into the downstream free-flowing section of the river. In the free-flowing section, channel dredging increases the flow

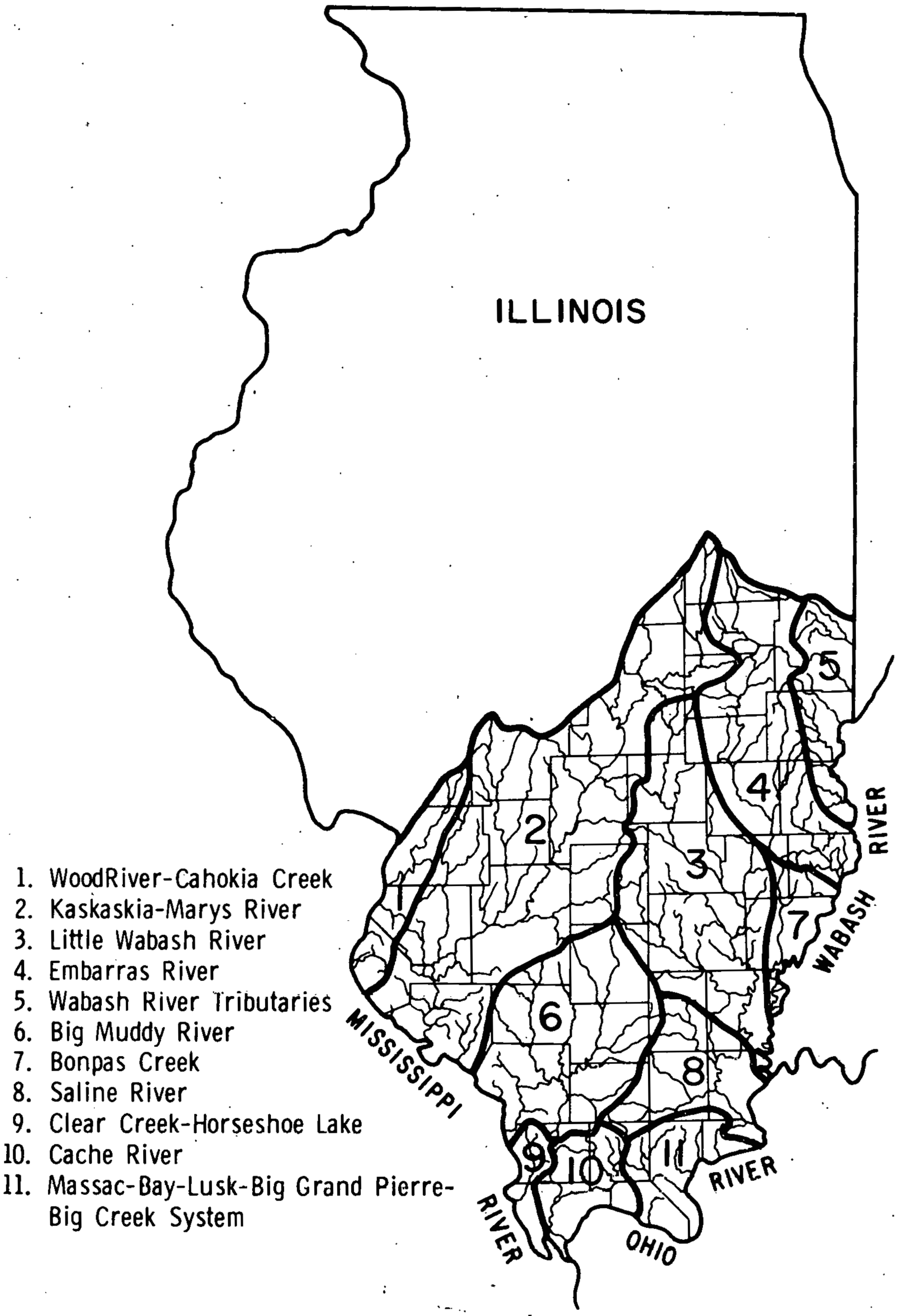


Fig. 9.8. Major Rivers and Tributary Drainage Basins in the SILSA.

Table 9.8. Selected Flow Data for Major Rivers in SILSA

River	Drainage Area (mi^2)	Maximum Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Low Flow 7day - 10yr (cfs)
Mississippi[a]	717,000	893,000	188,700	23,400	-
Ohio[b]	203,000	-	257,200	-	-
Wabash[c]	28,600	305,000	26,270	1,620	2250
Kaskaskia[d]	5,220	83,000	3,622	13	66
Big Muddy[e]	2,154	33,000	1,787	0	0

[a]At Thebes, Ill., Ref. No. 14.

[b]At Metropolis, Ill., Ref. No. 15.

[c]At Mount Carmel, Ill., Ref. No. 16.

[d]At New Athens, Ill., Ref. No. 16.

[e]At Murphysboro, Ill., Ref. No. 16.

locity and the majority of the river discharge is carried by the barge annel.[17] This allows colonization by species typical of free-flowing water.[18] ınerefore, a mixed assemblage of lake and reservoir species and species common in free-flowing rivers occurs in the Mississippi River where it borders the SILSA.

Primary production in the dredge channel may be insufficient to provide the necessary organic matter for herbivorous organisms within the system. However, drifting organisms from the upstream impoundments and input of organic detritus from lateral marshes and sloughs, provide the organic matter requirements in this section of the river. The herbivorous organisms are probably not food-limited and many species of benthic nematodes, annelids, mollusks, dragonflies, stoneflies, mayflies, and midges occur in this section.[18] These organisms provide food for a diverse array of forage fish species like minnows. Commercial fish (carp, buffalo, drum) and game fish (walleye, sauger, smallmouth bass) are common in this section and provide considerable fishing potential.[17] In general, this section of the river is rich in number of aquatic species.

The section of the Ohio River that forms the southeastern boundary of the SILSA consists of a series of impoundments. This reach extends from the confluence of the Ohio and Mississippi Rivers to the confluence of the Ohio and Wabash Rivers. It contains four lock and dam facilities that regulate the flow rates.[19] Annual cycles of discharge and velocity show less variation than the free-flowing section of the Mississippi previously described.[19] Shoal areas and marshes are present along the impoundment margins, but they are not as frequently affected by flooding, meandering, and low water levels when compared to the free-flowing sections of the Mississippi River.

The impoundments on the Ohio River develop thermal stratification and generally function more like long narrow lakes than flowing rivers. Although these areas probably exhibit lower habitat diversity than free-flowing rivers, the existing habitats provide greater seasonal and year to year stability.[18] However, this section of the Ohio River supports a less diverse biotic community and productivity is lower than in the section of the Mississippi River described above.[19] The construction of dams and contamination by industrial and domestic pollutants have affected the habitat and brought about changes in the biotic assemblages.[19]

Phytoplankton form the base of the trophic structure in the impoundments, but the major groups present include a proportion of blue-green algae that are not known to be important food for herbivorous organisms.[19] The zooplankton community consists primarily of rotifiers, but some cladoceran and copepod species do occur. The benthic macroinvertebrate populations are low in most areas, probably the direct result of silted substrate, low dissolved oxygen, and perhaps toxic pollutants. In response to declining production in these lower trophic levels, fish stocks declined. Populations of such game species as bass, walleye, sauger, and crappie have been all but extirpated from most of the lower section of the Ohio River. In addition, there is no measurable commercial fishing on this section of the river.[19]

The Wabash River forms the eastern border of the SILSA. It discharges the Ohio River at a point about 133 miles upstream from the Ohio-Mississippi River confluence. Habitat types within this section are primarily riffle-pool areas, but backwaters, marshes, and sloughs are common, particularly in the meandered segments. The main stem of the Wabash is free-flowing and no locks or dams are present.[20]

Water quality in the Wabash River has been impacted by agricultural, municipal and industrial discharges. Eutrophication resulting from excessive inputs of nitrates and phosphates has resulted in nuisance algal blooms.[21] Decaying algae and organic waste have reduced dissolved oxygen in some areas.

Periphytic algae and seasonal blooms of planktonic diatoms support the herbivores within the river. Macroinvertebrate populations include primarily pollution-tolerant species. Fish populations include some game species, but more tolerant species such as carp, drum and buffalo predominate. Some commercial fishing is conducted on the river but annual catches have declined drastically since the turn of the century. Commercial harvesting of mussel shells is still practiced in some areas of the Wabash River.[21]

The most important source of pollution in the major rivers is agricultural runoff. These rivers are located within and drain extensive portions of the cornbelt, which enhances their sediment and nutrient load. Total suspended solids in these rivers generally are greater than or equal to 1900 ppm.[22] Nitrate and phosphate fertilizers are also transported to these rivers from agricultural drainage, and indications of eutrophication have been observed in all three rivers. In addition, detectable but nontoxic concentrations of pesticides have been measured in these rivers.[22]

Other sources of potential perturbation to the major rivers include acid mine drainage, toxic element discharge, and waste heat. Acid mine drainage from tributary inputs enters all the major rivers. However, the availability of dilution water and natural buffering capacity in the rivers currently prevent acidity from exceeding alkalinity, and the pH remains at or above neutrality (pH = 7.1).

The mean concentrations of selected trace elements in the major rivers are shown in Table 9.9.[23] These values are roughly similar among the three rivers and they generally do not exceed the national average, the 1972 water quality criteria, or the toxicity threshold of most aquatic organisms.[24] The data do not suggest excessive trace element loading of the major rivers.

Thermal effluents are discharged to all the major rivers. These inputs may alter both the spatial and temporal aspects of the thermal regime in a river. Increased power developments that discharge heated effluent may cause changes in the biota and changes in some functional aspects of the river ecology. However, an extensive data base would be required to detect such changes.

9.5.2 Tributary Streams

Although a general description of the tributary streams (Fig. 9.8) within the SILSA is complicated by the variation in habitat and current pollution impacts, a few common features can be summarized.

Table 9.9. Comparison of Mean Concentrations (μg/1) of Trace Elements for Selected SILSA Rivers and the U. S.[23]

Element	Mississippi E. St. Louis, Ill.	Ohio Cairo, Ill.	Wabash New Harmony, Ind.	Mean United States
Zinc	35	18	51	64
Boron	75	43	72	101
Iron	31	27	27	52
Manganese	5.7	2.9	7.1	58
Copper	8	9	39	15
Barium	51	41	42	43
Strontium	94	103	133	217
Molybdenum	70	36	84	68
Phosphorus	132	-	-	120
Aluminum	-	27	48	74
Lead	-	13	35	23
Chromium	-	7	-	9.7

In general, these streams can be classified as warmwater streams. Their annual thermal cycle is quite variable, and depends upon the source of the water, the degree of shading, and the discharge volume. Their temperature range usually varies between the freezing point and 32°C.[14] Their seasonal discharge levels are highly variable and dessication of the aquatic communities is typical since droughts are a common feature in this area in the late summer months. Southern Illinois streams have a low gradient and they meander across the low-relief terrain. The basins are usually wooded, brushy areas wherever agricultural clearing has not removed the woody vegetation. Oxbow lakes, lateral swamps, impoundments, and sloughs are common in the lower reaches of these streams while riffle-pool habitat occurs in headwater areas where the stream gradients are steeper. Some level of channelization and/or ditching has occurred in most of the basins. This practice is required in some areas to encourage streamflow and prevent seasonal flooding of agricultural land.[14]

The major perturbations to these streams result from high intensity agriculture which has caused stream bed siltation in much of the region. As a result, total suspended solids and nutrient loads (nitrates and phosphates) are high in most drainages. Other pollution impacts include acid drainage from both strip and deep coal mining operations, oil field drainage, domestic sewage, and industrial wastes.[14]

The biota within the tributary streams is quite variable and is related) the perturbations described above. Phytoplankton populations are quite low ı the free-flowing sections. However, attached algal populations and aquatic macrophytes are abundant in some streams and are stimulated by high nutrient loads. These plants provide a portion of the organic matter required by herbivorous organisms in some streams. However, in other streams where plant populations are low, the consumer populations are primarily dependent upon organic detrital inputs for their supplies of organic matter.

Although macrobenthic populations are high in some areas, siltation of benthic habitat has probably reduced both the abundance and diversity of these organisms within many of the streams in the SILSA. Along with other factors, this has resulted in the loss of some fish species within these drainages. Abundance of fish species is declining in southern Illinois and some streams are presently devoid of fish.[14]

Table 9.10 provides a summary of the pertinent details of each of the individual drainage basins in the SILSA. It is clear from this summary and the observations on major rivers that the current level of perturbation to aquatic resources in the SILSA is severe.

9.6 WILDLIFE INVENTORY OF SOUTHERN ILLINOIS

9.6.1 Wildlife Resources

The distribution and abundance of wildlife species in southern Illinois are largely functions of the natural vegetation and man's influence on the natural communities. The southern third of Illinois includes two biotic provinces.[25] The Carolinian biotic province includes both deciduous forest and grassland communities. The Austroriparian biotic province is typified by floodplain forests and includes the extreme southern portion of the state (Alexander, Pulaski, Massac, and southern Pope Counties). As a result of the irregular terminus of the glaciation (see Fig. 9.6) grasslands in southern Illinois are disjunct (isolated and discontinuous) from the grasslands of central and northern Illinois. Consequently, some mammals, birds, and reptiles characteristic of the northern tall grass prairies are encountered in isolated areas of southern Illinois.

The animal communities of the SILSA are best categorized as a Deciduous Forest Biociation, a Deciduous Forest-Edge Biocies, and a Prairie Biociation.[26] The forest edge provides habitat for more wildlife species than do the deciduous forest proper and prairies. Some characteristic vertebrates of each type are listed in Table 9.11.

9.6.1.1 Mammals

The geographic ranges of fifty-one mammalian species encompass all or a portion of the southern third of Illinois (see Appendix Table 9A-2).[27,28] Common species inhabiting mesic deciduous forests include the eastern gray squirrel, eastern chipmunk, white-footed mouse, short-tailed shrew, big brown bat, little brown bat, gray fox, and opossum. The lowland and swamp forests of extreme southern Illinois provide habitat for the white-footed mouse, golden mouse, and raccoon. The rice rat, golden mouse, swamp rabbit, and beaver also inhabit lowland forests in southern Illinois. The pine vole and

Table 9.10. Selected Descriptive Features of Drainage Basins within the SILSA[14]

Drainage Basin	Potential Productivity Rating	Fish Species Present	Pollution Sources	Habitat Variety	Remarks
Wood River-Cahokia Creek	Poor	64	Agricultural silt, industrial, coal mine acid	Low	Subject to droughts
Kaskaskia-Marys River	Variable	104	Agricultural silt, industrial, oil fields	High	Dredging, reservoirs and barge traffic common
Little Wabash River	Lower-Poor Upper-Good	78	Agricultural silt, oil fields	Variable	Subject to droughts
Embarrass River	Variable	92	Agricultural silt, oil fields	High	Rechannelized
Wabash River Tributaries	Good	82	Oil fields	High	Subject to droughts
Big Muddy River	Very poor	88	Agricultural silt, industrial	Low-Variable	Subject to droughts, reservoirs common
Bonpas Creek	Fair	71	Agricultural silt, oil fields	Low	Subject to pond and lake drainage
Saline River	Poor	57	Agricultural silt, oil fields, coal mine acid	Low	Rechannelized and devoid of fish in some areas
Clear Creek-Horseshoe Lake	Excellent	99	Clean and fairly clear	High	Luxuriant vegetation and spring fed
Cache River	Good	81	Agricultural silt	High	Gravelly riffles, cypress swamps, some springs
Massac-Bay-Lusk-Big Grand Pierre-Big Creek System	Excellent-Good	79	Agricultural silt	High	Gravelly riffles, marginal lakes and swamps

Table 9.11. Representative Animals of Deciduous Forests, Deciduous Forest Edge, and Prairies in Southern Illinois[a,b]

Deciduous Forest	Deciduous Forest Edge	Prairie
Opossum	Eastern cottontail	Eastern cottontail
Short-tailed shrew	Woodchuck	Thirteen-lined ground squirrel
Eastern chipmunk	Fox squirrel	Deer mouse
Southern flying squirrel	Red fox	Meadow vole
Gray squirrel	Long-tailed weasel	Prairie vole
White-footed mouse	Striped skunk	Coyote
Gray fox	White-tailed deer	Long-tailed weasel
Racoon		
	Turkey vulture	Greater prairie chicken
Great horned owl	Red-tailed hawk	Horned lark
Barred owl	Sparrow hawk	Meadowlark
Whip-poor-will	Bobwhite	Dickcissel
Pileated woodpecker	Mourning dove	Upland plover
Red-bellied woodpecker	Common nighthawk	
Downy woodpecker	Ruby-throated hummingbird	Plains garter snake
Great crested flycatcher	Red-headed woodpecker	Fox snake
Eastern wood pewee	Flicker	Bullsnake
Black-capped chickadee	Eastern kingbird	Blue racer
Red-eyed vireo	Common crow	Eastern hognose
Ovenbird	Bluejay	American toad
	Catbird	Small-mouth salamander
Timber rattlesnake	Brown thrasher	
Northern copperhead	Robin	
Black rat snake	Yellow warbler	
Eastern box turtle	Brown-headed cowbird	
Five-lined skink	Common grackle	
Red-backed salamander	American goldfinch	
Wood frog	Field sparrow	
Eastern gray treefrog	Song sparrow	
	Blue racer	
	Eastern milk snake	
	Eastern garter snake	

[a] Modified from S. C. Kendeigh, *Ecology with Special Reference to Animals and Man*, Prentice Hall, Inc., Englewood Cliffs, N. J., 474 pp. (1974).

[b] P. W. Smith, *The Amphibians and Reptiles of Illinois*, Bull. Ill. Nat. Hist. Surv., Vol. 28, pp. 1-298, Urbana, Ill. (1961).

white-footed mouse occur predominantly in oak and pine savannas, while the meadow jumping mouse commonly inhabits sparsely wooded areas near streams. The woodchuck, red fox, striped skunk, eastern cottontail, and white-tailed deer are common throughout southern Illinois in forest-edge habitats. The bobcat is an endangered species[29] in Illinois; its occurrence is correlated with the presence of extensive (several hundred acres) floodplain forests.

Twelve bat species inhabit at least a portion of southern Illinois. Three species (hoary bat, red bat, silver-haired bat) are migratory, leaving the southern Illinois area in early fall. Most bats roost in trees or caves and are nocturnal insectivores that usually feed over bodies of open water or in wooded areas, particularly those of floodplains.

Several rodent species inhabit grasslands such as old fields, pastures, and grass-covered railroad and highway rights-of-way. The western harvest mouse, deer mouse, thirteen-lined ground squirrel, and eastern cottontail commonly inhabit mesic grasslands, while the meadow vole is very abundant in moist sites supporting a more dense cover of grasses and forbs.

9.6.1.2 Birds

A total of 246 bird species (see Appendix Table 9A-3) utilize southern Illinois habitats for all or part of their life cycles.[30] Eighty-six species are classified as migrants, 88 are summer residents, 56 are permanent residents, and 24 are winter residents. Some species are classified both as summer and winter residents since some individuals of a species overwinter in extreme southern Illinois and others breed in south central Illinois. A total of 238 species has been observed on the 43,000-acre Crab Orchard National Wildlife Refuge in Williamson County.[31]

Grasslands (old fields, pastures, etc.) provide nesting and foraging habitat for many passerine species as well as for birds of prey. Common nesting birds of grasslands include the red-winged blackbird, eastern meadowlark, bobwhite, and dickcissel. A meadowlark nesting study conducted in Jackson and Williamson Counties, Illinois,[32] revealed the following nest densities (no. nests/40 hectares or 100 acres): pastures, 20.9; hay fields, 12.6; old fields, 5.1; wheat field, 4.8; idle areas, 3.8; fallow fields, 2.0. In a comparable study of bobwhites in the same general area, Klimstra and Roseberry[33] found that nest sites were common on both agricultural fields (hay and pasture) and old fields. Most nest sites were in areas characterized by cheatgrass, panic grasses, annual lespedezas, and goldenrods.

The deciduous forests support a rather diverse avifauna as compared to that of grasslands. The tree stratum of upland oak-hickory and lowland ash-maple forests provides foraging and/or nesting habitat for such common residents as the hairy woodpecker, downy woodpecker, red-bellied woodpecker, great crested flycatcher, eastern wood pewee, black-capped chickadee, red-eyed vireo, white-breasted nuthatch, barred owl, and great horned owl. The understory or shrub stratum is used for nesting by the hooded warbler, cerulean warbler, tufted titmouse, and wood thrush. The ovenbird and whip-poor-will construct their nests in leaves on the forest floor. In general, the ovenbird and red-eyed vireo are the two most abundant species in deciduous forest stands. An average breeding population in deciduous forests for each of these species is 35-40 pairs per 40 hectares (100 acres).[26] An average total breeding bird density for eastern deciduous forests is 200 pairs per 40 hectares.[26]

Deciduous forest edge communities support the greatest bird species diversity of all southern Illinois communities. Characteristic forest edge species can be encountered in natural and artificial clearings as well as in the forest-grassland ecotone. Common passerine residents of forest-edge communities include the song sparrow, field sparrow, red-eyed towhee, American goldfinch, brown-headed cowbird, yellowthroat, yellow warbler, robin, eastern bluebird, catbird, brown thrasher, blue jay, common crow, eastern kingbird, flicker, red-headed woodpecker, common nighthawk, mourning dove, and yellow-billed cuckoo. The red-tailed hawk, turkey vulture, and sparrow hawk are the most common birds of prey inhabiting the forest edge. The bobwhite feeds primarily in agricultural areas but utilizes the forest edge as cover and nesting habitat.

Marshes, lakes, and ponds provide habitat for many overwintering migratory waterfowl and shorebirds. Mr. Steven Frick* (pers. comm.) estimates the 1975-76 winter population of Canada geese in southern Illinois at approximately 300,000. The mallard, black duck, gadwall, pintail, green-winged teal, American widgeon, shoveler, ring-necked duck, lesser scaup, common goldeneye, bufflehead, ruddy duck, hooded merganser, and common merganser are common winter resident waterfowl at the Crab Orchard National Wildlife Refuge.[29] The redhead and canvasback are now uncommon winter residents of the area. Wood ducks, mallards, and blue-winged teal are the most common nesting waterfowl species in southern Illinois. Other marsh species which breed in the area are: the pied-billed grebe, American bittern, green heron, black-crowned night heron, yellow-crowned night heron, and American woodcock.

9.6.1.3 Reptiles

The geographic ranges of 64 reptilian species include all or a portion of southern Illinois (see Appendix Table 9A-4).[34,35] The southern two tiers of Illinois counties provide habitat such as cypress swamps and lowland forests which are typical of more southern areas. Reptilian species occurring in this area, whose northern and eastern distribution reaches extreme southern Illinois and portions of the lower Mississippi and Ohio River Valleys, include the hieroglyphic turtle, alligator snapping turtle, green water snake, cottonmouth, scarlet snake, and western mud snake.[34]

Some mesic and xeric deciduous forests of southern Illinois are typically interspersed and dissected by sheer bluffs and rock outcrops. Forest openings in these communities are commonly inhabited by the northern fence lizard, ground skink, five-lined skink, and broad-headed skink. The northern copperhead, black rat snake, blue racer, and eastern box turtle are abundant in mesic deciduous forests.

South-central Illinois has less topographic relief than areas further south, such as the Shawnee National Forest. The south-central region is characterized by scattered woodlots, savannas, old fields, and poor quality

---

**Waterfowl Biologist, Crab Orchard National Wildlife Refuge, Herrin, Illinois.*

agricultural lands. Reptiles characteristic of the forest edge community in this region include the northern fence lizard, five-lined skink, broad-headed skink, eastern hognose snake, blue racer, rough green snake, brown snake, and midland water snake. Common species of the deciduous forest interior communities include the black rat snake, timber rattlesnake, and red milk snake. The skink species mentioned above are also abundant in deciduous forest openings created by natural causes or lumbering activities. Timber harvesting in the northern portion of the SILSA has resulted in substantially increased acreage of forest-edge habitat. The plains garter snake, fox snake, blue racer, eastern hognose, and ornate box turtle are common inhabitants of disjunct prairie areas[34] throughout the northern third of the SILSA.

Marshes, lakes, and floodplains of southern Illinois provide habitat for seven species of water snakes; the eastern garter snake, common snapping turtle, midland painted turtle, and western painted turtle.

9.6.1.4 Amphibians

Thirty-five species of amphibians are found in a variety of terrestrial and semi-aquatic habitats in the SILSA (Appendix Table 9A-4).[34,35] As is the case with reptiles, the amphibian species composition of the area is representative of tall grass prairies and deciduous forests. The influence of lowland forests and swamps is evident on the amphibian species composition of extreme southern Illinois. This area includes many species characteristic of the gulf coast and lower Mississippi River drainage basin whose northward distribution reaches southern Illinois.[34]

Four species--the eastern gray treefrog, woodfrog, central newt, and red-backed salamander--are encountered primarily in deciduous forests. Salamander species such as the cave slamander, long-tailed salamander, two-lined salamander, and dark-sided salamander spend all or most of their lifetime in rocky streams or around hillside springs in forested areas. The mudpuppy inhabits most rivers and streams in the area. The hellbender is found only in rocky streams that are tributaries of the Ohio and Wabash Rivers.[34] The bird-voiced treefrog, green treefrog, eastern spadefoot, and mole salamander occur primarily in floodplain forests of extreme southern Illinois. Other amphibian species are more difficult to assign to a given habitat type. Bullfrogs and leopard frogs inhabit farm ponds and lakes. The upland and western chorus frogs, American toad, and spring peeper are quite ubiquitous, and are commonly encountered during the breeding season in lakes, farm ponds, flooded agricultural fields, prairie areas, and along roadways.

9.6.2 <u>Wildlife Management and Hunting</u>

Wildlife management and hunting in southern Illinois primarily involve deer, upland game species (mourning doves, rabbits, squirrels), and waterfowl. A total of 16 species or species groups are classified as game (Table 9.12). The only large upland game species which have been the subject of game management programs are the wild turkey, pheasant, and white-tailed deer. Certain species can be considered peripheral game species when considering economic benefits, hunter interest, and annual harvest. The raccoon, red fox, and gray fox are examples of southern Illinois species which can be placed in this

Table 9.12. Wildlife Species Hunted in Southern Illinois

Mammals	Birds
Eastern cottontail	Wild turkey
Raccoon	Ring-necked pheasant
Red fox	Bobwhite
Gray fox	Mourning dove
Gray squirrel	Woodcock
Fox squirrel	Canada goose
White-tailed deer	Snow goose
	Ducks[a]

[a]Includes many species with the mallard being the most common.

category. Although the raccoon is abundant in lowland forests throughout the state, its value as a game species is much below that of the eastern cottontail, gray squirrel, and fox squirrel. The density of foxes in most areas of southern Illinois is relatively low; thus foxes are of lesser importance to hunters than are other mammals.

Hunting is one of the most important recreational activities in southern Illinois. Wildlife harvest data for the SILSA are provided in Appendix Table 9A-5. Although the data represent the efforts of only one percent of Illinois' licensed hunters, general comparisons of game harvest between counties can be made. The harvest data are also generally indicative of differences in species density between counties.

Waterfowl hunting is most intense in Williamson, Union, Alexander, and Jackson Counties. From an economic standpoint the Canada goose, snow goose, and a variety of ducks are the most important species hunted in three major conservation areas. The three areas most heavily hunted are: the Crab Orchard National Wildlife Refuge in Williamson Co. (43,000 acres), the Union County Conservation Area (6202 acres), and the Horseshoe Lake Conservation Area (7901 acres) in Alexander County. In all three areas, grains such as corn, wheat, barley, rye, and oats are planted as winter waterfowl food. These and other designated conservation areas and some state parks have ongoing programs to provide winter waterfowl habitat and hunting areas. All state conservation areas have a master plan for wildlife management.

One major function of the Illinois Department of Conservation is to fund wildlife research and management throughout the state. Three principal methods are employed for implementing the management and research programs:

(1) The Department of Conservation administrates the activities of wildlife biologists and park rangers in conservation areas and state parks (see Table 9.13 and Fig. 9.9).

(2) The Department of Conservation allocates funds to the Illinois Natural History Survey for wildlife research. Several studies have been conducted on various aspects of the life history, response to various management practices, and distribution of the pheasant and quail in central and southern Illinois.[36-39]

(3) Funds are provided to the Shawnee National Forest by the Department of Conservation for such activities as the improvement of duck habitat in lowland areas of the national forest.

Other wildlife research and management studies in southern Illinois have been conducted by the U. S. Fish and Wildlife Service at Crab Orchard National Wildlife Refuge and the Cooperative Wildlife Research Laboratory at Southern Illinois University.

The Shawnee National Forest also has a wildlife management plan[40] even though their primary emphasis is on forestry management and research. As of June 1968, national forest land consisted of 229,248 acres in portions of ten Illinois counties. Forestry management is hindered somewhat due to the large amount of privately owned land interspersed within forestry land. The Shawnee National Forest proclamation boundary encompasses 848,000 acres. Current wildlife management programs include the following:

(1) Approximately 1500 wildlife water areas averaging 0.5 to 1.0 acres are presently being developed.

(2) A total of 6000 wildlife clearings and food plots are being developed throughout the forest. These areas will average one acre per plot.

(3) Waterfowl habitat will be improved in areas such as the LaRue Pine Hills area (Union Co.), the Oakwood Bottoms (Jackson Co.), and Bell Pond (Pope Co.).

(4) A continuing effort will be made to establish and expand existing wild turkey and ruffed grouse populations.

(5) Existing habitat will be maintained in a manner conductive to wildlife.

(6) Specific management plans will be developed for endangered species.

The LaRue Pine Hills Ecological Area in Union County is a unique natural area within the Shawnee National Forest. It encompasses 1966 acres characterized by lowland forests (the LaRue "Swamp") and limestone bluffs that support deciduous and mixed coniferous-deciduous forests. The flora is unique in that one-third of all Illinois plant species have been recorded in the area, including approximately 40 species which are rare in Illinois.[41] wide variety of terrestrial vertebrates (40 mammals, 24 amphibians, 35 ptiles, 173 birds) has been recorded in the area.

Table 9.13. State Parks and State Conservation Areas in Southern Illinois

State Park or Conservation Area	County	Size (acres)[a]	Allows Hunting
Horseshoe Lake Conservation Area	Alexander	7,901	X
Carlyle Reservoir State Park	Clinton	18,729	
Lincoln Log Cabin State Park	Coles	86	
Fox Ridge State Park	Coles	752	
Ramsey Lake State Park	Fayette	815	X
Wayne Fitzgerald State Park	Franklin	3,300	X
Hamilton County Conservation Area	Hamilton	1,683	X
Cave-in-Rock State Park	Hardin	64	
Giant City State Park	Jackson	2,199	
Lake Murphysboro State Park	Jackson	904	
Sam Parr State Park	Jasper	790	
Pere Marquette State Park	Jersey	5,637	
Piasa Creek Conservation Area	Jersey	11	
Ferne Clyffe State Park	Johnson	1,073	
Red Hills State Park	Lawrence	948	X
Lincoln Trail Homestead State Park	Macon	162	
Spitler Woods State Park	Macon	203	
Beaver Dam State Park	Macoupin	737	
Stephen A. Forbes State Park	Marion	3,100	X
Mermet Lake Conservation Area	Massac	2,461	X
Fort Massac State Park	Massac	933	
Pyramid State Park	Perry	2,524	
Dixon Springs State Park	Pope	399	
Fort Kaskaskia State Park	Randolph	234	
Randolph County Conservation Area	Randolph	1,001	X
Saline County Conservation Area	Saline	1,208	X
Union County Conservation Area	Union	6,202	X
Beall Woods Nature Preserve and Conservation Area	Wabash	636	
Sam Dale Conservation Area	Wayne	1,301	
Washington County Conservation Area	Washington	1,378	X

[a]Acreages were taken from 1970 Official Highway Map of Illinois and information provided by Mr. Jack Golden of the Illinois Department of Conservation.

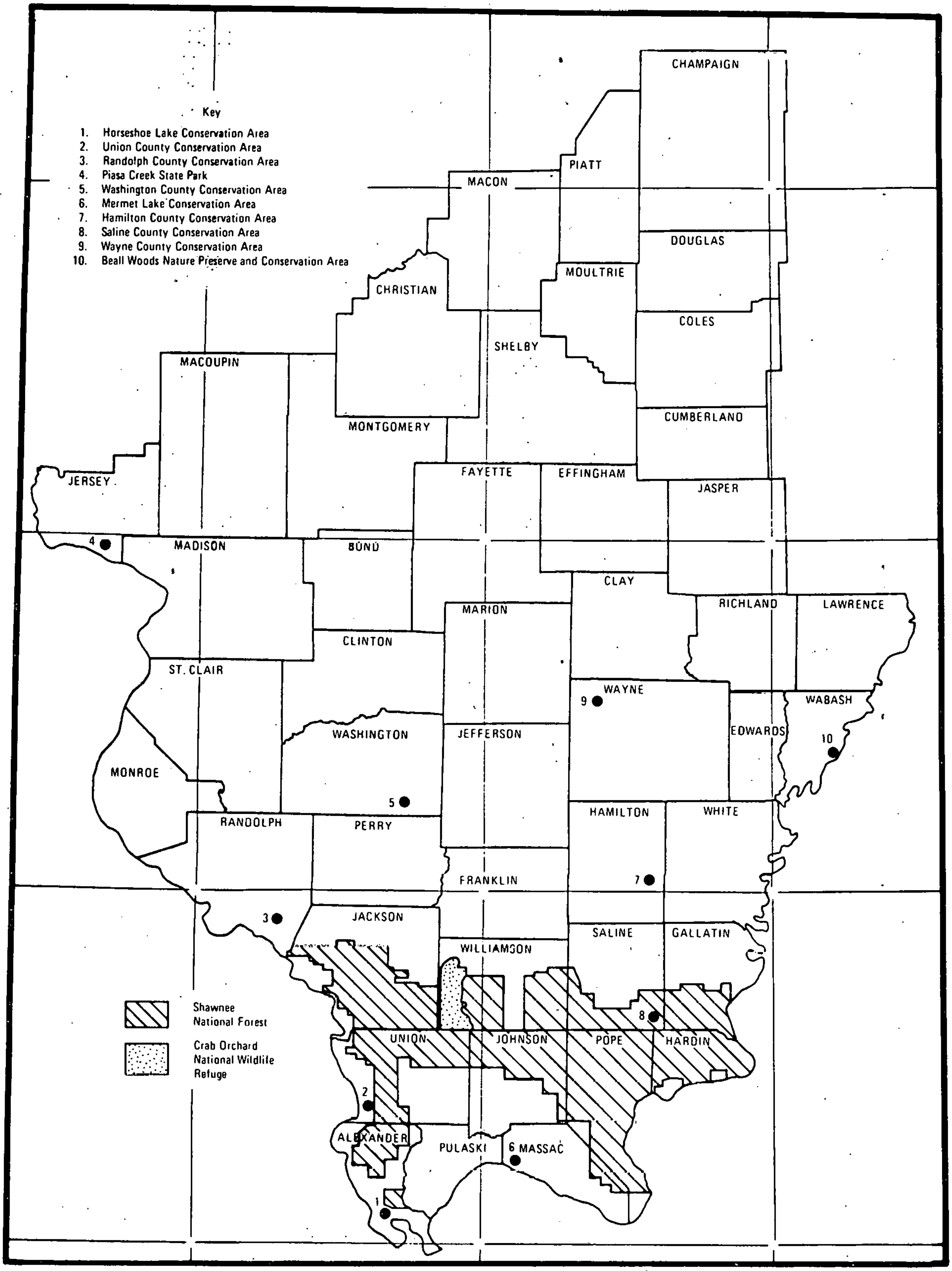


Fig. 9.9. Conservation Areas and National Forest in the SILSA.

In general, wildlife management practices involve the same ecological principles regardless of geographic setting. The establishment and maintenance of forest-edge habitat provides cover and habitat for the greatest number of wildlife species. Vegetation management through the seeding of small plots with grains such as corn, oats, wheat, and grasses such as bluestem and redtop is a commonly employed technique of providing food for upland game species such as rabbits and quail. Waterfowl benefit greatly from the planting of corn, oats, wheat, rye, and barley in agricultural fields adjacent to lakes and marshes. Mourning dove density and survival are enhanced by planting sunflowers. The fox squirrel, wild turkey, and ruffed grouse exhibit preference for hardwood forests interspersed with grass and shrub areas. Forested areas in which 5-10% of the total acreage consists of scattered openings (one-half to an acre in size), provide attractive ruffed grouse habitat. The white-tailed deer prefers forest-edge habitat. Forest clearing and the planting of shrubs such as autumn olive have substantially improved deer habitat throughout the southeastern United States including southern Illinois.

9.6.3 Important Game Species

9.6.3.1 Birds

Canada Goose

The majority of the Canada geese migrating along the Mississippi Flyway overwinter in southern Illinois and Missouri. The Illinois Department of Conservation estimates the current winter population of the Canada goose in Illinois at 300,000 to 350,000 individuals (Jack Golden, pers. comm.).* Winter populations at Crab Orchard Wildlife Refuge have gradually increased over the last five years. The peak population in 1971-72 was 64,000 compared to 87,000 in 1975-76.

Much of the recent increase in the populations of waterfowl utilizing southern Illinois as winter habitat can be attributed to the management practices of waterfowl biologists. Agricultural fields have been planted in corn, wheat, oats, rye, and barley to provide food for wintering waterfowl. Observations of feeding activity from October through March at Crab Orchard National Wildlife Refuge showed the following feeding-time allocation: cornfields, 41%; small grains, 24%; pasture, 22%; soybeans, 9%; wheat, stubble, and lespedeza fields, 4%.[42]

Bobwhite

The bobwhite is the most important game bird in southern Illinois. Suitable habitat is available in most southern Illinois counties. Studies conducted on the responses of bobwhite to vegetation management at Forbes State Park (Marion Co.) and the Sam Dale Lake Conservation Area (Wayne Co.)[36] indicate that quail are truly an early successional species and respond best to management schemes involving sharecropping and prescribed burning. Population densities increased from 56 per 100 acres in 1966 to 96 per 100 acres in

---

**Jack Golden, Illinois Department of Conservation, Region V Headquarters, Benton, Illinois.*

1968. This density increase was similar to that observed for a population in the Southern Illinois University Carbondale Research Area.[33] Densities of quail throughout southern Illinois range from 0.2 birds per acre in unmanaged areas to one bird per acre in managed optimum habitat.[36]

In the studies on bobwhite populations at the conservation areas mentioned above, vegetation management was employed. Crops planted in managed areas included corn and soybeans in the spring followed by wheat or oats in the fall. The following spring approximately one-third of each grain field was seeded with redtop and one-third with timothy or red clover. An analysis of the crops of over 1500 bobwhite indicated a preference for agricultural seeds such as corn, wheat, soybeans, and milo.[36] Natural food items commonly eaten were common ragweed and crabgrass. The percent of vegetative cover 6 to 18 months after sharecropping ranged from 15% to 36%. The successional species commonly encountered included ragweed, Korean lespedeza, goldenrod, fall white aster, and beggarticks.[36] This vegetative cover provided some canopy for protection and permitted quail to move freely in search of food.

In a quail nesting study conducted in Williamson County,[36] nest sites were found mainly in idle fields or along fence rows. Most nest sites were in areas covered by cheatgrasses, panic grasses, annual lespedezas, and goldenrods. Preferred nesting habitat was most abundant in idle fields during the perennial weed stage and early shrub stage. Approximately 56% of all nests were near shrubs or thickets, thus demonstrating the importance of forest-edge habitat to this species.

9.6.3.2 Mammals

Eastern Cottontail

The cottontail is abundant in pasture fields, abandoned fields, fencerows, highway, and railroad rights-of-way throughout southern Illinois. Kentucky bluegrass, red clover, crabgrass, alfalfa, and soybeans are important spring and summer food items.[43] The winter diet includes some of the above items plus buds, bark, and twigs of species such as dogwood, elm, rose, and apple.[27] Population densities vary seasonally and annually with highest densities generally occurring in late summer and early fall.

Gray and Fox Squirrels

Deciduous forests support populations of gray and fox squirrels throughout central and southern Illinois. Gray squirrels are commonly seen along city streets, and in trees, parks, wooded city lots, dense upland forests, and lowland forests.[27] The gray and fox squirrels usually do not inhabit the same woodlot in Illinois. Gray squirrels prefer more dense forest stands while fox squirrels are more common in forest edge habitat. The diet of both species consists of the buds, seeds, acorns, nuts, or fruits of nearly all trees.[27,44]

In a ten-year study of gray and fox squirrels in an oak-hickory forest southern Ohio,[45] population densities were shown to be strongly correlated th the previous year's seed production. The responses of squirrels to a heavy seed crop were (1) improved survival of the young from first litters of the season, (2) a lower rate of emigration of both young and adults, (3) an increase in fecundity, and (4) a positive correlation between adult survival and the size of the hickory seed crop. A minimum of 58.9 kg (130 lb) of seed per 0.4 ha (1 acre) was needed to sustain high squirrel densities (> 0.7/acre). These population levels were attainable in areas where the total basal area of seed-producing trees was 3.2-3.7 m^2/0.4 ha (35-40 ft^2/acre). The highest squirrel densities were recorded in areas where stands of mature hickories constituted 30-40% of the basal area of the forest stands.

