

CONCEPTUAL MODELS OF EROSION AND SEDIMENTATION IN ILLINOIS

Volume I. project summary

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*Prepared in cooperation with the Research Section,
Illinois Department of Energy and Natural Resources*

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Illinois State Water Survey

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ILLINOIS SCIENTIFIC SURVEYS JOINT REPORT 1

*Prepared in cooperation with the Research Section,
Illinois Department of Energy and Natural Resources*

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FOREWORD

Natural processes of soil erosion and sedimentation have been drastically impacted by human activities. Topsoil is being lost from farms, stream banks are being eroded away, lakes and reservoirs are being silted, and excessive erosion and sedimentation are significantly affecting the water quality and biological productivity of lakes and streams. Actions that may be taken collectively to minimize these problems must be based on sound scientific knowledge and accurate information.

In 1982, the Illinois Department of Energy and Natural Resources allocated research funds to the Board of Natural Resources and Conservation for projects vital to the State of Illinois. This research project on the development of "Conceptual Models of Erosion and Sedimentation in Illinois" is one such project that has been sponsored by my department. Scientists and engineers from the Water Survey, Geological Survey, and Natural History Survey were involved in this multidisciplinary effort in which questions on soil erosion and sedimentation were addressed in a systematic manner. The eleven "Conceptual Models" on erosion and sedimentation, the extensive bibliography, and the summary of data gaps and research needs represent the most complete analyses that have ever been done for the State of Illinois in this subject area, and show where we should direct our efforts to solve the problems of soil erosion and sedimentation.

A handwritten signature in black ink, reading "Michael B. Witte".

Michael B. Witte, Director
Illinois Department of Energy
and Natural Resources
Chairman, Board of Natural Resources
and Conservation

ABSTRACT

Erosion and sedimentation are natural processes that can neither be stopped nor eliminated. However, human activities have been instrumental in drastically accelerating these processes. Presently excessive amounts of soil loss from the watershed are impacting productivity of farms, changing the natural balance of the stream-watershed environment by aggrading stream beds and lakes, and altering the biological and geological continuity of the system. This complex process of erosion and sedimentation with its multi-dimensional facets can be examined in a coherent manner only by the development and interpretation of a set of conceptual models covering the total erosion and sedimentation phenomenon.

A set of eleven conceptual models has been developed consisting of a single Level I model and ten Level II models. The Level I model is a general model but it identifies the major subdivisions of the environment and the important natural and human factors that influence erosion and sedimentation processes. The Level II models each specifically depict one system or subsystem of the environment. These systems are: agriculture, grassland, forest, mining, urban, construction, streams and rivers, permanent wetland, seasonal wetland, and lakes and reservoirs. Detailed descriptions of each interaction within each model have also been developed. On the basis of an extensive review of the literature, discussion and active participation by various state and federal agencies, and workshop inputs, a list of data gaps and research needs has been developed and is included in the report.

The report has been divided into two volumes. Volume I contains the project summary, including a brief description of all the models and the list of information and data gaps. Volume II contains a detailed description of all Level II models and model interactions, listings of the related citations for each interaction for all the ten Level II models, a list of more than 500 keywords, and a bibliography with over 700 entries. Descriptions of the process of interpreting the Level II models and of the generation of the exhaustive list of citations are also included.

Keywords: Erosion, Sedimentation, Illinois, Conceptual Models, Rivers, Lakes, Agriculture, Forest, Urban, Construction, Upland, Wetland, Research Needs, Data Gaps

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Staff members who contributed substantially are Rodger Adams and Cheryl Peterson from the Water Survey, Mary Krick and Marjorie Eastin from the Geological Survey, and Monica Lusk, Carla Heister, and Faith Wetzel from the Natural History Survey. Typists who prepared the camera ready-copy are Kathleen Brown and Pamela Lovett from the Water Survey. Gail Taylor, Water Survey, edited the final copy of the report, and the graphics were prepared by the graphics personnel from the Water Survey under the supervision of John Brother. Lastly, we would like to thank Marcia Nelson, former Water Survey librarian, who assisted extensively in the preparation and the operation of the "Biblio" computer program used to enter, store, and sort the bibliographical references.

Printing was done at the State Geological Survey under the supervision of Dennis Reed.

REPORT FORMAT

This report has been divided into two volumes. Volume I is a summary of the project, describing the technical approach and some highlights of the results. An appendix to Volume I lists the participants in the workshop on the project that was held at Allerton House.

Volume II describes all the models in detail, lists and describes the interactions between various parameters for each model, and lists the bibliographical references that are closely related to each of the model interactions. It also lists the 513 keywords used for this project with the numerical codes relating them to the various models. It then presents the bibliography containing a total of 795 entries, including pertinent keywords.

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VOLUME I. PROJECT SUMMARY

INTRODUCTION

Soil erosion is the process by which soil particles are dislodged and carried away by water or wind. These particles may then be deposited as sediment in lakes, rivers, or streams. Erosion and sedimentation processes are natural events which have been in effect over geological time periods. Both processes are partially counteracted by other natural events: erosion by the chemical and biological process of new soil formation, and sedimentation by the renewed erosion and removal of sediments during floods or high winds. However, the balance of these natural events results in a slow net transfer of soil particles by erosion from landscape surfaces and in sediment deposition in lakes, streams, and oceans.

Though erosion and sedimentation are natural processes, human activities have drastically increased their rates. As a result, topsoil is lost from farms, lakes are accumulating deep layers of sediment, and rivers and streams frequently carry heavy loads of eroded soil particles which impact water quality and may settle as layers of sediment. In Illinois the current average annual soil loss (6.7 tons per acre) is 2.5 to 6 times greater than the natural rate. At this rate of soil loss, 1.5 bushels of topsoil are lost for every bushel of corn produced. In parts of Illinois, the current thickness of the topsoil is in the range of 4 to 15 inches compared to the original 10 to 18 inches. In other parts of Illinois nearly 70 percent of the topsoil has been lost due to wind and water erosion. Soil loss and sedimentation are also caused by activities other than agriculture, such as construction, mining, timber harvest, and livestock grazing.

Sedimentation rates have increased such that, for example, 15.4 million tons of sediment are deposited each year in the Illinois River Valley lakes, and 12.1 million tons are transported into the Mississippi River. Extensive lake sedimentation surveys in Illinois have shown that Illinois lakes are losing their capacities at the rate of about 0.1 to 3.5 percent per year. This indicates that some lakes will be almost useless in 25 to 30 years. As an example, it is estimated that Upper Peoria Lake will lose approximately half its volume by the year 2000.

The consequences of soil erosion and sedimentation are widespread, affecting virtually every sector of the state. For example, soil lost from farmlands causes reduced yields and consequently affects the agricultural industry. Sedimentation affects recreation, fish and wildlife, water quality, and the transportation industry. Thus, the interactions of erosion and sedimentation are quite complex, affecting farmland, urban land, and terrestrial and aquatic habitats. In addition, the erosion and sedimentation processes affect areas dealt with by numerous state and federal agencies. These include water quality (Illinois Environmental Protection Agency), farming (Illinois Department of Agriculture, Soil Conservation Service, and Soil and Water Conservation Districts), regulation of rivers (U.S. Corps of Engineers and Illinois Department of Transportation, Division of Water Resources), and preservation of natural streams and fish and waterfowl habitats (Illinois Department of Conservation).

Because the erosion and sedimentation processes are highly complex, and because governmental agency jurisdiction and responsibilities are complicated, the three Illinois State Scientific Surveys designed this study to provide a coherent approach to the issue as it exists in Illinois.

The state needs a comprehensive strategy to deal with the impacts of soil erosion and sedimentation and the regulatory decisions related to them. Considerable amounts of data and information exist regarding the erosion and sedimentation processes in Illinois; unfortunately, however, this information is not organized so as to be useful in determining the best course of action or in making decisions about soil and water resources.

Objectives of Project

The specific objectives of this study are:

- a) Collect and compile existing information on soil erosion and sedimentation processes in Illinois.
- b) Provide an organized framework for this information.
- c) Describe existing agency responsibilities with respect to these processes.
- d) Identify important gaps and future research needs.

The following pages describe the approach used by the three Surveys to accomplish these goals and then highlight some of the results.

Literature Review

The first task was to identify and gather all available literature relating to erosion and sedimentation processes in Illinois. This involved conducting extensive computer literature searches of seven national data bases, reviewing reports and publications of state and federal agencies, and obtaining information from current research programs in the state. The 795 bibliographic entries that were selected and reviewed are given in Volume II.

Survey of Agencies

In September 1982 a request for information was sent to 26 state, federal, and university agencies and departments whose programs deal with soil erosion and sedimentation. Information sought included bibliographic materials, a description of current research projects, opinions about existing information gaps, and specific recommendations regarding high priority research needs. Written or oral responses were received from 23 agencies. A summary of the agency responses is given in the next section.

ASSESSMENT OF AGENCY RESPONSIBILITIES

This section is subdivided into two parts: a) federal and Illinois laws on sedimentation and soil erosion, and b) agency responses based on inquiries made to them.

Federal and Illinois Laws on Sedimentation and Soil Erosion

I. Federal Laws

A. Public Soil Conservation Laws

1. The Soil Erosion Act of 1935 (Pub. L. No. 74-46, currently codified at 16 U.S.C. §590 (a-f)) authorizes the Secretary of Agriculture to undertake a wide variety of measures to prevent soil erosion, including engineering operations, new methods of cultivation, revegetation, and changes in land use. In addition, the Secretary may enter into agreements with or furnish aid to any agency or person in order to further the purposes of the Act. Assistance provided pursuant to the Act may be conditioned upon the enactment of state and local laws that impose suitable permanent restrictions on land use and otherwise provide for erosion prevention. The Secretary of Agriculture formed the Conservation Operations Program (COP), administered by the Soil Conservation Service (SCS), to implement the Act.
2. In 1936, Congress enacted the Soil Conservation and Domestic Allotment Act (Pub. L. No. 74-461, codified now at 16 U.S.C. §590 (g-q)). The Act primarily provides for cost-sharing assistance to farmers for growing crops or using land in ways which promote conservation. The Agricultural Conservation Program (ACP) was formed to implement the Act. ACP funds can pay up to 90 percent of the costs of conservation measures, although agency agreements usually require the government to shoulder only 50 to 75 percent of the conservation costs. No landowner may receive more than \$3,500 in ACP funds in a single year. The ACP is administered by the Agricultural Stabilization and Conservation Service (ASCS) of the USDA. The ASCS has offices in all states and most counties.
3. In 1977, Congress passed the Soil and Water Resource Conservation Act, known as the RCA (Pub. L. No. 95-192, codified at 16 U.S.C. §§2001-9). This Act requires the USDA to (1) appraise, on a continuing basis, the soil, water, and related resources on the non-federal land of the nation; (2) develop a program for furthering conservation and protection of these resources; and (3) evaluate conservation achievements annually. The Act instructed the USDA to recommend program changes to Congress by the end of 1980 and to repeat the appraisal and policy development process at five-year intervals. In November 1981, the USDA issued a "Revised Draft" Program Report which described a "preferred program" that would set priorities among conservation goals, channel part of the current

USDA conservation budget to states in the form of matching block grants, and establish conservation coordinating boards at local, state, and national levels. The present administration has endeavored to implement portions of the "preferred program" by requesting and receiving Congressional approval for \$10 million in matching block grants pursuant to the Agricultural and Food Act of 1981 (Pub. L. No. 97-93). Grants may be made to supplement technical assistance activities for conservation activities in areas with critical soil erosion or upstream flooding.

B. Nonpoint Pollution Control and Soil Conservation Programs

1. Section 208 of the Clean Water Act (33 U.S.C. §1288) comprises the pivotal statutory provision for controlling nonpoint source pollutants. These are pollutants from dispersed sources, as opposed to pollution from point sources such as pipelines or smokestacks. Agriculture accounts for a large percentage of nonpoint pollution. Modern farming practices which rely heavily on synthetic fertilizers, pesticides, and row crops can add greatly to sediments, nutrients, organic materials, and toxic chemicals in water bodies. Under Section 208, state police powers over land use and water pollution are envisioned as the principal legal bases of nonpoint source pollution controls. Section 208 essentially provides for areawide planning and management for waste treatment with the aim of coordinating the various control programs envisioned in the legislation. In 1975, Section 208 was construed by the courts to require areawide planning for all rural areas of the country.

In 1977, the USEPA issued criteria for approval of nonpoint source portions of state water quality management plans (SAM-31). To be fully approved, a plan must provide for adequate authority to control activities and pollutants on a regional level, authority to require the application of best management practices, a designated management agency, and other provisions.

The Clean Water Act of 1977 amended Section 208 to provide for a special cost-sharing program promoting best management practices on farmlands. Best Management Practices ("BMP") are particular land treatments that are especially effective in limiting soil movement into water bodies. The 1977 legislation authorized \$200 million to fund this program in 1979 and \$400 million in 1980.

II. Illinois Laws and Policies

A. Soil Conservation Districts

In 1936, the USDA released a Model Standard State Soil Conservation District Law. The model districts were special governmental units designated to oversee USDA's soil conservation service assistance to landowners, carry on projects for soil erosion control, and administer land use regulation relating to soil conservation. By 1947, all states had authorized soil conservation districts. Illinois' law, the "Soil and Water Conservation Districts Act" (codified at Illinois Revised Statutes, ch. 5, Par. 106-138.9) was enacted by the General Assembly in 1937.

Under the Illinois Act, soil conservation districts are independent units of local government. Landowners may petition the Illinois Department of Agriculture to establish a district. If the Department finds, after a public hearing, that formation of a district would be in the best interests of the public health, safety, and welfare of the area proposed and is administratively practicable and feasible, the Department will hold a voters' referendum in the area.

The Illinois Act was amended in 1977 to require district erosion and sediment control programs. State guidelines issued by the Department of Agriculture in 1980 require adherence to soil loss tolerance values (T-values) on all agricultural land in the state by January 1, 2000. (Illinois Department of Agriculture, Rules and Regulations Relating to Soil and Water Conservation Districts Act, Art. I, Regs. I-XIII, Rule 4.1.) In the interim, erosion losses are limited to declining multiples of T-values, beginning with four times T-values from January 1, 1983, until January 1, 1988. Districts may adopt standards more restrictive than the state minimum standards.

In support of district erosion control programs, Illinois has increased educational efforts and has established a cost-sharing program for inducing erosion and sediment control devices, structures, and practices. These measures are aimed at encouraging voluntary compliance with conservation standards. In the event that these measures prove inadequate, Illinois law provides for enforcement action based upon the state's pollution control authority — the Illinois Environmental Protection Agency (Illinois Revised Statutes, ch. 111 1/2, Par. 1001-1051). A formal complaint is investigated by a district agency. Upon verification of the complaint, a formal notice of violation is issued. The Department of Agriculture is required to prescribe specific procedures for correcting the violations and must offer cost-sharing assistance. If compliance is not achieved within a year of the notice, the Department must conduct a formal administrative hearing to determine the reasons for noncompliance.

B. Section 208 Plan: State Water Quality Management Plan

The Illinois "208" plan issued in 1979 in response to the Clean Water Act amendments contained recommendations for limits on agricultural runoff and for a state sediment control program offering technical assistance and some state cost-sharing funds for installation of erosion prevention improvements. The Illinois EPA was the lead agency for this planning effort. With regard to nonpoint pollution sources, the plan does not contain strong enforcement authorities, but it does include recommendations for several voluntary measures and incentives.

C. Pollution Control Board

To date, the Illinois Pollution Control Board has not adopted rules dealing with soil erosion, sedimentation, or nonpoint pollution sources in a comprehensive manner. There are specific rules dealing with the application of sludge from sewage treatment plants to land and with runoff from livestock operations.

Agency Involvement in Erosion/Sedimentation Programs

As mentioned previously, in September 1982 a letter was sent to various state, federal, and public agencies within the state of Illinois whose responsibilities and activities involve soil erosion and/or sedimentation. This letter requested that the agency describe its direct involvement in the soil erosion and sedimentation programs within the state and provide a list of bibliographic materials. Each agency was also requested to identify gaps in our knowledge about erosion and sedimentation in Illinois. Agency responses are summarized in this section.

Programs of the U.S. Army Corps of Engineers involve flood control, channel maintenance, erosion and sedimentation studies, and a stream sediment data collection program at a few locations designed to meet the needs of Corps project operation. Current projects include: shoaling of the St. Louis Harbor, erosion control in the Carlyle Lake area, Kaskaskia grade control structures, Mississippi River erosion control within the open river area, national streambank erosion control work, determinations of the Illinois river bottom sediment characteristics, identification of the sediment sources for the Fox Chain of Lakes area, reservoir sedimentation surveys, and beach erosion control.

The U.S. Geological Survey is also a primary federal agency entrusted with the collection of basic water resources data and information as well as some applied research. Examples of current project areas are: instream sediment monitoring, strip mine hydrology, urban construction and stream quality, water quality monitoring in coal mined areas, mine reclamation hydrology, sediment in Bay Creek, erosion of the Sheffield RAD Site, evaluation of bed load data, and shift control for estimating sediment discharges.

The U.S. Department of Agriculture, including the Agricultural Stabilization and Conservation Service and Soil Conservation Service, participates in the general area of soil conservation and farmland protection. Projects of the U.S. Department of Agriculture include water resources planning, water resources operations, river basin planning, and regional conservation and development. Specific programs involve the Agricultural Conservation Program (ACP), Rural Clean Water Program (RCWP), erosion, flooding, water conservation, farmland protection, water quality, critical soil loss, land use, and forage production.

The Illinois Environmental Protection Agency works primarily in the area of water quality as it is impacted by erosion and sedimentation. Other areas of involvement are soil erosion from construction sites and agricultural watersheds, and lake water quality impairment by sediment loads. IEPA has worked on two watershed studies in Illinois, one on Blue Creek and another one on the Highland Silver Lake area.

The Illinois Department of Agriculture's major concerns are in the areas of soil and water conservation, erosion and sediment control, assistance to the local Soil and Water Conservation Districts, coordination of state erosion and sediment control programs, and handling of the complaint process regarding excessive erosion.