White-Tailed Deer

From the standpoint of economy and hunter interest, the white-tailed deer and Canada goose are the most important Illinois game species. Forest edge habitat adjacent to corn fields and pasture provide ideal deer habitat. The Shawnee National Forest and Crab Orchard National Wildlife Refuge have wildlife management programs beneficial to deer. The planting of the shrub autumn olive in forest clearings provides deer cover and winter browse. Such tree species as persimmon, red cedar, apple, pin oak, and American elm are important deer browse. Sumac, wild grape, gooseberry, raspberry, and hawthorn are also important summer food items. Common food items consumed by deer in agricultural areas are corn and Kentucky bluegrass.[40]

In a six-year study[46] in Missouri, a seasonal shift was demonstrated in deer food habits. A volumetric analyses of 578 deer stomachs showed that oak mast, corn, and various fruits are staple deer foods in Missouri. Because forests and agricultural practices in southern Illinois and Missouri are similar, the food preferences shown in the Missouri study[46] are applicable to Illinois deer.

The annual Illinois deer harvest has fluctuated considerably over the past 20 years, probably due mainly to changes in deer abundance. Recorded harvests for eleven southern Illinois counties are provided in Table 9.14. The total deer kills in Hardin, Johnson, Pope, Williamson and Union Counties during the period from 1957 through 1968, far exceeds the totals for other counties in the SILSA.

9.7 ENDANGERED SPECIES OF SOUTHERN ILLINOIS

9.7.1 Endangered Plants of Southern Illinois

Although the Illinois Nature Preserves Commission has prepared a preliminary list of rare and endangered plant species of Illinois,* data relevant to distribution at the county level are lacking or incomplete for most species involved. Consequently, the federal list of threatened and endangered plant species[47] whose geographic range includes all or part of the SILSA will be used for the discussion of coal extraction and utilization impacts.

**Letter from Gerald A. Paulson, Illinois Nature Preserves Commission, to Carolyn J. Boone, Argonne National Laboratory, January 14, 1975.*

Table 9.14. Deer Kills in 11 Southern Illinois Counties[a]

<table>
<tr><th>County</th><th>1957</th><th>1958</th><th>1959</th><th>1960</th><th>1961</th><th>1962</th><th>1963</th><th>1964</th><th>1965</th><th>1966</th><th>1967</th><th>1968</th></tr>
<tr><td>Allexander</td><td>82</td><td>38</td><td>8</td><td>4</td><td>11</td><td>39</td><td>42</td><td>57</td><td>86</td><td>91</td><td>81</td><td>117</td></tr>
<tr><td>Gallatin</td><td>16</td><td>29</td><td>55</td><td>50</td><td>77</td><td>96</td><td>97</td><td>113</td><td>125</td><td>73</td><td>68</td><td>86</td></tr>
<tr><td>Hardin</td><td>59</td><td>116</td><td>197</td><td>175</td><td>245</td><td>370</td><td>281</td><td>255</td><td>241</td><td>210</td><td>234</td><td>286</td></tr>
<tr><td>Jackson</td><td>60</td><td>96</td><td>72</td><td>53</td><td>107</td><td>151</td><td>109</td><td>109</td><td>133</td><td>119</td><td>110</td><td>157</td></tr>
<tr><td>Johnson</td><td>15</td><td>29</td><td>56</td><td>67</td><td>131</td><td>224</td><td>296</td><td>310</td><td>299</td><td>325</td><td>315</td><td>356</td></tr>
<tr><td>Massac</td><td>2</td><td>0</td><td>3</td><td>31</td><td>38</td><td>57</td><td>96</td><td>79</td><td>72</td><td>54</td><td>38</td><td>34</td></tr>
<tr><td>North Pope</td><td rowspan="2">108</td><td rowspan="2">269</td><td rowspan="2">338</td><td rowspan="2">477</td><td rowspan="2">811</td><td rowspan="2">1,358</td><td rowspan="2">1,274</td><td>1,379</td><td>1,716</td><td>1,190</td><td>877</td><td>677</td></tr>
<tr><td>South Pope</td><td>229</td><td>287</td><td>254</td><td>174</td><td>168</td></tr>
<tr><td>Saline</td><td>4</td><td>14</td><td>33</td><td>41</td><td>62</td><td>194</td><td>127</td><td>107</td><td>130</td><td>134</td><td>150</td><td>163</td></tr>
<tr><td>Union</td><td>173</td><td>264</td><td>228</td><td>135</td><td>222</td><td>288</td><td>230</td><td>254</td><td>279</td><td>233</td><td>260</td><td>348</td></tr>
<tr><td>Williamson</td><td>41</td><td>80</td><td>84</td><td>90</td><td>163</td><td>226</td><td>227</td><td>254</td><td>278</td><td>223</td><td>222</td><td>298</td></tr>
<tr><td>Pulaski</td><td>0</td><td>0</td><td>1</td><td>0</td><td>3</td><td>3</td><td>6</td><td>10</td><td>10</td><td>11</td><td>16</td><td>22</td></tr>
<tr><td>Total</td><td>560</td><td>935</td><td>974</td><td>1,023</td><td>1,867</td><td>2,913</td><td>2,779</td><td>3,146</td><td>3,646</td><td>2,906</td><td>2,529</td><td>2,712</td></tr>
<tr><td>Total Illinois Kill</td><td>1,735</td><td>2,655</td><td>2,648</td><td>2,444</td><td>4,323</td><td>6,289</td><td>6,735</td><td>7,087</td><td>7,612</td><td>7,367</td><td>6,613</td><td>8,215</td></tr>
<tr><td>% of Kill in 11 Southern Counties</td><td>32.3</td><td>36.6</td><td>40.5</td><td>45.8</td><td>43.2</td><td>46.4</td><td>41.3</td><td>44.4</td><td>46.5</td><td>39.6</td><td>38.2</td><td>33.0</td></tr>
</table>

[a]Taken from C. J. Hendricks, *Wildlife Mangement Plan, Shawnee National Forest*, Forest Service, Eastern Region, U. S. Dep. Agric., Milwaukee, Wis., 52 pp. (1969).

9.7.2. Endangered Vertebrates of Southern Illinois

The ecological requirements and distribution of rare and endangered species must be accurately defined before the impacts associated with strip-mining can be properly addressed. The following section presents some of this information for endangered vertebrates (on both state and federal lists)[29,48] whose geographic distribution in Illinois includes all or a portion of the SILSA. The distributional data presented in Figures 9.10-9.13 are based on a state agency publication of rare and endangered vertebrates of Illinois.[29] In the case of some species, such as the southern bald eagle and timber rattlesnake, the distributional maps probably do not include all southern Illinois counties supporting established populations. The arctic peregrine falcon cannot readily be assigned to any county since it is a fall and spring migrant of the area.

Table 9.15 is an annotated list of threatened and endangered vertebrates (from both the state and federal lists) whose geographic distribution in Illinois includes all or a portion of the SILSA. In general, the species the table lists as rare are at the northern or eastern edge of the species range in southern Illinois and in some cases are relatively common in other states. Consequently, the annotated list includes only endangered species from the federal and state lists. The figures following the annotated list (Figs. 9.10-9.13) show county records for which specimens were collected or observed, as reported in Reference 29.

9.7.2.1 Fish

Cypress Minnow (*Hybognathus hayi*). This species possibly has been extirpated from the state. Illinois records are only from the lower Mississippi River.

Spring Cavefish (*Chologaster agassizi*). This species is known in the extreme southern tip of Illinois (Fig. 9.10). It inhabits springs at the bases of limestone outcrops in the LaRue-Pine Hills area of Union County.[49] Spring cavefish also have been observed in swamps below many springs in the Pine Hills areas. Cavefish feed mainly on isopods, planaria, and amphipods.

Bantam Sunfish (*Lepomis symmetricus*). This species is found in spring-fed swamps of northeastern Union County.[49] Drainage of floodplains and increased siltation have led to its decline (Fig. 9.10).

Harlequin Darter (*Etheostoma camurum*). The present distribution in Illinois includes only a ten-mile segment of the Embarrass River in Coles, Cumberland, and Jasper Counties (Fig. 9.10).[49]

Western Sand Darter (*Ammocrypta clara*). This species formerly inhabited sand-bottomed streams throughout central Illinois. Its current distribution in southern Illinois consists of isolated populations in the Mississippi and Kaskaskia Rivers.

Crystal Darter (*Ammocrypta asprella*). Formerly an inhabitant of clear streams in Effingham, Jo Davies, and Hancock Counties, this species has not been collected since 1900[29] and may have been extirpated from Illinois.

Table 9.15. Rare and Endangered Vertebrates of Southern Illinois

	Federal List		State List[c]	
	Endangered[a]	Threatened[b]	Endangered	Rare
Mammals				
Gray bat	X			X
Indiana bat	X		X	
Bobcat			X	
Eastern woodrat			X	
Southeastern bat				X
Southeastern big-eared bat				X
Cotton mouse				X
Golden mouse				X
Rice rat				X
Southeastern shrew				X
Plains pocket gopher				X
Birds[d]				
Arctic peregrine falcon	X		X	
Southern bald eagle	X		X	
Greater prairie chicken		X	X	
Double-crested cormorant			X	
Cooper's hawk			X	
Red-shouldered hawk			X	
Osprey			X	
Upland sandpiper			X	
Snowy egret				X
Little blue heron				X
Black-crowned night heron				X
Common snipe				X
Least tern				X
Barn owl				X
Western kingbird				X
Brown creeper				X
Bewick's wren				X
Loggerhead shrike				X
Swainson's warbler				X
Pine warbler				X
Bachman's sparrow				X
Purple gallinule				X
Mississippi kite				X
Black vulture				X
Cliff swallow				X
Reptiles				
Alligator snapping turtle			X	
Eastern coachwhip			X	
Scarlet snake			X	
Northern lined snake			X	
Timber rattlesnake			X	

Table 9.15. Continued

	Federal List		State List[c]	
	Endangered[a]	Threatened[b]	Endangered	Rare
Reptiles				
Mud turtle				X
Hieroglyphic turtle				X
Western slender glass lizard				X
Northern flat-headed snake				X
Green water snake				X
Amphibians				
Hellbender			X	
Dusky salamander			X	
Mole salamander				X
Eastern spadefoot				X
Western bird-voiced treefrog				X
Green treefrog				X
Eastern wood frog				X
Eastern narrow-mouthed toad				X
Fish				
Cypress minnow			X	
Spring cavefish			X	
Bantam sunfish			X	
Harlequin darter			X	
Pallid sturgeon				X
Alligator gar				X
River chub				X
Northern blacktail shiner				X
Northern madtom				X
Banded pigmy sunfish				X
Sicklefin chub				X
Bigeye shiner				X

[a] From "United States List of Endangered Fauna," U. S. Department of Interior, Fish and Wildlife Services. May 1974. 22 p.

[b] From "Threatened Wildlife of the United States," U. S. Department of Interior, Fish and Wildlife Service. Bureau Sport Fisheries and Wildlife. 1973. 28 p.

[c] From Ackerman, K., "Rare and Endangered Vertebrates of Illinois." Illinois Department of Transportation. Bureau of Environmental Science. 1975. 50 p.

[d] The list of rare birds does not include migratory waterfowl and many other nonbreeding birds presented in the state list.

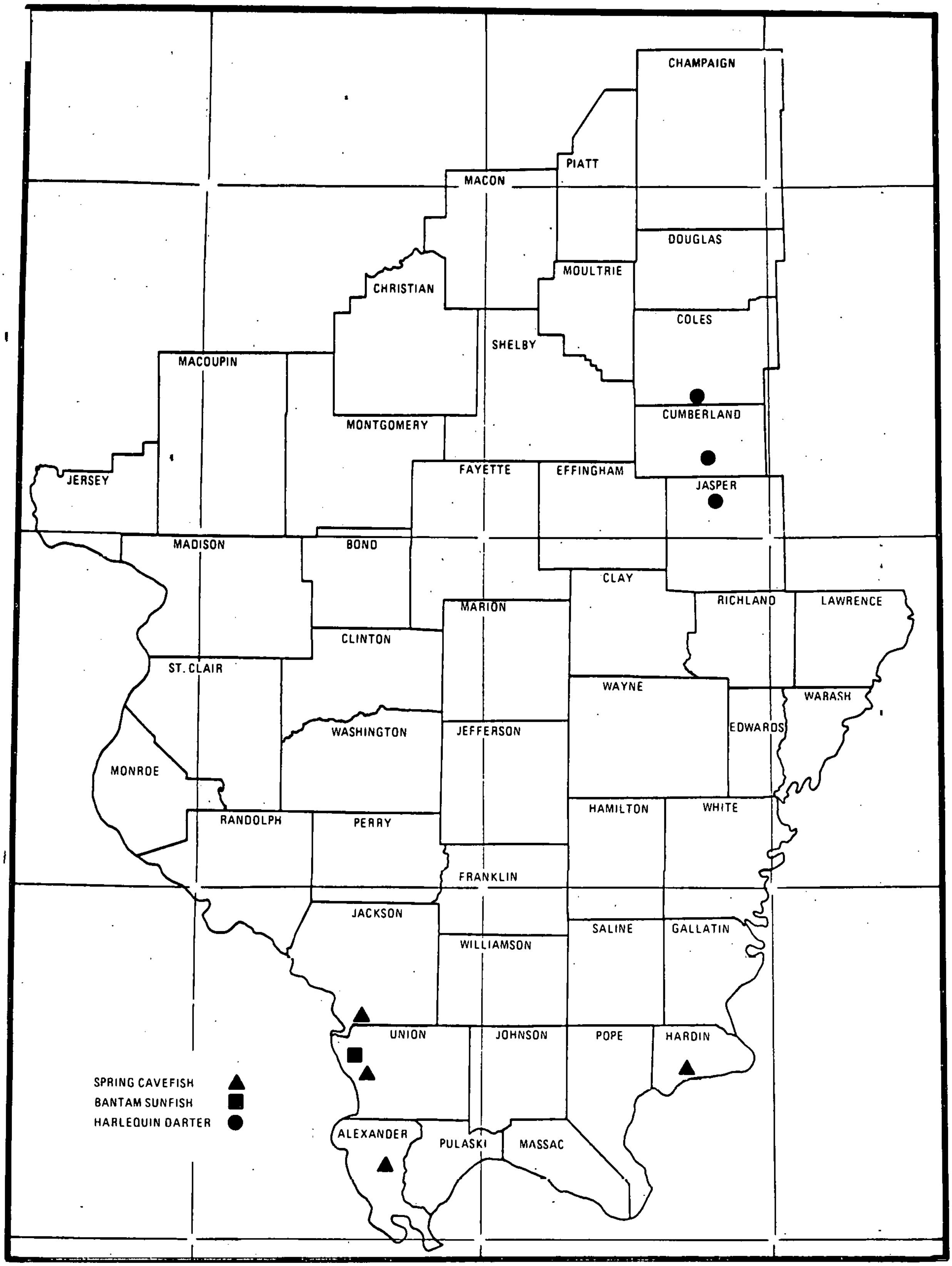


Fig. 9.10. Distribution of Federal and State Endangered Fish in the SILSA.

9.7.2.2 Amphibians

Hellbender (*Cryptobranchus a. alleganiensis*). The hellbender is found in southeastern Illinois (Fig. 9.11), occurring in fast-flowing tributaries of the Wabash and Ohio Rivers.[49] Well-aerated cool waters in rocky streams are characteristic habitat.[50,51] Crayfish, fish and aquatic insect larvae constitute the bulk of the diet.[50]

Dusky Salamander (*Desmognathus fuscus conanti*). This species is restricted to the extreme southern tip of Illinois.[34,49] Common habitat consists of areas along the margins of springs. The diet includes mostly small anthropods, segmented worms, snails, and other salamanders.[34]

9.7.2.3 Reptiles

Alligator Snapping Turtle (*Macroclemys temmincki*). This large snapping turtle inhabits mud bottoms of the Ohio and Mississippi Rivers in southern Illinois (Fig. 9.11).[34,49] It is thought to be highly sensitive to pollution. The diet consists mostly of fish.[34]

Eastern Coachwhip (*Masticophis f. flagellum*). This species is at the northern extent of its range, occurring only in Monroe County (Fig. 9.11). The coachwhip inhabits wooded bluffs along the Mississippi River and feeds primarily on birds and rodents.

Scarlet Snake (*Cemophora doliata*). The only known Illinois specimen was collected in the Pine Hills area of Union County in 1942. If this species still occurs in the area, it most likely inhabits the wooded bluffs above the swamp in Pine Hills.[34] Its diet consists of young mice, other snakes, and lizards.

Northern Lined Snake (*Tropidoclonion l. lineatum*). This species is known only in Macoupin County. Once a more common species of central Illinois, its numbers have declined due to habitat destruction resulting from increased cultivation.[34] Illinois specimens have been found under logs, rocks, and trash in disturbed areas. Earthworms are the principal food.[34]

Timber Rattlesnake (*Crotalus h. horridus*). Smith[52] indicates that this species is most likely found at more southern Illinois localities than those depicted in Figure 9.11. Forested bluffs and rock outcrops constitute the representative habitat in southern Illinois.[34] The diet consists mainly of mammals and birds.

9.7.2.4 Birds

Arctic Peregrine Falcon (*Falco peregrinus tundrius*). Only a few individuals are observed annually during migration along the Illinois and Mississippi Rivers in Illinois. In southern Illinois, this species is most likely to occur in the southwestern areas along the Mississippi River. Birds and rodents are its major prey.

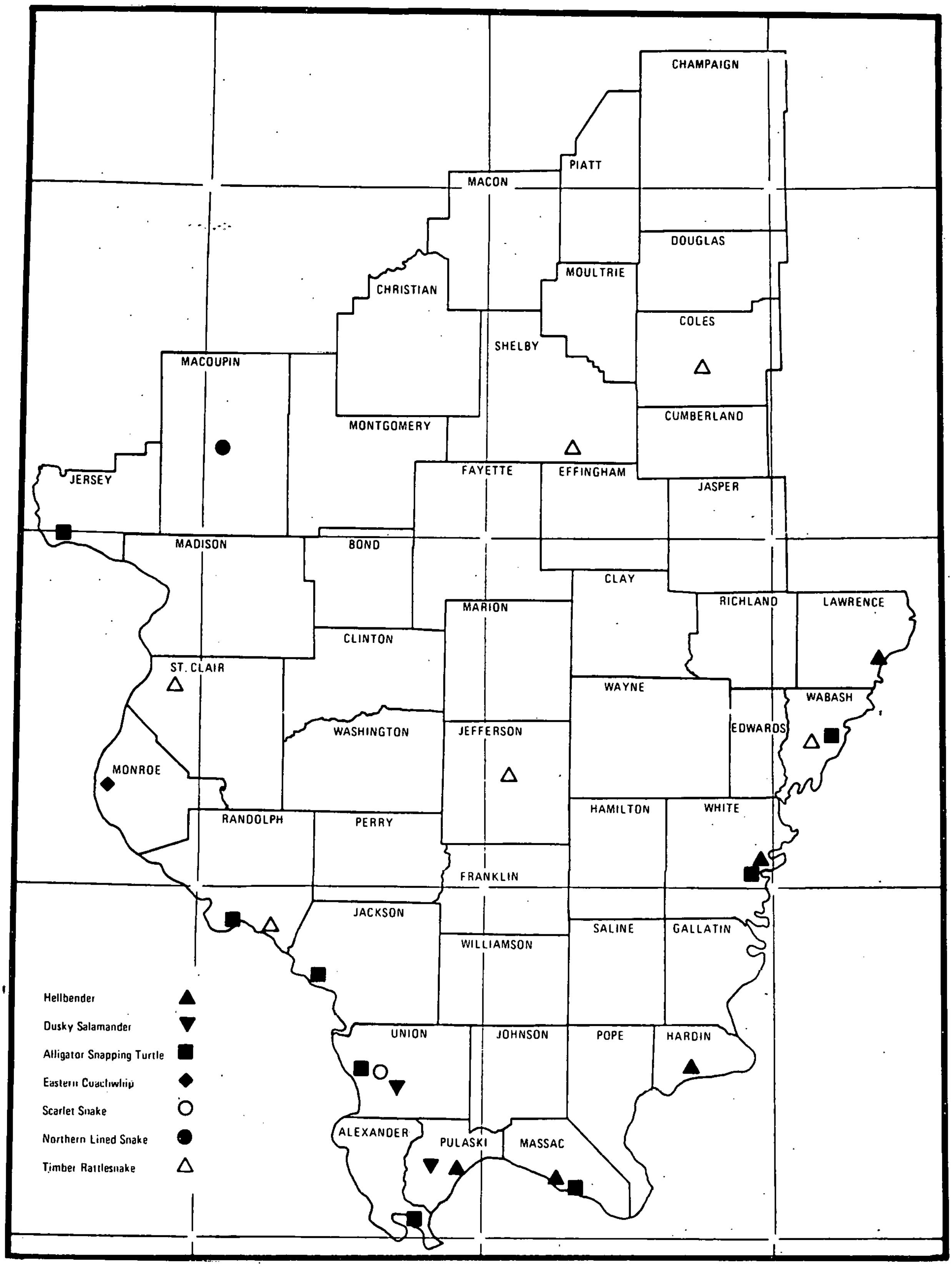


Fig. 9.11. Distribution of Federal and State Endangered Amphibians and Reptiles in the SILSA.

Southern Bald Eagle (*Haliaeetus l. leucocephalus*). This species overwinters in southern Illinois, inhabiting wooded areas along the Mississippi River, especially near locks and dams.[29] The winter diet consists mostly of fish. Two unsuccessful nesting attempts have been recorded recently at the Crab Orchard National Wildlife Refuge in Williamson County and at the Union County Conservation Area[29] (Fig. 9.12).

Greater Prairie Chicken (*Tympanuchus cupido pinnatus*). Two grassland sanctuaries in Jasper and Marion Counties provide most of the habitat for this species in Illinois (Fig. 9.12). The disappearance of tall grass prairie throughout the Midwest has resulted in a corresponding decline in prairie chicken populations. The Illinois National History Survey currently has funding from the Illinois Department of Conservation to improve existing habitat and secure additional prairie chicken habitat in southern Illinois. The current Illinois population is approximately 300. The diet consists primarily of grains, fruits, berries, and insects.[43,52]

Double-Crested Cormorant (*Phalacrocorax auritus*). This species is mainly a migrant in Illinois. The only known nests in Illinois are near Thomson (Carrol Co.) in extreme northwestern Illinois. Nesting habitat consists of sticks and weeds crudely arranged on cliffs, in trees, or on the ground.[52] The diet consists mainly of fish.

Cooper's Hawk (*Accipiter cooperii*). In southern Illinois this species is most commonly encountered in the Shawnee National Forest.[29] Nesting sites are located in deciduous forests, usually in tall trees. The diet consists mainly of birds.[52]

Red-Shouldered Hawk (*Buteo lineatus*). In southern Illinois this species is found in lowland deciduous forests. It currently nests in the Shawnee National Forest. Nests are constructed in the forks of trees. The diet consists mainly of small rodents and birds.[43,52-54]

Osprey (*Pandion haliaetus*). There are presently no known nesting sites in Illinois. Occurrence of this species in Illinois is only as a migrant. The diet consists only of fish.[43,52]

Upland Sandpiper (*Bartramia longicauda*). The distribution of this species is statewide. Common habitat types are short-grass prairies and pastures.[29] The diet consists mostly of insects.

9.7.2.5 Mammals

Indiana Bat (*Myotis sodalis*). This species is known to reside in caves in Union and Hardin Counties (Fig. 9.13).[54] The species in insectivorous and feeds primarily along forested streams.

Gray Bat (*Myotis grisescens*). This species is known to reside in limestone caves in Hardin County (Fig. 9.13).[29] Most individuals migrate southward during winter. Insects comprise the entire diet.

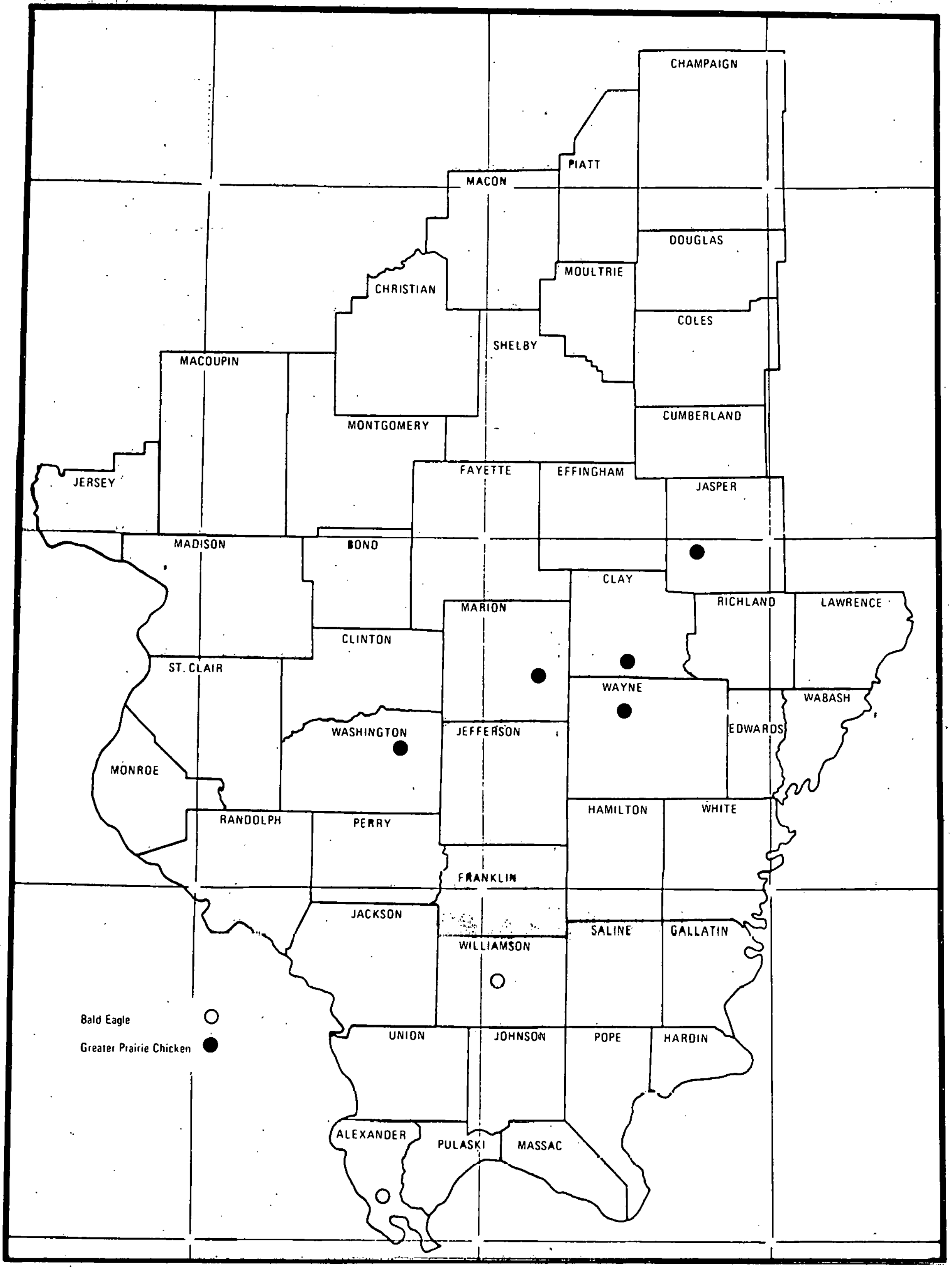


Fig. 9.12. Distribution of Federal and State Endangered Birds in the SILSA.

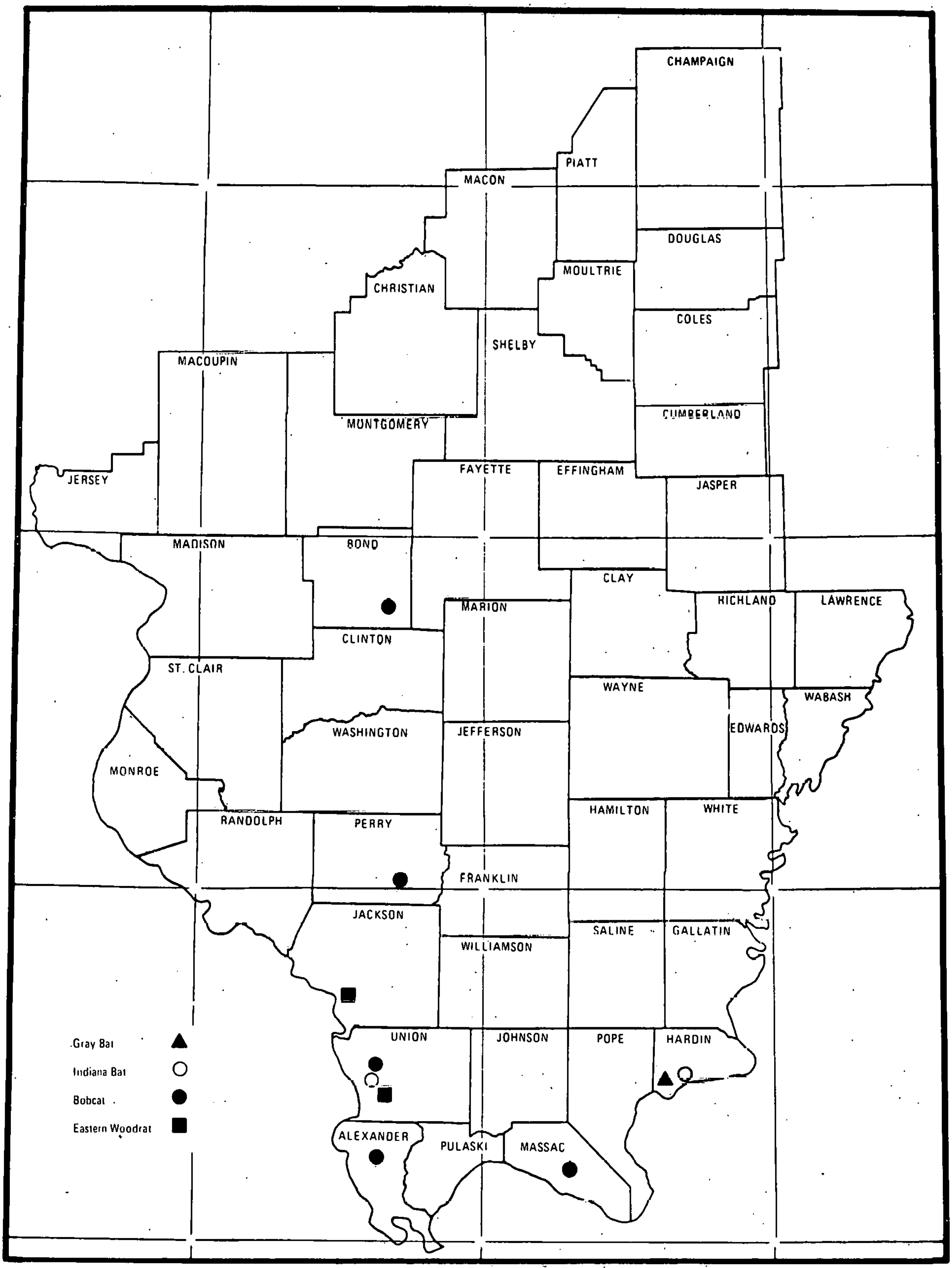


Fig. 9.13. Distribution of Federal and State Endangered Mammals in the SILSA.

Eastern Woodrat (*Neotoma floridana*). The woodrat inhabits cliffs and rocky bluffs along the Mississippi River floodplain (Fig. 9.13). The only three areas in Illinois known to support populations are the Pine Hills area (Union Co.), Fountain Bluff, and Horseshoe Bluff (Jackson Co.). Severe winter weather limits its northward distribution. Seeds and fruits constitute most of the diet.[43,55]

Bobcat (*Lynx rufus*). Wooded lowlands and bluffs along the major rivers bordering the state constitute most of the bobcat's habitat in Illinois[29] (Fig. 9.13). Rabbits, squirrels, and rodents comprise most of the diet.[43]

REFERENCES FOR SECTION 9.0

1. W. L. Denmark, 1969, *The Climate of Illinois*, Climates of the States Vol. 1., National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce, published by Water Information Center, Inc., Port Washington, N.Y., 90-107 (1974).

2. J. B. Fehrenbacher, G. O. Walker, and H. L. Wascher, *Soils of Illinois*, Agric. Exp. Sta. Bull. 725, University of Illinois, Urbana (1967).

3. *Glossary of Soil Science Terms*, Soil Science Society of America, February (1975).

4. W. H. Smith and J. B. Stall, *Coal and Water Resources for Coal Conversion in Illinois*, Illinois Geological Survey, Coop. Resour. Rep. 4, Urbana (1975).

5. E. C. A. Runge, L. E. Tyler, and S. G. Carmer, *Soil Type Acreages for Illinois--Statewide and County Summaries*, Agric. Exp. Sta. Bull. 735, University of Illinois, Urbana (1969).

6. E. N. Jones, *Flora of Illinois*, American Midland Naturalist Monograph No. 5, Univ. Notre Dame Press, Notre Dame, IN, 368 pp., (1950).

7. E. L. Braun, *Deciduous Forests of Eastern North America*, The Blakiston Co., Philadelphia, 596 pp., (1950).

8. E. N. Transeau, *The Prairie Peninsula*, Ecology 16(3):423-37, (1935).

9. F. C. Clements, *Plant Indicators, the Relation of Plant Communities to Process and Practice*, Carnegie Inst. Wash. Bull 290, 388 pp., (1920).

10. J. W. Voigt and R. H. Mohlenbrock, *Plant Communities of Southern Illinois*, Southern Ill. Univ. Press, Carbondale, 202 pp., (1964).

11. W. D. Thornbury, *Principles of Geomorphology*, John Wiley & Sons, N.Y., 618 pp., (1954).

12. D. T. Bell and S. K. Sipp, *Structure of the Tree Component of the Vegetation Gradient at the Edge of the Sangamon River in the Hart Memorial Woods, Champaign County, Ill.*, Annual Report FY-74 for the Springer-Sangamon Environmental Research Program, Dept. of Forestry and Ill. Agric. Expr. Sta., Univ. Ill., Urbana-Champaign, pp. 102-106, (July 1, 1974).

13. D. T. Bell, *Structural Aspects of the John M. Oldweiler Forest Site of the Springer-Sangamon Environmental Research Program*, loc. cit., pp. 107-112.

14. P. W. Smith, *Illinois Streams: A Classification Based on Their Fishes and an Analysis of Factors Responsible for Disappearance of Native Species*, Biological Notes No. 76. Illinois Natural History Survey, 14 pp. (1971).

15. United States Dept. of Interior Geological Survey, *Water Resources Data for Illinois*, 250 pp. (1969).

16. United States Dept. of Interior Geological Survey, *Water Resources Data for Indiana*, 345 pp. (1974).

17. United States Army Engineer District, St. Louis, *Upper Mississippi River Comprehensive Basin Study, Vol. 5*, Upper Mississippi River Basin Coordinating Committee (1970).

18. K. W. Cummins, *What is a River? - A Zoological Description*, in R. T. Oglesby et al., eds., "River Ecology and Man. Proc. Inter. Symp. on River Ecol. and Impacts of Man," Academic Press, pp. 33-53. (1972).

19. B. P. Butz et al., *Ohio River Cooling Water Study*, Environmental Protection Agency Rep. No. EPA-905/9-74-004, 385 pp. (1974).

20. J. R. Gammon, *The Effects of Thermal Inputs on the Populations of Fish and Macroinvertebrates in the Wabash River*, Water Resources Research Technical Rep. No. 32, 106 pp. (1973).

21. U. S. Army Corps of Engineers, *Wabash River Basin Comprehensive Study*, Louisville District (1971).

22. J. J. Geraghty et al., *Water Atlas of the United States*, Water Information Center, Inc., 250 pp. (1973).

23. J. F. Kopp and R. C. Kroner, *Trace Metals in Waters of the United States: A Five Year Summary of Trace Metals in Rivers and Lakes of the United States*, U. S. Dept. of Interior, Federal Water Pollution Control Admin., 250 pp. (1967).

24. A. J. Dvorak et al., *Health and Ecological Effects of Coal Utilization*, Argonne National Laboratory, Report NUREG-0000, U. S. Nuclear Regulatory Commission, Washington D. C. (1977).

25. L. R. Dice, *The Biotic Provinces of North America*, University of Michigan Press, Ann Arbor, 78 pp. (1943).

26. S. C. Kendeigh, *Ecology with Special Reference to Animals and Man*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 474 pp. (1974).

27. D. F. Hoffmeister and C. O. Mohr, *Fieldbook of Illinois Mammals*, Dover, N. Y., 233 pp. (1972).

28. W. H. Burt and R. P. Grossenheider, *A Field Guide to the Mammals*, Houghton Mifflin Co., Boston, 284 pp. (1964).

29. K. Ackerman, *Rare and Endangered Vertebrates of Illinois*, Bur. Environ. Sci., Ill. Dep. Transportation, Springfield, 50 pp. (1975).

30. C. S. Robbins, B. Brunn, and H. S. Zim, *A Guide to Field Identification, Birds of North America*, Golden Press, New York, 340 pp. (1966).

31. *Birds of Crab Orchard National Wildlife Refuge*, Bur. Sport Fish. Wildl., U. S. Dep. Interior, 14 pp. (1973).

32. J. L. Roseberry and W. D. Klimstra, *The Nesting Ecology and Reproductive Performance of the Eastern Meadowlark*, Wilson Bull., 82(3):243-267 (1970).

33. W. D. Klimstra and J. J. Roseberry, *Nesting Ecology of the Bobwhite in Southern Illinois*, Wildl. Monogr., No. 41:1-37 (1975).

34. P. W. Smith, *The Amphibians and Reptiles of Illinois*, Ill. Nat. Hist. Surv. Bull. Vol. 28, Art. 1, pp. 1-298 (1961).

35. R. Conant, *A Field Guide to Reptiles and Amphibians of Eastern and Central North America*, Houghton Mifflin Co., Boston, 429 pp. (1975).

36. J. A. Ellis, W. R. Edwards, and K. P. Thomas, *Responses of Bobwhite to Management in Illinois*, J. Wildl. Manage. 33:749-762 (1969).

37. W. R. Edwards and J. A. Ellis, *Responses of Three Avian Species to Burning*, Wilson Bull. 81:338-339 (1969).

38. W. L. Anderson and P. L. Stewart, *Chemical Elements and the Distribution of Pheasants in Illinois*, J. Wildl. Manage. 37:142-153 (1973).

39. G. B. Joselyn, J. E. Warnock, and S. L. Etter, *Manipulation of Roadside Cover for Nesting Pheasants A Preliminary Report*, J. Wildl. Manage. 32:217-233 (1968).

40. C. J. Hendricks, *Wildlife Management Plan, Shawnee National Forest*, For. Ser., Eastern Region, U. S. Dep. Agric., Milwaukee, Wis., 87 pp. (1969).

41. C. J. Hendricks, *Management Plan, LaRue-Pine Hills Ecological Area, Shawnee National Forest*, For. Serv., Eastern Region, U. S. Dep. Agric., Milwaukee, Wis., 52 pp. (1970).

42. R. Q. Bell and D. Klimstra, *Feeding Activities of Canada Geese in Southern Illinois*, Trans. Ill. State Acad. Sci., No. 63, pp. 295-304 (1970).

43. A. C. Martin, H. S. Zim, and A. L. Nelson, *American Wildlife and Plants. A Guide to Wildlife Food Habits*, Dover, N. Y., 500 pp. (1961).

44. C. M. Nixon, D. M. Worley, and M. W. McClain, *Food Habits of Squirrels in Southeast Ohio*, J. Wildl. Manage. 32(2):294-305 (1968).

45. C. M. Nixon, M. W. McClain, and R. W. Donohoe, *Effects of Hunting and Mast Crops on a Squirrel Population*, J. Wildl. Manage. 39(1):1-25 (1975).

46. L. J. Korschgen, *Food of Missouri Deer with Some Management Implications*, J. Wildl. Manage. 26(2):164-172 (1962).

47. *Threatened or Endangered Fauna or Flora. Review of Vascular Plants and Determination of "Critical Habitat"*, Fish Wildl. Serv., U.S. Dept. Interior, Fed. Reg. 40(127):27824-24924 (July 1, 1975).

48. *Threatened Wildlife of the United States*, 1973 Ed., Bur. Sport Fish. Wildl., Fish Wildl. Serv., U. S. Dept. Interior, 289 pp.