The Illinois Department of Transportation, Division of Water Resources, is entrusted with the regulation of rivers, lakes, streams, and floodplains. Most of their

projects are applied, and they also sponsor instream sediment data collection and lake sedimentation programs.

The Illinois Department of Conservation is interested in the impact of sediment on recreational and wildlife refuge lakes. They sponsor research for determining the best courses of action to revitalize lakes by reducing sediment deposition and improving water quality, and they have sponsored a number of lake rehabilitation programs.

The Illinois Department of Mines and Minerals is mainly concerned with the erosion and sedimentation process as it relates to surface mining programs of the State of Illinois.

The Illinois Pollution Control Board does not generate data or studies but does receive and store information from others in the general area of water pollution.

Research at the Agricultural Engineering Department at the University of Illinois includes studies on soil erosion from agricultural watersheds, conservation practices, economics, tillage systems, erosion control, and other agricultural areas. The Co-operative Extension Service is working to educate farmers and the general public on the value of soil conservation practices and the implementation of best management practices, especially conservation tillage.

The Illinois Department of Energy and Natural Resources is the primary natural resources agency for the State of Illinois. Not only is the department entrusted to evaluate the natural resources of the state and disseminate information to the people of Illinois, but it also sponsors applied research in water, soil, energy, and natural resources areas to answer vital questions and develop an information base for making intelligent decisions for the proper management of all state resources.

The three Scientific Surveys under the Illinois Department of Energy and Natural Resources, which are located at the University of Illinois at Urbana-Champaign, have been conducting research in the natural resources area for a long time. The major responsibilities of the Surveys are to collect, analyze, and disseminate information on natural, geological, water, and atmospheric resources of the state of Illinois.

The Illinois State Water Survey has conducted extensive research and data collections on lake sedimentation rates, erosion due to water and wind, transport of sediments in streams and rivers, effects of sediment on water quality, impacts of best management practices on receiving streams and lakes, and the evaluation of stream and lake morphology. The Water Survey is also presently maintaining a relatively small instream sediment monitoring network.

The State Geological Survey has conducted research in the areas of stream and lake sediment quality, long-term sedimentation rates, and other areas related to stream and lake sediments.

The impacts of erosion and sedimentation on natural, aquatic, and biological habitats and on the productivities of agricultural lands are some of the areas in which the Illinois Natural History Survey has been conducting research for a considerable period of time.

LEVEL I MODEL

Because of the complexity of the soil erosion and sedimentation processes, an organizing framework was needed to assess the interrelationships between various processes. The most useful framework is a conceptual model or diagram that clearly shows the important components and their interactions. To demonstrate the general framework for organizing information on erosion and sedimentation in Illinois, a single general model was constructed as shown in figure 1T. This Level I model is very general in nature but serves the important functions of identifying the major subdivisions of the environment and the important natural and human factors which influence erosion and sedimentation processes. In this Level I model, the state of Illinois is represented by the large box (dashed lines), which has been divided into four major systems: Upland, Riverine (streams and rivers), Palustrine (wetlands), and Lacustrine (lakes and reservoirs).

Two other systems which are absent in Illinois are the Estuarine and Marine Systems, represented by the lowermost box outside the dashed lines. However, it should be noted that most sediment and adsorbed materials are eventually deposited in these two systems. The classification of the state into the different systems generally follows the U.S. Fish and Wildlife Service's classification system for wetlands and deep water habitats (Cowardin et al., 1979).

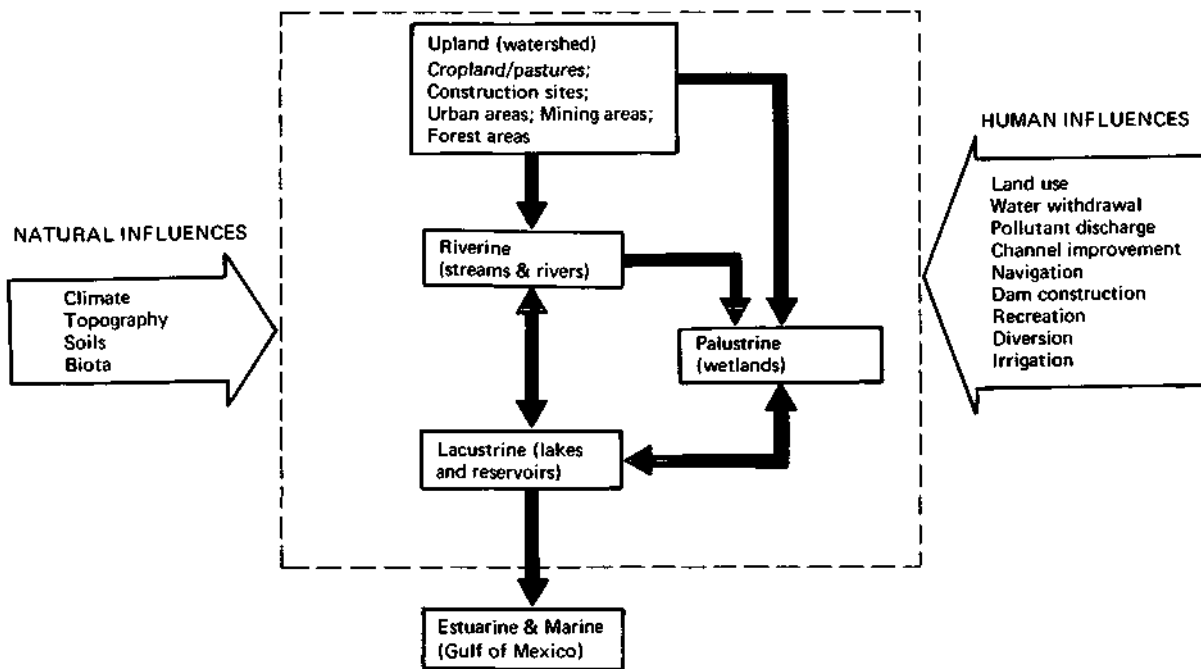


Figure 1-1. A conceptual model for the transport of sediment, biota, nutrients, and chemical pollutants by water in Illinois; Level I model

(Major sources and sinks of sediment and organic and inorganic matter are represented by the boxes. The flow of material from one environment to another is shown by the arrows. The natural and human influences are represented by two switches acting on the whole system representing the state of Illinois.)

The Upland System consists, by definition, of land surfaces which are not inundated by water from a river, lake, or reservoir even during extreme high water periods. This system includes most of the land use patterns such as agriculture, urban, mining, construction, pasture, and forest.

The Riverine System (streams and rivers) consists of stream and river channels and their border areas. Here there is either a continuous or periodical flow of fresh water in the channel.

The Lacustrine System (lakes and reservoirs) generally refers to natural lakes and man-made reservoirs, including most of the border areas flooded during periods of high water. In a Lacustrine System it is assumed that there will be some water in the deepest part of the lake or reservoir even during periods of low water.

The Palustrine System (wetlands) consists of most nontidal wetland including some tidal wetland where salinity is below 0.5 percent. Palustrine wetlands may be situated on the fringes of Riverine, Lacustrine, or Estuarine Systems. This system also consists of all temporary or permanent water bodies often called ponds. Wind and water movement have limited effects on the erosion potential of a Palustrine System. The Palustrine System can be temporarily flooded.

The movements of sediment, nutrients, biota, and chemical pollutants from one system to the other are indicated by the arrows between the different boxes in the model. The primary directions of material movement are generally from the Upland to the Riverine, from the Riverine to the Lacustrine, and finally to Estuarine or Marine Systems. Two-way arrows indicate the potential of two-way movement of material. For example, in areas where the Palustrine System is found, water, sediment, and adsorbed materials may be exchanged between the Palustrine System and the Lacustrine or Riverine Systems. If a dam is built on the main channel of a river or if a river originates from a lake or reservoir, material may move from the Lacustrine to the Riverine System, as indicated by the two-way arrow between the Riverine and Lacustrine Systems.

The processes of soil erosion, sediment transport, and sedimentation within each system and the interactions between the systems are controlled by natural and human influences exerted on the entire environment, as represented in the model by two switches acting on the large box, which represents the whole state. Among the natural factors which influence the erosion and sedimentation processes are soil characteristics, topography, vegetation, the natural biota, and climate, including seasonal and long-term changes in climate.

Human factors which influence the erosion and sedimentation processes may be classified into two broad categories: land use and water use patterns. Among the land use patterns are agriculture, pasture, urban, mining, construction, and forestry. The water use patterns include water withdrawal, nonpoint and point sources of pollution, recreation, diversion, and others.

Some studies describe erosion or sedimentation processes in terms of just one component or habitat, such as upland cropland. However, other studies concern more than one model component, for example, upland watersheds and the impacts on bottomland lake habitats. Similarly, many relevant questions address more than one component and also require information about one or more of the natural and human influences.

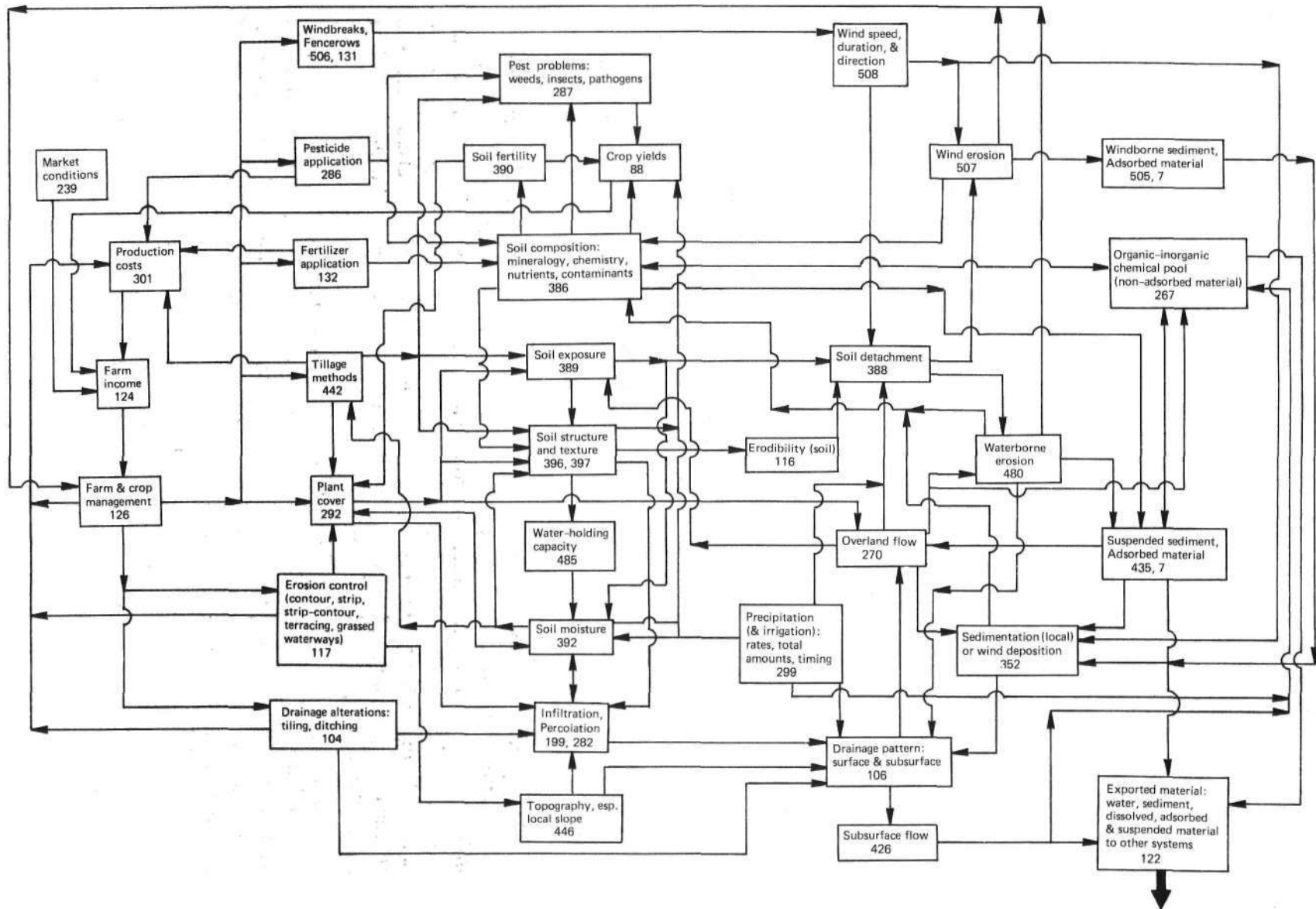


Figure I-2. Level II model for the Agriculture Subsystem

LEVEL II MODELS

Representation of the complex interrelationships between various systems and subsystems required the development of specific models designated here as Level II models. These models are for agriculture, grassland, forest, mining, urban, construction, streams and rivers (riverine), permanent wetland, seasonal wetland, and lakes and reservoirs (lacustrine). These models are fairly complex and contain a significant amount of information.

To demonstrate the complexity and the important contributions of Level II models, brief descriptions and illustrations of all the models are included in this section. Detailed descriptions of the models and their various interactions, and other associated materials, are included in Volume II.

Before a description of each model is included, it should be pointed out that within each model component, the parameters shown are also the keywords utilized in the literature search and in the identification of various related references dealing with specific interactions. Keywords have been arranged in alphabetical order and numbered in ascending order (see pages 227-231, Volume II). These numbers and the associated keywords form the components of each model, as will be described next.

Upland System

Agriculture Subsystem

Figure I-2 shows the Level II model for the Agriculture Subsystem. It includes all row-cropped acreage, cultivated nurseries, truck crops, and small grain crops. The model shown can be broadly subdivided into five categories from left to right: 1) economic factors imposed upon agriculture; 2) "management influences" or strategies needed at the farm level; 3) physical and natural characteristics of the watershed or the farmstead; 4) external physical constraints and the resultant erosion and sedimentation because of natural or man-made influences; and 5) the export of materials, both adsorbed and nonadsorbed types.

The interactions between various parameters are shown by arrows. It must be emphasized here that the arrows do not necessarily indicate the flow of materials such as soil and water. Rather, they show the cause and effect of a parameter on the other parameters, including the movement of materials.

The interaction of various components can be explained by considering one component of the model at a time. The production costs shown in Box 301 are influenced by many variables including pesticide application (Box 286), fertilizer application (Box 132), tillage methods (Box 442), farm and crop management practices (Box 126), erosion control techniques (Box 117), and drainage alterations (Box 104). Similarly, an analysis of other parameters such as soil fertility (Box 390) can be performed by tracing the "in" and "outward" arrows from this box. The second-, third-, and fourth-order interactions, and so on, can be traced starting with any one of the variables given within a specific box.

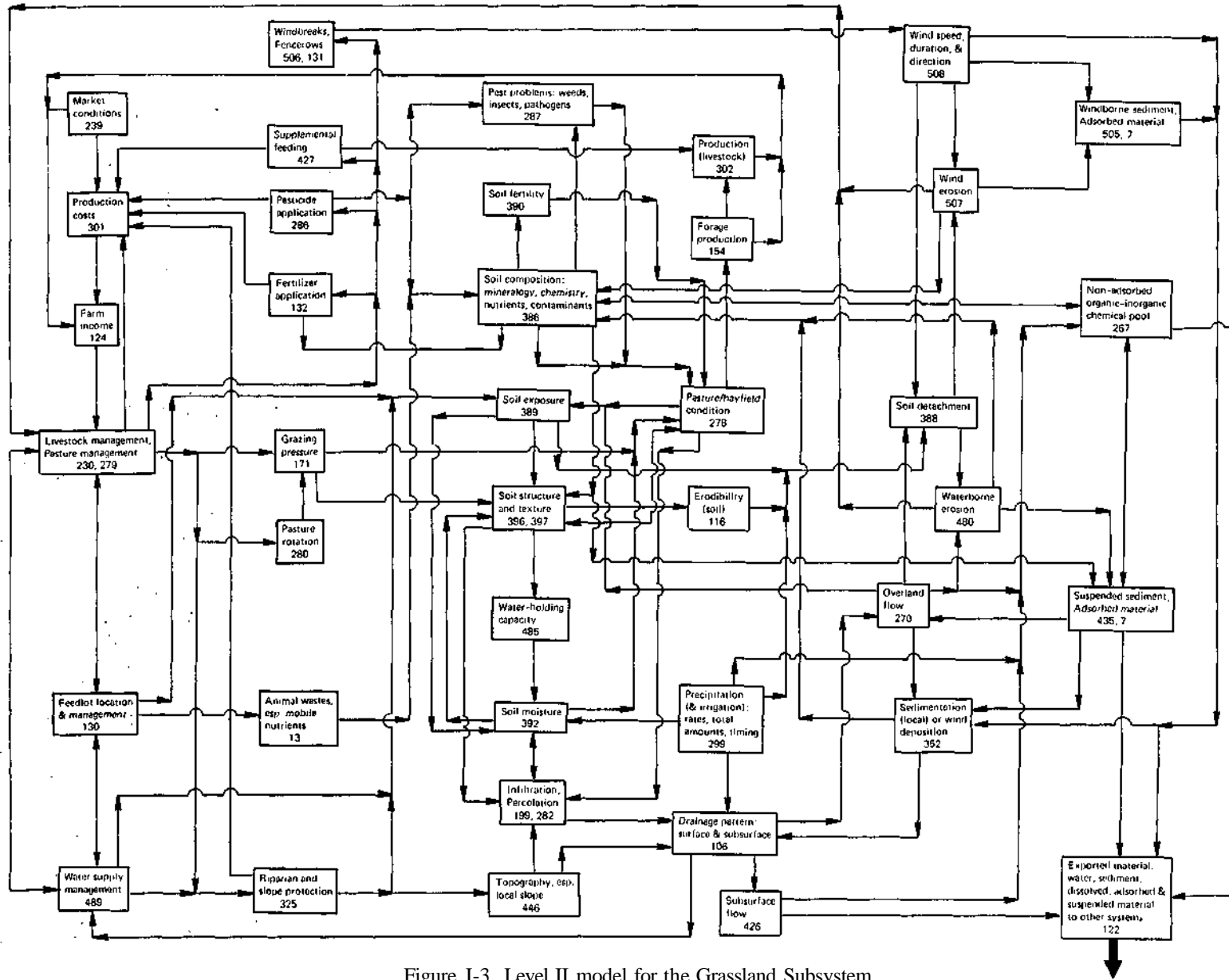


Figure I-3. Level II model for the Grassland Subsystem

Grassland Subsystem

Figure I-3 shows the Level II model for the Grassland Subsystem. This subsystem within the Upland System is similar to the Agriculture Subsystem model. It includes land uses such as natural grassland, pastures, hayfields, orchards, most highway right-of-ways, parks, and others.