49. N. M. Welch. *Report to the United States Forest Service on Chrologaster agassizi in Shawnee National Forest*, 4 pp. (1973).

50. S. A. Minton, Jr., *Amphibians and Reptiles of Indiana*, Indiana Acad. Sci. Monogr. 3 Indianapolis, 346 pp. (1972).

51. S. C. Bishop, *Handbook of Salamanders*, Comstock Publ. Co., Ithaca, N.Y., 555 pp. (1943).

52. E. L. Palmer and H. S. Fowler, *Fieldbook of Natural History*, McGraw-Hill Inc., New York. 799 pp. (1975).

53. J. J. Craighead and F. C. Craighead, Jr., *Hawks, Owls and Wildlife*, Dover, N. Y., 443 pp. (1969).

54. J. O. Whitaker Jr., *Bats of the Caves and Mines of the Shawnee National Forest of Southern Illlinois with Particular Emphasis on Myotis sodalis the Indiana Bat*, Distributional Studies of the Indiana Bat *(Myotis sodalis)* on Three National Forests of the Eastern Region, Forest Service, Eastern Region, U. S. Dept. Agric., pp. 26-64, (1975).

55. W. D. Klimstra, *The Southern Illinois Woodrat: An Endangered Species*. Unpublished report submitted to the U. S. Forest Service, Shawnee National Forest, 101 pp. (1974).

10.0 IMPACTS OF COAL EXTRACTION, PREPARATION, COMBUSTION AND LAND RECLAMATION

10.1 IMPACTS OF COAL EXTRACTION

10.1.1 Potential Sources of Impact from Coal Extraction

The impacts of surface mining differ from those of deep mining. The major impacts from strip mining are associated mainly with the total disruption of large acreages of land as overburden and parting layers are removed to gain access to the coal seams. Deep mines disturb the land surface little in comparison to surface (strip) mines. The extraction impacts of deep mines are primarily related to gob and slurry production, acid mine drainage and subsidence.

Gob material is mine waste consisting of rubble cut from the roof and floor of the coal seam and may be very rich in pyrites and/or trace elements and heavy metals. The term gob also can refer to waste remaining after the coal is separated from the raw mine output in a cleaning operation outside the mine. Gob material is brought to the surface and deposited. In southern Illinois, 15-20 years of mining have created gob piles 50-80 feet high, covering extensive areas. The potentially toxic material of these piles is usually very acidic ($pH < 3$) and does not permit secondary ecological succession typical of the area. In general, gob piles are completely devoid of vegetation. Rainfall combines with pyrite to form sulfuric acid in the surficial layers of the gob pile. Surface-water runoff from gob piles thus serves as a potential source of contamination for the local watershed. Gob and slurry production from coal washing will be discussed in Section 10.2.

Acid mine drainage, high total iron, and/or sediment-laden effluents are common to both strip mining and deep mining. Occasionally, surface mining activities have released acidic water which has collected over time in old underground mine shafts. This water which must be removed from the active strip pits, presents a new potential source of acid contamination to local watersheds and consequently is treated with lime and passed through a series of settling basins prior to release. Deep mines may also interrupt or contaminate aquifers and thus impact local wells and streams that receive a portion of their base flow from aquifer inputs. Aquifer interruptions, however, are not considered in this assessment.

Subsidence, historically a problem with deep mines, is the downward displacement of the soil and overburden resulting from the collapse of the mine roof. Subsidence is not visually apparent if 100 feet of overburden is present for every foot of seam thickness.

Strip mines disrupt large acreages of land. For seven Illinois counties (Table 10.1), the land disturbed to supply a 3000-MW plant with coal from 1975 to 1985 will average 441.6 acres per year. This value probably represents an underestimate since it does not allow for acres disturbed by haul roads, etc. The cumulative surface acreage disturbed to supply a 3000-MW plant will increase rom the year 1985 to 2020 (see Table 10.1).

Table 10.1. Estimated Strip Mine Land Disturbances in Southern Illinois

County	Assumed Seam Thickness (ft.)	Surface Area Disturbed[a] (Acres/Yr)		
		1975-1985	2000	2020
Gallatin	4	684.8	851.2	102.4
Jackson	9	300.8	377.6	454.4
Perry	7	390.4	486.4	582.4
St. Clair	7	390.4	486.4	582.4
Saline	5	544	684.8	819.2
Randolph	7	390.4	486.4	582
Williamson	7	390.4	486.4	582.4

[a]Represents acreage disturbed to supply the annual needs of a 3,000 MW plant based on the following assumptions: 8.97×10^6 Btu/MW hr; 12,000 Btu/lb coal; 82.64 lb/cu. ft (1.152×10^6 tons/mile = ft); 40% load-factor, 1975-1985; 50% load factor, 2000; 60% load-factor, 2020; 80% recovery of coal reserves.

10.1.2 Impacts of Coal Extraction on Terrestrial Ecosystems

10.1.2.1 Natural Vegetation

Deep Mining

Deep minable coal reserves occur under the majority of the vegetational community types of the study area. Thus the impacts of deep mining on the vegetation will be highly dependent upon the distribution of future mine sites. No projections concerning the distribution or extent of deep mining for the target years were made for this report, so the following discussion can only characterize the types of impacts which can be expected to be associated with deep mining. There are three aspects of deep mining which may lead to impacts on the vegetation: improvements at the mine site, subsidence, and mine refuse disposal.

Typical improvements at the mine site include the offices, maintenance sheds, railroad spurs, loading silos, belt conveyance systems, access roads, parking areas, etc. The total acreage involved is dependent upon the mine production levels and the number and location of mine sites. The acreage at each mine site should be relatively small, comparable in magnitude to a major construction site, but of longer duration. Estimates of the acreage used for facilities directly attributable to mining are conjectural because the mine site will often include mine mouth processing facilities, and may even include mine mouth gasification, liquefaction or combustion facilities.

When subsidence occurs within a forest community, there will be a temporary disruption of the forest vegetation as trees are toppled into the subsided land mass. The magnitude of this disturbance is typically no greater than the wind damage which may occur during an intense thunderstorm. Recovery by strictly natural processes should proceed as that expected following wind damage. As such, the time to recovery may be up to twenty years. Grassland and pasture vegetation should normally survive through subsidence, or in the worst case should sustain such limited damage that natural recovery may occur within a year or two. Subsidence can result in a diversion of the usual watershed drainage pattern creating marshes in some areas of southern Illinois.[1] In crop lands, there should be a loss of one or two years production, primarily due to the effect of subsidence upon the access to the land by farm machinery. It should be stressed that subsidence is relatively unlikely.

Where subsidence has occurred on Illinois agricultural lands,[1] two approaches have been employed to restore the land to its original use. If the subsidence areas are relatively small (6-8' deep by 20-30' diameter), topsoil has been used to cover aggregate. When entire fields have experienced subsidence, resulting in standing water, the fields have been tiled and graded.[1]

The major impact of deep mines is associated with the disposal of gob. The primary impact from gob deposition is the loss of vegetation at the disposal site. The extent of the impact is dependent on the rate of coal production. As stated earlier (Sec. 10.1.1) gob piles from former deep mining operations cover extensive areas (sometimes > 100 acres). Conditions on the gob piles are usually so severe that terrestrial vegetation cannot survive. In the future, impacts associated with gob piles will be short-term since current reclamation laws require that they be covered by four feet of topsoil and be revegetated.

Surface Mining

The impacts of surface mining on vegetation are much more extensive than those associated with deep mining. All of the vegetation is removed from the area during mining, and the soil profile is disrupted during coal extraction. The exact details of the subsurface disruption are dependent upon the equipment utilized for overburden removal, but basically the entire geologic (and soil) profile is inverted. Under present practice, the topsoil is removed and stockpiled to be replaced on the spoils after they have been recontoured. The remainder of the soil profile and geologic profile above the coal seam(s) is still inverted.

Only 18 counties in southern Illinois have strippable coal reserves. Table 10.2 shows the acreages by county which are expected to be disturbed by strip mining during the intervals ending with the target years. The acreage devoted to crop production, livestock production (including dairy), residential and urban development (including farm houses and their yards), and roads can be estimated on the basis of county agricultural data. The remaining acreage can be assumed to be in natural and quasi-natural vegetation. From this, the acreage of "natural" vegetation disturbed by mining can be estimated and apportioned between forest and grassland based on the presettlement distribution of forest. These estimates are given in Table 10.3.

Table 10.2. County Acreages to be Disturbed by Strip Mining[a]

County	Estimated Acres Disturbed 1975-1984	1985-1999	2000-2020	Total
Gallatin	-	-	4,474	4,474
Jackson	-	-	3,962	3,962
Madison	-	525	13,382	13,907
Perry	-	-	640	640
Randolph	3027	4928	8,300	16,255
St. Clair	-	3718	13,382	17,100
Williamson	-	2138	13,382	15,520

[a]Numbers modified after Table 5.7 of Vol. 1.

Table 10.3. Estimated County Acreages of Natural Vegetation to be Disturbed by Strip Mining

County	Estimated Acres Disturbed 1975-1984	1985-1999	2000-2020	Total	Total Forest	Total Grassland
Gallatin	-	-	800	800	650	150
Jackson	-	-	1400	1400	1000	400
Madison	-	100	2700	2800	1400	1400
Perry	-	-	250	250	150	100
Randolph	750	1400	2400	4550	2750	1800
St. Clair	-	700	2600	3300	1650	1650
Williamson	-	1100	6700	7800	6300	1500

The amount of natural vegetation disturbed by strip-mining currently ranges from approximately one-third to one-half of the total acreage strip-mined in Illinois.[2] The total acreage of forest land expected to be disturbed in seven southern Illinois counties (see Table 10.3) seems negligible when compared to the total county area. Forest lands disturbed by mining amounted to 30.76% and 30.50% of the total surface-mined land in Illinois in 1975[2] and 1976* respectively. Typically, forested land is returned to pasture and to a lesser extent row crop agriculture once mining has been completed. This practice will further alter the landscape mosaic of grassland, agricultural land and forested land in southern Illinois. The change in land use cannot be quantified due to the absence of data on the present acreage of forests and native grassland in areas to be mined.

10.1.2.2 Wildlife

The future impacts of coal mining on wildlife species are largely dependent upon the type of mining employed (strip mining or deep mining), land use in the areas being mined, and post-mining reclamation procedures. The impacts of deep mines on wildlife are mainly related to the amount, physical and chemical properties and disposition of gob and slurry materials. Acid runoff from gob piles results in a complete loss or modification of the vegetation adjacent to the gob pile. The degree to which this vegetation is modified, greatly influences the use of the area by wildlife.

The physical act of disrupting the land surface during strip mining will result in the displacement or death of many terrestrial vertebrates. The immediate fate of wildlife species following the onset of mining is primarily a function of their mobility. Relatively mobile vertebrates such as birds and most mammals will be displaced into adjacent areas where they will compete for resources with the resident fauna of those areas. The immediate fate of displaced individuals will depend largely on whether or not adjacent communities are at carrying capacity for the species in question. Less mobile vertebrates such as small mammals (burrowing rodents, shrews, moles) and some reptiles and amphibians (especially salamanders inhabiting upland deciduous forests) will be killed during the initial phase of overburden removal.

Impacts on Mammals

The kinds of species affected by surface mining are strongly dependent on the type of vegetation altered or destroyed. A reduction in the acreage of upland deciduous forest and forest edge will reduce the habitat available[3,4] for game species such as the red fox, gray fox, fox squirrel, gray squirrel, eastern cottontail, and white-tailed deer. Commonly occurring small mammals such as the eastern chipmunk, deer mouse, and short-tailed shrew will be eradicated or displaced from forested areas being strip-mined.

On the basis of a study of fox squirrel and gray squirrel population dynamics in oak-hickory and beech-maple forests of southeastern Ohio,[5] a loss of ∿ 200 ha (500 acres) of forest (the approximate acreage of land disturbed

---

Pers. comm., Mr. Eugene Filer, Department of Mines and Minerals. Supervisor, Division of Land Reclamation, Springfield, Illinois.

each year to supply a 3000-MW plant with coal) would eliminate nesting and foraging[6] habitat for about 385 squirrels. Although no density data are available for white-tailed deer in southern Illinois, a loss of forest-edge habitat will result in a loss of cover and mast such as acorns or browse (sumacs).[7] The destruction of forest edge communities will reduce the available habitat for red foxes. In a study of midwestern red fox populations, dens in Illinois were common in wooded areas of counties bordering the Mississippi River.[8] Dispersal from the den area occurred in early fall (Sept. and Oct.) with the mean distances between first and last recaptures averaging 31 km (19.4 miles) for males and 11 km (6.7 miles) for females.[8] A loss of forest-edge habitat for red foxes will not only eliminate foraging areas and den sites but may also alter their patterns of dispersal. The increased human activity and the onset of coal mining in an area may substantially reduce the area's carrying capacity for red foxes. Gray foxes are more common in dense forests[4] and will be most seriously impacted by coal mining in upland deciduous forest areas.

The disturbance of prairie (grasslands) will eliminate cover and foraging habitat for the eastern cottontail and common rodents such as the meadow vole, prairie vole, and deer mouse. These losses of habitat are comparatively temporary since many areas are returned to grasslands once mining has been completed.

Impacts on Birds

Strip mining in upland deciduous forests will eliminate nesting and foraging habitat for common nesting songbird (passerine) species such as the red-eyed vireo and ovenbird.[3] Other species groups such as woodpeckers, warblers, and thrushes will be displaced from forested areas being mined. Nesting and roosting sites for large birds of prey such as the great horned owl, barred owl, screech owl, and red-tailed hawk will also be eliminated as forests are cleared during surface mining.

Species commonly encountered in prairies and agricultural pasturelands include the horned lark, dickcissel, and eastern meadowlark. These species are not expected to be adversely impacted by surface mining due to the abundance of available habitat on farms throughout central and southern Illinois.

Impoundments allowed to form in the final cut, for retaining coal washing water and as retention basins for acid mine drainage from intersected deep mines, will also affect the avifauna. Retention ponds containing acidic water or water high in pyritic substances often contain dead or dying trees. The death of trees, while eliminating habitat for many passerine birds, creates new roosting, foraging and nesting habitats for other birds. During a visit to a coal mine in Saline County, Illinois, red-headed woodpeckers and wood ducks were observed using the dead trees for foraging and nesting. Red-winged blackbirds were observed nesting in impoundments containing cattails. The final cut impoundment will attract waterfowl during the spring and fall migratory periods. The extent to which waterfowl will use these impoundments is dependent upon the bathymetry of the impoundment, food availability in or near the impoundment, and reclamation practices carried out on adjacent lands (see section on reclamation impacts). Mine reclamation personnel in Saline County indicate that waterfowl generally avoid retention ponds having a pH lower than 2 or 3.

Impacts on Reptiles and Amphibians

The elimination of forest-edge and deciduous forest habitat will displace or eradicate characteristic herpetofaunal species[9] such as the five-lined skink, broad-headed skink, black rat snake, rough green snake, timber rattlesnake, northern copperhead, eastern box turtle, slimy salamander, eastern tiger salamander, spotted salamander, and woodfrog. For the reptilian species mentioned above, forest clearing will eradicate both breeding and foraging habitats. The eastern tiger salamander and spotted salamander, however, may breed either in forest ponds or in ponds adjacent to the woodlots.

Other species of amphibians and reptiles (leopard frog, green frog, bullfrog, painted turtle, snapping turtle, spiny softshell) are commonly encountered in marshes, ponds, lakes, or in riparian communities on agricultural land. The extent to which these species will suffer adverse impact will depend not only on destruction of habitat during extraction but on the control of runoff and discharge from the mine pit and the coal-washing facilities. Acid mine drainage from inactive deep mines is often a problem encountered by strip mine operators. The extent to which the acid mine drainage or coal-wash water is allowed to enter the local watershed will largely determine the impact to the herpetofauna.

Prairie species such as the ornate box turtle, blue racer, eastern garter snake, bullsnake, fox snake, eastern hognose, and American toad will be eradicated or displaced to adjacent areas by surface mining activities. Impacts to these species may be short-term since current reclamation amendments often require the return of a mined area to grassland or a comparable stage of succession.

10.1.3 Impacts of Coal Extraction on Agriculture

10.1.3.1 Deep Mining

The primary impact of deep mining will be loss of agricultural land due to the presence of haul roads, mine offices and maintenance buildings, railroad spurs, parking areas, etc. The extent of this loss of land will be influenced by the size of the mining operation. Potential secondary impacts of deep mining may result from subsidence and acid mine drainage.

Subsidence may create surface depressions 3-6 feet deep. These depressions are major obstacles for farm machinery. Extensive subsidence can cause either abandonment of a field or, at least, a severe reduction in the efficiency of the farming operation. As stated above, however, methods are presently available to restore agricultural lands impacted by subsidence.

Impacts to agriculture from acid mine drainage will be alleviated as long as the water is chemically treated before release to the watershed.

10.1.3.2 Surface Mining

Surface mining results in large tracts of land being removed from production each year. In the year 2020, productive land in Madison, St. Clair, Perry, Randolph and Williamson Counties will decrease by about 0.9 square mile in each county for a total of 4.55 mi^2 (3000 acres). The corresponding decrease for Jackson and Gallatin Counties will be about 500 and 1000 acres, respectively. Assuming that the land use patterns for areas to be disrupted by mining are similar to that of the state as a whole, row-crop agricultural land in Gallatin County will be decreased by about 670 acres (Table 10.4). Surface mining to provide fuel for the proposed 3000-MW power plants in Monroe, Jersey and Randolph Counties will begin in St. Clair, Madison and Williamson Counties prior to the year 2000. By 2020, other surface mines will have been opened in Randolph, Perry, Jackson and Gallatin Counties to provide fuel for mine-mouth power plants.

Considered only as one year of disturbance, the reduction of agricultural land from surface mining seems unimportant. It is important to note, however, that the percentages for land disturbances shown in Table 10.4 represent land which will be removed from production each year and, unless such lands are reclaimed, the losses will soon reach major significance. It is also important to realize that the data apply only to agricultural land suitable for the production of row crops. In the counties mentioned above, a significant proportion of agricultural lands is used for livestock production which will also be affected by future strip mining. The disruption of agricultural land results in losses of land for livestock grazing and for the production of corn and hay needed during the winter months.

If reclamation technology is effective, the only major impact will be the temporary loss (at least three years of production) of agricultural production on mined lands. However, various inadequacies of reclamation efforts will be reflected by the rate at which mining (an average of 550 acres/year for each 3000-MW power plant) cumulatively reduces agricultural production.

Table 10.4. Estimated Acreage of Row Crop Agricultural Land Lost Per Year to Surface Mining during 2020 in Seven Representative Counties of the SILSA

County	Total Acres in Row Crops	Total Acres Loss to Mining	% Loss to Mining
Gallatin	133,550	668	0.5
Jackson	128,124	128	0.1
Madison	254,821	255	0.1
Perry	89,262	179	0.2
Randolph	156,987	314	0.2
St. Clair	244,670	245	0.1
Williamson	29,975	60	0.2

10.1.4 Impacts of Coal Extraction on Aquatic Ecosystems

Impacts to specific aquatic ecosystems in the SILSA from coal mine and preparation plant development depends upon the location of coal reserves and the type of mines developed. The locations of coal reserves (by county) in the SILSA are listed in Table 10.5 (see Vol. I, Sec. 5). Mining development areas were identified by reserve location and the probable location of end-use facilities (see Vol. I, Sec. 4). Figure 10.1 shows these areas and the watersheds where major mining and preparation plant development may occur. The three watersheds identified are the Kaskaskia, Big Muddy, and Saline River Basins. The watersheds will be discussed following a general description of the impacts from new strip and deep coal mines.

10.1.4.1 Strip Mines

Preoperational impacts of new strip mines on waterways in the SILSA will result from construction activities. Removal of vegetation, grading of haul roads, and excavation of the pit and inclines may cause soil erosion and subsequent siltation of local streams. However, state law requires mitigative measures to control surface drainage at mine sites.[10] Diversion ditches, grass waterways along haul roads, and settling basins are employed to reduce the silt load in runoff water. Impacts of preoperation will likely be minimal providing these control measures are applied. Minimal impacts will not be detectable since the majority of streams in the SILSA have been silted by agricultural runoff for many years, and the indigneous organisms are those species which are specifically adapted to such conditions.[11]

Impacts to aquatic ecosystems from operation of strip mines have historically resulted from mineral laden effluent that was pumped to local waterways from low areas of the pit. High total dissolved and suspended solids, high acidity, and high trace element concentrations are common in effluents pumped from some mines. These discharges have resulted in the extirpation of some types of aquatic biota.[12] Fish stocks, for example, have been reduced in the Saline River due to acidic mine drainage.[11] However, discharges of this type are currently curtailed by the specifications outlined in the discharge permits issued by EPA.[10] Settling basins, acid neutralizing facilities, and chemical treatments to remove some toxic elements are being used to insure that effluents to local waterways do not impact the water quality or aquatic biota. In addition, some mining companies are finding that effluent treatment costs may be reduced when seepage water is rapidly removed from the pit. This reduces the accumulation of dissolved minerals by prolonged contact with the mineral bearing rock in the pit. These factors will probably reduce impacts to aquatic systems from new strip mines.

10.1.4.2 Deep Mines

Deep mines have also caused impacts to aquatic resources in some coal mining areas. The quantity of liquid effluent from deep mines may be less than the amount from strip mines producing equivalent coal tonnage, but impact-causing constituents in their effluents are similar. The quantity of land surface disturbed by deep mines is considerably less than that of strip mines. As a result, the degree of siltation in local streams from erosion of the disturbed land may be proportionally less for deep mines.

Table 10.5. Total Coal Reserves and Mining Methods in SILSA Counties

County	Total	Deep (>28")	Strip
Alexander	No Reserves		
Bond	1831	1831[a]	0
Champaign	No Reserves		
Clark	168	168	0
Clay	No Reserves		
Clinton	1322	1322	0
Coles	81	81	0
Crawford	443	443	0
Cumberland	4	0	4
*Douglas	412	412	0
Edgar	1750	1750	0
Edwards	54	54	0
Effingham	No Reserves		
Fayette	1174	1174	0
*Franklin	3038	3036	0
*Gallatin	1991	1761	230
Hamilton	2440	2440	0
Hardin	No Reserves		
*Jackson	526	227	299
Jasper	No Reserves		
*Jefferson	1801	1801	0
Johnson	No Reserves		
Lawrence	894	894	0
*Macoupin	3597	3421	176
Madison	1876	1367	509
Marion	421	421	0
Massac	No Reserves		
*Montgomery	3907	3907	0
Monroe	7	0	7
Moultrie	No Reserves		
*Perry	2174	1201	973
Piatt	No Reserves		
Pope	No Reserves		
Pulaski	No Reserves		
*Randolph	631	214	417
Richland	No Reserves		
*Saline	No Reserves		
Shelby	No Reserves		
*St. Clair	2114	951	1163
Union	No Reserves		
*Wabash	286	262	24
Washington	1563	1555	8
Wayne	89	89	0
White	992	992	0
*Williamson	2103	1573	530

*Currently producing coal.

[a]Numbers are $\times 10^6$ tons.

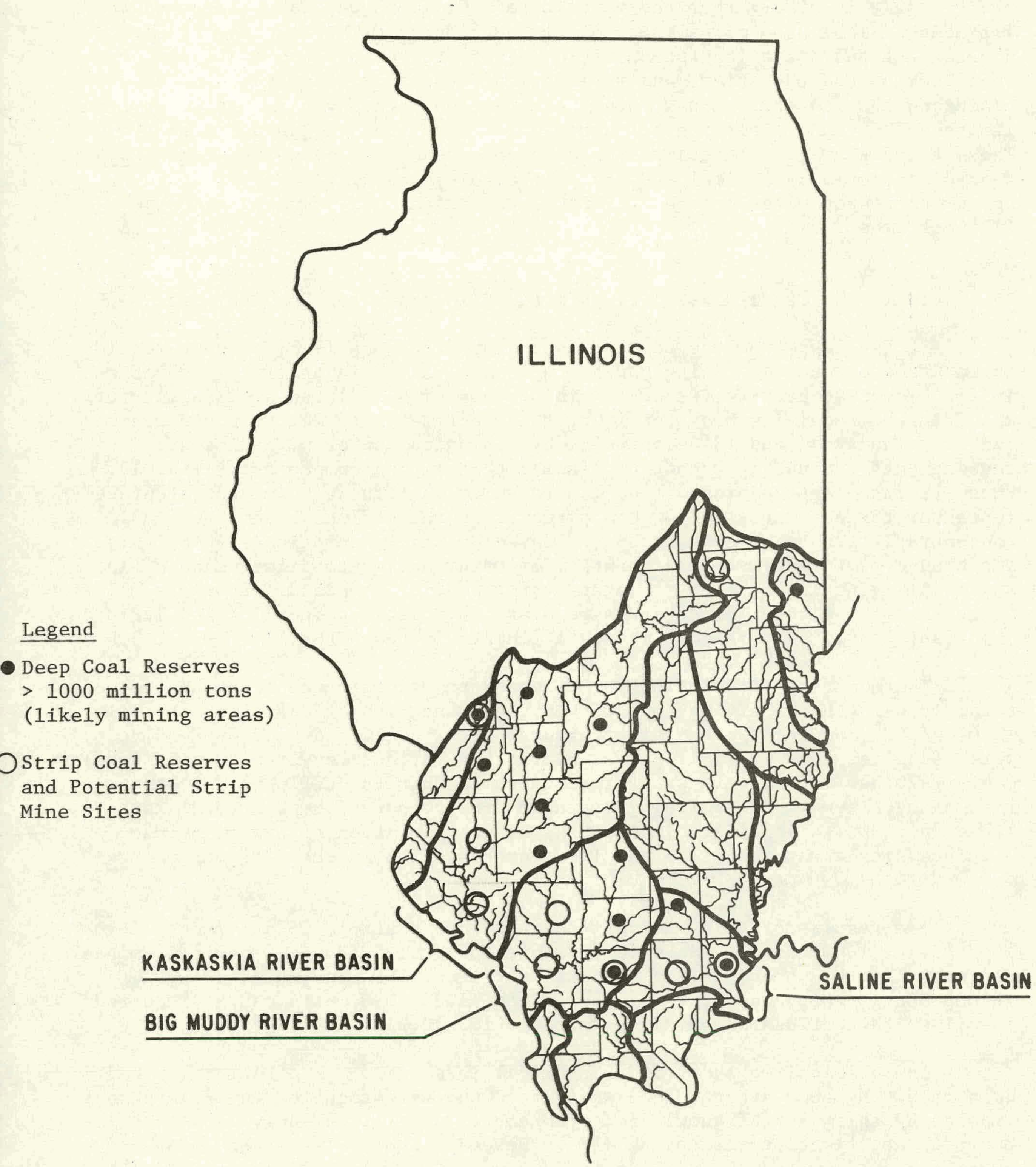


Fig. 10.1. Coal Reserves and Watersheds of Mining Development Areas in the SILSA.

Since strippable coal reserves in the SILSA are becoming increasingly scarce,[13] it is likely that the majority of new mines developed in southern Illinois will be deep mines (see Vol. I, Section 5). The aspects of deep mine development and operation (preoperation shaft excavation, preparation plant construction and operation, and reclamation) appear less hazardous to aquatic resources than do strip mines. Furthermore, the laws governing effluent limits and discharge permits for strip mines also apply to deep mines.[10] These factors suggest that impacts to aquatic resources by newly developed deep mines would be minimal. Based on the volume of discharge, it would appear that deep mines may be preferable to surface mines in the southern Illinois area.

10.1.4.3 Permissible Effluents and Dilution Water Requirements

It is clear from the observations above that the level of perturbation to watersheds from new mining depends upon (1) the effluent limits specified in the discharge permits issued to mining companies, (2) the availability of water in the receiving body to dilute these effluents to maintain the water quality standards, and (3) compliance by mining companies with discharge requirements. Since it cannot be assumed that mining companies will violate these limits and standards, it will be assumed that these standards accurately represent the concentration of constituents in the effluents and the final concentration in the receiving body. Based on this assumption, an analysis was conducted to estimate the quantity of water needed to dilute mine effluent and still maintain the most stringent water quality standard. Iron was selected as the example element since it is regulated by discharge permits and it is an important constituent in most mining effluents in the SILSA.

The quantity of dilution water needed to maintain the concentration of total iron in the receiving body within the boundaries of the effluent limit (3.0 mg/l)[10] and the water quality standard for public and food processing water supplies (0.3 mg/l)[10] was calculated for various levels of mining development (1-20 new mines). It was further assumed that the effluent discharge rate of each new mine, including drainage from preparation-plant ancillary areas was 1000 gallons per minute. The assumed location of new mines was within a single watershed and the iron concentration in the effluent was assumed to be 3.0 mg/l.

The results of this analysis suggest that a stream with a 7-day 10-year low flow of 1000 cfs may adequately dilute the effluent of 1-2 new coal mines and maintain the water quality standard for iron. However, a discharge of 10,000 cfs may be needed for 5-10 new mines, and 100,000 cfs may be required to dilute the effluent from 20 new mines (Fig. 10.2).

The chemical behavior and biological interaction of effluent discharged to a receiving body are not well understood and assessment of their impacts is impeded by this lack of knowledge. Therefore, a detailed analysis of the impacts on aquatic biota cannot be made. However, the analysis above does suggest that there is an upper boundary for the level of new mine development within any given watershed, and that the level of impact to aquatic resources is strongly dependent upon the availability of dilution water.

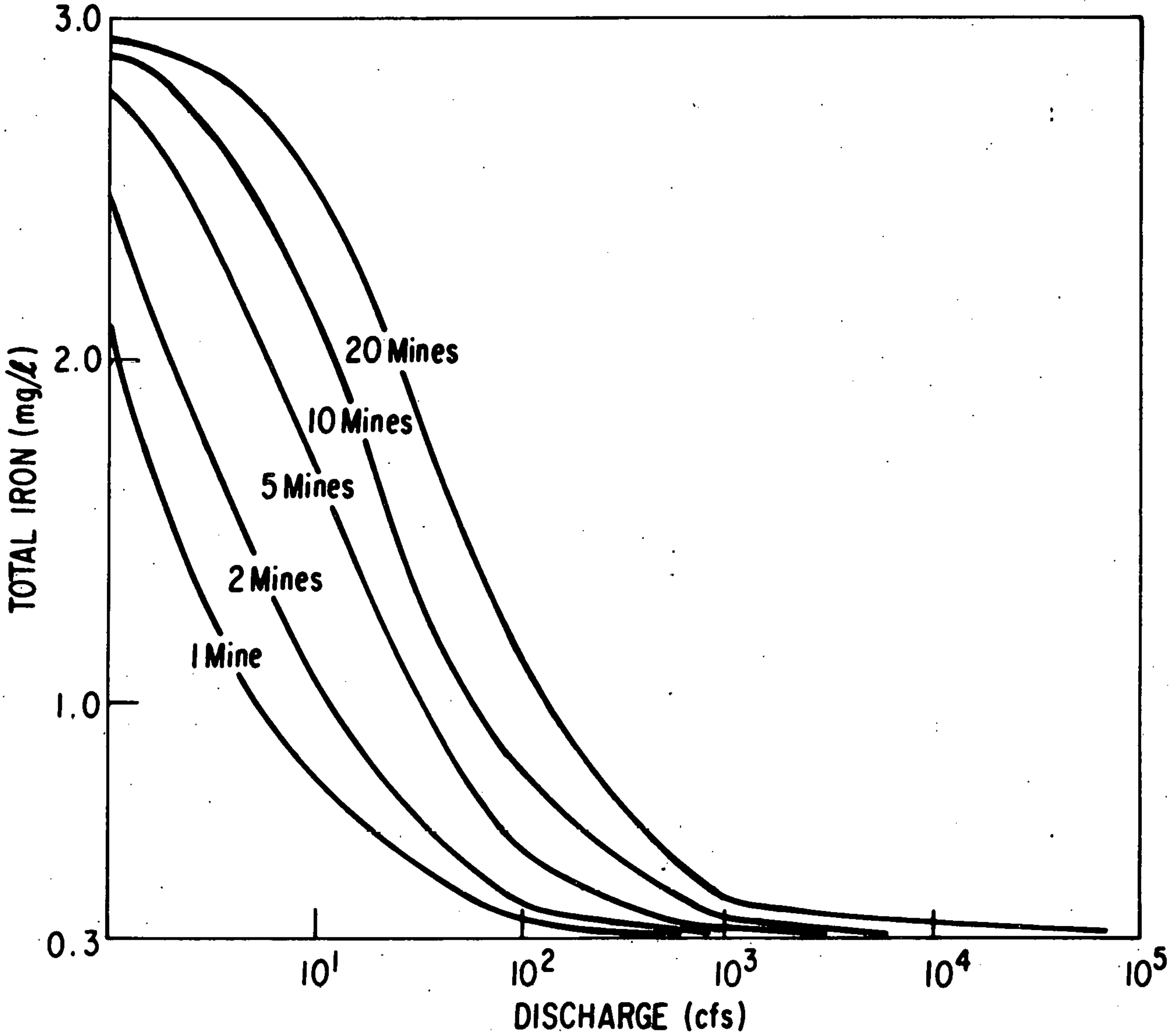


Fig. 10.2. Stream Discharge/Dilution Requirements for Total Iron from Mines.

Previously, the Kaskaskia, Big Muddy and Saline River Basins were identified as areas of new coal mine development in the SILSA. The 7-day 10-year low flow in these rivers is < 1000 cfs and it would appear from the analysis above that only minimal mining development could occur within these basins without increasing the concentration of some constituents to a level that exceeds the water quality standards for domestic and food processing water supplies. However, other water use categories are not as stringent (see Appendix 10.A). If a water quality standard of 1.0 mg/l total iron (standard for general use category)[10] were applied in these basins, then sufficient dilution water is probably available. It is unlikely that either wildlife or aquatic biota would be impacted within these basins by the less stringent standard, since the expression of a response to iron for most organisms is at levels in excess of 1.0 mg/l.[14]

10.1.4.4 Mine Development Areas in the SILSA

In the Kaskaskia River Basin, strip mine developments will probably occur in Randolph, St. Clair, and Clinton Counties located in the lower reaches of the drainage. The Herrin (No. 6) and Harrisburg-Springfield (No. 5) coal seams will be the targets of new mining.[13] The overburden material is primarily limestone and shale with excellent acid neutralizing capacity.[13] Pyritic shales are not abundant in this area and the production of acidic mine drainage is low. However, claystone dikes and fireclay deposits commonly overlay the coal seams and contribute to total suspended solids in the various liquid effluents from the mining operations.[13] In general, pollution loading of local streams from mining in this area is expected to be low and impacts minimal.

Deep mine coal reserves in the Kaskaskia River Basin are located farther upstream in the basin.[13] Potential deep mine development may occur in Clinton, Bond, Montgomery, Madison, and Fayette Counties. However, it appears unlikely that mining development will occur in the headwater region of the basin.

Between the present and the year 2020 about ten new mines may be developed in the Kaskaskia Basin. Based on the analysis conducted above, this level of development may approximate the carrying capacity for new mines in the basin without adverse impacts to water resources and aquatic biota.

Major mining developments in the Big Muddy River Drainage Basin may occur in portions of Jefferson, Franklin, Williamson, Perry, and Jackson Counties. The geology and coal bearing formations in these areas are similar to those in the Kaskaskia Drainage, but some acidic discharges have been reported in the Big Muddy Drainage.[13] However, a similar level of new development does not appear feasible in the Big Muddy Drainage since the availability of dilution water for mine effluents is approximately half that of the Kaskaskia River.[15] The carrying capacity for new development without adverse impacts is probably greater than 5 but less than 10 new mines in the Big Muddy Drainage Basin.

In the Saline River Drainage Basin, potential areas for coal development include portions of Saline, Gallatin, and Williamson Counties. However, the Saline River is impacted by acidic mine drainage and is currently one of the most heavily impacted rivers in the Central Interior Coal Province. Values of pH, iron, manganese, and total suspended and dissolved solids frequently exceed the least stringent water quality standards. Surface drainage from pre-law coal refuse (primarily pyritic shales) contains high concentrations of iron and sulfuric acid. It is unlikely that improvements in water quality of the Saline River could be affected without considerable expenditure to reclaim extensive areas of this acidic and highly ferrugenous spoil, although efforts are being made toward this goal. Availability and quality of dilution water in the Saline River does not appear adequate to receive effluent from new development.

10.1.5 Impacts of Coal Extraction on Endangered Species

Strip-mining and reclamation activities are not expected to have either a totally adverse or totally favorable impact on all State[16] or Federal[17] endangered species in the study area (see endangered species section for list of endangered wildlife species). This exception is due in part to the fact that the distribution for most endangered species lies outside the predicted areas for future coal mining. The discussion which follows includes only those species expected to inhabit the areas proposed for extensive coal mining. Although the impacts on endangered species from the loss of habitat cannot be quantified, the ensuing discussion gives some insight into the general impacts anticipated.

The timber rattlesnake (*Crotalus h. horridus*) inhabits rocky outcrops and bluffs in forested areas throughout southern Illinois.[9,16] A loss of upland deciduous forest will contribute further to the demise of this species in Illinois.

The arctic peregrine falcon (*Falco peregrinus tundrius*), an endangered species on both the State[16] and Federal lists,[17] is observed occasionally along the Mississippi River during migration. The lack of sightings and other evidence that this species uses any of the areas proposed for extensive mining suggests that it will not be impacted by increased mining activity.

The southern bald eagle (*Haliaeetus l. leucocephalus*), an endangered species on both State[16] and Federal[17] lists, overwinters in southern Illinois.[16] It also has been reported to attempt to nest in the Crab Orchard National Wildlife Refuge and at the Union County Conservation Area.[16] The establishment of deep impoundments in final-cut areas, if stocked with fish and isolated from people, may increase the available winter habitat. Bald eagles are observed each year along the lower Mississippi River, especially near locks and dams.

The cooper's hawk (*Accipiter cooperii*), a State endangered species, nests in deciduous forests and is most commonly encountered in the Shawnee National Forest.[16] The dependence on tall trees for nest sites suggests that this species will not become established in reclaimed strip mine areas until the latter stages of secondary succession. The loss of nest sites and foraging areas will adversely impact this species in Illinois.

The red-shouldered hawk (*Buteo lineatus*), also on the State list of endangered species,[16] inhabits lowland deciduous forests. It currently nests in the Shawnee National Forest. This species is not likely to be impacted by future coal mining in southern Illinois since most mine sites will be in areas removed from floodplain forests.

The bobcat (*Lynx rufus*) is on the State list of endangered species.[16] It inhabits lowland forests and wooded hillsides along the major waterways of southern Illinois. Any losses of deciduous forests in the vicinity of those habitats will further stress this species in Illinois.

The six endangered plant species in Illinois on the Federal list (see Sec. 9.6) occur in northern portions of the state, outside the areas proposed for surface mining.

10.2 IMPACTS OF COAL PREPARATION

10.2.1 Description

Newly mined or raw coal often contains high percentages of unwanted noncombustible materials or pyritic sulfur, and consequently is mechanically cleaned to reduce the concentrations of these substances. The quantity of unwanted (waste) material may be particularly high in deep-mined coal excavated by continuous mining machines, which fail to discriminate between coal and roof or bottom slate; such coal can include significant amounts of these waste materials.[18] Cleaning is therefore commonly practiced for deep-mined coal, and on a much more limited basis for strip and auger-mined coal.[19,20] In the SILSA, most if not all of the coal is cleaned irregardless of the mining methods.

Coal cleaning is highly desirable from both an economic and environmental standpoint. Removal of noncombustible materials from coals before shipment may greatly reduce transportation costs. Cleaning is known to remove as much as 25% of the mine output bulk (mostly slate and rocks).[21] Coal cleaning at the mine site prior to shipping generally presents less of a waste disposal problem than at the point of use. Coal washing also reduces the particulate levels in flue gases,[21] increases the heating value per pound of coal, and reduces the sulfur content, thereby improving coal properties and lowering the sulfur dioxide emission during combustion.

The washing facility is often part of a mine-mouth operation and can be associated with both strip and deep mining. Slurry ponds which are comprised of a fine wet refuse are also created as a result of the coal washing process. The portion of the slurry pond nearest the outfall from the washing facility is standing water.

Gob piles also result from the coal preparation process. Gob piles from old (pre-law) deep mines are highly visible in many areas of southern Illinois. Depending on the size of the mine, these piles may cover from a few to 50-100 acres. Gob piles contain coal which is lost in the refuse separation process and thus provide a potential for spontaneous combustion. Once ignited, the ensuing fire is often difficult to extinguish.

10.2.2 Impacts

The major problems and impacts associated with gob piles have been discussed under extraction (Sec. 10.1.1). The acidic runoff of the gob pile and its distance from the local waterways are probably the two most relevant factors determining the level of impact from an active gob pile. Streamflow or water volume diluting the incoming acid drainage along with the existing water quality will also influence the impacts to aquatic biota.