The model can be broken down into five separate categories from left to right: 1) primarily economic and farm level management factors, 2) "management influences" that directly or indirectly control the grassland system, and 3) natural and physical characteristics of the grassland (essentially the same parameters that were used within the Agriculture Subsystem). The fourth and fifth groups of parameters contain diverse factors such as production, erosion, sedimentation, and movement and transport of adsorbed and nonadsorbed particulate materials both within and out of the system.

The interactions and cause-and-effect relationships between any parameter and other parameters at first-, second-, and third-order levels can again be traced following the "in" and "outward" arrows from the specific boxes.

Among the features of the Grassland Subsystem not present in the Agriculture Subsystem are the presence of livestock on pasture, importance of the plant cover in grassland in the reduction of soil erosion, and the existence of relatively steeper slopes and riparian zones.

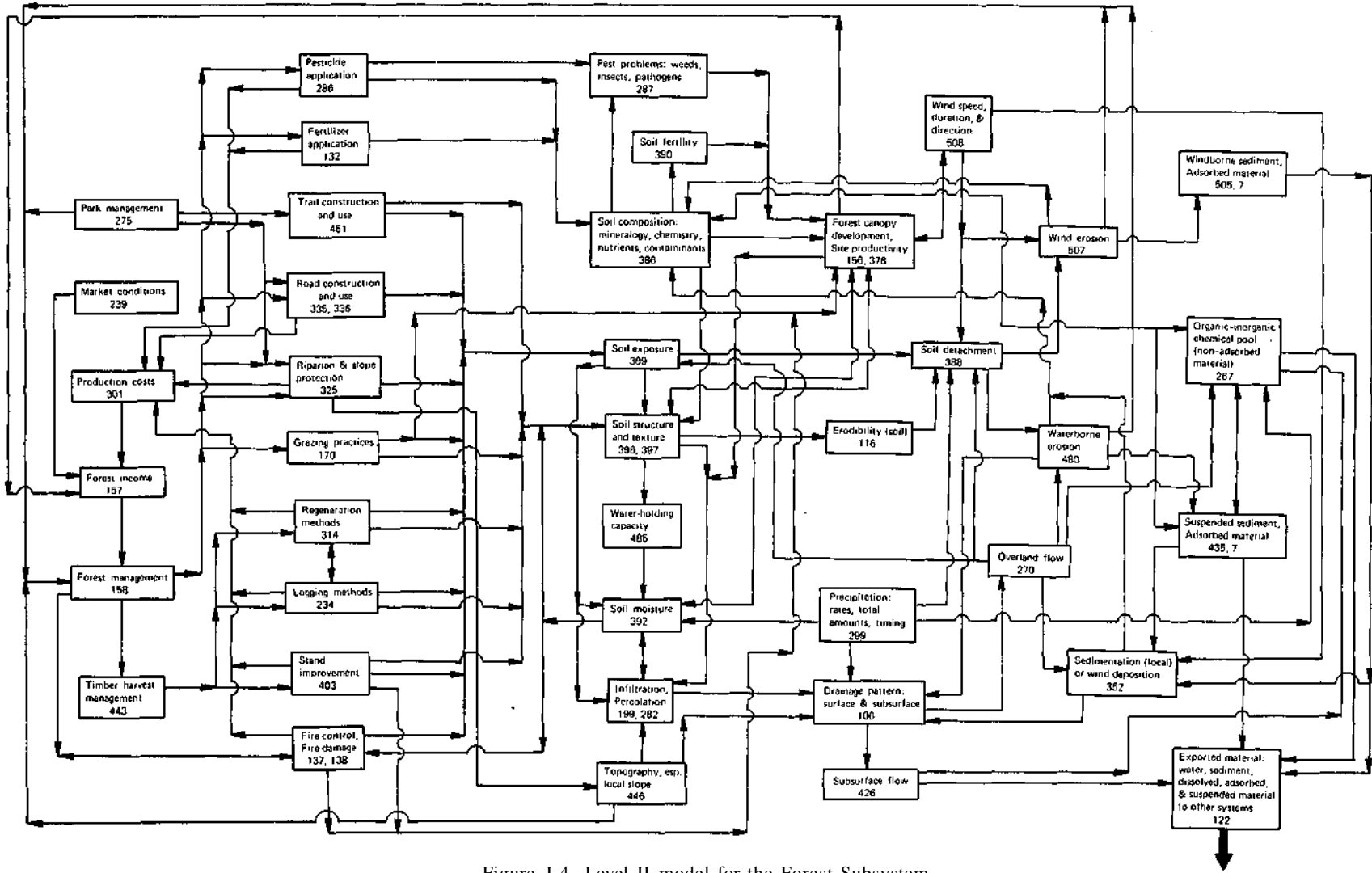


Figure I-4. Level II model for the Forest Subsystem

Forest Subsystem

Figure I-4 shows a diagram of the Level II model for the Forest Subsystem, another of the subsystems within the Upland System. This subsystem contains areas such as state and national forests, forests within parks, forested plantations, and areas with continuous canopy covers.

The model can again be broken down into 4 or 5 categories from left to right. The first set of parameters contains the economic and forest management factors. The second group of parameters can be broadly termed management influences, including some construction activities. The third, fourth, and fifth groups of parameters relate to water and soil and are essentially the same parameters given for the Grassland Subsystem (figure I-3).

Features of the Forest Subsystem differing from those of the Agriculture and Grassland Subsystems are the presence and construction of roads, less potential for fires than within the grasslands, and diverse use of the forests.

It is important to remember that the construction of logging roads and the clear cutting of forests on steep slopes are the major contributors to soil erosion within the forest subsystem. The first- and second-order interactions between parameters can again be traced starting from any specific box. An example would be logging methods (Box 234). Here timber harvest management (Box 443) impacts logging methods, which in turn impacts production costs (Box 301), soil exposure (Box 389), and soil structure and texture (Box 396,397). Third- and fourth-order interactions can similarly be deduced.

Mining Subsystem

Figure I-5 shows the Level II model for the Mining Subsystem. Even though this subsystem is within the Upland System, it differs considerably from the other three subsystems that have already been presented. This subsystem contains land and areas that are being disturbed, altered, and changed significantly with an associated modification of land use patterns.

The model can be broken down into five major categories from left to right: 1) parameters that influence mine management decisions; 2) factors imposed on the land as modifiers; 3) physical factors; 4) factors controlling the transport of materials from the mining area; and 5) factors indicating the quantity and quality of materials involved in the mined land and exported to other systems.

It must be pointed out that mine management decisions are based on economic factors, regulatory laws, quantity and quality of the materials to be mined, and environmental concerns. Within the mining subsystem, potential exists for extensive disturbance of the topographical features which in turn may generate significant amounts of soil erosion. Mine reclamation thus becomes very important for the reduction of the sediment load. Here again, the interaction between any two or more parameters can be examined by following the arrows either coming to or going away from a specific box.

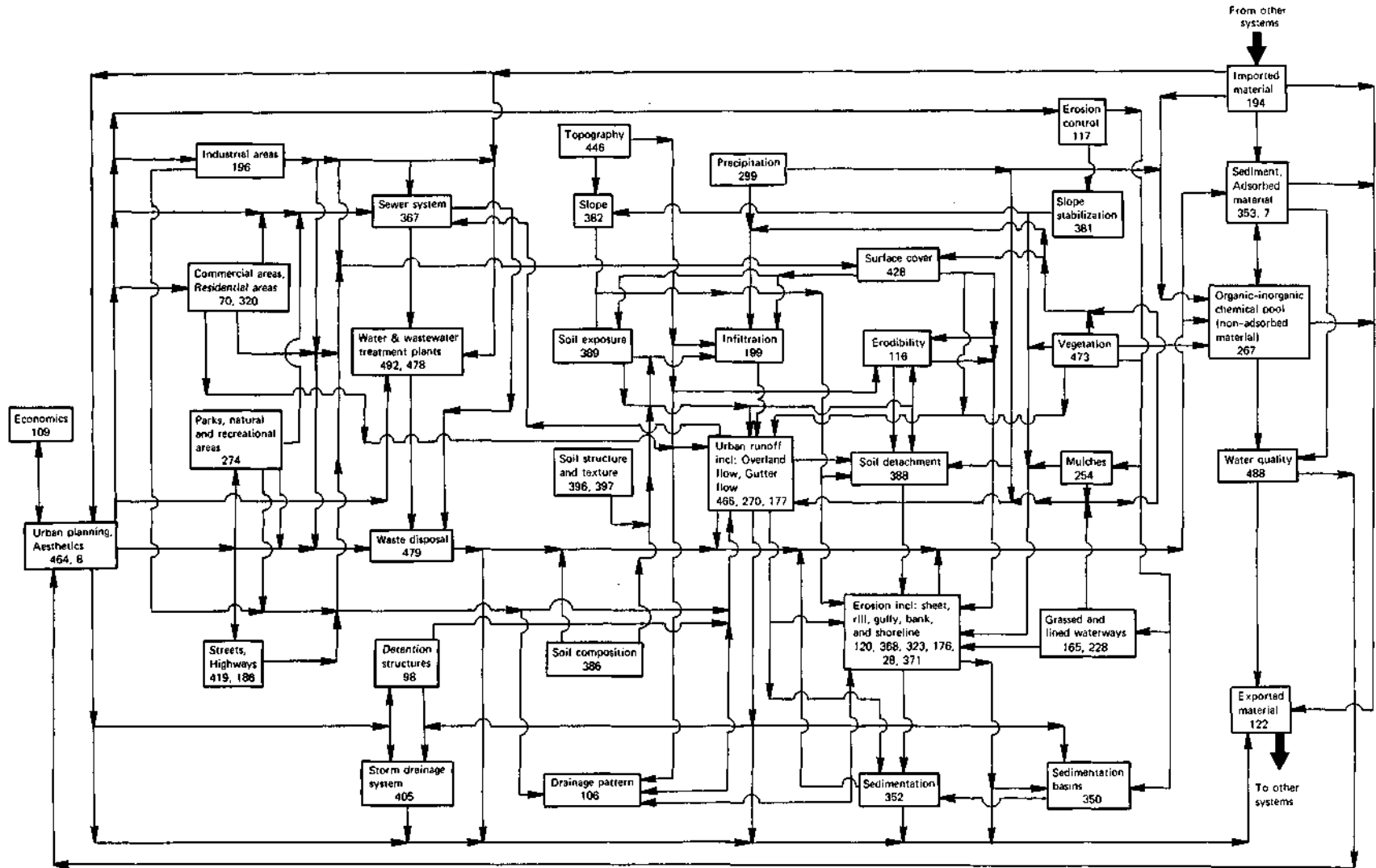


Figure I-6. Level II model for the Urban Subsystem

Urban Subsystem

Figure I-6 shows the Level II model for the Urban Subsystem. This model is significantly different from the other Level II models discussed so far because within this subsystem the land use pattern is varied, and the impacts of the changing land use patterns on the erosion and sedimentation processes are different from those within the Agriculture, Grassland, or Forest Subsystems.

The model can be subdivided into six categories from left to right: 1) urban planning and economics; 2) major source areas or subdivisions within the urban environment; 3) infrastructure for transport, treatment, and storage of water; 4) physical characteristics, including the mechanics of erosion and transport of sediment; 5) management practices that could be utilized to control erosion; and 6) the quantity and quality of materials moving in or out of the system.

The interactions between components of the model can again be evaluated by following the arrows between these components. As an example, the commercial and residential area parameter (Box 70,320) impacts sewer system (Box 367), drainage pattern (Box 106), waste disposal (Box 479), surface cover (Box 428), and urban runoff, overland flow, gutter flow (Box 465,270,177), whereas the commercial and residential area parameter is impacted by the urban planning and aesthetics parameters (Box 464,8). This example shows only the first-order interactions. The second-, third-, and fourth-order interactions can easily be deduced from the diagram.

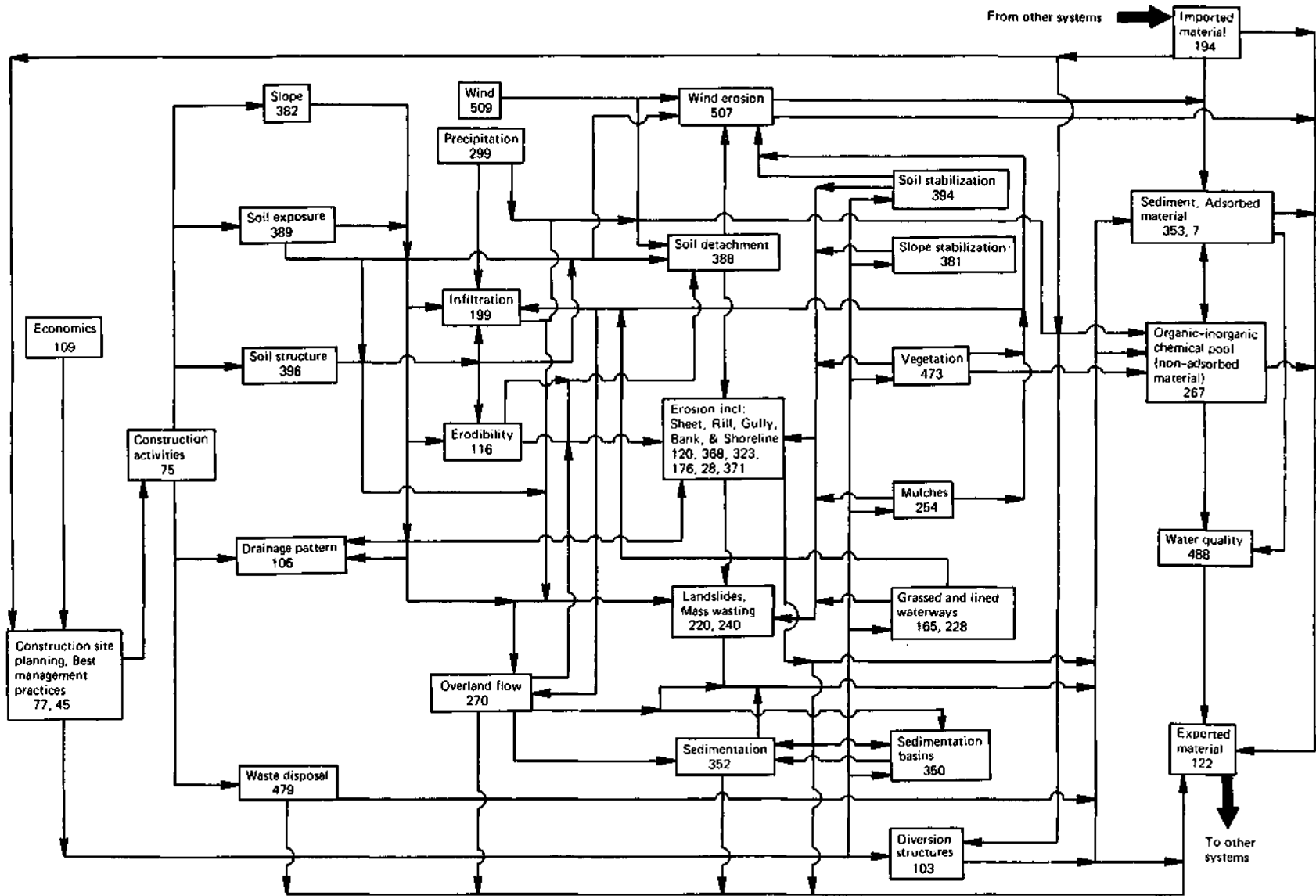


Figure I-7. Level II model for the Construction Subsystem

Construction Subsystem

Figure I-7 shows the Level II model for the Construction Subsystem, the last subsystem model under the Upland System. Similarities exist between this subsystem model and the Urban Subsystem model (figure I-6). This is another subsystem where excessive soil erosion within a fairly small area can significantly impact other systems or subsystems.

The model can be subdivided into six categories starting from the left: 1) construction site planning and management, 2) construction activities, 3) physical characteristics and the associated changes within the construction site, 4) erosion and sedimentation processes, 5) management practices needed for controlling erosion and sedimentation, and 6) quantity and quality of materials imported into or exported out of the system.

Construction activities normally make permanent changes within the watershed. The characteristics of soil erosion and deposition also change quite significantly. At the same time, some permanent solutions to the problem of soil erosion can be achieved within this subsystem.

The first-order interactions between construction activities (Box 75) and other components can be traced as follows: construction activities (Box 75) impact soil structure (Box 396), soil exposure (Box 389), slope (Box 382), drainage pattern (Box 106), and waste disposal (Box 479). On the other hand, construction site planning and best management practices (Box 77,45) will impact construction activities (Box 75). The second- and third-order interactions between this component and other components can similarly be examined.