Historically, adverse ecological impacts have resulted from the offsite disposal of process water from coal cleaning and preparation facilities, drainage from coal stockpiles, and drainage from gob and slurry disposal areas. Under current regulations, closed-circuit process water loops are required, and discharge of liquid effluents from the coal preparation facility is prohibited.[10] Drainage from ancillary areas such as stockpiles and refuse areas is controlled by specifications in the discharge permits.[10]

The potential of large slurry ponds for wildlife utilization is best thought of in terms of a gradient. Near the outfall from the washing facility, water is high in suspended coal particles and acidic debris. This area is generally devoid of vegetation and is unsuitable for most wildlife species. As the water flows further from the outfall, sedimentation occurs and water quality improves. At the point where vegetation characteristic of wetlands is established, wildlife species become more abundant. In a slurry pond in St. Clair County the following species have been observed: beaver, muskrat, red-winged blackbird, mallard, blue-winged teal, leopard frog, cricket frog, and bullfrog. Marsh plants such as cattails (*Typha* sp.) and reed (*Phragmites communis*) invade the dry portions and periphery of slurry ponds. In St. Clair and Saline Counties, reed grows in dense stands on dry, filled portions of the ponds. Reed sends stolons 10-30 m long over the surface of the slurry.

Small coal washing operations will create slurry ponds of only a few acres. These ponds are considered less likely to provide attractive wildlife habitat due to their high sediment content and acidic conditions. The high acidity and toxicity of the coal washings will prevent amphibians and reptiles from using the slurry ponds as breeding sites. Waterfowl are observed on occasion in small slurry ponds but are not expected to forage or nest in the ponds. Larger bodies of water such as a final cut reservoir are more likely to provide suitable habitat for wildlife. The limited exposure to small slurry ponds is not expected to result in adverse impacts to most wildlife species.

10.3 IMPACTS OF STRIP MINE RECLAMATION

10.3.1 Impacts on Agriculture

Until recently, grasses, legumes, and selected trees were the primary species planted on reclaimed land. Grass and legume plantings on strip-mine spoils have been extensively studied by the Forest Service Experiment Station at Berea, Kentucky; by university personnel; and by industry.[22-26] There has been very little research on the reclamation of surface-mined lands for row-crop agriculture.

Grasses and legumes are known to germinate well on strip-mine spoils except under extremely acid (< pH 3.0) conditions. The ease of reclaiming to pasture makes it the most popular post-mining land use choice.[27] Depending upon the individual operation, the spoils should be regraded and seeded by about three years after the initiation of mining. Legume species that have been readily established on spoils in southern Illinois include alfalfa, birdsfoot trefoil, red clover, sweet clover, and lespedeza. Orchard grass and bromegrass are commonly used grass species. Other grasses, notably Kentucky bluegrass, timothy, redtop, and reed canary grass, require more time to become established than do the legumes. Grandt and Lang[27] estimate that at least two years or more are required to establish good pasture.

Pasture establishment should prove valuable in the majority of the counties to be strip-mined for coal in southern Illinois. Farms in Randolph and Williamson Counties derive 55% of their income from livestock while farmers in Madison, Perry, and Gallatin Counties depend on livestock for only 25% of their agricultural income. St. Clair County is the least dependent (13% of income) on livestock.

Successful reclamation to row-crop agricultural lands is somewhat uncertain. Research is in its infancy and little information is available. Successful growth of row crops is highly dependent upon good soil, available soil water, and nutrients, all of which are difficult to reestablish. Current legislation recognizes the need for a good rooting medium. The darkened surface soil must be removed to a depth of at least 18 in., stockpiled, and reapplied after grading. Eighty percent of the material 4 ft below the darkened surface layer must be capable of passing through a 4-mm sieve and cannot contain rocks greater than 6 in. in diameter.

Research is lacking of time necessary initially used to prepare the soil (e.g., legumes and grasses), the length of time necessary before row crops can be planted, and management procedures for reclaimed land. A report issued by the Environmental Policy Institute[28] states that reconstruction of high-quality farm land after surface mining, could take from 10 to 30 years. With such a lag in the return of agricultrual land to full production, surface mining would have a significant negative impact both on the land surface disturbed and the agricultural incomes of the counties involved.

Of the two most common agricultural crops grown in the SILSA, soybeans and corn, the former may be less expensive to produce on reclaimed mined lands. Soybean, a legume, does not require as much nitrogen fertilization as does corn. Wheat is tolerant of acidic soils[29] and thus may be the best initial crop for row-crop agriculture on strip-mine spoils.

10.3.2 Impacts on Native Terrestrial Ecosystems

10.3.2.1 Vegetative Succession

The predictability of the end results of ecological succession on reclaimed mine spoils is low since most studies of secondary ecological succession have been conducted on areas after burning or on abandoned agricultural fields. The extent to which secondary succession on reclaimed spoils follows the pattern typical for various regions in southern Illinois, will have a strong influence on the ultimate ecosystem composition. To gain some nderstanding of the course of succession and its importance to wildlife in any given area being reclaimed, it is necessary to examine and evaluate the revegetation procedures being utilized.

The full course of "ordinary" secondary forest succession in south-central Illinois requires more than 75 years from the cessation of the disturbance to the development of a climax oak-hickory forest. Because of this, it is generally not feasible to manage succession to its end result. Hence, most revegetation efforts merely initiate succession, assuming that natural processes will eventually establish the desired end result. However, there are three other goals of reclamation which often become constraints on any attempt to direct succession. Reclamation must be directed toward physical stabilization of the spoils in order to reduce erosion and subsequent siltation into aquatic systems, and toward chemical stabilization of the spoils in order to immobilize any heavy metals, trace elements, or other potentially toxic materials from the clay partings in the spoils. Also, mined land must be returned to a level of productivity greater than or equal to pre-mining productivity.

Current practices for spoils reclamation in Illinois begin during mine development (Appendix 10.A). The surficial material (nominally, the topsoil) is removed and stockpiled. Following the initial placement of the spoils, the spoils are recontoured and any toxic material is buried under non-toxic spoils. Then, the stockpiled topsoil is placed on the spoils with or without seedbed preparation (such as disking) to mitigate the effects of compaction by the earthmoving equipment. This is typically followed by liming and fertilizing. Finally, a cover crop is broadcast seeded (often by aerial seeding) on the seedbed. Although there are numerous deviations from this procedure at several specific mine sites throughout the state, the above outline can be taken as the reasonable minimum reclamation procedure to be followed in Illinois.

Succession on orphaned prelaw spoils, differs in several important ways from "ordinary" secondary sucession. A typical "ordinary" disturbance which initiates secondary succession involves the complete destruction of only the above-ground vegetation. This is generally accompanied by partial removal of the topsoil, or "A" horizon (complete removal in gullies) due to erosion, and by ashing of some of the organic material in the soil (in the case of fire) or reduction in available nutrients (in the case of agricultural fields). Otherwise, the soil ecosystem is largely unaffected by those disturbances which initiate "ordinary" secondary succession. By contrast, the disturbance due to strip mining affects the above-ground ecosystem, soil ecosystem, and the entire geologic profile above the deepest seam mined. The soil factors affected include the physical structure, inorganic and organic chemical structure, and the living components (Table 10.6). Essentially, succession on pre-law spoils is better characterized as primary succession than as secondary succession in the usual sense.

Natural primary succession is quite slow. The initial growth will be annual weeds (sedges, wild mustards) and perhaps a few perennial weeds (crabgrass, ragweed) sparsely scattered on the site. It may take several years efore these weeds consolidate to form an ecologically interacting community. owever, the immediate requirements for spoil stabilization preclude the possibility of waiting for natural succession to begin.

Table 10.6. Effects of Surface Mining on Soil Structure

Factor	Pre-mine Soils	Spoils (pre-law)
Physical	Vertical distribution patterns of particle sizes	Unsorted
Chemical		
Inorganic	Weathered, leached zones reprecipitation zones (e.g., fragipan)	Unweathered, unleached
Organic	Organic horizon(s) at surface microbes in upper horizons fauna in upper horizons	No living organisms

Topsoiling is utilized as a mitigative measure to lessen the severity of the impact to the soil structure by returning an organic layer which includes a living component. Although such practice does nothing to alter the physical and inorganic chemical impacts of mining, it does appear to allow the revegetation plan to start at the consolidation stage of succession rather than at the pioneer stage. This allows broadcast seeding of grasses (orchard grass, brome, fescue) and legumes (lespedeza) for quick cover. Additional possibilities for seeding include commercially available* native forbs (coneflower, black-eyed susan, coreopsis) or introduced forbs (cornflower, ox-eye daisy, larkspur). After a few years, this planted early successional community can be upgraded to pasture by broadcast seeding a forage mixture (developed in cooperation with the Agricultural Extension Service, county agent), plowed under and replaced with crops, or altered to induce natural succession toward the desired end result. For prairie restoration, this may require seeding to prairie grasses (switchgrass, Indiangrass, bluestems) and perhaps to commercially available prairie forbs. For reforestation, it may be necessary, or at least advantageous, to plant shrubs (sumac, redbud, plum, dogwood) and trees (elm, cherry, boxelder, ash, oaks, hickories). On the most severe spoils, pine and/or cedar plantings may be beneficial.

10.3.2.2 Wildlife

Current reclamation amendments emphasize the establishment of a vegetative cover as soon as possible after final grading has been completed. Often a mixture of grasses is applied by aerial seeding. Reclamation personnel in St. Clair and Saline Counties, Illinois, indicate that areas reclaimed to grasses provided foraging habitat for hawks during the spring and fall migration. This indicates a successful immigration of prey species such as the meadow vole, prairie vole, deer mouse, and eastern cottontail. The red-tailed hawk, marsh hawk, and sparrow hawk were observed foraging in reclaimed grasslands in April 1976 in St. Clair and Saline Counties during a visit with

**Data from Environmental Seed Producers, Inc., El Monte, Calif., "Computer Pack."*

eclamation personnel. The bobwhite population should increase in areas eclaimed to grasses, provided that these areas are near forest-edge habitat needed for nesting. Other grassland birds such as the horned lark, eastern meadowlark, and dickcissel should increase in abundance in areas planted in wheat, lespedeza, clover, or fescue grass.

Wildlife management practices which involve the establishment of forest edge provide the greatest diversity of habitat.[3,30,31] The planting of the shrub autumn olive improves the wildlife value of an area by providing excellent browse and cover for white-tailed deer and by increasing the types of nesting sites for songbirds. Forest-edge habitat has been increased by planting shortleaf and loblolly pines. Although pines help control soil erosion and provide nesting sites for birds, they are considered poor habitat for game species such as the gray squirrel, fox squirrel, white-tailed deer, and eastern cottontail.

The slow-growing nature of many oaks and hickories discourages their use in reclamation as wildlife plantings. Unfortunately, areas that were covered with extensive upland deciduous forests before mining will not be reclaimed to deciduous forest. This will prevent the invasion of these areas by the gray squirrel and fox squirrel; species highly dependent for food upon the acorns and nuts of oaks and hickories.[5,6,32] This permanent change in land use will affect other wildlife species characteristic of deciduous forests. Many birds, mammals, reptiles, and amphibians that require the physical and biotic resources of a multistrata plant community will be unable to establish breeding populations on areas reclaimed with pine plantations. When pines and shrubs are planted with adequate spacing, the natural invasion of oaks and hickories may be enhanced.

The impoundments created in the final cut or during the grading of mine spoils represent a potential increase in habitat for waterfowl, marsh birds, amphibians, reptiles, and many other wildlife species. Shallow impoundments (1-3 meters deep) with soft bottoms will provide foraging habitat for ducks such as the mallard, blue-winged teal, ring-necked duck, and black duck. The shallow areas of the impoundments will permit the growth of rooted aquatic plants, algae, and aquatic insects which will serve as food sources for surface feeders and dabbling ducks. The large deep impoundments, while undoubtedly serving to attract migrating and winter resident waterfowl, will not be utilized for long periods (several days or weeks) due to their lack of aquatic plants and insects. Canada geese, snow geese, and mallards may remain in the vicinity of these impoundments if agricultural row crops such as corn, wheat, and oats are planted in areas adjacent to the impoundments. The increase in the number of impoundments is not expected to attract large numbers of Canada geese and snow geese from established large overwintering refugia such as the Horseshoe Lake Conservation Area (Alexander Co.), Union County Conservation Area, and Crab Orchard National Wildlife Refuge (Williamson Co.).

10.3.3 Impacts on Aquatic Ecosystems

The primary impact to the aquatic resources within an area which has experienced surface mining is directly related to the creation of final cut reservoirs and other impoundments.

The final-cut and inclines (exit ramps) at a mined-out pit may be used as disposal areas for refuse from coal preparation facilities, but historically they were left to fill with seepage and surface drainage water forming a reservoir. Although the majority of new mines developed in the SILSA will likely be underground, some surface mining will be conducted and new final-cut reservoirs may be included in the reclamation plan. In this section, the physical, chemical, and biological aspects of these reservoirs will be described and their impacts on land use and aquatic habitat discussed.

10.3.3.1 Physical Description

Final-cut reservoirs are typically long narrow lakes (the pit) with 3-5 perpendicular side arms (the inclines), ranging in depth from 15-45 feet.[33] The water surface area per unit of mined land and the configuration of these lakes depend upon the reclamation law in effect during the final grading process. Before 1968 (Law I), spoil areas were not reclaimed and consisted of rugged spoil ridges with V-shaped valleys which often became filled with water. The resulting lakes were very dendritic in nature with considerable shore length per unit of water surface. Law II, in effect between 1968 and 1972, required grading the top of spoil ridges to a width of 18 feet. The resulting lakes were also dendritic and their surface area accounted for approximately 20-25% of the total mine area (see Sec. 10.3.3.4). Since 1972, the present reclamation law (Law III) has been in effect. It stipulates that the mined-out land surface must be graded to a slope not greater than 15% and not greater than 30% on the margins of the final cut and inclines.[10] This has reduced the dendritic nature of final cut reservoirs and the water surface area per unit of mined land is approximately 15-20%, under Law III (see Sec. 11.3.3.4). Shore length is also considerably reduced as compared to Law I and II reservoirs.

10.3.3.2 Water Quality

Water quality in the final-cut reservoirs depends primarily on the mineral nature of the overburden material at the mine site. In southeastern Illinois, particularly the Saline River Basin, pyritic minerals in the shale oxidize and combine with water to form sulfuric acid and ferric hydroxide which produce highly acidic water. Acidity may range from 100-30,000 ppm and pH levels of 3.0 or less are common.[33] High levels of total iron and manganese are also common.[33] In some cases these reservoirs are being used to dispose of gob and slurry, and upon filling they will be covered with non-acidic materials and revegetated.[33] In other cases, where the development of a reservoir with high quality water is likely, direct application of lime, limestone, soda ash, or caustic soda to the lake have proved successful in treating water with less severe acidity. With proper grading and burial of acidic spoils, some reservoirs effectively neutralize themselves, and in one such lake a pH of 7.6 developed in two years after it started to fill with water.[33] By the time aquatic biota begin to develop in the reservoirs, the water quality has usually improved considerably. The water appears clear and clean and pH values usually range from 7.5 to 8.5.[33]

In southwestern Illinois, final cut reservoirs are not very subject to acidification, since pyritic shales are not common in the overburden and no acid neutralizing treatment is required. Fine-grained soil may cause turbidity in some of the newly developed reservoirs in this area, but this condition is usually temporary as the soil soon settles. Proper grading and rapid revegetation of the surrounding area reduce the source of this material. High quality water is the general case in final cut reservoirs located in southwestern Illinois.

10.3.3.3 Biota

Final-cut reservoirs initially contain poorly developed populations of aquatic biota. However, as water quality improves and the physical-chemical aspects of the reservoir become more stable, biotic colonization by planktonic algae and invertebrate fauna occurs rapidly. Migration and drift of organisms may enhance colonization in reservoirs that receive stream inputs. Some of these organisms can reproduce in the lake-type habitat and may establish permanent residence in the reservoirs. Drainage from heavily fertilized adjacent reclamation land probably increases nutrient (nitrates and phosphates) levels in the water encouraging growth of flora and herbivorous fauna, which, if uncontrolled, promotes eutrophication.

As plants and invertebrate organisms develop, they establish a food supply for populations of various fish species. The fish may be minnow and sunfish species which rapidly multiply and provide a forage crop for predaceous fish species. However, natural colonization may not provide the most desirable community of fish species. These reservoirs usually do not have well-developed predator fish (game fish) populations, and stocking programs have been utilized by some mining companies to enhance the propogation of game fish species. Combinations of predator-prey fish have been utilized. A sunfish-bass combination was introduced into some reservoirs in the SILSA. The stocking rate was a 10:1 ratio of sunfish to bass and a healthy sport fishery for bass developed.[33] Other prey species include minnows and perch while other predator species used are walleye pike, northern pike, and muskellunge. During the initial years of community development in the reservoirs, growth rates of organisms and populations should be high since space and food are not limiting.

Management practices should include not only the stocking programs, but also habitat development and water quality management. The reservoirs generally lack shallow areas or littoral zones since the basins which they occupy are steep-walled. Development of shoal areas during final grading of the land area may encourage the development of littoral flora, fauna, and waterfowl, and enhance the over-all development of the reservoir community. Direct application of fertilizer may be necessary to increase primary production in the reservoir and rotenone treatment may be required to reduce populations of undesirable fish species. Other fish species may also be added to the community to increase the diversity and stability of the community.

The rate of community development may fluctuate among different reservoirs, but the communities should stabilize within 5-15 years. Proper management of final-cut reservoirs can yield high quality aquatic habitat for recreation and wildlife proliferation.

10.3.3.4 Available Aquatic Habitat - Before and After Mining

An analysis was conducted to determine the change in the acreage of aquatic habitat per unit of land area, caused by strip-mine reclamation practices. Representative samples of land undisturbed by mining were selected from aerial photographs of portions of the Saline and Kaskaskia River Drainage Basins. The acreage of farm ponds and lakes in each sample was measured. The total length of wooded stream segments in each sample was measured and multiplied by a stream width of 100 feet to determine stream habitat acreage. Stream habitat and pond areas were combined to form an estimate of the total acreage of aquatic habitat in each sample. Surface water acreage from representative samples of reclaimed strip mines was determined similarly. Strip mines reclaimed under both Law II (1968-1972) and III (1972-present) were utilized. The percentage of the land surface covered by aquatic habitat was calculated for both mined and un-mined samples.

The results of this analysis suggest that approximately 5-6% of the land area in the portions of the two counties examined consists of aquatic habitat prior to strip mining. Approximately 0.5-1.0% is pond habitat and about 3.5-5.5% is stream habitat. Reclamation activities appear to increase aquatic habitat. Law II reclamation areas contain approximately 20-25% aquatic habitat, and Law III areas have about 15-20% (Table 10.7). Based on Law III values, this represents a 330% increase in aquatic habitat as a result of strip mine reclamation. The habitat produced is lake type habitat, and very little if any stream habitat is created or remains following reclamation.

10.3.3.5 Potential Uses of Final-Cut Reservoirs

A considerable increase in aquatic habitat and water resources results from strip mine reclamation under the current law. However, the final disposition of reclaimed land and the utilization of the aquatic resources is a complicated question that revolves about those who may be affected by the decision. In southern Illinois, where lake habitat is not particularly abundant and seasonal droughts result in intermittent flow of many smaller streams, these reservoirs are a valuable aquatic resource.

Contenders in the affair would probably include the mining company, original land owner or lessor, adjacent property owners, township, or county and state authorities. It is likely that each could present a convincing case for their utilization of the resources. Some potential uses, outlined in Table 10.8, hint at the complexity of the problem.

From a water quality and aquatic impact point of view, some potential uses appear more favorable than others. However, preservation and protection of aquatic resources is but one of the many aspects concerning the final disposition of these resources, and a decision based on this aspect alone may not provide an adequate answer. Considerable social, economic, and environmental information is needed to make mutually satisfactory decisions concerning the ultimate disposition of these resources.

Table 10.7. Comparison of Aquatic Habitat Acreage Before and After Strip Mining in Two SILSA Locations

Undisturbed Land (No Mining)	Saline River Basin (Saline County)	Kaskaskia River Basin (Randolph County)
Total Acreage Examined	3380	5000
Stream Habitat Acreage	180	175
Farm Pond Acreage	25	55
Total Aquatic Habitat Acreage	205	230
Percent Aquatic Habitat	6.0%	4.6%
Mined-Out Land (Grading complete and reservoirs full)		
Total Acreage-Law II Spoil	546	2420
Total Aquatic Habitat Acreage	122	587
Percent Aquatic Habitat	22%	24%
Total Acreage-Law III Spoil	870	436
Total Aquatic Habitat Acreage	175	64
Percent Aquatic Habitat	20%	15%
Percent Increase in Post-Mining Aquatic Habitat Acreage	330%	330%

10.4 IMPACTS OF COAL COMBUSTION

10.4.1 Combustion Emission Products

10.4.1.1 Impacts of Gaseous Pollutants on Terrestrial Ecosystems

The purpose of this section is to evaluate the potential ecological impacts of the major gaseous primary pollutants (SO_2, NO_x, CO, and hydrocarbons) emitted from new coal-fired electric generating plants to be located in the SILSA as a result of increased coal utilization projected for the year 2020. For this assessment, the increased coal utilization is considered to be represented by a number of 3000-MW coal-fired model plants. The model plants are assumed to be sited either singly or in a clustered configuration, with a total of 12 plants located within a 36-square-mile area. The siting patterns and constraints for the single and clustered plants, the model plant operating characteristics, and pollutant emission rates are discussed in detail in Vol. 1, Sections 4 and 6 of this document.

Table 10.8. Potential Uses for Strip-Mine Reclamation Land and Newly Created Aquatic Resources

I. Fill Final Cut Pits and Return Land to Original Proportion of Aquatic Habitat

Use: A. Pasture or Hay
B. Row Crop
C. Timber Crop
D. Municipal or Industrial Waste Disposal

II. Generate Aquatic Resources

Use: A. Public Recreation

a. Fishing
b. Hunting
c. Boating and Swimming
d. Camping

B. Private Recreation

a. Private Clubs
b. Recreational Home Development

C. Wildlife Preserves

a. Waterfowl Sanctuary
b. Fish Rearing Facilities for Stocking Programs

D. Aquaculture

E. Water Supply

a. Public
b. Industrial
c. Agricultural-Irrigation

For the pollutants being considered, biota are usually affected by the igh, short-term pollutant concentrations resulting from stack gas plume impinging the ground surface (fumigation) near the power plant during conditions of a temperature inversion.[34] Therefore, conservative short-term meteorological assumptions were applied that give rise to the highest reasonable estimates of pollutant concentrations that might occur around the model plant. These assumptions are discussed in Sections 6.3 and 6A.3 of Volume 1. Application of this approach results in a worst-case estimate for the effluents from the model plant.

The SILSA is predominantly rural and devoted primarily to agricultural production. However, substantial portions of the area are used for non-agricultural purposes, the Shawnee National Forest being the most notable of such exceptions. For this assessment, it is assumed that land use patterns will remain relatively stable through the year 2020. Section 9 of this volume presents a detailed ecological characterization of the SILSA.

Sources of Pollutants

Gaseous pollutants resulting from coal-fired electric power generation amount to about 7% (by weight) of the total primary pollutants currently generated by human activities and emitted to the atmosphere in the United States. The largest proportion (about 47%) of total pollutants consists of carbon monoxide, primarily from internal combustion engine exhausts.[35] Coal combustion in power plants accounts for about 40% of the total sulfur-compound emissions, and about 11% of the total nitrogen oxide (NO_x) emissions in the United States.[36,37] Sulfur oxides and NO_x account for approximately 98% of the total gaseous pollutant emissions from a coal-fired plant. Carbon dioxide and water vapor are major emission products, but are usually not considered as primary pollutants. Carbon monoxide, hydrocarbons, and various other organic and inorganic compounds make up the remaining 2% of the emitted pollutants.[35]

Factors Affecting the Responses of Biota to Gaseous Pollutants

The effects of air pollutants on plants and animals may be classified into three rather broad categories: acute, chronic and long-term. Acute effects are those which result from relatively short (< 1 hr to 1 month) exposures to high concentrations of pollutants. Chronic effects occur when organisms are exposed for months or even years to comparatively low levels of pollutants. Long-term effects include abnormal changes in ecosystems and subtle physiological alterations in organisms which may result from the coexistence of air contaminants and living systems for decades or longer. Chronic effects are caused by the gaseous pollutant acting directly on the organism, while long-term effects may be indirect or caused by secondary agents such as changes in soil pH caused by acid rain (see following discussion) which, in turn, is formed primarily from atmospheric SO_2 and airborne water droplets.

The literature on the effects of air pollutants on biota is characterized by a preponderance of studies of experimental fumigations in chambers hat utilize doses of pollutant sufficient to induce symptoms of acute injury. nformation obtained from natural conditions, field conditions, and studies dealing with chronic levels of injury is limited, although, in general, pollutants reach levels associated with chronic injury more frequently than they reach levels which cause acute injury. Studies of long-term effects of pollutants are virtually nonexistent. This situation is partly due to the fact that acute injury symptoms in sensitive species are frequently easily recognized and lend themselves to quantitative assessment, in contrast to the more subtle effects of lower dosages.

In assessing pollutant effects on biota, the concept of dose (concentration per unit time) is extremely important. For example, a brief (several minutes to hours) exposure to a relatively high concentration of a pollutant may have no measurable adverse effect on an organism, but if exposed to the same concentration for a longer period of time, severe injury could result.

The meteorological conditions that would create worst-case ground-level effluent concentrations from the model plant occur during an event described as plume fumigation.[38] Plume fumigation occurs when the stack gas plume is trapped by the bottom of an inversion layer rising above the top of the stack after sunrise or lying within a few thousand feet of the top of the stack. Under these conditions, the stack effluents mix downward rapidly, fumigating the ground within the plume sector. Upward mixing is limited by the inversion. The highest concentrations are usually reached within a few kilometers of the plant. Under actual field conditions of plume fumigation, organisms are never exposed to single pollutants. Rather, they are exposed to relatively high concentrations of all the plume constituents plus usually lesser concentrations of the pollutants present in the ambient air. It is well documented that certain combinations of pollutants cause synergistic responses in biota.[36,37] In these cases, two gases at concentrations too low to cause visible injury when applied alone, cause damage as a mixture.

Because of insufficient quantitative field data, it is not yet possible to evaluate in detail the chronic or long-term ecological effects of primary pollutants such as SO_2 and NO_x from the model plant, or the effects of secondary pollutants such as ozone (O_3) peroxyacetyl nitrate (PAN), and acid rain formed from NO_x, SO_2, whose chemical properties may be changed in the presence of catalysts, water-vapor, and/or sunlight. However, these secondary pollutants may themselves have effects on biota or they may synergistically intensify the effects of the primary pollutants SO_2 and NO_x. These adverse effects are usually limited to periods when stable meteorological conditions prevail in the region of the plant.

Analysis of Effects of Predicted Model Plant Pollutant Doses on Biota

The calculated pollutant concentration values and corresponding isopleths are presented in Tables 6A.8a to C and Figures 6A.5 and 6 of Sections 6, Volume 1. SO_2 is the most abundant primary gaseous pollutant produced by the model plant. Some of the potential 24-hour dose levels (Vol. 1, Table 6A.8C) fall within the acute SO_2 injury range for sensitive vegetation (131 to 1300 $\mu g/m^3$ for 8 hr) and approach the threshold injury level for plants of intermediate sensitivity.[39] However, these doses are well below the injury threshold ($\sim$ 13,100 $\mu g/m^3$) for vertebrate animals.[37,40] The quantitative data on SO_2 sensitivity of invertebrate animal species in this study was found inadequate o establish an injury threshold. Observational data indicate that some nsect species are adversely affected by concentrations > 13,100 $\mu g/m^3$ when exposed for a period of days.[41]

Nitrogen oxides are the next most abundant pollutant produced by coal-fired plants. Both animals and plants can be directly affected by NO_x, but acute and chronic threshold injury levels are at higher doses ($\sim$ 2000 $\mu g/m^3$) than any of the doses predicted in the vicinity of the model plant.[36] The direct impacts of NO_x, in this case, are considered to be negligible and therefore will not be addressed further here.

Perhaps the most important problem associated with NO_x is not the toxicity of such gases themselves, but the secondary pollutants (O_3 and PAN) that are produced when NO_x reacts with airborne hydrocarbons. Other, larger sources of NO_x (i.e., transportation) also contribute to the formation of secondary pollutants. Because of the diverse and diffuse nature of the reactants that form O_3 and PAN, as well as variable reaction times, secondary pollutants tend to affect large areas and are difficult to associate with a specific point source such as a coal-fired power plant.

Comparatively small amounts (relative to SO_2 and NO_x) of carbon monoxide (Tables 6A.8a to c, Sec. 6, Vol. 1) and hydrocarbons[42] will be emitted by the model plant. The expected maximum concentrations of neither CO nor hydrocarbons considered alone are sufficient to cause measureable direct impacts to biota in the vicinity of the plant.[35] However, model plant emissions will cause increases in the local ambient levels of both pollutants, each of which are source components of secondary pollutants. However, secondary pollutants are not being considered in this report.

In summary, the preceding analysis indicates that SO_2 is the only primary gaseous pollutant resulting from operation of the model 3000-MW plant, sited singly or in the clustered configuration, that may cause measurable ecological impacts. The expected impacts will be limited to vegetation, primarily those plant species in the SO_2 sensitive category. NO_x, CO, and hydrocarbons will have negligible effects as primary pollutants. This being the case, a more detailed evaluation of the effects of SO_2 on vegetation will be presented below.

General Effects of SO_2 on Vegetation

Acute injury to vegetation, usually associated with short-term exposure to high SO_2 concentrations, is characterized by collapsed marginal or intercostal leaf areas that first have a water-soaked appearance. Later, these dead areas dry and bleach to an ivory color in most species, but in some they become brown or brownish red. Chronic SO_2 injury results in light to severe damage, and is characterized by leaf yellowing (chlorosis) that develops from exposure to sublethal concentrations of the gas over a long period of time.[39]

Acute and chronic SO_2 injury can result in death of the plant or in transient reductions of live plant biomass. If the fumigations occur intermittently, affected plants may recover by continued or increased growth and eplacement of damaged tissue during periods when conditions are favorable.

However, if the amount of damaged tissue exceeds 5-30 percent of the total amount of foliar tissue (depending on species), productivity or yield may be decreased.[43,44] Subtle long-term effects are also possible, in which the SO_2 interferes with physiological or biochemical processes without visible symptoms but which result in effects on growth and possibly on yield.[39]

Plant species and varieties show a considerable range of sensitivity to SO_2. This range is the result of interactions among microclimatic (temperature, humidity, light, etc.) edaphic, phenological, morphological, and genetic factors that influence plant response. Threshold injury in various plants may be caused by short-term SO_2 concentrations ranging from < 1 ppm to > 10 ppm.[39] In other words, a level of SO_2 that may kill one species may not affect another species. Figures 10.3 through 10.5 give the SO_2 dose-injury curves for plants in the sensitive, intermediate, and resistant classes, respectively. The concentrations and exposure times (doses) shown for each susceptibility grouping are applicable only when the plants are growing under the most sensitive environmental conditions and stage of plant maturity.[39]

Interactions and synergistic effects of SO_2 and other pollutants have been reported.[39] These preliminary studies have shown injury to several species, resulting from the interaction of NO_x and SO_2. In most cases the injury resulting from NO_x and SO_2 applied together is greater than the injury caused by the same concentrations of either gas alone.

<u>Mechanism of SO_2 Injury</u>. SO_2 enters the plant principally through the leaf stomata and passes into the intercellular spaces of the mesophyll, where it is absorbed on the moist cell walls and combined with water to form sulfurous acid and sulfite salts.[45] The sulfites are presumably oxidized to sulfates which can be metabolized normally by the plant. These sulfates can actually stimulate growth if the plant is deficient in sulfur.[46] However, if plant tissues accumulate SO_2 faster than it can be oxidized and assimilated, concentrations of sulfite become toxic and damage occurs as a result of chlorophyll destruction and cell collapse.[45]

<u>Effects of SO_2 on Crops</u>. In general, effects of SO_2 on crop yield have not been found unless accompanied by visible injury.[39] However, the amount of research in this area has been small and studies attempting to relate both visible injury and invisible physiological effects to decreases in yield are continuing.

In one study,[47] a total of 1127 acres of soybeans (a SO_2-sensitive plant) distributed among 62 fields near a large coal-fired electric generating station, were exposed to SO_2 levels which caused some severe leaf injury on 0.5 m-tall plants at an early pre-blooming stage. Eighteen variables, including leaf injury (chlorosis and necrosis) by SO_2, were examined to determine if possible yield losses were attributable to SO_2. The SO_2-induced leaf injury was not a significant factor in accounting for yield variation from most of the 110 fields studied. Factors contributing to poor yields were low soil fertility, soybean cyst nematode infestation, continuous soybean cropping, and late planting, rather than SO_2 injury. Apparently, most of the affected plants attained near-normal growth after the SO_2 injury episode. In several

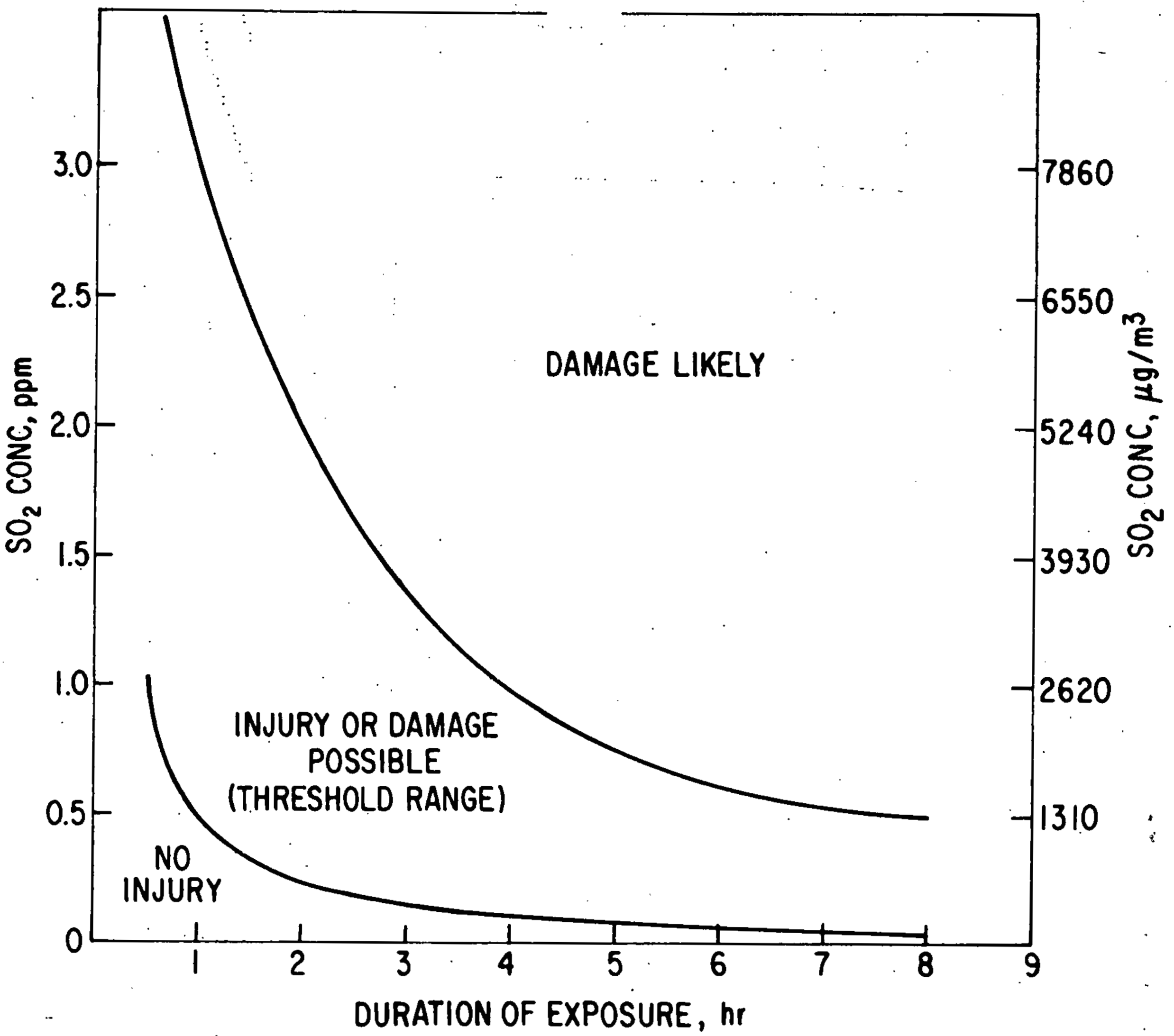


Fig. 10.3. SO_2 Dose-Injury Curves for Sensitive Plant Species.

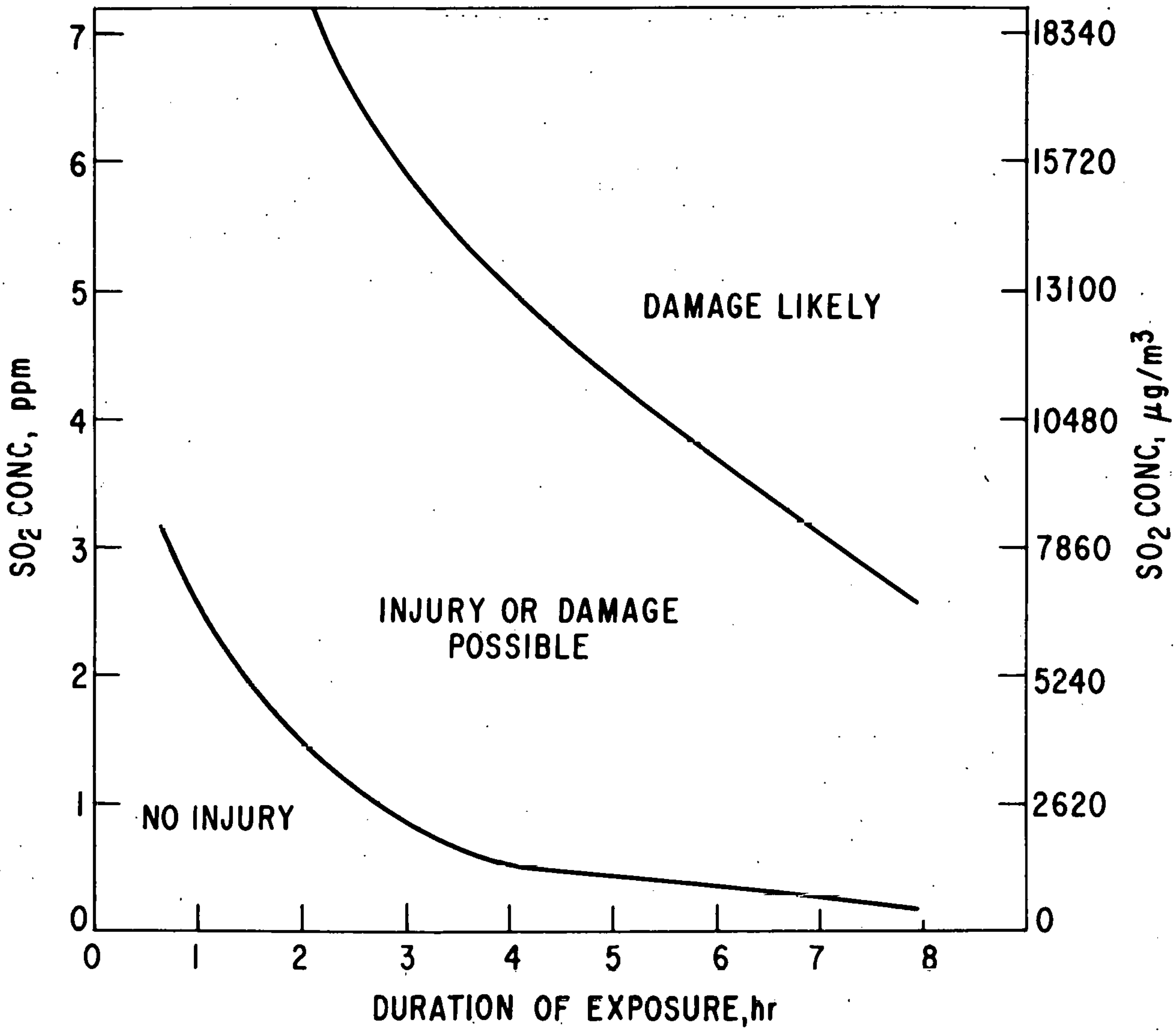


Fig. 10.4. SO_2 Dose-Injury Curves for Intermediate Plant Species.