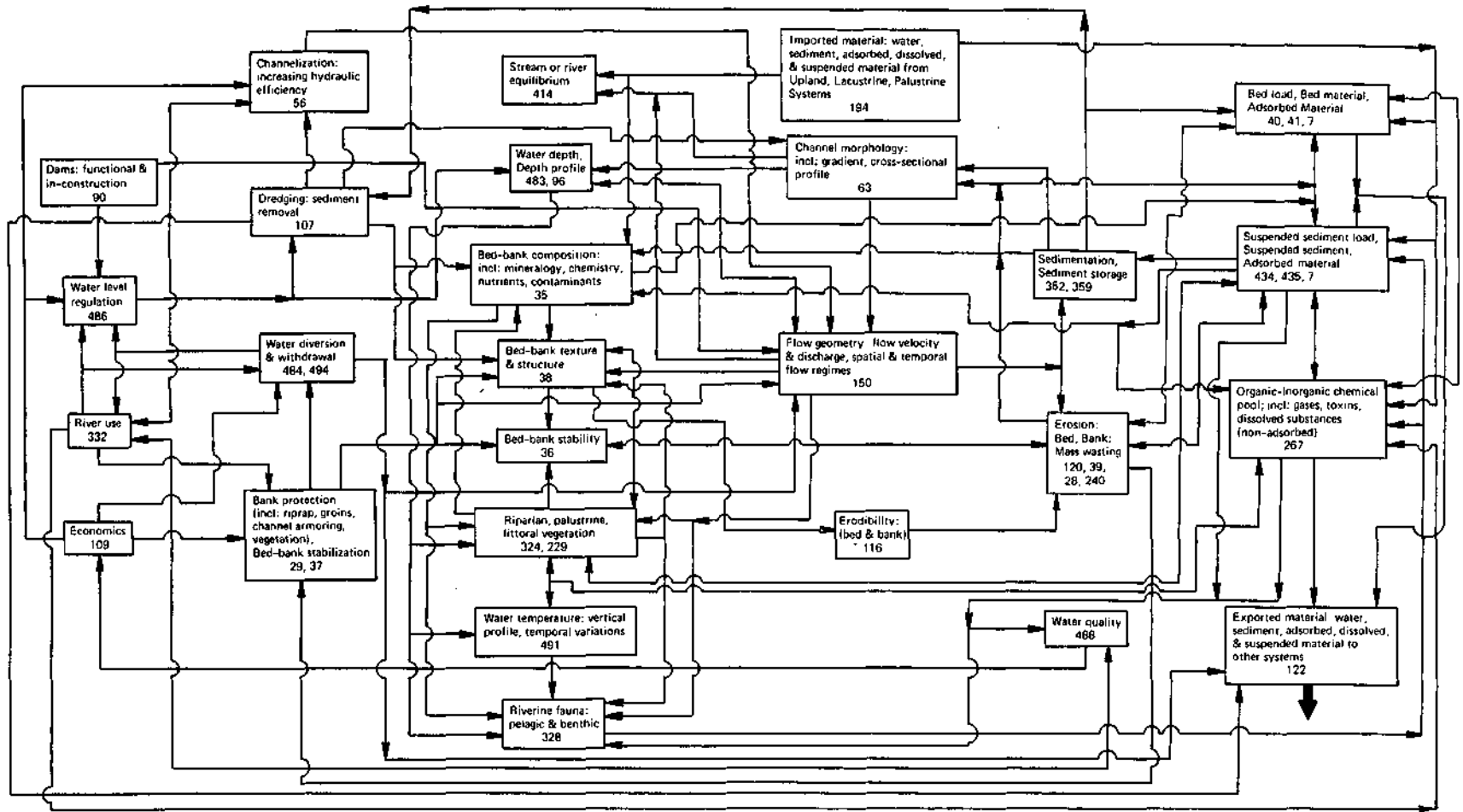


Figure I-8. Level II model for the Streams and Rivers (Riverine) System

Streams and Rivers (Riverine) System

Figure I-8 shows the Level II model for the Streams and Rivers System. This model encompasses the system which is primarily responsible for the transport and movement of eroded sediments downstream from source areas. Moreover, transport and movement of sediment become visible within this system.

The model can be subdivided into four major categories from left to right: hydraulic and hydrologic controls including modifiers, physical characteristics of the system, factors controlling the movement of water and sediment, and quantity and composition of the materials imported into or exported out of the system.

Most streams and rivers in Illinois are not significantly controlled except for man-made dams and locks and dams on the three major rivers. Most of the rivers are in a state of dynamic equilibrium where erosion and sedimentation processes are constantly taking place. The dynamic equilibrium is generally altered when an excessive amount of sediment or water is delivered to the system or when man-made changes such as dams or straightening of meanders take place.

An example of first-order interactions within this system is as follows: erosion, including bed, bank, and mass wasting (Box 120,39,28,240) is impacted by flow geometry (Box 150) and erodibility of bed and bank (Box 116), whereas erosion impacts bank protection, bed-bank stabilization (Box 29,37); channel morphology (Box 63); and bed-bank composition (Box 35). Two-way interactions exist between erosion and bed-bank stability (Box 36); suspended sediment load, suspended sediment, adsorbed material (Box 434,435,7); and bed load, bed material, adsorbed material (Box 40,41,7). Second- and third-order interactions can be deduced by following arrows from any one of these boxes.

Wetland System (Palustrine System)

The Palustrine System has been subdivided into the Permanent Wetland Subsystem and the Seasonal Wetland Subsystem. Figures I-9 and I-10 show the Level II models for the Permanent and Seasonal Wetland Subsystems, respectively. A permanent wetland is always under water, whereas a seasonal wetland will be without surface water for at least part of the year. Both wetland subsystems have emergent vegetation that can exist either independently or within the fringes of streams or lakes. Wetlands play significant roles by exchanging organic and inorganic matter between the Upland, Riverine, and Lacustrine (Lakes and Reservoirs) Systems.

Both models can be subdivided into four categories from left to right." In the Permanent Wetland Subsystem, wetland use, economics, and wetland changes constitute the first group of parameters, while in the Seasonal Wetland Subsystem, economics, land use, and wetland control structures constitute the first group of parameters. The remaining groups of parameters are the same for both subsystems: physical features and structures, habitats, and vegetation; mechanics and types of soil erosion and the way these are impacted by the hydraulic geometry of the wetland system; and imported and exported material and storage variables related to the erosion and sedimentation cycle.

The first-, second-, or third-order interactions of the parameters can again be analyzed by following the arrows from any of the specific boxes.