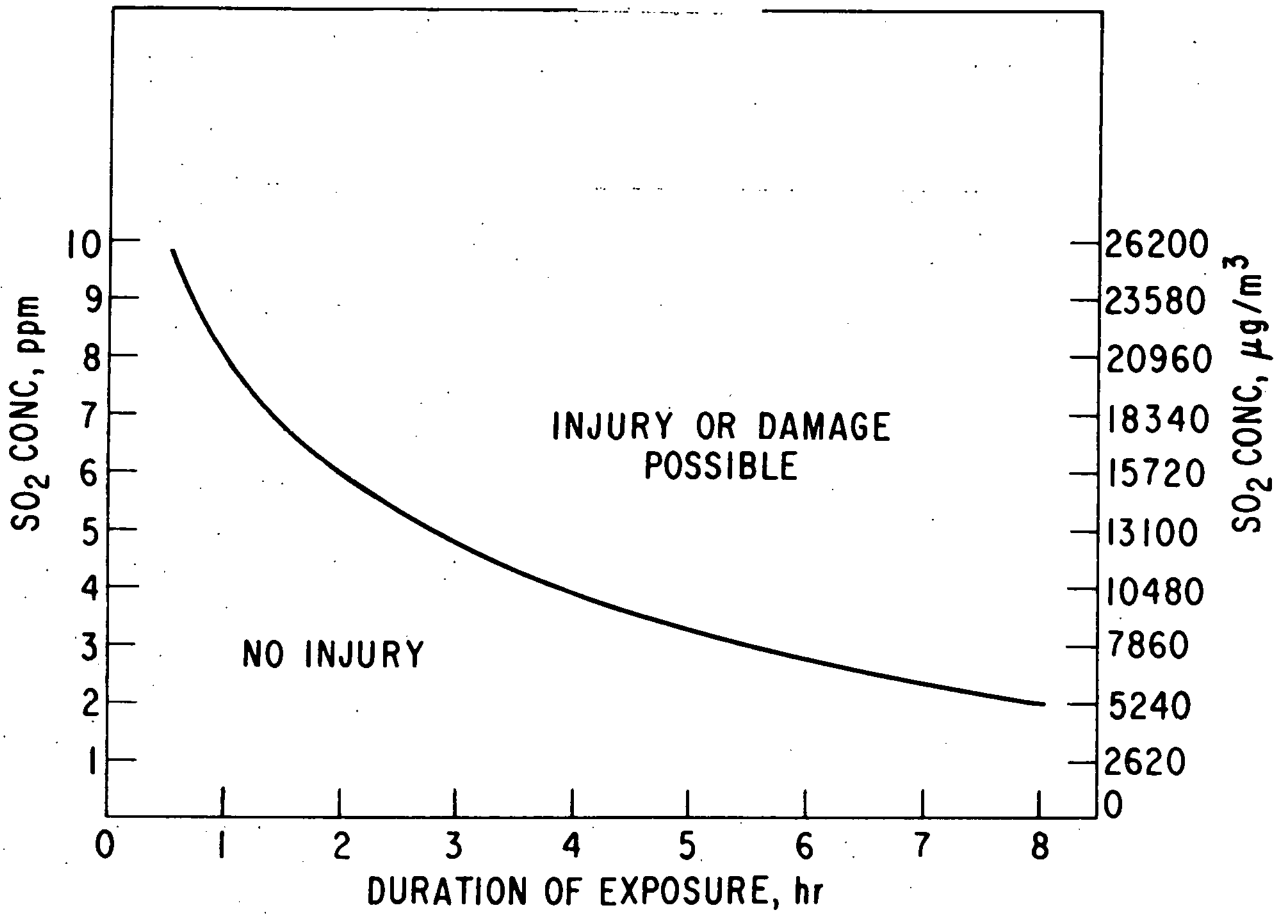


Fig. 10.5. SO_2 Dose-Injury Curve for Resistant Plant Species.

other studies[48] on soybeans it was found that if the SO_2 exposure occurs between August 15 and the first week in September (the flowering period) and if leaf chlorosis is greater than about 5%, some yield reduction can be expected. Exposures before or after these dates probably will not result in yield reduction unless chlorosis is severe.

Grain, vegetable, pasture and forage crops, most of which are also in the sensitive class, are probably susceptible to SO_2 injury for most of the growing season. Corn, on the other hand, is one of the most resistant crop species and has rarely been injured by SO_2 under field conditions.[39] In areas where pollutant fumigation is known to be a problem, resistant agricultural varieties or entirely different, more resistant crops may be planted.

Effects of SO_2 on Natural Ecosystems

In addition to acute SO_2 effects, which can result in visible injury to plants wherever they grow, the chronic and long-term SO_2 effects take on added significance in natural ecosystems because of the relative permanence of the vegetation and the delicate balances that exist between ecosystem components. As a contrast, in areas supporting managed agricultural ecosystems where the existing forage or crop plants are harvested and replaced by new plants each growing season, the chronic and long-term effects of SO_2 may be virtually eliminated.

It is likely that, in natural ecosystems subjected to persistent SO_2 levels, annual and perennial plant species would be affected differently. For example, a population of annual plants would be affected sooner and perhaps more severely by factors impairing sexual reproduction and/or seed germination than would a population of perennial plants. Such chronic and/or long-term SO_2 effects may result in changes in diversity (through elimination of sensitive species), community structure, productivity, stability, nutrient cycling, etc. These changes would, in turn, affect the animal components of the ecosystem via changes in habitat, food availability, population dynamics, etc. These effects would be in addition to the poorly known direct long-term effects of SO_2 on animal species.

Predicted Impacts of SO_2 from the Model Plants in the SILSA in 2020

As pointed out earlier, the short-term meteorological assumptions upon which this evaluation is based are quite conservative and occur very infrequently. It should also be pointed out that the values in Tables 6A.8a,b,c (Sec. 6, Vol. 1) are maximum values (the highest average for the particular averaging period per year) and are not average (mean) values. Even though this study indicates that SO_2 is the only primary pollutant emitted by the model plant that may have measurable ecological impacts, it does not preclude the possibility of unknown long-term effects of any of the primary pollutants on any biotic species, even though it is not yet possible to evaluate these effects.

About 65% of the total land area in the SILSA was used for crop production in 1975. Crop acreages were apportioned as follows: corn, 35%; soybeans 43%; wheat, 15%; hay, 5.5%; and 1.5% was used for minor crops such as oats, 'arley, rye, fruits and vegetable crops.[49] It is assumed that the cropland se allocations will be essentially the same in 2020, and that any SO_2-ımpacted area will contain the above mix of crops and that the remaining 35% of land area will support pasture, woodlots, ornamental vegetation, and recreational, residential, and commercial areas.

Based on the 24-hour maximum SO_2 values (Table 6A.8c and Fig. 6A.5, Sec. 6, Vol. 1), the effluent from a single 3000-MW model plant could cause acute visible injury to sensitive vegetation occurring within an area of about 608 acres (isopleths 1 and 2). Within this 608 acres, on an area of about 64 acres (isopleth 1), vegetation in the sensitive category (See Fig. 10.3) could exhibit injury symptoms ranging from moderate to severe levels, depending on species and environmental conditions.

For the clustered configuration of 12 model plants (3 plants on each corner of a township) the total area in which visible SO_2 injury to sensitive vegetation may occur could exceed 22,000 acres (Fig. 6A.6, Sec. 6, Vol. 1). The area in which moderate to severe injury to sensitive vegetation may occur would be approximately 6400 acres.

The severity of the impact to vegetation would be directly related to the percentage of damaged foliar area of a particular plant. Based on local maximum concentrations given in Tables 6A.8a,b,c (Sec. 6, Vol. 1) there could be small areas within each impacted area (both single and clustered siting) in which vegetation of intermediate sensitivity could sustain threshold SO_2 injury. If the impacted area contained an agricultural crop, the likelihood of yield reduction would be small, since the fumigation episode would have to occur during a relatively short and sensitive portion of the plant life cycle (e.g., only during the flowering period of soybeans). There is a positive correlation between the amount of SO_2-induced leaf chlorosis and reductions in yield for some crops (soybeans and alfalfa) when the area of foliage injured exceeds about 1% of the total foliage area.[43] Impacts on the vegetation of natural ecosystems are more difficult to assess, since there are no good criteria for measuring effects of SO_2 injury. If the impacted area includes stands of pine, some species of which are very sensitive to SO_2, visible needle-tip burn would probably occur. However, unless several fumigations occurred within a given growing season, this level of injury probably would not measurably affect stand productivity (in terms of commercial wood production).[50]

Table 10.9 presents lists of native, ornamental and crop plant species that occur in the SILSA, and for which SO_2 sensitivity has been determined. The plants are grouped in the sensitive, intermediate, and resistant categories. These lists can be used in conjunction with the dose-response curves (Figs. 10.3-5) to determine the likelihood of injury to any plant listed for a specific SO_2 dose.

At the sites with a single 3000-MW model plant, voluntary load reductions during the infrequent periods of adverse meteorological conditions (inversions), as is currently practiced at some large generating plants, would probably reduce the possibility of SO_2 injury to vegetation. With the capabil-:y of load reduction based on meteorological conditions, the single siting of ›del plants proposed for the SILSA would be an acceptable option. However,

Table 10.9 SO_2 Sensitivity Groupings for Vegetation in SILSA*

Scientific Name	Common Name	Reference
	VEGETATION	
Sensitive		
Pinus strobus	White pine	c
Solidago sp.	Goldenrod	a
Populus deltoides	Cottonwood	a
Parthenocissus quinquefolia	Virginia creeper	a
Aster sp.	Aster	b
Ribes sp.	Gooseberry	b
Ulmus sp.	Elm	b
Vitis spp.	Wild grape	b
Ulmus americana	American elm	d
Fraxinus americana	White ash	e
Pinus virginiana	Virginia pine	e
Liriodendron tulipifera	Tulip tree	e
Intermediate		
Acer sp.	Maple	b
Parthenocissus quinquefolia	Virginia creeper	b
Quercus alba	White oak	a
Ulmus	Elm	d
Pinus echinata	Shortleaf pine	f
Aster sp.	Aster	f
Tilia sp.	Linden	d
Resistant		
Acer saccharum	Sugar maple	c
Phlox sp.	Phlox	a
Quercus sp.	Oak	a
Acer sp.	Maple	f
Salix tristis	Shrubby willow	c
	CROPS	
Sensitive		
Medicago sativa	Alfalfa	a
Hordeum vulgare	Barley	b
Avena sativa	Oats	b

*The same species may appear in more than one SO_2 sensitivity category since the list for each region was compiled from the publications of several researchers, each of whom may have determined the sensitivity under different environmental conditions.

Table 10.9. Continued

Scientific Name	Common Name	Reference
Secale cereale	Rye	b
Triticum aestivum	Wheat	b
Ipomea batata	Sweet potato	b
Glycine max	Soybean	b
Meliotus sp.	Sweet clover	b
Gossypium hirsutum	Cotton	b
Nicotiana tabacum	Tobacco	b
Trifolium sp.	Clover	f
Intermediate		
Solanum tuberosum	Irish potato	b
Trifolium sp.	Clover	a
Meliotus sp.	Sweet clover	f
Resistant		
Zea mays	Corn	b
	Sorghum	e

[a] S. N. Linzon, W. D. McIlveen, and P. J. Temple, "Sulphur Dioxide Injury to Vegetation in the Vicinity of a Sulphite Pulp and Paper Mill," Water Air Soil Pollut., 2(1973):129-134, 1972.

[b] "Effects of Sulfur Oxides in the Atmosphere on Vegetation," Revised Chapter 5 for Air Quality Criteria for Sulfur Oxides, Nat. Environ. Res. Center, EPA R3-73-030, Office of Research and Development, USEPA, Research Triangle Park, NC, Sept. 1973.

[c] W. H. Smith and L. S. Dochinger (Eds.), "Air Pollution and Woody Vegetation in the Megalopol-Research, USDA, Forest Service, p. 117, undated.

[d] "Air Pollution Damages Trees," USDA Forest Service, Northeastern Area, State and Private Forestry, Upper Darby, Penn., 31 pp., 1973.

[e] J. M. Skelly and R. C. Lame, "Diagnosis of Air Pollution Injury to Plants," Virginia Polytechnic Institute and State University, Publ. 568, 14 pp., 1974.

[f] M. Treshow, "Environment and Plant Response," McGraw-Hill Book Company, New York, 422 pp., 1970.

if a SO_2 fumigation episode were to occur at a clustered configuration site, the very large areas that could be impacted by SO_2 (up to 22,000 acres) and the probable difficulties of simultaneous load reductions at 12 plants appears to make the clustered siting an ecologically unacceptable option for the SILSA.

Acid Rain

Recent studies[51-53] in both the U.S. and Europe have documented the occurrance of acid rain with a measured pH between 3.0-5.0 and occasionally as low as 2.1 at distances over 620 miles downwind from large industrial centers. Rainwater is normally slightly acidic, pH 5.7, due to the equilibrium reaction between carbon dioxide (CO_2) and water (H_2O) in the atmosphere, forming weak carbonic acid (H_2CO_3).[53] The discovery of acid rain is not new, however, for it was measured as early as 1907 in the vicinity of the industrial city of Leeds, England.[51]

Higher acidity is associated primarily with increased levels of sulfates and nitrates. One contributing source of these two compounds is the combustion of fossil fuels. Sulfur oxides are produced by the oxidation of sulfur contained in fossil fuels during combustion; oxides of nitrogen are formed at high combustion temperatures. Both oxides undergo chemical transformation in the atmosphere. SO_2 in the atmosphere may be oxidized to SO_3, whereupon it rapidly reacts with water to form sulfuric acid. The sulfuric acid may remain suspended as an aerosol, or combine with other compounds to form sulfates. These sulfates, whether acids or salts, are often washed out of the air by rain.[39] Section 6.8 of Volume 1 discusses the long-range transport of sulfur and its implications.

Acid rain impacts the terrestrial ecosystem by effecting changes in the chemical properties of the soil and affecting above-ground portions of the plants intercepting the precipitation. The degree to which soils are altered is dependent on the buffering capacity of the soil. The buffering capacity of soils originating from carbonaceous sedimentary parent materials is high, but low for noncalcareous soils formed from granites and quartzites. A lowering of the soil pH causes a decrease in the cation exchange capacity of the soil and cations such as Mn^{++}, Ni^{++}, Fe^{+++}, and Ca^{++} are leached from the soil profile. The leaching of cations, notable when the pH of rainwater is approximately 4.0, increases markedly as the pH decreases below 3.0.[54-56] A reduced soil pH (below 5.0) results in increased availability of zinc and aluminum such that these elements become toxic, and decreased availability of phosphorus. The effects of acid rain on the soil can be ameliorated by applications of lime.

The effect of acid rain on terrestrial vegetation is variable depending on the pH and the tolerance of affected plant species. The effects of acid rain, as determined in laboratory studies, include reduction in growth, damage to leaves, death of leaves or whole plants, alteration of the chemical composition of plant tissue, increased leaching of substances from leaves, decreased chlorophyll, and reduced productivity.[56]

Nonrooted plants such as mosses and lichens are more susceptible to :id rain damage because water and minerals are obtained directly from precipitation, eliminating the potential moderating effect of the soil.[57]

Isolines of predicted pH of precipitation over the eastern United States during the period 1955-1956 indicated a normal pH 5.6 of precipitation in Illinois. The isoline for a slightly higher acidity (pH 5.0) occurred further east, almost on the border of Indiana and Ohio.[53] For the 1965-1966 period, the eastern half of southern Illinois corresponded with pH isoline of 5.0-5.6, indicating that the acidity of rainfall occurring in Illinois had increased over a ten-year period. It is not possible to quantitatively assess the changes in the acidity of rainfall in southern Illinois as a result of increased sitings of coal-fired power plants. However, emissions of oxides of sulfur and nitrogen from the model plants can be expected to increase rain acidity to some degree.

Fluoride

Fluoride in Soils and Plants. Fluoride is widely distributed in soils, usually increasing in concentration with depth. The normal range of fluoride in soils is 10-1000 ppm although certain soils, notably some in Idaho (3870 ppm) and Tennessee (8300 ppm), are much higher.[58,59] Fluoride is usually insoluble or tightly bound to soil particles (except in very acid soils).[60-63] Over 90% of soil fluoride may be unavailable for plant uptake. Fluoride compounds are relatively persistent and not biodegradable.[61]

Airborne fluorides, including both gaseous and particulate forms, pose a greater potential hazard to vegetation than does fluoride uptake from soils.[58] Particulate fluorides are deposited on plant leaf surfaces while gaseous fluorides enter plants directly through the stomata. Upon absorption by the plant, the compounds are usually translocated to the leaves where they tend to accumulate in the leaf tips and margins.[64-66] The concentration of fluoride in these areas is usually several times higher than the concentration in the leaf as a whole.[64]

Some sensitive broadleaf plants, such as apricot, gladiolus, and grape, respond initially to fluoride by developing a dull, gray-green water-soaked discoloration of tissues along leaf margins and tips, usually within 24 hours after exposure to several parts per billion fluoride.[64] After 48 hours, in hot weather, necrosis ensues and a characteristic reddish-brown band between necrotic and healthy tissue develops. Cool temperatures can cause the delay of symptom expression by several days.[64] In other broadleaf species including citrus, poplar, and cherry, the characteristic symptom of fluoride accumulation is chlorosis.[64,65] Flower and fruit production are usually not affected by fluoride pollution; however, peaches can develop "suture red spot" (a form of "soft suture" due to fluorides) rendering the fruit unmarketable.[64,65,67] Symptoms similar to "suture red spot" have been described for other fruits, including apricot, cherry, and pear.[64,65] As a group, conifers are among the plants most sensitive to airborne fluorides.[58,65] Phytotoxic symptoms are primarily confined to the current year's growth and the method of injury and mptoms are similar to those of broadleaf plants.[64,65] Some monocots such as adiolus are extremely sensitive to airborne fluorides. Cereal grain crops are more resistant to fluoride pollution than are corn and sorghum. Symptoms of injury in monocots generally include chlorosis and necrosis.[64,65]

Fluoride in Animals. Toxic effects in animals due to ingestion of fluoride-contaminated vegetation and inhalation have been studied primarily in cattle, the most susceptible domestic animals.[58,60,68,69] Controlled experiments indicate that long term ingestion by dairy cattle of diets containing concentrations in excess of 40 ppm fluoride may have severe toxic effects.[70] However, forage plants can tolerate several times this concentration[71] and thus could be potentially toxic to grazing animals. Although the majority of research on animals to date has been conducted on herbivores, one report indicated that fluoride may accumulate throughout the food chain.[72]

Animals exhibit three levels of symptoms due to the dose of fluoride ingested.[73] The most serious (acute toxicity) involves metabolic changes that result in severe toxic symptoms which include gastroenteritis, clonic convulsions, muscular weakness, pulmonary congestion, skeletal changes, and respiratory and cardiac failure.[58,70] A second level (chronic toxicity) is manifested by abnormal tooth development, especially in young animals. This condition can result in malnutrition, particularly in cattle. Changes in bone structure along with stiffness and lameness may also appear in cases of chronic fluoride toxicity.[58,60,73] The third level, resulting from very low levels of fluoride ingestion, involves tooth discoloration. Usually, no other visible symptoms are observed.[73] Fluoride concentration in the bone is the most reliable indicator of toxicity as approximately 99% of the body burden is stored there.[70]

Fluoride Toxicity. Gaseous fluorides constitute a greater threat to vegetation than do particulate fluorides. Gaseous fluorides can enter the leaf directly through the stomata, whereas particulates deposited on the leaf surface enter the leaf only after being dissolved.[66] As with other gaseous pollutants, fluoride toxicity is influenced by concentration, duration of exposure, sequence and frequency of exposure, and is modified by environmental variables such as time of day (light intensity) and temperature.[63,74] For example, high temperatures will speed up the development of phytotoxic symptoms. Suture red spot in peaches is influenced by calcium and boron nutrition.[64] Damage to fruit trees is usually more severe in orchards that have been neglected and are in poor condition, than in nearby, well-managed, well-irrigated orchards.[65,66]

Species vary greatly in susceptibility to gaseous fluorides. The most susceptible species appear to be gladiolus and some other horticultural plants, some conifers, citrus, and some other fruit trees, notably apricot. Some varieties of corn and sorghum are quite susceptible to fluoride.[58] Wheat is generally considered fairly resistant.[58,65] Several researchers have reported that beans are moderately resistant to fluoride.[58,59] It is difficult to correlate observed vegetative damage with plant productivity and yield. McCune[75] has summarized the literature on fluoride toxicity in plants.

Dietary fluoride is generally accepted as the major source of fluoride toxicity in animals. For cattle, the safe range for soluble fluorides is listed at 30-50 ppm, and for insoluble fluorides 60-100 ppm.[76] Sheep and wine are less sensitive to soluble fluorides (70-100 ppm); horses are intermediate.[58] Poultry are the least sensitive of livestock with safe fluoride levels as high as 150-300 ppm for chickens and 300-400 ppm for turkeys.[76]

The National Academy of Science Committee on Biological Effects of Atmospheric Pollutants,[58] Yamartino et al.,[68] and Treshow[63] have provided a more complete review of the literature on fluoride.

<u>Impacts of Fluoride Emissions on Terrestrial Ecosystems in the SILSA</u>. In general, emissions from coal combustion contain fluorine in the form of hydrogen fluoride and silicon tetrafluoride. The measurable impacts of fluoride on vegetation in the SILSA are expected to occur downwind of the 12-plant clustered siting. Fluoride emissions from the single 3000-MWe plant siting are not expected to be high enough to have adverse impacts on vegetation.

The impacts of fluoride emissions on vegetation are most likely to occur in sensitive species such as sorghum, fruit trees (peaches, cherries and apricots), and conifers. Since fluoride is an accumulative toxicant, injury usually occurs as a result of a fluoride buildup in the leaves of the affected vegetation over a period of weeks or months.[66] In sorghum, the long-term exposure to annual average ground-level concentrations of fluoride could cause foliar markings. The threshold for foliar markings is 0.4-0.5 $\mu g/m^3$ after 7-20 days exposure.[75] Since the maximum annual ground-level concentrations of fluoride north of the 12-plant cluster will average 0.065 $\mu g/m^3$ (Table 6A.3, Vol. I), it is likely that at least a portion of the 202 km^2 area enclosed by Isopleth I (Vol. I, Fig. 6A.4) could be subjected to fluoride levels which may accumulate over the growing season to concentrations injurious to sorghum. Reduced yield has been correlated in some cases with foliar markings.[58] Also, there is some experimental evidence that when fluoride exposure occurs at specific stages of tassel development, grain yield can be significantly reduced without the appearance of any leaf symptoms.[58] However, care must be exercised in the extrapolation of controlled fumigation experiments that attempt to imitate field exposures resulting from industrial sources, since it is difficult to reproduce the temporal distribution of fluoride exposure and the variations in climatic and edaphic conditions.

Table 10.10 provides information on maximum, short-term, ground-level concentrations of fluorides for the 12-plant clustered siting configuration. According to McCune,[75] threshold fluoride damage in fruit trees and conifers occurs as a result of a dose of 3 $\mu g/m^3$ fluoride for 24 hours. This value is close to the 24 hr maximum, short-term, ground-level concentration of 2.02 $\mu g/m^3$ predicted for the clustered siting with a west wind (Table 10.10).

Fluoride concentrations in vegetation are not expected to reach levels which will adversely impact grazing animals or other livestock. Vegetation utilized by cattle (the most sensitive grazing animals in the SILSA) is not expected to contain fluorides in concentrations high enough to result in observable toxic effects (see Fluoride Toxicity).

Table 10.10. Maximum Short-term Ground-level Concentrations of Gaseous Fluorides Emitted by a Clustered Power Plant Configuration in the SILSA

Wind Direction with Respect to Site	Maximum Ground-level Concentration ($\mu g/m^3$)		
	15 Min. Max.[c]	3 Hr. Max.[d]	24 Hr. Max.[e]
W[a] (perpendicular)	5.06	3.09	2.02
SW[b] (oblique)	4.04	2.46	1.62

[a]Values taken from Figure 6A.6a in Volume I.

[b]Values taken from Figure 6A.6b in Volume I.

[c]Values taken from Table 6A.8a in Volume I.

[d]Values taken from Table 6A.8b in Volume I.

[e]Values taken from Table 6A.8c in Volume I.

10.4.1.2 Impacts of Particulate Emissions on Terrestrial Ecosystems

Arsenic

Arsenic in Soils and Plants. Arsenic usually exists in the soil solution as a divalent anion resembling phosphate. Like phosphate, it is fixed (converted from a readily available to a less available form) in the soil by iron, aluminum, and calcium and is more soluble under neutral or calcareous conditions (calcium forms are more soluble than iron or aluminum forms).[77,78] Wauchope[78] observed relatively higher levels of sorption of arsenate than phosphate in experiments utilizing alluvial soils. Although arsenic tends to be retained in the soil surface layers, it can be leached slowly to the lower soil horizons when it is in the soil solution.[77,79,80]

Total endogenous soil concentrations of arsenic generally range from 0.1-40 ppm ($\mu g/g$) with an average of 6.0 ppm.[60] However, total soil arsenic levels can reach several hundred ppm in areas where large amounts of arsenical pesticides have been used.[80]

Arsenic emissions from coal combustion may have the greatest effect in areas already subjected to high levels of arsenic. Areas of potential arsenic insult include sites near lead, copper, and gold smelting plants, some nickel and cadmium smelting plants, and sites near cotton gins and their trash-burning areas (arsenic is used as a dessicant for cotton plants prior to picking).[81] The use of arsenical pesticides and herbicides in orchards and other agricultural areas can cause a residue buildup to toxic levels.[60,80,81] This problem has decreased since the introduction of organic pesticides.[60] Lime, organic matter, zinc compounds or chelates, and iron and aluminum compounds added to the soil may aid in maintaining the available arsenic (present in the soil in a form that can be readily absorbed and assimilated by growing plants) below toxic levels, while phosphate fertilization may enhance availability and thus toxicity.[79]

According to Allaway,[60] plants grown on uncontaminated soils rarely ontain greater than 1 ppm arsenic. In cases of arsenic toxicity the roots are usually severely affected, and plant growth is limited before much arsenic is translocated to the tops.[60,77,82] Asparagus, tomato, carrot, tobacco, grape, and red raspberry appear to be among the most tolerant commercial plants while legumes, cucumber, sweet corn, and onions have little or no tolerance to arsenic.[80,82]

Arsenic in Animals. Arsenic compounds do not accumulate in mammals.[80,83] Differences in the toxicity of various compounds have been correlated with animal excretion rates; compounds that are most slowly excreted tend to be the most toxic.[80,83] The biological half-lives of arsenic compounds range from 30-60 hours.[81,83] The greatest danger to animals from arsenic emissions may be through the ingestion of arsenic-contaminated dust or soil on forage.[77] Arsenic and its compounds do not appear to be carcinogenic, although there is some dispute about this in the literature.[60,81,83] Frost,[83] Buchanan[84] and Vallee, Ulmer, and Wacker[80] have reviewed the toxicity and biological effects of arsenic in man and animals.

Arsenic Toxicity. Arsenic toxicity is dependent upon its oxidation state; the pentavalent state, which is most common in aerated soils, is much less toxic than the trivalent state.[60,77,79] Organic arsenates such as cacodylic acid [$(CH_3)_2HAsO_2$] are toxic to plants but less toxic to animals, while the reverse is true for calcium and lead arsenates.[81] Extremely toxic arsine gas (AsH_3) may be produced by fungi in the soil.[77] Elemental arsenic is considered to be relatively nontoxic.[77,81]

Crop damage has been reported on soils containing 3-9 ppm (μg/g) soluble arsenic.[77] In greenhouse pot experiments, Deuel and Swoboda[85] observed significantly decreased growth in the above-ground biomass of soybean and cotton plants which had tissue concentrations of 1 and 4.4 ppm respectively. Lindner[86] reported toxicity in peach trees with leaf tissue concentrations of 2 ppm. In tomato, a more tolerant species, toxic symptoms did not appear at leaf tissue concentrations below 70 ppm.[87]

Arsenic concentrations as low as 3.4 ppm have been reported to be toxic to sheep.[77] Grass containing 52 ppm arsenic trioxide was lethal to sheep grazing near a copper smelter in Montana; horses died after feeding on hay containing 285 ppm arsenic trioxide grown in the same area.[81] Toxic levels of each arsenic compound are not known for all animal species. However, the most toxic arsenicals seem to be tolerated by most animals at dietary levels of 10-20 ppm, whereas the least toxic arsenicals may not be injurious at 1000 ppm in the diet.[83]

Beryllium

Beryllium in Soils. Beryllium is strongly fixed (converted from a readily available to a less available form) in soils and can readily displace other divalent cations (including barium, calcium, magnesium, and strontium) at sorption sites on the cation exchange complex.[79,88] Beryllium can also undergo isomorphic substitution in secondary clay minerals because of its chemical similarity to aluminum.[88] Like other cations, beryllium is more soluble and thus more available (present in the soil in a form that can be readily absorbed and assimilated by growing plants) in acidic soils than in neutral or alkaline soils. Total endogenous concentrations of beryllium in uncontaminated soils generally range from 0.1-40 ppm (μg/g) with an average of 6 ppm.[60]

Beryllium Toxicity. Romney and Childress[88] have demonstrated that beryllium can inhibit plant growth when it is present in the soil in a soluble form. In a series of experiments utilizing several crop plants and soil amended with beryllium to levels of 0, 10, and 20% of the cation exchange capacity, soluble $Be(NO_3)_2$ and $BeSO_4$ decreased yields, while insoluble $BeCO_3$ and BeO had no effect on plant growth.[88] Because of beryllium's strong tendency to form complexes and colloidal aggregates when the soil pH is above 5.5, toxicity to plants is greatly reduced when soil pH is above this level.[79,88] Beryllium tends to accumulate in plant roots; relatively little is translocated to plant tops.[60,77,88,89] Of the aerial plant parts, leaves generally accumulate higher levels than stems, and fruits have the lowest concentrations.[88,89] The toxic effects of beryllium on plant growth appear to be centered in the root tissues,[88,89] where beryllium may affect certain enzyme systems.[90,91]

In nutrient solution culture, concentrations of beryllium (as $BeCl_2$) greater than 2 ppm (μg/ml) were found to significantly reduce the growth of peas, barley, alfalfa, and lettuce.[88] The growth of bush bean in solution culture was reduced by 1 ppm beryllium.[89] The yields of beans, wheat, and ladino clover were significantly reduced when they were grown in three different soils amended with beryllium sulfate ($BeSO_4$) at levels equivalent to 4% of the cation exchange capacity.[68]

Beryllium and all of its known compounds (soluble or insoluble) are believed to be toxic to man depending on the quantity and duration of exposure (dose).[92] Very little information on the effects of beryllium on animals exists except for studies on laboratory animals. The major hazard to humans, and presumably to animals, is through inhalation.[77,92] The result is berylliosis which has a mortality rate of 30%.[77,93] The disease affects all regions of the respiratory tract and can involve all organs of the body except those in the pelvic area.[92,93] Because beryllium has a long residence time in the body, it is a suspected carcinogen.[92] Standards for the atmospheric concentration of beryllium in areas other than work places require that the average, short-term (24-hour) or monthly concentrations not exceed 0.01 $\mu g/m^3$.[77,92,93]

It is believed that the soil-plant system is an effective barrier to movement of beryllium into the rest of the food chain, because plant growth is usually severely inhibited before the amounts of beryllium translocated to plant tops reach toxic concentrations.[77]

Cadmium

Cadmium in Soils and Plants. Like other divalent cations, cadmium is usually more available (present in the soil in a form that can be readily absorbed and assimilated by growing plants) in acid, sandy soils than in eutral or alkaline soils with large amounts of clay or organic matter.[79,94] n inverse relationship between soil pH and cadmium uptake by plants has been observed by several workers.[95-99] Also, as the cation exchange capacity of the soil is increased, cadmium uptake has been found to decrease.[95,97,100] Results of experiments by Haghiri[100] indicate that soil organic matter fixes (converts from a readily available to a less available form) cadmium primarily through its cation exchange properties rather than its chelating ability. There is some evidence that the concentrations of certain elements in the soil (including Ca, Zn, P, K, and Al) may affect cadmium uptake.[95,97,101,102] Cadmium levels in plant tissue may subsequently affect the balance of essential elements in the plant.[101,102]

Cadmium occurs naturally in close association with zinc, usually in concentrations directly related to zinc levels.[103] Cadmium to zinc ratios vary; for most soils and minerals, ratios of 1:1000 to 1:12,000 have been reported.[104] Since zinc is essential for most life-forms, cadmium is probably present in all naturally occurring organic materials.[104] In most uncontaminated soils, cadmium levels range from 0.01-7.0 ppm (μg/g) with an average of 0.06 ppm.[60] Much higher levels of soil cadmium have been reported in localized areas as a result of industrial activities, including zinc, lead, and copper smelting, galvanizing, steel production, and the manufacture of plastics, batteries, pigments, and alloys. Other sources of increased soil cadmium levels include combustion of fossil fuels, mining, automobile tire wear, and the application of sewage sludge or agricultural chemicals containing cadmium impurities.[94,104,105]

Although plants normally contain < 0.5 ppm cadmium,[60] many species may accumulate much higher concentrations (up to several hundred ppm) when they are grown on soils with elevated cadmium concentrations.[79,95-98,100,106] Unlike other trace elements, such as beryllium, lead, and arsenic, plants generally translocate relatively more cadmium to the above-ground plant parts.[107,108] However, each species varies in its ability to accumulate cadmium.

Cadmium in Animals. Cadmium is an accumulative poison in animals[77,94] Mammals seem to lack the ability to excrete cadmium, and they will continually absorb it, even though body levels are high.[77] The biological half-life of cadmium is quite long compared to that of some other elements. Half-lives of several hundred days for mice, greater than two years for squirrel monkeys, and from 10-25 years for man have been estimated.[94,104,105] It has been reported that cadmium can adversely affect the respiratory, cardiovascular, nervous, and reproductive systems, disrupt kidney and liver function, and cause gastric and intestinal disorders and anemia.[103] Usually, 50-75% of the total cadmium body burden resides in the kidney and liver.[94] It has been demonstrated that cadmium and its compounds can be carcinogenic in laboratory animals.[103,104] As yet, there is no conclusive evidence that cadmium is carcinogenic in humans.[103,104] Friberg et al.,[104] Flick et al.,[109] and Athanassiadis[103] have reviewed the toxicity and biological effects of cadmium in man and animals.

Cadmium Toxicity. The gross effects of cadmium toxicity in plants include wilting, chlorosis, necrosis, and a reduction of growth.[94,102] Huang et al.[110] found that cadmium generally inhibited soybean metabolism, and adversely affected nitrogen fixation and photosynthesis. In greenhouse pot experiments, Haghiri[111] observed a sharp decline in dry matter yields in soybean, wheat, and lettuce at 2.5 ppm (μg/g) total cadmium in the soil. Tissue concentrations in the above-ground plant parts of these species were 7, 3, and 11.5 ppm respectively. These concentrations are among the lowest cadmium levels reported to be toxic to plants.

Cadmium levels of 15 ppm in food may be injurious to man.[112] The critical level of cadmium accumulation in man is believed to be 200 ppm in the renal cortex.[94] Yamagata and Shigematsu[113] have shown that it is possible for cadmium to be incorporated into the food chain from contaminated soils and waters in quantities which are toxic to man. Carroll[114] demonstrated a close correlation between atmospheric cadmium levels and death from hypertension and arteriosclerotic heart disease in 28 U. S. cities. Hiatt and Huff[94] point out that cadmium concentrations in cigarettes and food could cause heavy smokers to come dangerously close to the "threshold of observable symptoms of cadmium poisoning" if exposed to additional sources of cadmium. All of this suggests that addition of cadmium to the environment from any source may have serious adverse effects to the food chain and man.

Lead

Lead in Soils and Plants. Lead is a ubiquitous metal, with a worldwide soil content ranging from 0.8-500 ppm (μg/g) and having an average of 17 ppm.[115] Numerous studies have shown it to be nonessential to plants or animals, except in a few instances where some indirect benefits have been observed (see discussion of plants).[116] At elevated levels, lead is highly toxic to most plants, and animals,[115,117-121] so abnormal sources and concentrations of this metal are of considerable concern.

Lead accumulates naturally in U. S. soils from precipitation and dustfall at an average rate of 1.2 $\mu g/cm^2/year$.[115,122] The largest single source of airborne lead is automobile exhaust, which emits 2.5×10^6 kg of the metal into the atmosphere every year.[123] This alone accounts for 98% of yearly emissions from human sources. Coal combustion is the second major source; however, it contributes only 0.5% on a yearly basis.[124]

Lead occurs in automobile exhaust in the form of halides or phosphate halide compounds. It is a divalent cation, and a chalcophilic (sulfide-loving) metal, and will react to form the sulfate, phosphate, or carbonate once it reaches the soil.[125] Lead from stack emissions is usually in the sulfate form, and once it reaches the soil, its behavior is the same as lead from other sources. Once in the soil, lead remains as the sulfate, phosphate, or carbonate; these compounds may be chelated to form an organic complex.[115] In the chelated form, lead is less mobile in the soil and less available (present in the soil in a form that can be readily absorbed and assimilated by growing plants) to the roots of plants, and under these conditions large concentrations accumulate in the surface horizons near sources of contamination.[115,126-129] Levels exceeding 700 ppm adjacent to heavily traveled roads are not uncommon.[130] However, the lead content decreases rapidly not only with soil depth but with distance from the highway, and background level are reached 100-150 meters from the road.[131] It is important to note that only 50% of the lead emissions are deposited in this manner; the remainder is scattered over large areas by the wind.

Once in the soil, only a small percentage of lead compounds is absorbed by the roots of plants in a largely pH-dependent translocation.[132] The soil-root transfer is governed by an inverse relationship, so that basic soils like those found in the Midwest generally mitigate against lead uptake by the roots unless very high soil lead concentrations are present. Other factors that affect lead uptake by the roots are: 1) soil texture, 2) percent organic matter (humus), 3) total soil cation concentration, 4) soil drainage, and 5) soil lead concentration.

Once in the roots, lead is seldom translocated to the aerial portions of the plant. High concentrations reported in the stems and leaves of a wide variety of roadside species are the result of airborne contamination.[115,122,126,132] The amount of lead present on the stems and leaves depends on the surface texture of the plant, time of exposure, surface area, and prevailing winds.[133]

Lead in Animals. The effects of lead poisoning on a number of animals, including man, are well documented.[134,135] The source that is historically responsible for such poisoning has been lead-base paint. Data on assimilated lead in plants has never provided a basis for assuming a dietary hazard to man, although animals consuming unwashed vegetation ingest lead accumulated on the plants' surface.[115] Recent studies on lead uptake by a variety of animal populations in the wild have given insight into the behavior of this metal in the food chain.[131,136,137]

Many terrestrial invertebrates possess the ability to accumulate large concentrations of lead without apparent toxic effects. Levels of lead in some invertebrates (e.g. earthworms[131,138]) are often found to be present in direct proportion to concentrations in the soil. Concentrations of lead in earthworms reached levels that were suspected to be poisonous to their predators.[138] Herbivorous insects ingest large amounts of lead when they consume leaves. This is ultimately stored in the chitinous parts of their bodies. Lead in fecal material, exoskeletons, and carcasses is reincorporated into the living components of the ecosystem directly through consumption of these materials. It is reintroduced indirectly via decomposition and uptake from the soil by invertebrates or the roots of plants.[139,140]

The movement of lead from lower levels in the food chain to vertebrates has only recently been studied. Herbivorous small mammals show significant differences in the lead concentration of liver, kidney, and bone tissues that vary directly with levels found in plants and soil, and increasing traffic volume.[136,141,142] Lead levels in shrews and seed-eating rodents also varied directly with these parameters.[136] None of the animals studied, however, exhibited greater concentrations in any of their tissues than were found in their source of food.[136,141,142] Most of the lead ingested is eliminated in the feces; most reaching the bloodstream is excreted by efficient vertebrate kidneys; the remaining body burden gradually increases with the age of the animal.[136] Studies clearly point to the fact that wild vertebrates seldom accumulate lead in quantities harmful to themselves because lead that is assimilated is gradually stored in bone. Because of its method of storage in the vertebrate body, lead is virtually unavailable to carnivores that consume herbivores and insectivores.[136]

Lead Toxicity. Lead is not essential for plant growth, although its presence may stimulate soil nitrification, which is indirectly beneficial to plants. When present in plant tissue, lead was found to directly inhibit growth by impinging such vital plant processes as photosynthesis, mitosis, water absorption, and copper assimilation.[121,143-145] Lead also binds with phosphate to produce an enzyme deficiency which inhibits oxidative phosphorylation.[123]

Small concentrations of lead can affect the growth of plants under conditions of phosphate deficiency. As little as 24 ppm (μg/g) of $Pb(NO_3)_2$ inhibits corn growth when grown in phosphate-deficient sand media.[121] Such deficiencies seldom occur in nature, however, and both natural and agricultural vegetative species have been found growing in soil adjacent to highways with lead concentrations exceeding 700 ppm.[115,121,131] There is evidence that soil concentrations exceeding 1000 ppm are lethal to lettuce (*Lactuca* sp.)[127] but concentrations of this magnitude are seldom, if ever, reached under the most severe conditions.[131]

The effects of lead on animal populations in the wild are difficult to ascertain because sampling is naturally biased towards healthy individuals. Small mammals trapped in areas with high background levels of lead in soil and vegetation (200-400 ppm in the soil and 121 ppm in leaves), had significantly higher concentrations of the metal in liver, kidney, bone, and whole body;[136] however, no difference in weight or overall health was noted in these individuals.

Domestic animals, on the other hand, have shown considerable susceptibility to high levels of environmental lead under specialized circumstances.[124,146] Seasonal changes of the lead concentration in the animals' diet occur when winter hay is consumed because the dry weight concentration of winter hay is much larger than that of the fresh weight.[124] Lead poisoning occurred in cattle, that were fed corn and silage grown adjacent to a lead smelter. It is thought that lead concentrations of 300 ppm in foliage will induce lead poisoning in grazing animals.[115] Animals such as horses may ingest lead at a greater rate because of their habit of consuming quantities of soil while grazing. Susceptibility varies widely among different domestic species.[124]

Selenium

Selenium in Soils and Plants. Selenium fallout from coal combustion occurs in the form of elemental selenium, which is relatively insoluble and only slowly oxidized, and SeO_2, which forms soluble selenite salts.[147] In acidic soils, selenium is usually fixed (converted from a readily available to a less available form) as insoluble ferric selenite and is therefore largely unavailable to plants.[79,147-149] In arid, alkaline soils (pH > 8) selenium is generally available (present in the soil in a form that can be readily absorbed and assimilated by growing plants) to plants as soluble calcium selenate and soluble organic selenium compounds.[60,78,147,148]

In the United States, seleniferous soils (soils containing high levels of Se: some reported as high as 80-90 ppm) are distributed patchily from North Dakota south to Texas and west to the Pacific.[148,150] These soils are

-enerally alkaline in nature, contain $CaCO_3$, and are located in areas receiving ess than 20 in. annual rainfall. However, most soils contain less than 1 ppm (μg/g) selenium.[147]

Most of the research on the effects of selenium on plant species has been performed on selenium accumulator-indicator species. Certain plants, such as some *Astragalus* (milk vetch) species, are found growing only on soils containing selenium. They usually contain 1000 to 10,000 ppm selenium.[77,150,151] Secondary selenium accumulators [e.g., some species of *Atriplex* (saltbush) and *Aster* (aster)] are not restricted to seleniferous soils, but can accumulate 50 to 500 ppm when they grow on such soils.[150,151] However, most crop plants, grains and native grasses generally accumulate low levels (maximum, 30 ppm) of selenium.[150] In the Midwest, the normal concentration of selenium in crops is expected to be less than 0.5 ppm.[60,149]

Selenium appears to be biologically associated with sulfur,[60,147] and research has indicated that some crop plants accumulate selenium from selenate in direct proportion to their sulfur requirements.[152] Organic analysis indicates that selenium appears to replace sulfur in some simple amino acids.[60,147]

Selenium in Animals. The major cause of selenium poisoning in livestock is through the consumption of accumulator-indicator species. Most cases of poisoning have occurred west of the Mississippi River. In other areas, particularly in the northeastern states, available soil selenium levels are so low that selenium deficiencies occur in animals.[60,77,149,150] No evidence was found of selenium poisoning of animals as a result of air pollution.

Upon consumption, selenium is transmitted via the circulatory system to all organs. Depending on the quantity and chemical form of the ingested selenium, high concentrations have been found in the liver, kidney, blood, spleen, brain, stomach, heart, lung, muscles, hair, skeleton, and hooves.[150]

There are two levels of selenium poisoning in livestock: acute and chronic. Acute poisoning results in abnormal movement and posture, elevated temperature, rapid pulse and finally death due to respiratory failure. Chronic selenium poisoning of livestock is manifested by two distinct types of symptoms, each dependent upon the chemical nature of the selenium compound ingested. Blind staggers results from the ingestion of moderate amounts of accumulator-indicator plants containing organically-bound selenium plus water soluble selenates. Alkali disease results from the consumption of grains and grasses containing protein-bound selenium which is relatively insoluble in water.[150]

Selenium Toxicity. The primary indication of selenium injury in plants is growth inhibition. An additional symptom of selenate toxicity in grains is white chlorosis of some or all of the leaves. Leaves usually turn a darker green than normal in cases of selenite injury.[150] In a review article, Lisk[79] reported that cereal grains and onions may accumulate 30 ppm selenium without toxic effects while grasses, clovers, and vegetables have a much lower tolerance (5 ppm). However, the literature contains many conflicting reports on the concentrations of selenium that can be tolerated by various non-accumulator crop plants and native grasses (up to a maximum of around 300 ppm). Variability is caused by different growth conditions, such as soil type, chemic form of selenium in the soil, presence of other elements in the soil, and whether the selenium occurs naturally in the soil or was added to the soil for purposes of investigation.

Selenium is required at low dietary levels (0.04-0.2 ppm depending on the kind of animal, type of diet, and chemical form of Se) by animals and humans; however, it can be toxic in the diet when in the range of 4.0 to 5.0 ppm or greater.[60,147] This presents a problem for animals feeding on vegetation which has accumulated even relatively low levels of selenium.[60,77,148] Consumption of corn, grain, grasses, and hay containing 10-30 ppm selenium has caused alkali disease.[150] Hogs fed corn containing 5 ppm selenium did not develop alkali disease, while individuals fed corn containing 10 ppm developed symptoms of the disease including loss of hair, lesions on hooves and dewclaws, and sloughing of hoof keratin.[150,153]

For a more complete review of selenium toxicity, chemistry, sources, and biological effects see Rosenfeld and Beath,[150] Stahl,[151] and Muth, Oldfield, and Weswig.[154]

Impacts of Trace Element Emissions in the SILSA

Due to the difficulty in accurately predicting the fate of trace elements in terrestrial ecosystems, a worst-case analysis may be the most expedient approach to assessment of impacts from trace element emissions. At least elements that appear to have little chance of seriously affecting terrestrial systems may be separated from those that have potential for adverse impacts. Further research is needed in order to make better estimates of trace element availability and toxicity, and pathways in food webs. However, even with such information, the fate and effects of trace elements at a given location will utimately be determined by site-specific variables, including soil types, environmental conditions, and species adaptations to the given site. The terrestrial impacts of arsenic, beryllium, cadmium, lead, and selenium emissions from coal combustion in the SILSA were assessed for a single 3000-MWe power plant site and a clustered siting of twelve 3000-MWe plants. The predicted deposition rates for each siting pattern are presented in Tables 6A.4 and 6A.5 in Volume I. Tables 10.11 and 10.12 present the calculated trace element depositions and resulting soil concentrations given worst-case conditions and a 30-year plant operating life.

The calculations in Tables 10.11 and 10.12 are based on the following assumptions. In order to create the worst case, Columns III and IV assume that all arsenic, beryllium, cadmium, lead, and selenium emissions deposited in the area over 30 years, reach the soil surface and are retained in the top 3 cm of the soil.* The soil concentrations in Column IV are based on a bulk density

**Little and Martin[155] found most of the acetic acid soluble lead, cadmium, and zinc in the upper 3 cm of polluted soils near a large lead and zinc smelting complex. Hutchinson and Whitby[156] found the highest concentrations of nick copper, and cobalt in the surface soils surrounding a smelting complex producing these elements. In a study measuring the enrichment of trace elements in soils around a coal-fired power plant, Klein and Russell[157] assumed that enrichment was confined to the upper 2 cm of the soil.*

Table 10.11. Arsenic, Beryllium, Cadmium, Lead, and Selenium Deposition and Soil Concentrations around the Single 3000-MWe Source Siting

	I Contour Line Intervals	II Area between Contour Lines, km^2	III Deposition $g/m^2/30$ yr	IV Increased Soil Concentration, μg/g (3 cm depth)	V Increase over Total Endogenous Concentrations, % (3 cm depth)
Maximum[a]	0	0	3.03(-3)[b]	6.88(-2)	1.15
	0-2	77.8	2.28(-3)	5.18(-2)	8.63(-1)
As	2-3	602.2	1.52(-3)	3.45(-2)	5.75(-1)
	3-4	2306.7	7.59(-4)	1.72(-2)	2.87(-1)
	4-5	3317.7	3.03(-4)	6.88(-3)	1.15(-1)
Maximum	0	0	7.62(-5)	1.73(-3)	2.88(-2)
	0-2	77.8	5.73(-5)	1.30(-3)	2.17(-2)
Be	2-3	602.2	3.84(-5)	8.72(-4)	1.45(-2)
	3-4	2306.7	1.91(-5)	4.34(-4)	7.23(-3)
	4-5	3317.7	7.62(-6)	1.73(-4)	2.88(-3)
Maximum	0	0	3.63(-5)	8.24(-4)	1.37
	0-2	77.8	2.72(-5)	6.17(-4)	1.03
Cd	2-3	602.2	1.82(-5)	4.13(-4)	6.88(-1)
	3-4	2306.7	9.09(-6)	2.06(-4)	3.43(-1)
	4-5	3317.7	3.63(-6)	8.24(-5)	1.37(-1)
Maximum	0	0	4.80(-3)	1.09(-1)	1.09
	0-2	77.8	3.60(-3)	8.17(-2)	8.17(-1)
Pb	2-3	602.2	2.41(-3)	5.47(-2)	5.47(-1)
	3-4	2306.7	1.20(-3)	2.72(-2)	2.72(-1)
	4-5	3317.7	4.80(-4)	1.09(-2)	1.09(-1)
Maximum	0	0	7.08(-4)	1.61(-2)	8.05
	0-2	77.8	5.34(-4)	1.21(-2)	6.05
Se	2-3	602.2	3.54(-4)	8.06(-3)	4.03
	3-4	2306.7	1.77(-4)	4.02(-3)	2.01
	4-5	3317.7	7.08(-5)	1.61(-3)	8.05(-1)

Table 10.11. Continued

[a]Refers to a maximum deposition at a point location.

[b]Parenthetical expression refers to 10 to the minus power.

Column I - Contour lines correspond to isopleths in Fig. 6A.2 (Vol. I).

Column II - Area calculated with a planimeter.

Column III - Deposition rates presented in Table 6A.4 (Vol. I) times the 30-year life expectancy of the plant.

Column IV - Assumes bulk density of soil is 1.47 g soil/cm^3. Assumes all deposition reaches the soil and remains in the top 3 cm.

Column V - Assumes average total endogenous soil concentrations are: As, 6.0 ppm; Be, 6.0 ppm; Cd, 0.06 ppm; Pb, 10.0 ppm; Se, 0.2 ppm.[159]

Table 10.12. Arsenic, Beryllium, Cadmium, Lead, and Selenium Deposition and Soil Concentrations around the Clustered Source Siting

	I Contour Line Intervals	II Area between Contour Lines, km^2	III Deposition $g/m^2/30$ yr	IV Increased Soil Concentration, μg/g (3 cm depth)	V Increase over Total Endogenous Concentrations, % (3 cm depth)
Maximum[a]	0	0	2.39(-2)[b]	5.43(-1)	9.05
	0-1	202.2	2.12(-2)	4.81(-1)	8.02
As	1-2	611.1	1.70(-2)	3.86(-1)	6.43
	2-3	1424.5	1.28(-2)	2.91(-1)	4.85
	3-4	1917.7	8.49(-3)	1.93(-1)	3.22
	4-5	2176.3	4.23(-3)	9.60(-2)	1.60
Maximum	0	0	6.03(-4)	1.37(-2)	2.28(-1)
	0-1	202.2	5.31(-4)	1.21(-2)	2.02(-1)
Be	1-2	611.1	4.26(-4)	9.67(-3)	1.61(-1)
	2-3	1424.5	3.21(-4)	7.29(-3)	1.22(-1)
	3-4	1917.7	2.13(-4)	4.84(-3)	8.07(-2)
	4-5	2176.3	1.13(-4)	2.57(-3)	4.28(-2)
Maximum	0	0	2.87(-4)	6.51(-3)	10.90
	0-1	202.2	2.54(-4)	5.77(-3)	9.62
Cd	1-2	611.1	2.03(-4)	4.61(-3)	7.68
	2-3	1424.5	1.52(-4)	3.45(-3)	5.75
	3-4	1917.7	1.02(-4)	2.32(-3)	3.87
	4-5	2176.3	5.07(-5)	1.15(-3)	1.92
Maximum	0	0	3.78(-2)	8.58(-1)	8.58
	0-1	202.2	3.36(-2)	7.63(-1)	7.63
Pb	1-2	611.1	2.68(-2)	6.08(-1)	6.08
	2-3	1424.5	2.00(-2)	4.54(-1)	4.54
	3-4	1917.7	1.34(-2)	3.04(-1)	3.04
	4-5	2176.3	6.69(-3)	1.52(-1)	1.52

Table 10.12. Continued

	I Contour Line Intervals	II Area between Contour Lines, km^2	III Deposition $g/m^2/30$ yr	IV Increased Soil Concentration, µg/g (3 cm depth)	V Increase over Total Endogenous Concentrations, % (3 cm depth)
<u>Maximum</u>	0	0	5.58(-3)	1.27(-1)	63.50
	0-1	202.2	4.98(-3)	1.13(-1)	56.50
Se	1-2	611.1	3.93(-3)	8.92(-2)	44.60
	2-3	1424.5	2.95(-3)	6.70(-2)	33.50
	3-4	1917.7	1.98(-3)	4.49(-2)	22.45
	4-5	2176.3	9.87(-4)	2.24(-2)	11.20

[a]Refers to a maximum deposition at a point location.

[b]Parenthetical expression refers to 10 to the minus power.

Column I - Contour lines correspond to isopleths in Fig. 6A.4 (Vol. I).

Column II - Area calculated with a planimeter.

Column III - Deposition rates presented in Table 6A.5 (Vol. I) times the 30-year life expectancy of the plant.

Column IV - Assumes bulk density of soil is 1.47 g soil/cm^3. Assumes all deposition reaches the soil and remains in the top 3 cm.

Column V - Assumes average total endogenous soil concentrations are:
As, 6.0 ppm; Be, 6.0 ppm; Cd, 0.06 ppm; Pb, 10.0 ppm; Se, 0.2 ppm.[159]

of 1.47 g soil/cm^3. Bulk densities generally range from 1.0-2.0 g soil/cm^3.[158] However, a change in trace element concentration in the soil based on this factor is relatively insignificant when compared to the errors induced by the conservative assumptions of this analysis. Lastly, average endogenous soil concentrations of the five trace elements could not be found for southern Illinois soils. Therefore, Column V assumes that the total endogenous concentration of each element in the soil surrounding the model plant sites is the same as the average concentration cited in Bowen[159] (which is a compilation of data from all over the world).

At sites with a single 3000-MWe model plant, no serious adverse impacts due to arsenic, beryllium, cadmium, lead, and selenium on deposited particulates are expected (Table 10.11). However, soil concentrations of the five trace elements are about an order of magnitude higher for the clustered siting (Table 10.12). Table 10.13 presents a calculated estimate, for the clustered configuration, of trace element uptake by vegetation (Column III) growing on soil with the maximum increased soil concentrations of each element (from Column IV, Table 10.12). The assumptions made in this estimation are given with the table.

Although all elements in this analysis except beryllium show at least an 8.5% increase over total endogenous soil concentrations for the clustered configuration, the sum of the increased soil concentration (due to deposition) and the total endogenous soil concentration for each element is below the soil concentrations that generally have been reported toxic to plants (See As, Be, Cd, Pb, and Se Toxicity). The calculated plant uptake (Column III, Table 10.13) for each element is also below reported toxic levels.

Because of uncertainties in the estimation of deposition rates, evaluation of the potential impacts should consider the possibility of an order of magnitude increase or decrease in actual deposition rates (see Section 6A.2, Vol. 1). Of course, a decrease should lessen the possibility of potential trace element impacts, but an increase would result in the following maximum increases in soil concentrations around the model plants in the clustered configuration: As, 5.43 μg/g (ppm); Be, 0.137 μg/g; Cd, 0.0651 μg/g; Pb, 8.58 μg/g; and Se, 1.27 μg/g. The resultant calculated plant uptake is presented in Column IV of Table 10.13. Based on available literature, arsenic is the only element in this analysis which may be accumulated to toxic levels by plants. A tissue concentration of 1 μg/g in soybean has been reported to be toxic.[85] Soybean and other legumes are not considered to have much tolerance to arsenic.[80,82] An area of 4156 km^2 (within isopleths 1, 2, 3, and 4, Fig. 6A.4, Vol. I) may have arsenic depositions resulting in calculated plant uptakes of 1.11 μg/g or greater (to a maximum of 1.60 μg/g).

Therefore, in areas surrounding model plants in the clustered configuration, the deposition of coal-derived arsenic emissions may have adverse effects on vegetation of low tolerance, particularly if there are areas with higher than average endogenous soil arsenic concentrations. It should be pointed out that because of the conservative assumptions and other uncertainties of this analysis, it cannot be predicted that arsenic emissions will have adverse effects on vegetation. Rather, it can only be said that the possibility of adverse effects cannot be ruled out by this analysis. Beryllium, cadmium, lead, and selenium emissions are not expected to have adverse impacts on

Table 10.13 Calculated Maximum Trace Element Uptake by Vegetation for the Clustered Source Siting

I	II	III	IV
Element	Concentration Ratio	Uptake, µg/g	Uptake, µg/g (when deposition is increased)
As	0.14	0.92	1.60
Be	0.02	0.12	0.12
Cd	10.0	0.67	1.25
Pb	0.45	4.89	8.06
Se	1.0	0.33	1.47

Column II is a generalized approximation of the ability of plants to accumulate trace elements similar to the method employed by Hodgson.[107] The concentration ratio is the ratio of the average concentration of each trace element in plants (taken from Chapman[160] for As and Pb, and from Bowen[159] for Be, Cd, and Se) to the average concentration of each trace element in soils (taken from Bowen[159]). There are limitations to this approach, such as plant species response to the trace element, variation in the soil types and properties, and environmental variables.

Column III assumes that the concentration of each element deposited and retained in the top 3 cm of the soil (Column IV, Table 10.12) moves into the root zone (without dilution) and that both endogenous and deposited trace elements are totally available to plants. Calculated: Endogenous soil concentration (footnotes, Table 10.12) plus increased soil concentration (Column IV, Table 10.12) times concentration ratio (Column II).

Column IV assumes the same conditions as Column III. Calculations were carried out as in Column III, except increased soil concentrations were multiplied by 10 to adjust for uncertainties in estimation of deposition rates (see Section 6A.2, Vol. I).

vegetation, unless endogenous soil levels are already just below toxic levels or other sources of these elements are entering the region.

Based on dietary levels of arsenic, cadmium, lead, and selenium reported to be toxic to grazing animals (See As, Cd, Pb, and Se Toxicity), no impacts are expected for these animals. Ingestion of arsenic and lead in dust and soil on forage is often considered the greatest danger to animals.[77] However, deposition rates for these sites are not expected to be high enough to be toxic (except, perhaps, in isolated situations). Inhalation of beryllium is the major hazard to animals and man. However, increased aerial concentrations of beryllium are not expected to reach unsafe levels. The highest predicted 24-hour maximum ground-level concentration for both siting patterns is 0.00576 $\mu g/m^3$ (See Table 6A.8c in Vol. I), which is below the 0.01 $\mu g/m^3$ standard. The quantities of arsenic, beryllium, cadmium, lead, and selenium which may be incorporated into other levels of the food web were not assessed. However, cadmium is accumulated in soft tissues and not readily excreted by mammals.[77,94] Therefore, the possibility of adverse effects in food chains may be greater for this element than for the other elements in this study. As mentioned previously, any additional sources of cadmium may bring some people dangerously close to the "threshold of observable symptoms of cadmium poisoning."[94]

10.4.1.3 Impacts of Airborne Combustion Emissions on Aquatic Ecosystems

SO_x and NO_x

Oxides of sulfur and nitrogen combine with rain to produce acidic precipitation.[53] Acidification of surface water from acid rain may reduce the pH level and adversely affect aquatic biota. The impacts of acid rain usually occur in areas where the acid neutralizing capacity (buffering capacity) of the soil and surface water is exceedingly low.[14] In the SILSA the buffering capacity of most streams is moderately high due to abundant alkaline minerals in the soil and limestone or dolomite rock outcrops.[161] It is unlikely that acidic precipitation would affect these streams. Table 10.14 shows the primary constituents affecting acid buffering capacity of two larger tributary streams in the SILSA, the Kaskaskia and Little Wabash Rivers.[161] High total alkalinity and hardness in these rivers indicate their high buffering capacity.

However, some rivers in the SILSA, e.g., the Big Muddy and Saline Rivers, receive acidic mine drainage, primarily from abandoned coal refuse piles. Pyritic minerals (iron sulfides) exposed to oxidation by coal mining produce sulfuric acid. Acidic surface drainage then enters the rivers and combines with the acid neutralizing anions. This increases the total acidity of the rivers and reduces their ability to buffer additional acidic inputs. Higher concentrations of sulfate and lower concentrations of carbonate, alkalinity, and hardness indicate this effect (Table 10.14).[161]

Acidic inputs from abandoned coal refuse will continue until the mine spoil areas are reclaimed, but acidic inputs from new mining development are unlikely since the discharge of acidic drainage is specifically prohibited by discharge permits and reclamation activities are required to cover pyritic spoil.

Table 10.14. Concentration of Primary Constituents Affecting Acid Buffering of Four Rivers in SILSA

High Acid Buffering Capacity (mg/l)	CO_3 (mg/l)	SO_4 (mg/l)	Alkalinity (mg/l as $CaCO_3$)	Hardness (mg/l as $CaCO_3$)	TDS (mg/l)
Kaskaskia River	86	48	144	202	280
Little Wabash River	78	46	131	192	281
Low Acid Buffering Capacity					
Saline River	17	92	29	115	196
Big Muddy River	22	112	36	125	254

Potential sites for at least three new coal-fired power plants were selected in the Big Muddy Drainage Basin (see Vol. I, Sec. 4). If acidic precipitation produced by these new plants falls within the drainage basin, the total surface water acidity may be increased and this may adversely affect the biota in the river. It is difficult if not impossible to estimate the resulting change in pH and total acidity that may result, but the sensitivity of some rivers in the SILSA to additional acidic inputs is clearly evident. If pH values are reduced below 4.5, adverse impacts to aquatic biota are likely.[162]

Trace Elements

Inputs of some trace elements from combustion emissions to surface waters may enrich the ambient concentration in the receiving water. Impacts to the aquatic community may result when trace element concentration exceeds the toxicity threshold of specific aquatic organisms.

A worst possible case estimate of trace element enrichment was calculated for selected drainage basins in the SILSA. The basins selected for this study contain a number of potential sites for new coal-fired power plants (see Vol. 1, Sec. 4). The assumptions and equations used to calculate the enrichment factors and final concentrations of specific trace elements are given below.

1. The annual trace element emission rates, as given in Volume I, Section 6, were multiplied by the number of potential new 3000-MWe power plants located within each drainage basin. This value was assumed to represent the total annual emission in the basin.

2. The total annual emission for each element was assumed to be transported into the water of the drainage basin and dissolved in the total annual discharge volume of each river.

3. The total annual discharge volume was determined by multiplying mean annual discharge (cfs) times seconds per year and then converting this to liters per year.

4. The final concentration (FC) was calculated as:

$$FC = \frac{AE}{AD} + AC$$

where, AE = total annual emission (mg/yr)

AD = total annual discharge (liters/yr)

AC = ambient concentration of the trace element in the river water before inputs (mg/liter).[163]

5. The enrichment factor (EF) was calculated as:

$$EF = \frac{FC}{AC}$$

Enrichment factors that were less than a 10% increase over the ambient concentration were assumed to indicate no measurable increase (NMI).

Table 10.15. Estimated Trace Element Enrichment Factors for the SILSA Rivers near 3000-MWe Coal-Fired Power Plants

Element	Wabash (Enrichment	Big Muddy Factor = Final	Kaskaskia Concentration/Ambient	Ohio	Mississippi Concentration)
Arsenic	NMI[a]	2.2	NMI	NMI	NMI
Beryllium	1.4	11.5	13.9	NMI	1.3
Cadmium	NMI	1.2	NMI	NMI	NMI
Fluorine	NMI	3.5	1.9	NMI	NMI
Mercury	1.6	13.6	5.7	NMI	1.3
Lead	1.2	2.9	1.7	NMI	NMI
Selenium	11.0	200.2	74.0	2.4	6.5

[a]No measurable increase.

Table 10.16. Comparison of Trace Element Concentrations and Toxicity Tresholds for Aquatic Biota in the Big Muddy and Kaskaskia Rivers

Element	Final Concentration		Water Quality[b] Criteria	Toxicity[c] Threshold
	Big Muddy	Kaskaskia		
Arsenic	0.15	0.10	0.05	>1.0
Beryllium	0.0023	0.003	0.011-1.1	>1.0
Cadmium	0.007	NMI[a]	0.01	>.0005
Fluorine	1.03	0.57	1.4-2.4	>.10
Mercury	0.0014	0.0006	0.002	>.00005
Lead	0.20	0.12	0.05	>.01
Selenium	0.02	0.0074	0.01	>.001

[a]No measurable increase.

[b]U. S. Environmental Protection Agency, "Quality Criteria for Water," EPA-440/9-76-023 (1976).

[c]Estimated from data presented in footnote b.

The results of this analysis suggest that in smaller drainage basins, :ch as the Big Muddy and Kaskaskia Rivers, sufficient dilution water may not be available to prevent measurable increases in trace element concentrations. However, in larger basins, such as the Mississippi and Ohio Rivers, availability of dilution water may prevent measurable trace element enrichment (Table 10.15).

The importance of trace element enrichment may be elucidated by comparing the estimated final concentration of specific trace elements with the water quality criteria and the probable toxicity threshold for sensitive aquatic biota. This comparison was made with the estimated final concentration values for the smaller Big Muddy and Kaskaskia Rivers, since only minor increases were detected in the larger rivers. The results of this comparison suggest that inputs of trace elements to these rivers may increase the concentration in excess of the water quality criteria and the toxicity threshold (Table 10.16). Although sufficient cooling water may be available for location of power plants on these two rivers, sufficient dilution water may not be available to dilute trace element inputs and prevent impacts to aquatic biota. This conclusion is based on the assumption that all of the yearly emission is incorporated in the receiving body. Clearly, a lower potential for impact would exist if a portion of the trace elements deposited annually were trapped within the soil prior to runoff and incorporation in water body. However, sufficient data on the soil chemistry of trace elements are not available to present a more accurate evaluation of stream enrichment by trace element runoff. The worst possible case assumption used for this assessment therefore provides an indication of potential impact and the values shown should not be construed as a measure of enrichment.

10.4.2 Combustion By-Products

10.4.2.1 Impacts of Waste from Coal Combustion on Aquatic Ecosystems

The 3000-MW model power plant will produce three types of solid waste: fly ash, scrubber waste, and concentrated material in blowdown. Disposal of the first two types of material has been accomplished by combining the wastes with water and pumping the resultant slurry to pre-excavated basins. In the basins, the solids settle out and the supernatant is discharged to the surrounding environment. The discharge contains various amounts of trace elements depending on: (1) the type of coal burned in the power plant, and (2) the scrubbing process. Discharging of liquid effluent from the settling ponds or as blowdown is regulated by permits from USEPA through NPDES (National Pollution Discharge Elimination System). For new power plants, effluents will be regulated by NSPS (New Source Performance Standards). NSPS do not allow discharges from fly ash settling ponds nor from the flue-gas desulfurization system (scrubber waste). Therefore under NSPS regulations, the extent of effluents from the model plant will be limited to blowdown from the mechanical-draft wet cooling towers.

Disposal of fly ash and scrubber solid wastes is assumed to be by burial. In mine-mouth plant operations, the solid waste can be placed in pre-·ned areas, used for fill, and covered. At power plants where old excava-ons are not available, the wastes will be discharged to holding ponds, dewatered by evaporation, and then either covered or removed to another area for burial. Disposal of solid wastes in this manner could contaminate ground water with trace materials. However, information on leaching and transport rates is limited. Sealing of the bottom of disposal pits with clay or other non-reactive nonporous materials is being employed to mitigate this problem.

Blowdown composition under NSPS is given in Section 8 (Water Quality). The majority of trace materials will be in flyash and scrubber waste. The concentrations of the trace materials in the blowdown are within the limits of concentrations allowed by NSPS. The concentrations of these materials in the blowdown discharge are generally below the loading factors established by the USEPA[164] to maintain acceptable water quality. Predictions of water quality parameters given in Section 8 (Water Quality) indicate that toxic limits will not be exceeded. Therefore, impacts from solid wastes, either as fly ash, scrubber waste, or contained in blowdown, are expected to be minor, if detectable.

10.4.2.2 Impacts on Terrestrial Ecosystems

Description

Scrubber wastes and fly ash represent by-products that accumulate in the smoke stacks and electrostatic precipitators. These wastes are normally discharged to a settling basin near the generating station. Groundwater and surface water contamination from these materials will not be a problem if the underlying substrate and the walls of the basin are composed of impervious materials. The abundance of clay soil for dikes and retaining walls should permit adequate sealing of the basins.

Impacts

The highly alkaline nature (pH 9-12) of the water in the fly ash settling basins will not permit colonization by aquatic invertebrates or the marsh vegetation required by waterfowl and most marsh birds. Common species such as snapping turtles or painted turtles are likely to enter the basins but are not expected to suffer bodily harm. Reproducing populations are not likely to become established due to the lack of cover and food. Amphibians are not expected to use these basins for reproduction. The greatest impact of the basins to terrestrial biota is in the loss of habitat as the waste materials are deposited.

10.4.3 <u>Effects of the Cooling System</u>

10.4.3.1 Intake

The makeup water requirement for the model plant is approximately 60 cfs. It is assumed that water will be withdrawn from rivers through a sidewall intake structure by a single pump. The intake structure is also assumed to contain a travelling screen with 3/8-inch mesh and trash racks to prevent the entrainment of debris. The size of the aperture of the intake forebay is important since impingement is caused by the inability of fish to resist the flow of water entering the intake. Swimming speed of fish is proportional to size.[165,166] At lower approach velocities (< 1 fps), smaller fish can resist the intake flow and escape impingement.[167] Theoretically, with a flow requirement of 60 cfs and an approach velocity of 1.0 fps, the forebay opening will be 60 square feet. At an approach velocity of 0.5 fps, the opening will be 120 square feet or an area 10 feet by 12 feet. This size intake is assumed since, with the lower approach velocity, impingement should be less.

The impingement or entrainment impacts for the model plant will be extrapolated from the Quad Cities Power Station located on the Mississippi River. Data presented are from Semi-Annual Reports to Commonwealth Edison Company.[168,169] The station is located on Pool 14 of the Mississippi River, above Davenport, Iowa. Quad Cities Station consists of two 809-MW boiling water reactors which withdraw up to 2270 cfs of cooling water. In order to make the extrapolation, several assumptions must be made; (1) the aquatic community composition and structure of Pool 14 is similar to other impoundments on the rivers of the SILSA, (2) intake structure, approach velocity, flow patterns, and protective devices are similar, and (3) impact is proportional to the amount of water withdrawn. For example, a model plant in the same location as the reference plant, Quad Cities Station, would incur impacts proportional to the ratio of the intake volumes: in this example, 60 cfs over 2270 cfs or 2.6%. If the impacts associated with the reference plant are minor, then the impacts from the model plant would be negligible.

The following presents the known impacts from Quad Cities Station to the non-fish biota. These biotic communities appear to be relatively unaffected by the Quad Cities Station. Phytoplankton density peaked in late spring and again in a minor pulse in late fall. Density and community composition appear to be influenced to a much greater degree by flow and temperature rather than by station operation.[168,169] Zooplankton densities attain a late spring peak similar to phytoplankton.[168,169] Abundance is greatest in the warm, slow-flowing slough areas, particularly in early summer following the phytoplankton bloom.[168,169] In 1972 and 1973, densities of total zooplankton ranged from $1000/m^3$ to $600,000/m^3$.[168,169] One of the major physical factors affecting abundance and species composition is flow.[168,169] Abundance is usually inversely proportional to flow while species richness, the number of species present, is directly proportional to flow. Total zooplankton and three major groups of zooplankton were compared at locations upstream and downstream from the station prior to and during all phases of operation from 1971 to mid-1974. Differences observed were not attributable to the plant but depended on temperature and flow. Similar results were determined for macroinvertebrates. Changes in benthic community composition were related to changes in season, flow, and substrate conditions.

Entrainment impacts to phytoplankton and zooplankton would result in the removal of a certain portion of the populations, probably less than 5% assuming that impact is proportional to the amount of water withdrawn. However, these populations have the reproductive capacity to recover from such losses. The recovery rate of phytoplankton and zooplankton populations is dependent on the reproductive rate and turnover time of the species involved. Turnover time is the amount of time required for the species population to reproduce itself. Hutchinson[170] stated that unicellular phytoplankton probably divide two to ten times per month, and at the higher rate, populations of 10^{15} or 10^{20} individuals could be produced from a single cell in one season. In the case of zooplankton, the life span is short compared to the length of the growing season, and several generations can be expected each year.[170] For example, several species of *Daphnia* were examined to determine their turnover times in lakes in Michigan[171] and Montana.[172] The turnover times of the populations of these species during summer ranged from 4 to 10 days. This indicates that plankton have the potential to mitigate impacts quickly, assuming that an unreasonably high proportion is not lost.

Impingment at Quad Cities Station in 1973 and 1974 was estimated at 128,159 fish and 55,041 fish, respectively.[169] In 1973 and 1974, 74.9% and 63.9% of the total fish were gizzard shad, primarily young of the year. Impingement composition is given in Table 10.17. Concurrent estimates of total standing crop of the major species, i.e., of commercial or sport importance, were also made and compared to impingement (Table 10.18) to estimate the impact. The impingement impact estimate for all species was less than 2.5%. The commercial catch in Pool 14 was compared to the standing crop. This indicated that a much greater impact to fish populations results from fishing than from impingement (Table 10.19).

Impacts associated with the intake from Quad Cities Station appear minor, if detectable at all. The 3000-MWe model plant for this study will withdraw only 2.6% of the water that the Quad Cities Station uses. Therefore, it is highly unlikely that intake impacts from the model plant will be significant.

Table 10.17. Composition of Fish Impingement at Quad Cities Station in 1973 and 1974

Fish	1973 %	1974 %
Gizzard shad	74.9	63.9
Freshwater drum	8.2	27.9
Crappies	3.9	
Carp	3.7	
Buffaloes	2.9	
White bass	2.5	1.5
Mooneye	1.0	
Channel catfish	0.9	1.7
Bluegill	0.9	
Others	1.1	5.0

Table 10.18. Impingement Impact Percentage from Projected Pounds of Fish Impinged at Quad Cities Station Divided by Estimated Standing Crop in 1973 and 1974

Species	% Impinged 1973	% Impinged 1974
Gizzard shad	1.367	1.243
Carp	0.034	0.025
Carpsuckers	0.012	0.011
Buffaloes	0.113	0.046
Bullheads	0.121	0.114
Channel catfish	0.361	0.198
White bass	2.057	1.598
Largemouth bass	0.088	0.117
Crappies	0.318	0.195
Sauger & walleye	0.565	0.573
Freshwater drum	0.482	0.644

Table 10.19. Commercial Catch in Mississippi River Pool 14 as Percentage Estimated Standing Crop

Species	1970	1971	1972
Carp	10.6	11.2	10.5
Carpsuckers	0	0.2	0.1
Buffaloes	16.2	19.1	22.2
Bullheads	0.4	0.4	0.7
Channel catfish	35.7	34.5	47.7
Freshwater drum	3.2	3.6	6.4

The projected model plant locations and numbers for the SILSA are Mississippi River 5, Kaskaskia River 3, Big Muddy River 3, Wabash River 1, Saline River 1, and Embarrass River 1. Only those on the Mississippi and Wabash Rivers will be located on cooling water reservoirs or impoundments. In all locations, the volume of makeup water required and the size of the intake structure considered with respect to the size of the water body present, indicate that impacts from impingement and entrainment should be minimal.

10.4.3.2 Discharge

Physical Impacts

The annual maximum and minimum river temperatures in the SILSA usually occur during August and February, respectively. The thermal inputs of the model plant will affect ambient temperatures. The discharge structure is assumed to be a diffuser type which will discharge blowdown at a high velocity and result in rapid mixing and a limited mixing zone. The magnitude of the temperature difference (ΔT) will depend on a number of factors which affect the efficiency of wet mechanical-draft cooling towers, such as river water temperature, weather conditions, relative humidity, and amount of cooling water recycling. The predicted discharge of blowdown is 16.7 cfs, but may be reduced to 1.4 cfs under conditions of maximum water reuse.

The siting criteria state that the intake flow must be less than 20% of the 7-day, 10-year low flow (see siting section). Since the predicted intake flow is approximately 60 cfs for the model plant, the minimum flow of a river at the plant site must be 300 cfs. The maximum discharge, 16.7 cfs, would be approximately 6.5% of the total flow during the 7-day, 10-year low flow period: 16.7 cfs (blowdown)/300 cfs (river flow) - 60 cfs (intake flow) + 16.7 cfs (discharge) = 0.065. This is the maximum proportion of the total river flow that the blowdown volume could make up. However, localized thermal gradients will be established in the vicinity of the discharge. The diffuser type discharge should create a velocity gradient that corresponds to the thermal gradient, i.e., areas of maximum temperature will also have maximum velocity.

Impacts will occur during construction of the discharge structure. Although these impacts are site specific, they can be identified generically. Initially, there will be disruption of a certain area of bottom habitat due to digging and some siltation. However, the majority of the discharge structure will be buried so the bottom area can be recolonized. Siltation will probably be minor since the amount of material removed is small. A twenty-inch pipe could be used to convey the discharge to the diffuser.

Biological Impacts

Increased temperatures can affect the biota which are exposed to the thermal plume. Phytoplankton productivity may be increased due to the increased metabolic rates caused by higher temperatures, and species composition may be changed if natural temperature ranges are exceeded.[173] Invertebrates may be affected if the discharge is above their thermal tolerance range which at any given time depends on acclimation. Certainly some area of bottom will be disturbed by the diffuser and the discharge. However, non-lethal temperatures may not affect invertebrates seriously. In the upper Mississippi River, Fremling[174] found no correlation between mayfly emergence and water temperature or water level. Wojtalik and Waters[175] found that water temperature may affect the amount of aquatic insect drift within the daily drift cycle but the timing of the cycle does not seem to be affected. Fish normally select areas which are near their thermal preference.[176] The velocities associated with the diffuser should exclude fish from the areas of maximum temperature.

In the smaller rivers of the SILSA, i.e., the Kaskaskia, Big Muddy, Little Wabash, etc., the model plant would be located on cooling-water reservoirs. The volume of water contained in the reservoir will be much greater than the discharge. Impacts which may occur will be restricted to a comparatively minor area, and therefore should be localized. On the major rivers that border the SILSA, the magnitude of the discharge will be insignificant relative to the total flow. The area affected should be negligible compared to the total area of the river.

Far Field Impacts

The assessments of near field impacts from trace elements, impingement, entrainment, and thermal additions have indicated no unacceptable impacts from a single model plant. The overall consideration is far field impacts. If there will be minor or negligible impacts in the area proximal to a single plant, it is highly unlikely that there will be far field effects. The far field effects from the combined operation of five plants on the Mississippi River (year 2020 scenario) should be limited to a minor, if detectable, change in water quality. Since the NSPS will be in effect, no serious degradation of water quality should occur. The biota should be similarly unaffected. Since the Mississippi River is free-flowing throughout the section that borders the SILSA, and the projected plant sites are not clustered, no unacceptable impacts should occur. Similar minor impacts are projected for the two plants proposed for the Wabash River. The major premise involved from assessing impacts to the free-flowing rivers is that sufficient distance be maintained between plant sites such that there is no overlap of effects. A population dynamics point of view is concerned with the functional limit to a population in terms of river distance, or at what point individual populations can be separated within a free flowing river. When physical barriers exist, such as dams, waterfalls, etc., the limits are pre-defined. However, for an uninterrupted river the problem is more difficult. For nonmigratory fish species with limited movement, such as bass and sunfish, population boundaries may be within distances of 150 m.[177,178] However, species with spawning migrations may have population boundaries that are hundreds of miles apart. The major economic and sport fishes in the SILSA do not undergo extensive migrations. While definitive population boundaries cannot be determined, the distance between plants on the free-flowing sections of the Mississippi River is at least 15 miles. Due to active turbulent mixing in free-flowing rivers, this distance seems sufficient to avoid impact overlap.

The other power plant sites in the SILSA are either on impoundments or cooling water reservoirs. Each impoundment or cooling water reservoir can be considered as a lake. The ecosystem no longer functions as a free-flowing river. Each impoundment has its own biotic communities. Any impacts that occur are limited to the specific impoundment. Each population within the impoundment will respond to impact. In the case of animals, many species have density-dependent population regulation.[179] Through mechanisms involving reproductive rates, survival rates, and/or growth rates, the population can compensate for losses. Density-dependent population regulation has been demonstrated for fish species.[180-182] The reproductive rates and turnover times of planktonic organisms should enable them to compensate for losses and maintain existing levels of export to the river downstream.

REFERENCES FOR SECTION 10.0

1. L. E. Young, *Surface Subsidence in Illinois Resulting from Coal Mining*, Ill. State Geological Survey Bul. 17, pp. 1-112 (1916).

2. *1975 Annual Report - Surface-Mined Land Conservation and Reclamation*, Dept. of Mines and Minerals, Division of Land Reclamation, Springfield, Ill. pp. 1-35.

3. S. C. Kendeigh, *Ecology, with Special Reference to Animals and Man*, Prentice-Hall, Englewood Cliffs, N. J., 474 pp. (1974).

4. D. F. Hoffmeister and C. O. Mohr, *Fieldbook of Illinois Mammals*, Dover, N. Y., 233 pp. (1972).

5. C. M. Nixon, M. W. McClain and R. W. Donohoe, *Effects of Hunting and Mast Crops on a Squirrel Population*, J. Wildl. Manage. 39(1):1-25 (1975).

6. C. M. Nixon, D. M. Worley, and M. W. McClain, *Food Habits of Squirrels in Southeast Ohio*, J. Wildl. Manage. 32(2):294-305 (1968).

7. L. J. Korschgen, *Foods of Missouri Deer with Some Management Implications*, J. Wildl. Manage. 26(2):164-172 (1962).

8. G. L. Storm et al., *Morphology, Reproduction, Dispersal and Mortality of Midwestern Red Fox Populations*, Wildl. Monogr. No. 49, 82 pp. (1976).

9. P. W. Smith, *Amphibians and Reptiles of Illinois*, Bull. Ill. Nat. Hist. Surv., Vol. 28, Art. 1, pp. 1-298 (1961).

10. Energy and Environmental Analysis, Inc., *Laws and Regulations Affecting Coal*, United States Dept. of Interior, Contract No. 14-01-0001-2115.

11. P. W. Smith, *Illinois Streams: A Classification Based on Their Fishes and an Analysis of Factors Responsible for Disappearance of Native Species*, Biological Notes No. 76. Illinois Natural History Survey. 14 pp. (1971).

12. M. E. Jewell, *The Fauna of an Acid Stream*, Ecology 3:22-28 (1922).

13. W. H. Smith and I. B. Stall, *Coal and Water Resources for Coal Conversion in Illinois*, Cooperative Resources Report No. 4. Illinois State Water Survey and Illinois State Geological Survey. 80 pp. (1975).

14. A. J. Dvorak et al. Nuclear Regulatory Commission, *The Environmental Effects of Using Coal for Generating Electricity*, Argonne National Laboratory. Report NUREG 0000, U. S. Nuclear Regulatory Commission, Washington, D. C. (1977).

15. U. S. Dept. of Interior, *Water Resources Data for Illinois*, 250 pp. (1969).

16. K. Ackerman, *Rare and Endangered Vertebrates of Illinois*, Bur. Environ. Sci., Ill. Dept. Transportation, 50 pp. (1975).

17. Fish and Wildlife Service, *U. S. List of Endangered Fauna*, U. S. Dept. Interior, 22 pp. (1974).

18. A. W. Deurbrouck, *Coal Preparation* 1973, Mining Congress Journal, pp. 65-67 (Feb. 1974).

19. R. A. Schmidt, *Current Trends in Coal Preparation*, Coal Mining and Pocessing, 12(9):74-76 (Sept. 1975).

20. J. C. Anderson, J. W. Leonard, and C. T. Holland, "Raw Coal Preparation," in J. W. Leonard and D. R. Mitchell, Eds., *Coal Preparation*, The American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., New York, pp. 6-1 to 6-38 (1968).

21. J. L. Walker, *Coal is Upgraded in Unique Preparation Plant*, Power Engineering 79(3):62-64 (March 1975).

22. G. Davis, *Comparison of Fall and Spring Planting on Strip-mine Spoils in the Bituminous Region of Pennsylvania*, Northeast. For. Exp. Stn., USDA Paper IV-9, pp. 525-538.

23. A. L. Fleming, J. W. Schwartz, and C. D. Foy, *Chemical Factors Controlling the Adaption of Weeping Lovegrass and Tall Fescue to Acid Mine Spoils*, Agron. J. 66:715-719 (1974).

24. H. Van Lear, *Effects of Spoil Texture on Growth of K-31 Tall Fescue*, Northeast. For. Exp. Stn., USDA For. Serv. Res., Note NE-141, 7 pp. (1971).

25. W. G. Vogel, *Weeping Lovegrass for Vegetating Strip-mine Spoils in Appalachia*, 1973-711-062/5, U. S. Goverment Printing Office, Washington, D. C., pp. 152-162 (1973).

26. W. G. Vogel and W. A. Berg, *Grasses and Legumes for Cover on Acid Strip-mine Spoils*, J. Soil Water Conserv., pp. 89-91 (May-June 1968).

27. A. F. Grandt and A. L. Lang, *Reclaiming Illinois Strip Coal Land with Legumes and Grasses*, Univ. Ill. Agric. Exp. Stn. Bull. 628, 64 pp. (1958).

28. M. Morrison, ed., *EPI Cautions about Strip-mining Illinois Corn Belt*, Coal Week, p. 2 (July 26, 1976).

29. B. B. Green and S. D. Zellmer, *Grundy County Demonstration Site. Phase II. Progress Report for 1975-1976*, Energy and Environmental Systems Division, Argonne National Laboratory, Argonne, Ill., 16 pp. (1976).

30. A. H. Benton and W. E. Werner, Jr., *Field Biology and Ecology*, McGraw-Hill, New York, 564 pp. (1974).

31. R. H. Giles, Ed., *Wildlife Management Techniques*, Wildlife Society, Washington, D. C., 623 pp. (1969).

32. A. C. Martin, H. S. Zim, and A. L. Nelson, *American Wildlife and Plants, A Guide to Wildlife Food Habits*, Dover N. Y., 500 pp. (1961).

33. R. A. Hill, *Water Quality and Biotic Development In and Around Final-Cut Reservoirs at the Peabody Coal Company Will Scarlet Mine*, Peabody Coal Co. Report. 12 pp. (1976).

34. C. C. Gordon and P. C. Tourangeau, *Biological Effects of Coal-fired Power Plants*, Proceedings of the Fort Union Coal Field Symposium. Vol. 5 Montana Academy of Sciences, Billings, pp. 509-530 (1975).

35. J. B. Mudd and T. T. Kozlowski, *Responses of Plants to Air Pollution*, Academic Press, New York, pp. 1-22 (1975).

36. *Air Quality Criteria for Nitrogen Oxides*, Environmental Protection Agency, Publication AP-84 (Jan. 1971).

37. *Air Quality Criteria for Sulfur Oxides*, U. S. Department of Health, Education and Welfare, Publication AP-50 (Jan. 1969).

38. M. Neiburger, J. G. Edinger, and W. D. Bonner, *Understanding Our Atmospheric Environment*, W. H. Freeman and Co., San Francisco, pp. 241-245. (1973).

39. *Effects of Sulfur Oxides in the Atmosphere on Vegetation*, Revised Chapter 5 for air quality criteria for sulfur oxides, National Environmental Research Center, EPA-R3-73-030 (Sept. 1973).

40. Y. C. Alarie et al., *Long Term Exposure to Sulfur Dioxide, Sulfuric Acid Mist, Fly Ash, and Their Mixtures -- Results of Studies in Monkeys and Guinea Pigs*, Arch. Environ. Health 30:254-262 (1975).

41. J. J. Bromenshenk, *Biological Impact of Air Pollutants on Insects*, Proceedings of the Fort Union Coal Field Symposium, Montana Academy of Sciences, Billings 5:596-607 (1975).

42. *Compilation of Air Pollution Emission Factors*, 2nd Edition, U. S. Environmental Protection Agency, Publication AP-42, p. 1.1-3 (April 1973).

43. C. R. Davis, *Sulfur Dioxide Fumigation of Soybeans: Effect on Yield*, Journal of the Air Pollution Control Association 22(12):964-966 (1972).

44. *Air Pollution Effects on Soybeans*, TVA Today 5(3):2-3 (October 1974).

45. M. Treshow, *Environment and Plant Response*, McGraw-Hill Book Co., New York, 422 pp. (1970).

46. A. Grennard and F. Ross, *Progress Report on Sulfur Dioxide*, Combustion (Jan. 1974).

47. H. C. Jones et al., *Investigation of Alleged Air Pollution Effects on Yield of Soybeans in the Vicinity of the Shawnee Steam Plant*, Tennessee Valley Authority Publication E-EB-73-3 (1973).

48. H. C. Jones, Personal communication, Tennessee Valley Authority, Muscle Shoals, Alabama (1976).

49. *Illinois Agricultural Statistics*, Annual Summary, 1975, Illinois Cooperative Crop Reporting Service, Bulletin 75-1 (September 1975).

50. R. A. Loman, R. A. Blanel and D. Hocking, *Sulfur Dioxide and Forest Vegetation*, Report No. NOR-X-49, Northern Forest Research Centre, Edmonton, Alberta (1972).

51. G. E. Likens, F. H. Bormann and N. M. Johnson, *Acid Rain*, Environment 14:33-40 (1972).

52. G. E. Likens and F. H. Bormann, *Acid Rain: A Serious Regional Environmental Problem*, Science 184:1176-1179 (1974).

53. C. V. Cogbill and G. E. Likens, *Acid Precipitation in the North Eastern United States*, Water Resources, 10(6)1133-1137 (Dec. 1974).

54. J. W. A. Fairfay and N. W. Lepp, *Effect of Simulated "Acid Rain" on Action Loss from Leaves*, Nature 255:324-325 (1975).

55. J. Biddings and J. N. Galloway, *Literature Reviews on Acid Precipitation I. The Effects of Acid Precipitation on Aquatic and Terrestrial Ecosystems*, Center for Environ. Qual. Manag., Cornell University, Ithaca, N. Y. (1976).

56. R. W. Farenbaugh, *Effects of Acid Rain on Phaseolus Vulgaris*, L. Amer. J. Bot. 63:283-288 (1976).

57. R. P. Sheridan and R. Rosenstreter, *The Effect of Hydrogen Ion Concentrations in Simulated Rain on the Moss Tortula ruralis (hedw.)*, Sm. Bryologist 76:168-173 (1973).

58. Natl. Res. Council, Committee on Biol. Effects of Atmos. Pollutants, *Fluorides*, Natl. Academy of Sciences, ISBN 0-309-01922-2, Washington, D. C., 295 pp. (1971).

59. M. R. Pack, *Effects of Hydrogen Fluoride on Production and Organic Reserves of Bean Seed*, Environ. Sci. Technol. 5:1128-1132 (1971).

60. W. H. Allaway, *Agronomic Controls over the Environmental Cycling of Trace Elements*, Advan. in Agron. 20:235-274 (1968).

61. E. Groth III, *An Evaluation of the Potential for Ecological Damage by Chronic, Low-Level Environmental Pollution by Fluoride*, Fluoride 8:224-240 (1975).

62. R. F. Brewer, "Fluorine," in H. D. Chapman, ed., *Diagnostic Criteria for Plants and Soils*, Div. Agric. Sci., Univ. Calif., pp. 180-196 (1966).

63. M. Treshow, *Fluorides as Air Pollutants Affecting Plants*, Ann. Review Phytopath. 9:21-44 (1971).

64. M. Treshow and M. R. Pack, "Fluoride," in J. S. Jacobson and A. C. Hill, eds., *Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas*, Informative Report 1, TR-7 Agricultural Committee, Air Pollution Control Association, Pittsburgh, pp. D1-D17 (1970), cited in Ref. 58.

65. M. Treshow, op. cit. Ref. 45, pp. 267-301.

66. A. C. Hill, *Air Quality Standards for Fluoride Vegetation Effects*, J. Air Pollut. Control Assoc., 19:331-336 (1969).

67. L. H. Weinstein and D. C. McCune, *Effects of Fluoride on Agriculture*, J. Air Pollut. Control Assoc., 21:410-413 (1971).

68. R. J. Yamartino, Jr., et al., *Environmental Implications of Ground-Base and Airborne Hydrogen Fluoride Laser Operations*, Energy and Environmental Systems Division, Argonne National Laboratory, Argonne, Illinois, 106 pp. (Draft Report) (1976).

69. J. W. Suttie, J. R. Carlson, and C. C. Faltin, *Effects of Alternating Periods of High- and Low-Fluoride Ingestion in Dairy Cattle*, J. Dairy Sci., 55:790-804 (1972).

70. *Effects of Fluorides in Animals*, Natl. Academy of Sciences, ISBN 0-309-02219-3, Washington, D. C., 70 pp. (1974).

71. P. H. Phillips et al., *The Fluorosis Problem in Livestock Production*, Natl. Academy of Sciences, Natl. Res. Council Publ. 381 (1955), cited in Ref. 62.

72. C. E. Carlson, *Fluoride Pollution in Montana*, Fluoride 6:127-137 (1973).

73. J. W. Suttie, Univ. of Wisconsin-Madison, Personal communication, 1976.

74. D. C. McCune and A. E. Hitchcock, "Fluoride in Forage: Factors Determining Its Accumulation from the Atmosphere and Concentration in the Plant," in H. M. Englund and W. T. Beery, eds., *Proc. Second Int. Clean Air Congress*, Academic Press, New York, pp. 289-292 (1971).

75. D. C. McCune, *On the Establishment of Air Quality Criteria with Reference to the Effects of Atmospheric Fluorine on Vegetation*, Air Qual. Monogr. 69-3, American Petroleum Institute, New York, 33 pp. (1969).

76. P. H. Phillips et al., *The Fluorosis Problem in Livestock Production*, A Report of the Committee on Animal Nutrition, NAS-NRC Publication 824, Washington, D. C., 29 pp. (1960), cited in Ref. 58.

77. W. L. Berry and A. Wallace, *Trace Elements in the Environment-Their Role and Potential Toxicity as Related to Fossil Fuels - a Preliminary Study*, Univ. Calif. Lab. Nuclear Med. and Rad. Biol., AEC Contract No. AT(04-1) GEN 12. 66 pp. (1974).

78. R. D. Wauchope, *Fixation of Arsenical Herbicides, Phosphate, and Arsenate in Alluvial Soils*, J. Environ. Qual. 4:355-357 (1975).

79. D. J. Lisk, *Trace Metals in Soils, Plants, and Animals*, Advan. in Agron. 24:267-325 (1972).

80. B. L. Vallee, D. D. Ulmer, and W. E. C. Wacker, *Arsenic Toxicology and Biochemistry*, Arch. Indust. Health 21:132-151 (1960).

81. R. J. Sullivan, *Air Pollution Aspects of Arsenic and its Compounds*, Litton Systems, Inc., Bethesda, MD, NTIS, Springfield, VA. 63 pp. (1969).

82. G. F. Liebig, Jr., "Arsenic," in H. D. Chapman, ed., *Diagnostic Criteria for Plants and Soils*, Div. Agric. Sci. Univ. Calif., pp. 13-23. (1966).

83. D. V. Frost, *Arsenicals in Biology - Retrospect and Prospect*, Fed. Proc. 26:194-208 (1967).

84. W. D. Buchanan, *Toxicity of Arsenic Compounds*, Van Nostrand, New Jersey (1962).

85. L. E. Deuel and A. R. Swoboda, *Arsenic Toxicity to Cotton and Soybeans*, J. Environ. Qual. 1:317-320 (1972).

86. R. C. Lindner, *Arsenic Injury of Peach Trees*, Proc. Amer. Soc. Hort. Sci. 42:275-279, 1943, cited in Ref. 77.

87. I. F. Fergus, "A Note on Arsenic Toxicity in some Queensland Soils," Queensland J. Agric. Sci. 12:95-100 (1955), cited in H. D. Chapman, ed., *Diagnostic Criteria for Plants and Soils*, Appendix 1, Div. Agric. Sci., Univ. Calif., pp. 570-728 (1966).

88. E. M. Romney and J. D. Childress, *Effects of Beryllium in Plants and Soil*, Soil Sci. 100:210-217 (1965).

89. E. M. Romney, J. D. Childress, and G. V. Alexander, *Beryllium and the Growth of Bush Beans*, Science 135:786-787 (1962).

90. M. B. Hoagland, *Beryllium and Growth: III. The Effect of Beryllium on Plant Phosphatase*, Arch. Biochem. Biophys. 35:259-267 (1952), cited in Ref. 88.

91. F. W. Klemperer, *The Effect of Beryllium on Certain Enzymes*, J. Biol. Chem. 187:189-196 (1950), cited in Ref. 88.

92. N. L. Durocher, *Air Pollution Aspects of Beryllium and its Compounds*, Litton Systems, Inc., Bethesda, MD, NTIS, Springfield, VA. 82 pp. (1969).

93. J. Schubert, *Beryllium and Berylliosis*, Sci. Amer. 199:27-33 (1958).

94. V. Hiatt and J. E. Huff, *The Environmental Impact of Cadmium: An Overview*, Intern. J. Environ. Studies 7:277-285 (1975).

95. J. E. Miller, J. J. Hassett, and D. E. Koeppe, *Uptake of Cadmium by Soybeans as Influenced by Soil Cation Exchange Capacity, pH, and Available Phosphorus*, J. Environ. Qual. 5:157-160 (1976).

96. M. K. John, *Uptake of Soil-applied Cadmium and its Distribution in Radishes*, Can. J. Plant Sci. 52:715-719 (1972).

97. M. K. John, C. J. Van Laerhoven, and H. H. Chuah, *Factors Affecting Plant Uptake and Phytotoxicity of Cadmium Added to Soils*, Environ. Sci. Technol. 6:1005-1009 (1972).

98. J. V. Lagerwerff, *Uptake of Cadmium, Lead, and Zinc by Radish from Soil and Air*, Soil Sci. 111:129-133 (1971).

99. J. Santillan-Medrano and J. J. Jurinak, *The Chemistry of Lead and Cadmium in Soil: Solid Phase Formation*, Soil Sci. Soc. Amer. Proc. 39:851-856 (1975).

100. F. Haghiri, *Plant Uptake of Cadmium as Influenced by Cation Exchange Capacity, Organic Matter, Zinc, and Soil Temperature*, J. Environ. Qual. 3:180-183 (1974).

101. M. K. John, *Interrelationships between Plant Cadmium and Uptake of Some Other Elements from Culture Solutions by Oats and Lettuce*, Environ. Pollut. 11:85-95 (1976).

102. R. A. Root, R. J. Miller, and D. E. Koeppe, *Uptake of Cadmium--Its Toxicity, and Effect on the Iron Ratio in Hydroponically Grown Corn*, J. Environ. Qual. 4:473-476 (1975).

˙03. Y. C. Athanassiadis, *Air Pollution Aspects of Cadmium and its Compounds*, Litton Systems, Inc., Bethesda, MD, NTIS, Springfield, VA. 82 pp. (1969).

104. L. Friberg, M. Piscator, and G. Nordberg, *Cadmium in the Environment*, CRC Press, Cleveland, Ohio. 166 pp. (1971).

105. J. V. Lagerwerff, "Lead, Mercury, and Cadmium as Environmental Contaminants," in J. J. Mortvedt, P. M. Giordano, and W. L. Lindsay, eds., *Micronutrients in Agriculture*, Soil Sci. Amer., Inc., Madison, WI (1972).

106. M. K. John, *Cadmium Uptake by Eight Food Crops as Influenced by Various Soil Levels of Cadmium*, Environ. Pollut. 4:7-15 (1973).

107. J. F. Hodgson, "Chemistry of Trace Elements in Soils with Reference to Trace Element Concentration in Plants," in D. D. Hemphill, ed., *Proc. Univ. Mo. 3rd Ann. Conf. Trace Substances in Environmental Health*, 3:45-58, Univ. Mo. Press, Columbia, MO. (1969).

108. B. E. Vaughan et al., *Review of Potential Impact on Health and Environmental Quality from Metals Entering the Environment as a Result of Coal Utilization*, Battelle Energy Prog. Rep., Battelle Pacific Northwest Laboratories, Richland, WA. 75 pp. (1975).

109. D. F. Flick, H. F. Kraybill, and J. M. Dimitroff, *Toxic Effects of Cadmium: A Review*, Environ. Res. 4:71-85 (1971).

110. C. Y. Huang, F. A. Bazzaz, and L. N. Vanderhoef, *The Inhibition of Soybean Metabolism by Cadmium and Lead*, Plant Physiol. 54:122-124 (1974).

111. F. Haghiri, *Cadmium Uptake by Plants*, J. Environ. Qual. 2:93-96 (1973).

112. E. J. Underwood, *Trace Elements in Human and Animal Nutrition*, Academic Press, New York and London (1962), cited in Ref. 77.

113. N. Yamagata and I. Shigematsu, *Cadmium Pollution in Perspective*, Inst. of Public Health, Tokyo. Bull. 19:1-27 (1970), cited in Ref. 77.

114. R. E. Carroll, *The Relationship of Cadmium in the Air to Cardiovascular Disease Death Rate*, J. Amer. Med. Assn. 198:267-269 (1966), cited in Ref. 77.

115. R. L. Zimdahl and J. H. Arvik, *Lead in Soils and Plants: A Literature Review*, CRC Critical Reviews in Environmental Control, 3:213-224 (1973).

116. T. C. Broyer, C. M. Johnson, and R. E. Paul, *Some Aspects of Lead in Plant Nutrition*, Plant and Soil 36:301-313 (1972).

117. F. A. Bazzaz, R. W. Carlson, and G. L. Rolfe, *Inhibition of Corn and Sunflower Photosynthesis by Lead*, Physiol. Plant. 34:326-329 (1975).

118. __________, *The Effect of Heavy Metals on Plants: Part I. Inhibition of Gas Exchange in Sunflower by Pb, Cd, Ni, and Ti*, Environ. Pollut. 7:241-246 (1974).

119. F. A. Bazzaz, G. L. Rolfe, and P. Windle, *Differing Sensitivity of Corn and Soybean Photosynthesis and Transpiration of Lead Contamination*, J. Environ. Qual. 3:157-158 (1974).

120. R. W. Carlson, F. A. Bazzaz, and G. L. Rolfe, *The Effect of Heavy Metals on Plants: Part III. Whole Corn and Sunflower Plants Treated with Pb, Cd, Ni, and Ti*, Environ. Res. 10:113-120 (1975).

121. R. J. Miller and D. E. Koeppe, *Accumulation and Physiological Effects of Lead in Corn*, Proc. 4th Annual Conf. on Trace Substances in Environmental Health, Univ. of Mo., Columbia, Mo., 4:186-193 (1970).

122. A. L. Lazrus, E. Lorange, and J. P. Lodge, Jr., *Lead and Other Metal Ions in U. S. Precipitation*, Environ. Sci. Tech. 4:55-58 (1970).

123. D. E. Koeppe and R. J. Miller, *Lead Effects on Corn Mitochondrial Respiration*, Science 167:1376-1377 (1970).

124. *Lead. Airborne Lead in Perspective*, Committee on Biologic Affects of Atmospheric Pollutants, National Research Council, National Academy of Sciences, ISBN 0-309-01941-9, 330 pp. (1972).

125. D. H. Klein, A. W. Andren, and N. E. Bolton, *Trace Element Discharges from Coal Combustion for Power Production*, Water, Air, and Soil Pollution, 5:71-72 (1975).

126. J. H. Arvik and R. L. Zimdahl, *Barriers to the Foliar Uptake of Lead*, J. Environ. Qual. 3:369-373 (1974).

127. M. K. John and C. Van Laerhoven, *Lead Uptake by Lettuce and Oats as Affected by Lime, Nitrogen, and Sources of Lead*, J. Environ. Qual. 1:169-171 (1972).

128. J. V. Lagerwerff, W. H. Armiger, and A. W. Specht, *Uptake of Lead by Alfalfa and Corn from Soil and Air*, Soil Sci. 115:455-460 (1972).

129. G. L. Ter Haar, R. R. Dedolph, R. B. Holtzman, and H. F. Lucas, Jr., *The Lead Uptake by Perennial Ryegrass and Radishes from Air, Water, and Soil*, Environ. Res. 2:267-271 (1969).

130. M. Singer and L. Hanson, *Lead Accumulation in Soils Near Highways in the Twin Cities Metropolitan Area*, Soil Sci. Soc. Amer. Proc. 33:152-153 (1969).

131. R. C. Stupka, *An Analysis of the Behavior and Effects of Lead Pollution on a Terrestrial and Aquatic Ecosystem in the Upper Great Lakes Region*, Final Project Report, National Science Foundation Grant Number GY-9135 176 pp. (1971).

132. G. Ter Haar, *Air as a Source of Lead in Edible Crops*, Environ. Sci. Tech. 4:226-229 (1970).

133. A. L. Page, T. J. Ganje, and M. S. Joshi, *Lead Quantities in Plants, Soil, and Air Near Some Major Highways in California*, Hilgardia 410:31 (1971).

134. I. R. Campbell and E. G. Mergard, *Biological Aspects of Lead: An Annotated Bibliography*, Two Volumes, U. S. Environmental Protection Agency, Washington, D. C., 935 pp., with updates (1972).

135. A. Cantarow and Trumper, *Lead Poisoning*, The Williams and Wilkins Company, Baltimore, MD., 264 pp. (1944).

136. R. C. Stupka, *Lead Deposition in the Meadow Vole, Microtus pennsylvanicus, as a Functional of Traffic Density*, Masters Thesis, Northern Illinois University, DeKalb, Illinois, 49 pp. (1975).

137. D. Ehorn, *An Analysis of Lead Pollution in an Illinois River System*, Final Project Report, National Science Foundation Grant Number GV-9661, 300 pp. (1972).

138. C. D. Gish and R. Christenson, *Cadmium, Nickel, Lead, and Zinc in Earthworms from Roadside Soil*, Environ. Sci. Tech. 7:1060-1062 (1973).

139. P. N. Booth and G. Knauer, *The Possible Importance of Fecal Material in the Biological Amplification of Trace and Heavy Metals*, Limnol. and Oceanogr. 17:270-275 (1972).

140. J. H. Martin, *The Possible Transport of Trace Metals Via Moulted Copepod Exoskeletons*, Limnol. and Oceanogr. 13:756-761 (1970).

141. W. R. Welch and D. L. Dick, *Lead Concentrations in Tissues of Roadside Mice*, Environ. Pollut. 8:15-21 (1975).

142. G. W. Mierau and B. E. Favara, *Lead Poisoning Roadside Populations of Deer Mice*, Environ. Pollut. 8:55-64 (1975).

143. F. A. Gilbert, *Copper in Nutrition*, Advan. in Agron., 4:147 (1952).

144. F. S. Hammet, *Studies in the Biology of Metals*, Protoplasma 4:183 (1928).

145. T. H. Keller and R. Zuber, *Lead Uptake and Distribution in Young Spruce Plants*, Forstwissenschaftliches Centralblatt 40:20 (1970).

146. R. Allcroft, *Lead Poisoning in Cattle and Sheep*, Vet. Rec. 63:583-590 (1951).

147. H. W. Lakin, "Selenium in Our Environment," in E. L. Kothny, ed., *Trace Elements in the Environment*, Advan. in Chem. Series #123, Amer. Chem. Soc., Washington, D. C., pp. 96-111, (1973).

148. T. J. Ganje, "Selenium," in H. D. Chapman, ed., *Diagnostic Criteria for Plants and Soils*, Div. Agric. Sci., Univ. Calif., pp. 394-404, (1966).

149. W. H. Allaway, E. E. Cary, and C. F. Ehlig, "The Cycling of Low Levels of Selenium in Soils, Plants, and Animals," in O. H. Muth, J. E. Oldfield, and P. H. Weswig, eds., *Symposium: Selenium in Biomedicine*, The Avi Publ. Co. Inc., Westport, Conn. pp. 273-296, (1967).

150. I. Rosenfeld and O. A. Beath, *Selenium, Geobotany, Biochemistry, Toxicity, and Nutrition*, Academic Press, New York, 411 pp. (1964).

151. Q. R. Stahl, *Air Pollution Aspects of Selenium and Its Compounds*, Litton Systems, Inc., Bethesda, MD., 78 pp. (1969).

152. A. M. Hurd-Karrer, *Selenium Absorption by Crop Plants as Related to Their Sulphur Requirement*, J. Agric. Res. 54:601-608 (1937), cited in Ref. 150.

153. H. W. Schoening, *Production of So-Called Alkali Disease in Hogs by Feeding Corn Grown in Affected Areas*, North Am. Veterinarian 17:22-28 (1936), cited in Ref. 150.

154. O. H. Muth, J. E. Oldfield, and P. H. Weswig, eds, *Symposium: Selenium in Biomedicine*, The Avi Publ. Co. Inc., Westport, Conn. (1967).

155. P. Little and M. H. Martin, *A Survey of Zinc, Lead and Cadmium in Soil and Natural Vegetation around a Smelting Complex*, Environ. Pollut. 3:241-254 (1972).

156. T. C. Hutchinson and L. M. Whitby, *Heavy-Metal Pollution in the Sudbury Mining and Smelting Region of Canada, I. Soil and Vegetation Contamination by Nickel, Copper, and other Metals*, Environ. Conserv. 1:123-132 (1974).

157. D. H. Klein and P. Russell, *Heavy Metals: Fallout around a Power Plant*, Environ. Sci. Technol. 7:357-358 (1973).

158. N. C. Brady, *The Nature and Property of Soils*, 8th Edition. Macmillan Publishing Co., Inc., New York. 639 pp. (1974).

159. H. J. M. Bowen, *Trace Elements in Biochemistry*, Academic Press, New York. 241 pp. (1966).

160. H. D. Chapman, ed., *Diagnostic Criteria for Plants and Soils*, Div. Agric. Sci., Univ. of Calif. (1966).

161. M. M. Nienkerk and R. C. Flemal, *Regional Distribution of the Major Dissolved Solids in the Streams of Illinois*, Water Resources Research Report No. 109. 56 pp. (1976).

162. EIFAC (European Inland Fisheries Advisory Committee), *Water Quality Criteria for European Freshwater Fish: Report on Extreme pH Values and Inland Fisheries*, Water Res. 3:593-611 (1969).

163. J. F. Kopp and R. C. Kroner, *Trace Metals in Waters of the United States: A Five Year Summary of Trace Metals in Rivers and Lakes of the United States*, U. S. Dept. of Interior, Federal Water Pollution Control Admin. 250 pp. (1967).

164. *EPA 1973. Water Quality Criteria*, EPA R. 73.033, 1973 (1972).

165. D. R. Jones, J. W. Kiceniuk, and O. S. Bamford, *Evaluation of the Swimming Performance of Several Fish Species from the Mactewzic River*, J. Fish. Res. Bd. Canada 31(10):1641-1647 (1974).

166. K. F. Lagler, J. E. Bardach, and R. R. Miller, *Ichthyology*, John Wiley & Sons, Inc., New York, 545 pp. (1962).

167. J. E. Kerr, *Studies on Fish Preservation at Contra Costa Steam Plant of Pacific Gas and Electric Company*, Calif. Dept. Fish & Game Fish. Bull. 92 (1953).

168. Industrial Bio-Test Laboratories, Inc., *Operational Environmental Monitoring in the Mississippi River near Quad-Cities Station*, February 1974 through July 1974, Semi-Annual Report to Commonwealth Edison Company, Chicago, Illinois (1974).

169. Ibid., August 1974 through January 1975 (1975).

170. G. E. Hutchinson, *A Treatise on Limnology*, Vol. II, Introduction to Lake Biology and the Limnoplankton, John Wiley & Sons, Inc., N. Y., 1115 pp. (1967).

171. D. Hall, *An Experimental Approach to the Dynamics of a Natural Population of Daphnia galeata mendotae*, Ecology, 45:94-112 (1964).

172. J. C. Wright, *The Population Dynamics and Production of Daphnia in Canyon Ferry Reservoir, Montana*, Limnol. & Oceanogr., 10:583-591 (1965).

173. R. Patrick, "Some Effects of Temperature on Freshwater Algae," in, D. A. Kremkel and F. L. Parker (ed.), *Biological Aspects of Thermal Pollution*, Vanderbilt University Press, pp. 161-185 (1969).

174. C. R. Fremling, *Biology of Large Mayfly, Hexagenia bilineata (Say), of the Upper Mississippi River*, Iowa State Univ., Res. Bull. 482 (1960).

175. T. A. Wojtalik and T. F. Waters, *Some Effects of Heated Water on the Drift of Two Species of Stream Invertebrates*, Trans. Amer. Fish. Soc., 99(4):782-788 (1970).

176. D. S. Cherry, K. L. Dickson, and J. Cairns Jr., *Temperatures Selected and Avoided by Fish at Various Acclimation Temperatures*, J. Fish. Res. Bd. Canada, 32(4):485-591 (1975).

177. S. D. Gerking, *Evidence for the Concepts of Home Range and Territory in Stream Fishes*, Ecology 34:347-365 (1953).

178. S. D. Gerking, *The Restricted Movements of Fish Populations*, Biol. Rev. 34:221-242 (1959).

179. L. B. Slobodkin, *Growth and Regulation of Animal Populations*, Holt, Rinehart and Winston, New York, 184 pp. (1961).

180. W. E. Johnson, *On Mechanisms of Self-Regulation of Population Abundance in Oncorhynchus nerka*, Mitt. Internat. Verein, Limnol. 13:66-87 (1965).

181. W. R. Nicholson, *Growth Compensation in Four Year Classes of Striped Bass, Roccus saxatilus, from Albermarle Sound, North Carolina*, Chesap. Sci. 5(3):145-149 (1964).

182. G. Nikolsky, A. Bogdanov, and Y. Lapin, "On Fecundity as a Regulatory Mechanism in Fish Population Dynamics," in, B. B. Parrish (ed.) *Fish Stocks and Recruitment*, Proc. Symp. Aarhus 7-10, July 1970, pp. 174-177.

APPENDIX 9A. BIOTA OF SOUTHERN ILLINOIS
(Appendix to Section 9)

Table 9A-1. Plants of Southern Illinois[a]
(Native species cited in the text of Section 9)

PINACEAE	PINE FAMILY
Pinus echinata	Yellow pine
TAXODIACEAE	CYPRESS FAMILY
Taxodium distichum	Bald cypress
GRAMINEAE	GRASS FAMILY
Poa pratensis	Kentucky bluegrass
Elymus canadensis	Wild rye
Koeleria cristata	June grass
Spartina pectinata	Cord grass
Bouteloua curtipendula	Side-oats grama
Panicum virgatum	Switch grass
Andropogon scoparius	Little bluestem
Andropogon furcatus	Big bluestem
Sorgastrum nutans	Indian grass
SALICACEAE	WILLOW FAMILY
Populus heterophylla	Swamp cottonwood
Populus deltoides	Cottonwood
Salix nigra	Black willow
JUGLANDACEAE	WALNUT FAMILY
Juglans nigra	Black walnut
Carya ovata	Shagbark hickory
Carya texana	Black hickory (Buckley's hickory)
BETULACEAE	BIRCH FAMILY
Betula nigra	River birch
FAGACEAE	BEECH FAMILY
Fagus grandifolia	American beech
Quercus marilandica	Blackjack oak
Quercus falcata	Spanish oak
Quercus rubra	Red oak
Quercus palustris	Pin oak
Quercus velutina	Black oak
Quercus alba	White oak
Quercus stellata	Post oak
ULMACEAE	ELM FAMILY
Celtis occidentalis	Hackberry
MAGNOLIACEAE	MAGNOLIA FAMILY
Lirodendron tulipifera	Tulip tree
PLATANACEAE	PLANE-TREE FAMILY
Platanus occidentalis	Sycamore
ACERACEAE	MAPLE FAMILY
Acer saccharinum	Silver maple
Acer saccharum	Sugar maple
CORNACEAE	DOGWOOD FAMILY
Nyssa aquatica	Tupelo gum

Table 9A-1. Continued

OLEACEAE	OLIVE FAMILY
Fraxinus pennsylvanica	Red ash
Fraxinus tomentosa	Pumpkin ash
Fraxinus lanceolata	Green ash

Nomenclature follows E. N. Jones, *Flora of Illinois*, American Midland Naturalist Monograph No. 5, Univ. of Notre Dame, Notre Dame, Ind. 368 pp. (1950)

Table 9A-2. Mammals of Southern Illinois[a]

Order Rodentia	
Castor canadensis	Beaver
Ondatra z. zibethicus	Muskrat
Marmota m. monax	Woodchuck
Sciurus niger rufiventer	Eastern fox squirrel
Sciurus carolinensis	Eastern gray squirrel
Glaucomys v. volans	Southern flying squirrel
Tamias striatus	Eastern chipmunk
Citellus franklini	Franklin's ground squirrel
Reithrodontomys megalotis dychei	Western harvest mouse
Peromyscus maniculatus bairdi	Deer mouse
Peromyscus nuttali	Golden mouse
Peromyscus l. leucopus	White-footed mouse
Peromyscus gossypinus megacephalus	Cotton mouse
Oryzomys p. palustris	Rice rat
Neotoma floridana illinoensis[b]	Eastern woodrat
Synaptomys cooperi gossii	Southern bog lemming
Microtus o. ochrogaster	Prairie vole
Microtus p. pennsylvanicus	Meadow vole
Pitymys pinetorum auricularis	Pine vole
Zapus hudsonius intermedius	Meadow jumping mouse
Rattus norvegicus	Norway rat
Mus musculus	House mouse
Order Lagomorpha	
Sylvilagus floridanus	Eastern cottontail
Sylvilagus a. aquaticus	Swamp rabbit
Order Carnivora	
Lynx r. rufus[b]	Bobcat
Procyon lotor	Raccoon
Lutra canadensis	River otter
Mustela frenata noveboracensis	Long-tailed weasel
Mustela vison	Mink
Mephitis mephitis	Striped skunk
Vulpes vulpes	Red fox
Urocyon c. cinereoargenteus	Gray fox
Canis latrans	Coyote
Order Chiroptera	
Corynorhinus rafinesquii	Southeastern big-eared bat
Eptesicus fuscus	Big brown bat
Myotis austroriparius	Southeastern bat
Myotis lucifugus	Little brown bat
Myotis griescens	Gray bat
Myotis keenii	Keen's bat
Myotis sodalis[b,c]	Indiana bat
Lasiurus borealis	Red bat

Table 9A-2. Continued

Order Chiroptera (continued)	
Lasiurus cinereus	Hoary bat
Nycticeius humeralis	Evening bat
Pipistrellus s. subflavus	Eastern pipistrel
Lasionycteris noctivagans	Silver-haired bat
Order Insectivora	
Blarina brevicanda carolinensis	Short-tailed shrew
Cryptotis parva harlani	Least shrew
Sorex longirostris	Southeastern shrew
Scalopus aquaticus machrinus	Eastern mole
Order Marsupialia	
Didelphis marsupialis	Opossum
Order Artiodactyla	
Odocoileus virginianus	White-tailed deer

[a]Includes Illinois mammals whose geographic range encompasses a portion or all of the southern third of Illinois.

[b]On Illinois Endangered Species List.

[c]On U. S. Endangered Species List.

Table 9A-3. Birds of Southern Illinois[a]

		Residency Status[b]
Order Podicipediformes		
Podilymbus podiceps	Pied-billed grebe	S
Podiceps auritus	Horned grebe	M
Podiceps grisegena	Red-necked grebe	M
Podiceps dominicus	Least grebe	S
Order Gaviiformes		
Gavia immer	Common loon	M
Order Pelicaniformes		
Phalacrocorax auritus[c]	Double-crested cormorant	M
Order Anseriformes		
Branta canadensis	Canada goose	W,M
Chen hyperborea	Snow goose	M
Anas platyrhynchos	Mallard	P
Anas rubripes	Black duck	P
Anas acuta	Pintail	M,W
Anas strepera	Gadwall	M,W
Mareca americana	American widgeon	M,W
Spatula clypeata	Shoveler	M
Anas discors	Blue-winged teal	P,M
Anas carolinensis	Green-winged teal	M,W
Aix sponsa	Wood duck	S
Aythya americana	Redhead	M,W
Aythya valisneria	Canvasback	M,W
Aythya collaris	Ring-necked duck	M
Aythya marila	Greater scaup	M
Aythya affinis	Lesser scaup	M
Bucephala islandica	Common goldeneye	W
Bucephala albeola	Bufflehead	W
Oxyura jamaicensis	Ruddy duck	M
Mergus merganser	Common merganser	W
Mergus serrator	Red-breasted merganser	M
Lophodytes cucullatus	Hooded merganser	M
Order Falconiformes		
Cathartes aura	Turkey vulture	S,W
Coragyps atratus	Black vulture	S
Accipiter cooperii[c]	Cooper's hawk	P
Accipiter striatus	Sharp-shinned hawk	P
Circus cyaneus	Marsh hawk	P
Buteo lagopus	Rough-legged hawk	W
Buteo jamaicensis	Red-tailed hawk	P
Buteo lineatus[c]	Red-shouldered hawk	P
Buteo platypterus	Broad-winged hawk	S
Aquila chrysaetos	Golden eagle	W
Haliaeetus leucocephalus	Bald eagle	W

Table 9A-3. Continued

		Residency Status[b]
Order Falconiformes (cont.)		
Pandion haliaetus	Osprey	M
Falco peregrinus[c;d]	Peregrine falcon	M
Falco columbarius	Pigeon hawk	M
Falco sparverius	Sparrow hawk	P
Order Galliformes		
Maleagris gallopavo	Turkey	P
Tympanuchus cupido[c]	Greater prairie chicken	P
Colinus virginianus	Bobwhite	P
Order Ciconiiformes		
Casmerodius albus	Common egret	S
Ardea herodias	Great blue heron	P,S
Butorides virescens	Green heron	S
Nycticorax nycticorax	Black-crowned night heron	P,S
Botaurus lentiginosus	American bittern	S
Ixobrychus exilis	Least bittern	S
Grus canadensis	Sandhill crane	M
Rallus limicola	Virginia rail	S
Porzana carolina	Sora	S
Coturnicops noveboracensis[c]	Yellow rail	M
Laterallus jamaicensis[c]	Black rail	S
Rallus elegans	King rail	S
Gallinula chloropus	Common gallinule	S
Fulica americanus	American coot	P,S
Order Charadriiformes		
Pluvialis dominica	American golden plover	M
Squatarola squatarola	Black-bellied plover	M
Charadrius melodus	Piping plover	M
Charadrius semipalmatus	Semipalmated plover	M
Charadrius vociferus	Killdeer	P
Bartramia longicauda[c]	Upland plover	S
Tringa solitaria	Solitary sandpiper	M
Actitis macularia	Spotted sandpiper	S
Totanus melanoleucus	Greater yellowlegs	M
Totanus flavipes	Lesser yellowlegs	M
Micropalama himantopus	Stilt sandpiper	M
Limnodromus griseus	Short-billed dowitcher	M
Limnodromus scolopaceus	Long-billed dowitcher	M
Arenaria interpres	Ruddy turnstone	M
Erolia melanotus	Pectoral sandpiper	M
Erolia alpina	Dunlin	M
Crocethia alba	Sanderling	M
Erolia fuscicollis	White-rumped sandpiper	M
Erolia minutilla	Least sandpiper	M
Ereunetes pusillus	Semipalmated sandpiper	M

Table 9A-3. Continued

		Residency Status[b]
Order Passeriformes (cont.)		
Myiarchus crinitus	Great crested flycatcher	S
Sayornis phoebe	Eastern phoebe	S
Empidonax flaviventris	Yellow-bellied flycatcher	M
Ampidonax virescens	Acadian flycatcher	S
Empidonax traillii	Traill's flycatcher	S
Empidonax minimus	Least flycatcher	M
Contopus virens	Eastern wood pewee	S
Nuttallornis borealis	Olive-sided flycatcher	M
Eremophila alpestris	Horned lark	P
Hirundo rustica	Barn swallow	S
Petrochelidon pyrrhonota	Cliff swallow	S
Iridoprocne bicolor	Tree swallow	M
Riparia riparia	Bank swallow	S
Stelgidopteryx ruficollis	Rough-winged swallow	S
Progne subis	Purple martin	S
Cyanocitta cristata	Blue jay	P
Corvus brachyrhynchos	Common crow	P
Parus atricapillus	Black-capped chickadee	P
Parus carolinensis	Carolina chickadee	P
Parus bicolor	Tufted titmouse	P
Sitta carolinensis	White-breasted nuthatch	P
Sitta canadensis	Red-breasted nuthatch	W
Certhia familiaris	Brown creeper	W
Troglodytes aedon	House wren	S
Troglodytes troglodytes	Winter wren	M,W
Thryomanes bewickii	Bewick's wren	P,S
Thryothorus ludovicianus	Carolina wren	P
Telmatodytes palustris	Long-billed marsh wren	S
Cistothorus platensis	Short-billed marsh wren	
Mimus polyglottus	Mockingbird	P
Dumetella carolinensis	Catbird	S
Toxostoma rufum	Brown thrasher	S
Turdus migratorius	Robin	P
Hylocichla mustelina	Wood thrush	S
Hylocichla guttata	Hermit thrush	M,W
Hylocichla ustulata	Swainson's thrush	M
Hylocichla minima	Gray-cheeked thrush	M
Hylocichla fuscescens	Veery	M
Sialia sialis	Eastern bluebird	P
Polioptila caerulea	Blue-gray gnatcatcher	S
Regulus satrapa	Golden-crowned kinglet	W
Regulus calendula	Ruby-crowned kinglet	M
Anthus spinoletta	Water pipit	M
Bombycilla cedrorum	Cedar waxwing	W
Lanius excubitor	Northern shrike	W
Lanius ludovicianus	Loggerhead shrike	P
Sturnus vulgaris	Starling	P

Table 9A-3. Continued

		Residency Status[b]
Order Charadriiformes (cont.)		
Philohela minor	American woodcock	S
Capella gallinago	Common snipe	W
Larus argentatus	Herring gull	M
Larus delawarensis	Ring-billed gull	M
Larus philadelphia	Bonaparte's gull	M
Sterna hirundo	Common tern	M
Hydroprogne caspia	Caspian tern	M
Chlidonias niger	Black tern	M
Order Columbiformes		
Columba livia	Rockdove	P
Zenaidura macroura	Mourning dove	P
Order Cuculiformes		
Coccyzus americanus	Yellow-billed cuckoo	S
Coccyzus erythropthalmus	Black-billed cuckoo	S
Order Strigiformes		
Otus asio	Screech owl	P
Bubo virginianus	Great horned owl	P
Asio otus	Long-eared owl	P
Asio flammeus	Short-eared owl	P,W
Tyto alba	Barn owl	P
Strix varia	Barred owl	P
Aegolius acadicus	Saw-whet owl	P,W
Caprimulgus carolinensis	Chuck-will's widow	S
Caprimulgus vociferus	Whip-poor-will	S
Chordeiles minor	Common nighthawk	S
Order Apodiformes		
Chaetura pelagica	Chimney swift	S
Archilochus colubris	Ruby-throated hummingbird	S
Order Coraciformes		
Megaceryle alcyon	Belted kingfisher	P
Order Piciformes		
Colaptes auratus	Flicker	P
Dryocopus pileatus	Pileated woodpecker	P
Centurus carolinus	Red-bellied woodpecker	P
Melanerpes erythrocephalus	Red-headed woodpecker	P
Sphyrapicus varius	Yellow-bellied sapsucker	W
Dendrocopos villosus	Hairy woodpecker	P
Dendrocopos pubescens	Downy woodpecker	P
:der Passeriformes		
Tyrannus tyrannus	Eastern kingbird	S

Table 9A-3. Continued

		Residency Status[b]
Order Passeriformes (cont.)		
Vireo solitarius	Solitary vireo	M
Vireo griseus	White-eyed vireo	S
Vireo bellii	Bell's vireo	S
Vireo flavifrons	Yellow-throated vireo	S
Vireo olivaceous	Red-eyed vireo	S
Vireo philadelphicus	Philadelphia vireo	M
Vireo gilvus	Warbling vireo	S
Mniotilta varia	Black-and-white	S
Protonotaria citrea	Prothonotary warbler	S
Helmitheros vermivorous	Worm-eating warbler	S
Vermivora chrysoptera	Golden-winged warbler	M
Vermivora pinus	Blue-winged warbler	S
Vermivora peregrina	Tennessee warbler	M
Vermivora celata	Orange-crowned warbler	M
Vermivora ruficapilla	Nashville warbler	M
Parula americana	Parula warbler	S
Dendroica petechia	Yellow warbler	S
Dendroica magnolia	Magnolia warbler	M
Dendroica tigrina	Cape may warbler	M
Dendroica coronata	Wyrtle warbler	M
Dendroica virens	Black-throated green warbler	M
Dendroica caerulescens	Black-throated blue warbler	M
Dendroica cerulea	Cerulean warbler	S
Dendroica dominica	Yellow-throated warbler	S
Dendroica fusca	Blackburnian warbler	M
Dendroica pennsylvanica	Chestnut-sided warbler	M
Dendroica castanea	Bay-breasted warbler	M
Dendroica striata	Blackpoll warbler	M
Dendroica pinus	Pine warbler	S
Dendroica discolor	Prairie warbler	S
Dendroica palmarum	Palm warbler	M
Seiurus aurocapillus	Overbird	S
Seiurus noveboracensis	Northern waterthrush	M
Seiurus motacilla	Louisiana waterthrush	S
Geothlypis trichas	Yellowthroat	S
Icteria virens	Yellow-breasted chat	S
Oporonis formosus	Kentucky warbler	S
Oporornis philadelphia	Mourning warbler	M
Oporornis agilis	Connecticut warbler	M
Wilsonia citrina	Hooded warbler	S
Wilsonia pusilla	Wilson's warbler	M
Wilsonia canadensis	Canada warbler	M
Setophaga ruticilla	American redstart	S
Passer domesticus	House sparrow	P
Passer montanus	European tree sparrow	P
Polichonyx oryzivorous	Bobolink	M
Sturnella magna	Eastern meadowlark	P

Table 9A-3. Continued

		Residency Status[b]
Order Passeriformes (cont.)		
Sturnella neglecta	Western meadowlark	S
Agelaius phoeniceus	Red-winged blackbird	P,S
Euphagus carolinus	Rusty blackbird	M
Euphagus cyanocephalus	Brewer's blackbird	M
Quiscalus quiscula	Common grackle	S,P
Molothrus ater	Brown-headed cowbird	S
Icterus spurius	Orchard oriole	S
Icterus galbula	Baltimore oriole	S
Piranga olivacea	Scarlet tanager	S
Piranga rubra	Summer tanager	S
Richmondera cardinalis	Cardinal	P
Pheucticus ludovicianus	Rose-breasted grosbeak	S
Hesperiphona vespertina	Evening grosbeak	W
Passerina cyanea	Indigo bunting	S
Carpodacus purpureus	Purple finch	S
Spinus pinus	Pine siskin	W
Spinus tristis	American goldfinch	P
Spiza americana	Dickcissel	S
Pipilo erythrophthalmus	Red-eyed towhee	P
Passerculus sandwichensis	Savannah sparrow	M
Ammodramus savannarum	Grasshopper sparrow	S
Passerherbulus henslowii[c]	Henslow's sparrow	M,S
Passerherbulus caudacutus	LeConte's sparrow	M
Ammospiza caudacuta	Sharp-tailed sparrow	M
Pooecetes gramineus	Vesper sparrow	S
Chondestes grammacus	Lark sparrow	S
Junco hyemalis	Dark-eyed junco	W
Aimophila aestivalis	Bachman's sparrow	S
Spizella arborea	Tree sparrow	W
Spizella passerina	Chipping sparrow	S
Spizella pusilla	Field sparrow	S,P
Zonotrichia leucophrys	White-crowned sparrow	P,M
Zonotrichia albicollis	White-throated sparrow	W,M
Passerella iliaca	Fox sparrow	W
Melospiza lincolnii	Lincoln's sparrow	M
Melospiza georgiana	Swamp sparrow	W
Melospiza melodia	Song sparrow	P
Calcarius lapponicus	Lapland longspur	W

[a]Species list from C. S. Robbins, B. Brunn, and H. S. Zim, *A Guide to Field Identification, Birds of North America*. Golden Press, New York, 340 pp. (1966).

[b]Residency status categories: P = permanent resident, W = winter resident, S = summer resident, M = migrant.

[c]On Illinois Endangered Species List.

[d]On U. S. Endangered Species List.

Table 9A-4. Amphibians and Reptiles of Southern Illinois[a]

Scientific Name	Common Name
Cryptobranchus a. alleganiensis[b]	Hellbender
Ambystoma maculatum	Spotted salamander
Ambystoma opacum	Marbled salamander
Ambystoma talpoideum	Mole salamander
Ambystoma texanum	Small-mouthed salamander
Ambystoma t. tigrinum	Eastern tiger salamander
Notophthalmus viridescens louisianensis	Central newt
Eurycea bislineata rivicola	Midwest two-lined salamander
Eurycea l. longicauda	Long-tailed salamander
Eurycea longicauda melanopleura	Dark-sided salamander
Eurycea lucifuga	Cave salamander
Plethodon c. cinereus	Red-backed salamander
Plethodon dorsalis	Zigzag salamander
Plethodon g. glutinosus	Slimy salamander
Desmognathus fuscus conanti[b]	Dusky salamander
Necturus m. maculosus	Mudpuppy
Siren itermedia nettingi	Western lesser siren
Scaphiopus holbrooki	Eastern spadefoot toad
Bufo a. americanus	American toad
Bufo americanus charlesmithi	Dwarf american toad
Bufo woodhousei fowleri	Fowler's toad
Acris crepitans blanchardi	Blanchard's cricket frog
Pseudacris triseriata feriarum	Upland chorus frog
Pseudacris t. triseriata	Western chorus frog
Hyla g. avivoca	Western bird-voiced treefrog
Hyla cinerea	Green treefrog
Hyla c. crucifer	Northern spring peeper
Hyla chrysoscelis	Southern gray treefrog
Hyla v. versicolor	Eastern gray treefrog
Rana catesbeiana	Bullfrog
Rana clamitans melanota	Green frog
Rana palustris	Pickerel frog
Rana pipiens sphenocephala	Southern leopard frog
Rana sylvatica	Wood frog
Gastrophryne c. carolinensis	Eastern narrow-mouthed toad
Chelydra s. serpentina	Common snapping turtle
Macroclemmys temmincki[b]	Alligator snapping turtle
Sternothaerus odoratus	Stinkpot
Kinosternon s. subrubrum	Mud turtle
Terrapene c. carolina	Eastern box turtle
Terrapene o. ornata	Ornate box turtle
Chrysemys picta marginata	Midland painted turtle
Chrysemys picta belli	Western painted turtle
Pseudemys scripta elegans	Red-eared turtle
Pseudemys concinna x *floridana*	Hieroglyphic turtle

Table 9A-4. Continued

Scientific Name	Common Name
Graptemys pseudogeographica	False map turtle
Graptemys geographica	Map turtle
Trionyx m. muticus	Smooth softshell
Trionyx s. spinifer	Eastern spiny softshell
Sceloporus undulatus hyacinthinus	Northern fence lizard
Ophisaurus a. attenuatus	Western slender glass lizard
Cnemidophorus s. sexlineatus	Six-lined racerunner
Leiolopisma laterale	Ground skink
Eumeces fasciatus	Five-lined skink
Eumeces laticeps	Broad-headed skink
Carphophis amoenus helenae	Midwest worm snake
Carphophis amoenus vermis	Western worm snake
Faranica abacura reinwardti	Western mud snake
Diadophis punctatus edwardsi	Northern ringneck snake
Diadophis punctatus arnyi	Prairie ringneck snake
Diadophis punctatus sticfogenys	Mississippi ringneck snake
Heterodon platyrhinos	Eastern hognose snake
Opheodrys aestivus	Rough green snake
Opheodrys vernalis blanchardi	Western smooth green snake
Coluber constrictor foxi	Blue racer
Coluber c. constrictor	Northern black racer
Masticophis f. flagellum[b]	Eastern coachwhip
Elaphe guttata emoryi	Great plains rat snake
Elaphe o. obsoleta	Black rat snake
Elaphe obsoleta spiloides	Gray rat snake
Elaphe v. vulpina	Western fox snake
Lampropeltis c. calligaster	Prairie kingsnake
Lampropeltis getulus holbrooki	Speckled kingsnake
Lampropeltis getulus niger	Black kingsnake
Lamporopeltis triangulum syspita	Red milk snake
Lampropeltis t. triangutum	Eastern milk snake
Cemophora doliata[b]	Scarlet snake
Tantilla gracilis hallowelli	Northern flat-headed snake
Thamnophis p. proximus	Western ribbon snake
Thamnophis sauritus septentrionalis	Northern ribbon snake
Thamnophis r. radix	Eastern plains garter snake
Thamnophis s. sirtalis	Eastern garter snake
Tropidoclonion l. lineatum[b]	Northern lined snake
Virginia valeriae elegans	Western earth snake
Storeria dekayi wrightorum	Midland brown snake
Storeria o. occipitomaculata	Northern red-bellied snake
Natrix c. cyclopion	Green water snake
Natrix erythrogaster flavigaster	Yellow-bellied water snake
Natrix erythrogaster neglecta	Northern copperbelly
Natrix grahami	Graham's water snake

Table 9A-4. Continued

Scientific Name	Common Name
Natrix r. rhombifera	Diamond-backed water snake
Natrix s. sipedon	Northern water snake
Natrix sipedon pleuralis	Midland water snake
Agkistrodon piscivorous leucostomus	Western cottonmouth
Agkistrodon contortrix mokasen	Northern copperhead
Agkistrodon c. contortrix	Southern copperhead
Sistrurus c. catenatus	Eastern massasauga
Crotalus h. horridus[b]	Timber rattlesnake
Crotalus horridus atricaudatus	Canebrake rattlesnake

[a]Species list compiled from P. W. Smith, *The Amphibians and Reptiles of Illinois*, Ill. Nat. Hist. Surv. Bull., Vol. 28, Art. 1, Urbana, 298 pp. (1961); and R. Conant, *A Field Guide to Reptiles and Amphibians of Eastern and Central North America*, Houghton Mifflin Co., Boston, 429 pp. (1975).

[b]Listed as endangered in Illinois in K. Ackerman, *Rare and Endangered Vertebrates of Illinois*, Bur. Environ. Sci., Ill. Dep. Transportation, 50 pp. (1975).

Table 9A-5. Southern Illinois Wildlife Harvest Data for 1975-1976[a]

County	No. Hunters	No. Hunts	No. Killed	No. Hunters	No. Hunts	No. Killed
	Mourning Dove			Pheasant		
Alexander	6	43	118	1	28	0
Bond	5	37	248	3	8	4
Champaign	10	35	96	76	305	208
Christian	10	46	81	33	188	104
Clay	6	30	231	1	2	1
Clinton	12	72	378	38	72	98
Coles	11	62	168	23	142	72
Cumberland	3	19	134	4	6	6
Douglas	5	16	38	31	125	76
Edwards	0	0	0	0	0	0
Effingham	14	67	337	3	10	6
Fayette	11	65	128	2	2	2
Franklin	7	52	333	15	41	74
Gallatin	5	29	110	0	0	0
Hamilton	5	35	136	0	0	0
Hardin	1	2	20	0	0	0
Jackson	11	53	296	0	0	0
Jasper	14	65	272	2	7	1
Jefferson	7	54	286	2	3	4
Jersey	3	23	14	2	3	5
Johnson	2	6	20	2	4	3
Lawrence	5	52	278	0	0	0
Macon	12	69	101	43	249	63
Macoupin	16	118	636	1	1	0
Madison	27	158	700	3	5	2
Marion	17	86	243	0	0	0
Massac	14	30	114	0	0	0
Monroe	7	30	120	1	2	3
Montgomery	10	41	159	8	34	22
Moultrie	8	26	98	15	117	55
Perry	11	85	187	0	0	0
Piatt	9	37	76	21	107	64
Pope	3	15	50	0	0	0
Pulaski	1	15	100	0	0	0
Randolph	13	78	251	3	5	9
Richland	7	33	107	20	49	89
St. Clair	27	202	674	1	3	0
Saline	8	53	265	0	0	0
Shelby	9	22	78	25	119	75
Union	5	20	40	1	1	0
Wabash	1	20	15	0	0	0
Wayne	8	53	236	0	0	0
Washington	17	164	952	0	0	0
White	9	43	190	0	0	0
illiamson	14	134	325	0	0	0

Table 9A-5. Continued

County	No. Hunters	No. Hunts	No. Killed	No. Hunters	No. Hunts	No. Killed
	Quail			Woodcock		
Alexander	4	10	41	1	1	1
Bond	12	51	127	0	0	0
Champaign	2	5	0	2	5	6
Christian	26	145	95	3	6	6
Clay	11	65	204	3	14	34
Clinton	15	94	286	1	20	17
Coles	16	87	69	3	12	4
Cumberland	5	55	50	0	0	0
Douglas	3	3	2	1	3	2
Edwards	5	70	259	0	0	0
Effingham	18	97	113	1	1	1
Fayette	17	124	100	3	24	1
Franklin	24	235	494	2	31	2
Gallatin	5	31	56	0	0	0
Hamilton	10	36	106	1	1	2
Hardin	7	38	105	0	0	0
Jackson	12	57	81	0	0	0
Jasper	14	63	226	2	5	3
Jefferson	8	76	177	2	15	9
Jersey	8	31	67	0	0	0
Johnson	5	48	108	1	6	2
Lawrence	8	83	254	0	0	0
Macon	22	161	25	0	0	0
Macoupin	34	198	466	1	5	6
Madison	35	194	274	2	9	6
Marion	21	223	464	0	0	0
Massac	7	31	74	0	0	0
Monroe	4	37	39	3	20	13
Montgomery	11	41	87	0	0	0
Moultrie	8	70	14	2	16	7
Perry	14	116	397	1	2	4
Piatt	1	4	0	3	8	6
Pope	9	81	390	1	1	2
Pulaski	1	1	0	0	0	0
Randolph	19	125	273	3	21	23
Richland	15	116	262	2	16	3
St. Clair	20	104	161	4	35	22
Saline	8	41	122	0	0	0
Shelby	24	158	254	2	3	5
Union	9	43	58	1	1	3
Wabash	2	48	174	0	0	0
Wayne	10	51	70	0	0	0
Washington	22	160	641	4	24	9
White	12	129	288	1	39	26
Williamson	20	183	230	1	1	1

Table 9A-5. Continued

County	No. Hunters	No. Hunts	No. Killed	No. Hunters	No. Hunts	No. Killed
	Ducks			Geese		
Alexander	6	41	65	44	109	116
Bond	4	23	22	0	0	0
Champaign	0	0	0	0	0	0
Christian	9	47	47	4	18	14
Clay	1	4	6	0	0	0
Clinton	18	142	174	4	22	27
Coles	2	3	2	0	0	0
Cumberland	0	0	0	0	0	0
Douglas	0	0	0	0	0	0
Edwards	0	0	0	0	0	0
Effingham	0	0	0	0	0	0
Fayette	4	23	46	1	2	0
Franklin	3	28	43	3	50	32
Gallatin	1	2	0	1	2	0
Hamilton	0	0	0	0	0	0
Hardin	2	14	24	0	0	0
Jackson	12	102	147	6	39	9
Jasper	0	0	0	0	0	0
Jefferson	8	65	101	3	39	4
Jersey	12	302	401	5	182	72
Johnson	2	16	8	1	6	2
Lawrence	1	5	3	0	0	0
Macon	3	42	45	0	0	0
Macoupin	3	35	13	2	3	4
Madison	10	158	288	4	15	16
Marion	2	27	21	2	26	4
Massac	1	30	38	0	0	0
Monroe	7	38	50	0	0	0
Montgomery	3	16	8	2	7	3
Moultrie	3	5	6	1	1	0
Perry	3	22	27	2	2	0
Piatt	0	0	0	0	0	0
Pope	0	0	0	0	0	0
Pulaski	0	0	0	0	0	0
Randolph	5	38	44	2	6	0
Richland	1	6	15	1	1	1
St. Clair	16	202	146	4	65	7
Saline	2	22	23	0	0	0
Shelby	7	59	232	0	0	0
Union	13	55	48	49	121	151
Wabash	0	0	0	0	0	0
Wayne	0	0	0	0	0	0
Washington	0	0	0	0	0	0
White	1	10	8	0	0	0
illiamson	10	67	56	29	183	79

Table 9A-5. Continued

County	No. Hunters	No. Hunts	No. Killed	No. Hunters	No. Hunts	No. Killed
	Fox Squirrel			Gray Squirrel		
Alexander	9	53	39	8	48	55
Bond	12	88	106	11	83	83
Champaign	9	38	38	6	28	0
Christian	17	124	135	11	76	27
Clay	16	59	119	14	44	33
Clinton	20	189	138	19	179	219
Coles	14	67	65	11	59	40
Cumberland	3	12	23	2	7	9
Douglas	6	26	18	5	20	0
Edwards	5	26	42	6	30	55
Effingham	21	186	184	19	164	83
Fayette	24	207	210	23	211	210
Franklin	18	128	130	18	125	306
Gallatin	4	42	24	3	32	15
Hamilton	4	28	36	6	59	69
Hardin	1	5	3	4	13	30
Jackson	19	153	142	18	173	242
Jasper	16	148	149	16	156	142
Jefferson	12	100	96	11	98	120
Jersey	25	169	262	24	180	146
Johnson	15	87	64	13	74	125
Lawrence	8	47	45	6	41	30
Macon	16	160	200	10	69	20
Macoupin	16	118	636	31	255	582
Madison	27	158	700	41	254	399
Marion	17	86	243	20	152	225
Massac	11	88	72	9	87	40
Monroe	17	126	99	16	121	208
Montgomery	7	78	124	7	82	92
Moultrie	3	9	15	2	4	4
Perry	19	124	124	16	101	68
Piatt	6	44	55	3	17	1
Pope	9	43	36	14	82	221
Pulaski	6	32	46	6	32	51
Randolph	32	230	298	30	231	206
Richland	16	121	157	16	121	153
St. Clair	39	363	372	31	261	335
Saline	13	179	182	9	152	131
Shelby	27	210	238	28	206	141
Union	12	70	62	12	67	101
Wabash	4	41	59	3	41	12
Wayne	19	103	120	17	98	99
Washington	15	114	161	16	125	118
White	13	81	124	13	81	83
Williamson	14	207	142	14	194	127

Table 9A-5. Continued

County	No. Hunters	No. Hunts	No. Killed	No. Hunters	No. Hunts	No. Killed
	Eastern Cottontail			Raccoon		
Alexander	9	75	88	1	8	0
Bond	15	98	164	0	0	0
Champaign	30	157	86	2	13	3
Christian	29	211	193	2	11	13
Clay	17	102	215	2	2	2
Clinton	25	143	213	4	44	21
Coles	24	128	144	5	49	31
Cumberland	4	22	13	0	0	0
Douglas	16	95	82	4	30	19
Edwards	8	41	58	8	56	32
Effingham	23	160	220	2	37	51
Fayette	27	189	230	3	22	9
Franklin	27	157	273	5	18	11
Gallatin	7	64	188	0	0	0
Hamilton	9	74	181	2	12	9
Hardin	6	19	28	0	0	0
Jackson	12	105	222	4	21	33
Jasper	13	71	133	4	66	40
Jefferson	12	61	134	3	59	34
Jersey	13	65	110	1	3	1
Johnson	10	35	37	2	6	3
Lawrence	10	74	154	1	1	1
Macon	34	207	74	0	0	0
Macoupin	41	218	411	5	45	64
Madison	81	472	687	5	34	51
Marion	28	205	319	3	53	40
Massac	8	32	44	1	8	7
Monroe	12	102	98	4	19	12
Montgomery	19	122	159	0	0	0
Moultrie	9	73	54	1	15	3
Perry	24	207	422	2	15	5
Piatt	17	69	52	0	0	0
Pope	3	6	5	0	0	0
Pulaski	4	50	77	1	20	35
Randolph	32	238	379	0	0	0
Richland	19	107	157	2	14	7
St. Clair	58	284	459	6	71	71
Saline	16	152	202	2	24	29
Shelby	28	169	214	5	98	114
Union	12	66	105	3	6	10
Wabash	5	76	49	0	0	0
Wayne	14	83	146	0	0	0
Washington	29	112	204	2	50	39
White	18	113	167	5	81	67
illiamson	22	187	262	0	0	0

Table 9A-5. Continued

County	No. Hunters	No. Hunts	No. Killed
	Fox		
Alexander	1	1	1
Bond	1	1	1
Champaign	2	6	1
Christian	0	0	0
Clay	0	0	0
Clinton	1	1	1
Coles	2	5	2
Cumberland	0	0	0
Douglas	3	11	2
Edwards	0	0	0
Effingham	1	1	1
Fayette	0	0	0
Franklin	1	2	0
Gallatin	0	0	0
Hamilton	0	0	0
Hardin	0	0	0
Jackson	0	0	0
Jasper	2	61	7
Jefferson	1	4	1
Jersey	1	1	1
Johnson	2	6	1
Lawrence	0	0	0
Macon	2	8	1
Macoupin	2	7	2
Madison	3	7	3
Marion	1	1	0
Massac	0	0	0
Monroe	0	0	0
Montgomery	1	25	6
Moultrie	1	1	1
Perry	2	6	3
Piatt	0	0	0
Pope	1	6	1
Pulaski	0	0	0
Randolph	3	14	5
Richland	1	5	0
St. Clair	5	23	11
Saline	1	8	5
Shelby	3	10	0
Union	0	0	0
Wabash	0	0	0
Wayne	0	0	0
Washington	0	0	0
White	0	0	0
Williamson	1	1	1

[a]Data were taken from an Illinois Department of Conservation survey of approximately 361,800 Illinois hunters. The data presented here represent a response of approximately one percent. Information was provided by Mr. Jack Ellis, Staff Biologist, of the Illinois Department of Conservation.

APPENDIX 10-A. LAWS AND REGULATIONS
(Appendix to Section 10)

WATER POLLUTION REGULATIONS AFFECTING MINING AND THE PREPARATION OF COAL

Federal Regulations

The objective of the 1972 Federal Water Pollution Control Act Amendments (P.L. 92-500) is to achieve or maintain specified ambient water quality standards. The two approaches used to meet this goal concern control of point and nonpoint sources of pollution discharge. National Pollution Discharge Elimination System (NPDES) permits are being issued by either federal or delegated state authorities that specify effluent limits and compliance schedules for discharging from point sources; i.e., coal mines and preparation plants. Wastes from abandoned mines and other nonpoint sources are controlled by Section 208 in P.L. 92-500, which specifies that federal funding be provided to local areas for planning and implementing the control of water pollution. Federal authority provides strong enforcement for these regulations.

The basis for permit development involves effluent limits, New Source Performance Standards (NSPS), and water quality standards. Current effluent limits for permit preparation are listed in the proposed Final Effluent Guidelines and the NSPS were presented in the Federal Register by EPA in May 1976 (Tables 10A-1 and 10A-2). A proposed addition to these regulations would include promulgation of effluent limitations on specific toxic substances. However, these have not been established to date. Ambient water quality standards are currently being revised that will provide protection for aquatic life and primary contact recreation (swimming).

Table 10A-1 Proposed Final Effluent Guidelines, provided by EPA in the May 13, 1976, Federal Register notice for coal mines and preparation plant effluents.[a]

Parameter	Coal Prep. Plant	Coal Prep. Ancillary Areas		Acid Mines		Alkaline Mines	
		Daily Max.	30-day Avg.	Daily Max.	30-day Avg.	Daily Max.	30-day Avg.
Total iron (mg/l)	No discharge of pollutants	3.5	3.0	3.5	3.0	3.5	3.0
Dissolved iron (mg/l)				0.6	0.3		
Total manganese (mg/l)		4.0	2.0	4.0	2.0		
Suspended solids (mg/l)		40	20	40	20	40	20
pH (standard units)	Within the range 6.0-9.0						

[a]U. S. Dept. of the Interior, *Laws and Regulations Affecting Coal*, 1976.

Table 10A-2 New Source Performance Standards, provided by EPA in the May 13, 1976, Fedral Register notice, for coal preparation and ancillary areas.[a]

Parameter	Coal Prep. Plant		Coal Prep. Ancillary Areas	
	Daily Max.	30-day Avg.	Daily Max.	30-day Avg.
Total iron (mg/l)	No Discharge of pollutants		3.5	3.0
Total manganese (mg/l)			4.0	2.0
Suspended solids (mg/l)			70	35
pH (standard units)	Within the range 6.0-9.0			

[a]U. S. Dept. of the Interior, *Laws and Regulations Affecting Coal*, 1976.

State Regulations

P.L. 92-500 allows delegating the permit-issuance authority to states that demonstrate the capacity to administer the provisions of the Act. Illinois law contains the provisions necessary to receive this delegated authority. However, the state has not been delegated such authority at present, pending resolution of the Memorandum of Agreement with EPA Region V.

The provisions of the Illinois Environmental Protection Act concerning effluent discharges from coal mines and preparation plants are contained in Title 3 of the Act. They require an NPDES permit, establish effluent and water quality standards, and specify mine operating regulations.

The effluent standards are contained in Chapter 4 of the Act and are shown in Table 10A-3. In addition to these standards, mine drainage may not contain settleable solids, floating debris, visible oil, grease, scum, or sludge solids, and color and odor must not be noticeable.

The water quality standards as shown in Table 10A-4 are subject to the following provisions. The effluent mixing zone may not exceed (1) the area of a circle with a 600-ft radius ($\sim$26 acres) and (2) 25% of the discharge of the cross-sectional area of the stream (except where the dilution ratio is $\leq$ 3:1). These provisions apply only when the discharge of the receiving body is greater than the 7-day, 10-year low flow.

Regulations for mine operation are summarized below. Spoil deposition and mine operation shall not interfere with state waters. Drainage ditches are required and runoff shall be impounded. Drill holes and all openings shall be sealed when no longer in use. Refuse piles shall be constructed to prevent runoff and pollution of state waters. Acid refuse shall be spread, compacted, and covered at least every 30 days. Thickness of the refuse layers is to be specified in the permit. Refuse shall be graded and vegetated within one year after use. Compliance reports must be issued to the state. Abandonment of mines shall be done by permit only.

The state and federal laws provide considerable protection of the aquatic resources and should adequately prevent future perturbations due to coal mining and preparation.

ILLINOIS RECLAMATION LAW

The Illinois Reclamation Law concerning lands disturbed by surface mining allows postmining use of such lands for forests, pastures, crops, horticulture, homesites, recreation, industries, or other purposes including, but not limited to food, shelter, and ground cover for wildlife.[1] Each application for a permit* to mine must contain a proposed reclamation plan and map which delineates those portions of the affected lands that will be reclaimed

---

A permit from the Department of Mines and Minerals is required if more than 10 acres of land will be affected or if the overburden is greater than 10 feet.

Table 10A-3 Illinois Effluent Limits for Coal Mines, provided by the Illinois Environmental Protection Act.[a]

Parameter	Effluent Limit
Total iron (mg/l)	7
Total zinc (mg/l)	5
Suspended solids (mg/l)	50
Acid	Total acidity less than total alkalinity
pH (standard units)	Within the range 5-10 (not subject to averaging)

[a]U. S. Dept. of the Interior, *Laws and Regulations Affecting Coal*, 1976.

Table 10A-4 Illinois Water Quality Standards for Various Use Catagories, provided by Illinois Environmental Protection Act.[a]

Parameter	General Use	Public and Food Processing	Secondary Contact
Total iron (mg/l)	1.0	0.3	2.0
Total manganese (mg/l)	1.0	0.05	1.0
Total nickel (mg/l)	1.0	1.0	1.0
Total zinc (mg/l)	1.0	1.0	1.0
Sulfate	500	250	Not specified
Total dissolved solids (mg/l)	1000	500	Not specified
pH (standard units)	6.5-9.0	6.5-9.0	6.0-9.0

[a]U. S. Dept. of the Interior, *Laws and Regulations Affecting Coal*, 1976.

to the above-listed land uses. The decision to accept the proposed reclamation plan rests with the State Department of Mines and Minerals, but the opinions of the county government(s) of those counties having lands to be affected by the proposed mining, viewpoints of interested persons, and the advice of relevant experts such as foresters, agronomists and engineers are considered by the persons responsible for making this decision.

General Reclamation Requirements

The law requires that the grading of spoil piles be completed within 11 months after June 30th of the fiscal year in which mining occurred.[1] Either during grading or by selective placement of spoils, overburden materials containing acid-forming materials (iron pyrites) are to be covered with a minimum of four feet of water or other toxic-free overburden. The resultant topography is to be gently rolling with slopes less than 15%. However, slopes can be steeper (≤ 30%) on lands reclaimed for forest plantation, enhancement of wildlife, or recreational sites and if the original slope was steeper, because final slopes do not have to be reduced below the initial slope. After grading is finished, all other reclamation activities (i.e., revegetation) must be carried out during the next 25 months of three years after June 30th of the fiscal year in which mining occurred.

Reclamation is not required in depressions where pools or lakes capable of supporting aquatic life may be formed if approved by the State Mines and Minerals Department. A vegetative cover must be established on those areas requiring reclamation after grading. Reforestation criteria require a minimum of 500 living trees per acre after one growing season, and 450 living trees after two growing seasons.[1] The rules and regulations contain the suggestion that the mine operator consider Bulletin 628, "Reclaiming Illinois Strip Coal Land with Legumes and Grasses," University of Illinois Agricultural Experiment Station, for establishing pasture. Regulations pertaining to pasture establishment require a 65% stand of grasses and legumes in August through October of the seeding year or an 85% stand the following year.[1] Chapter 12 of the rules and regulations contains more detailed criteria establishing various postmining land uses through reclamation.

Reclamation to Row-Crop Agriculture

Reclaiming land to row-crop agriculture requires manipulation of surface materials in addition to that noted above.[2] Prior to stripping, all or part of the darker surface soil, up to 18 inches but not less than 8 inches, is removed separately, stockpiled, and reapplied as surface soil material after the area is regraded. Regrading after mining should result in a topography similar to the original contour of the land. Below the reapplied darkened surface soil, the subsoil material must be suitable as a plant growth material and as an agricultural root medium down to a depth of four feet.

The definition of a suitable plant growth material is presented in Rule 1104,[3] which contains eight sections. The first four sections pertain to the final slope, No. 5 discusses the definition of a suitable growth material and is presented below:

"The materials under the darkened surface soil suitable as a root medium shall contain no more than 20% coarse material greater than 2mm in size by volume. No more than half of the coarse material may be between 3 inches and 10 inches in the greatest dimension. No fragments shall be greater in size than 10 inches in the greatest dimension. In no case may clay material of less than 2 microns be greater than 40% by weight.

"These texture requirements do not apply if the soil conditions of the affected land prior to mining did not meet the standards included herein (i.e., if more than 20% coarse material by volume existed in the root medium below the darkened surface soil prior to mining, the same percentage of coarse material in the root medium will be allowed after mining; if more than one-half of the coarse material consisted of rocks in the 3 to 10 inch size category prior to mining, that same percentage will be permitted after mining; and if more than 40% by weight of clay materials less than 2 microns in size existed in the root medium below the darkened surface soil prior to mining, a like percentage by weight will be allowed after mining in the material under the darkened surface soil.)

"In addition to meeting texture requirements, the materials under the darkened surface soil, must be chemically suitable as an agricultural root medium. Materials suitable as an agricultural root medium shall be of a vertical thickness adequate, including the darkened surface soil, to ensure a total depth of four feet. Pyritic material capable of producing toxic acidic conditions shall not be incorporated within the surface four foot layer of finally graded lands."

The purpose for specifying the particle sizes and therefore the area occupied by coarse material between the four-foot depth and the reapplied darkened surface material is to insure water availability to crops during the dry months of July and August. This criteria should result in 8 to 10 inches of water in the upper four feet. An exception can be made to the textural requirements under Rule 1104 if "a clear and convincing showing that to vary such requirements would better effectuate the purposes of the act than would enforcing the standards herein."

Gob and Slurry Reclamation

Reclamation of gob and slurry disposal areas is required within one year after active use.[1] Gob which will not support vegetative growth must be covered with at least four feet of material capable of supporting vegetation, and planted to an acceptable vegetative cover. The criteria presented earlier for reforestation and pasture pertains also to revegetating buried or covered gob.

Slurry disposal areas occur in depressions among the prelaw mined areas r behind man-made levees or dams. The law requires that these areas be screened with trees planted along the border of the disposal areas. The slurry material does not have to be buried or covered.

REFERENCES FOR APPENDIX 10A

1. State of Illinois, Department of Mines and Minerals. Surface-Mined Land Conservation and Reclamation Act (PA 78-1295/effective July 1, 1975) - Rules and Regulations (Effective February 6, 1976).

2. Illinois Surface-Mined Land Conservation and Reclamation Act - 1971 as amended by House Bill 1277 and the 78th General Assembly. Effective July 1, 1975.

3. State of Illinois, Department of Mines and Minerals. Rules and Regulations pertaining to the Surface-Mined Land Conservation and Reclamation Act - Rule 1104 . . . "Lands to be Reclaimed for Row Crop Agriculture." Undated.