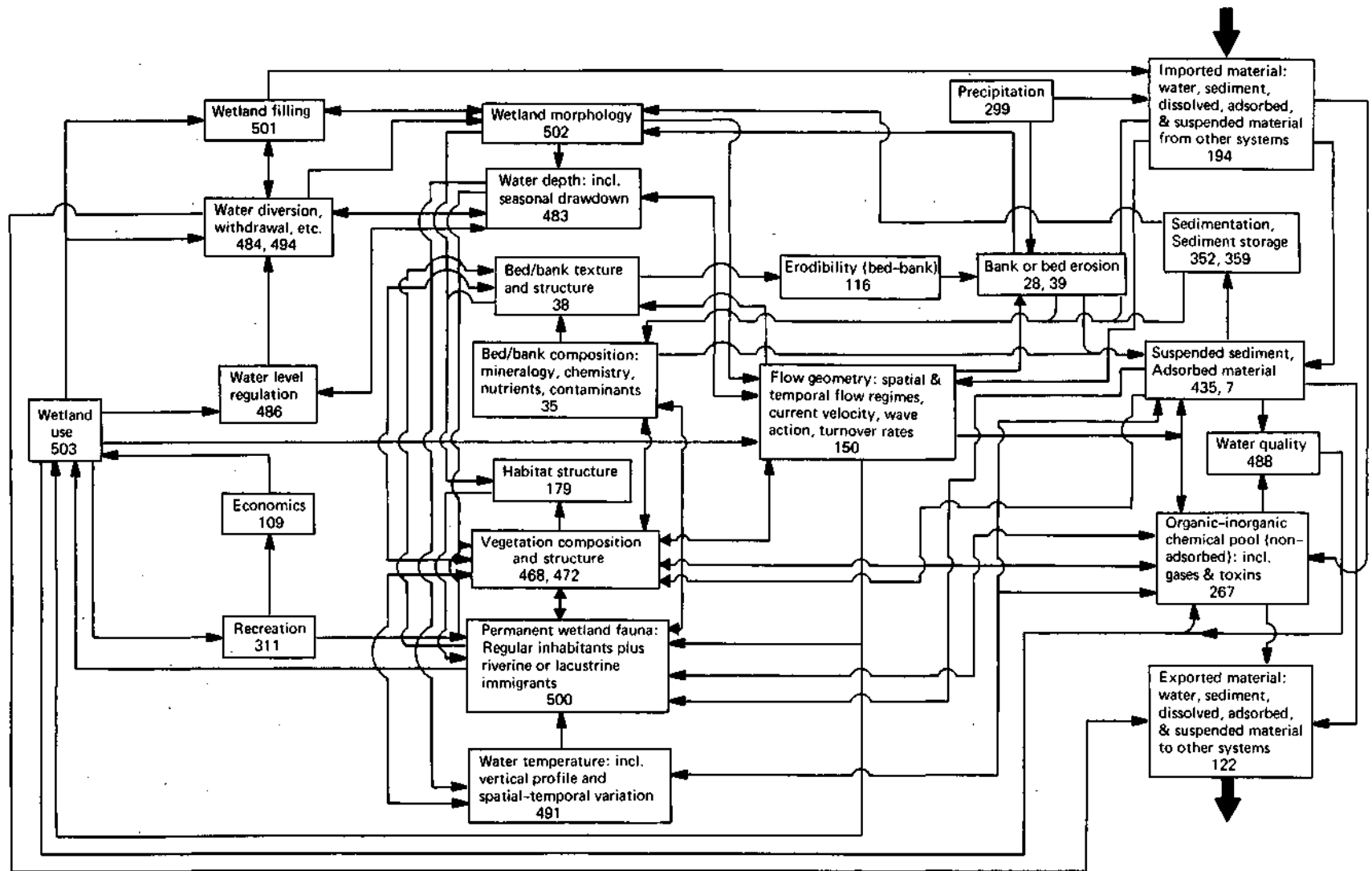


Figure I-9. Level II model for the Permanent Wetland Subsystem

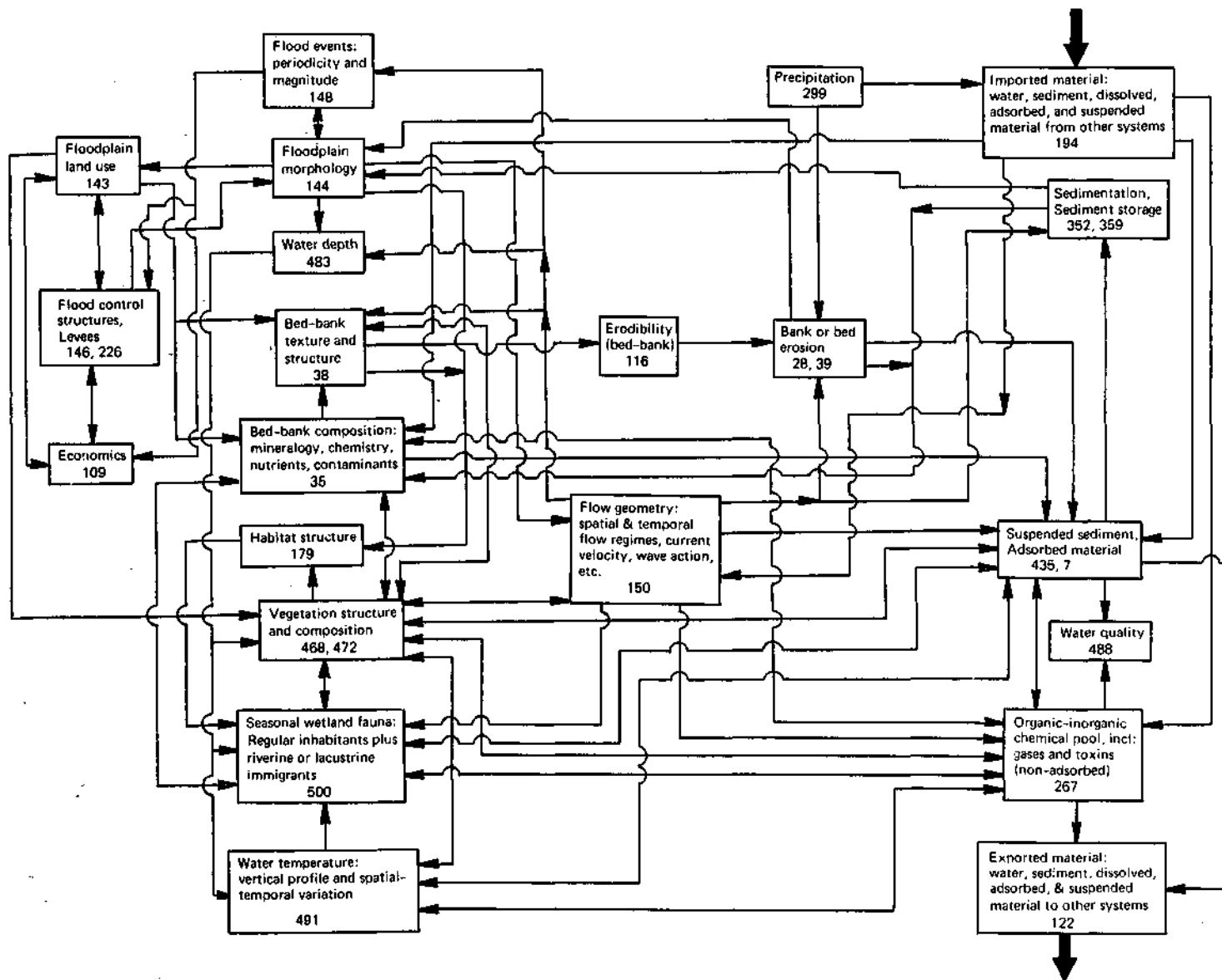


Figure I-10. Level II model for the Seasonal Wetland Subsystem

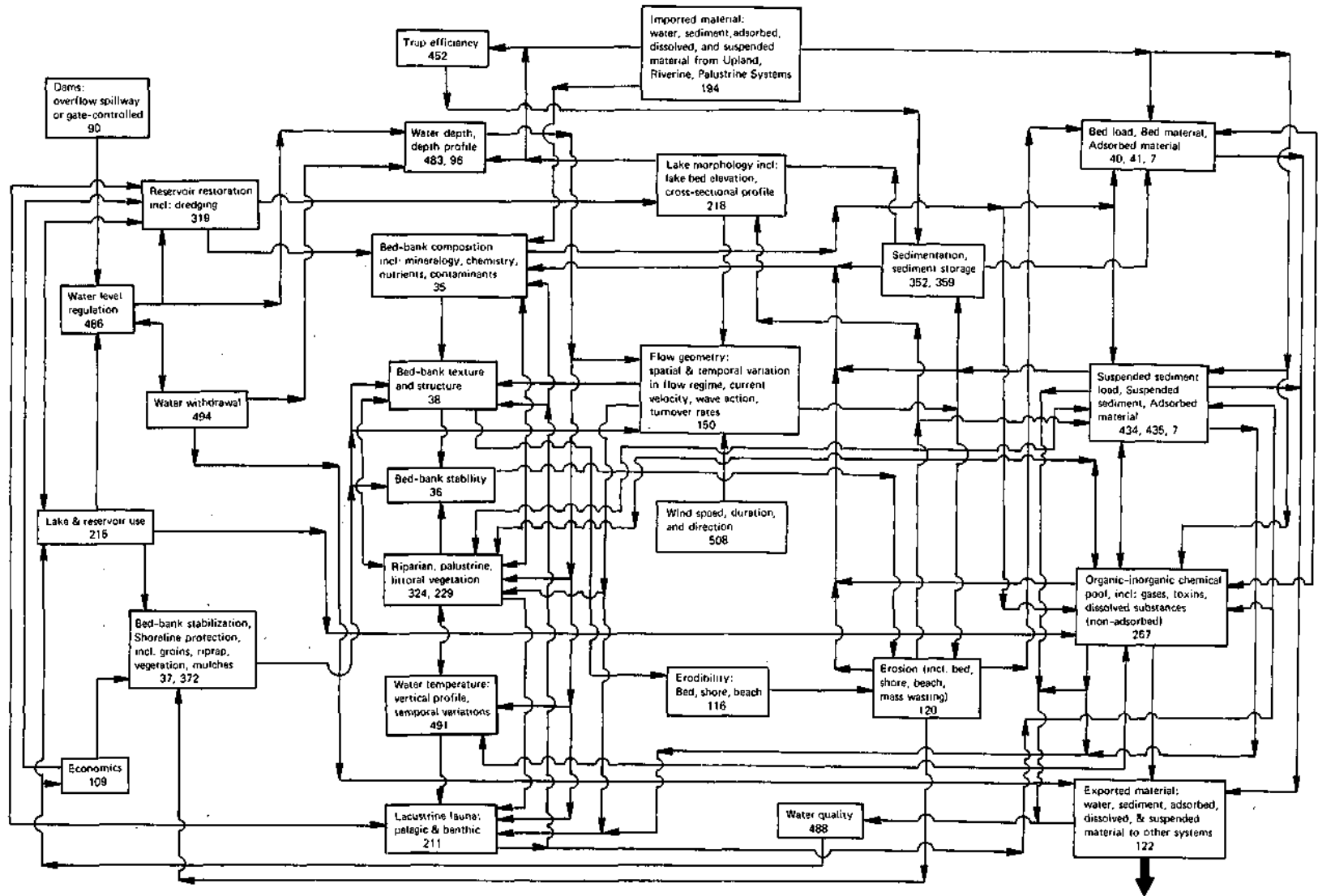


Figure I-11. Level II model for the Lakes and Reservoirs (Lacustrine) System

Lakes and Reservoirs (Lacustrine) System

Figure I-11 shows the Level II model for the Lakes and Reservoirs System. This model encompasses all Illinois lakes including backwater lakes, farm ponds, man-made or natural lakes, oxbow lakes, and reservoirs.

The model can be subdivided into four major categories from left to right: use, management, and alteration of lakes; physical characteristics of lakes; physical and geometrical factors that control the movement and deposition of sediment; and the quantity and quality of the sediment that is being deposited in or exported out of the system.

Lakes and reservoirs are extremely important for the health, welfare, and economic growth of Illinois. Most Illinois lakes serve as public water supply sources, and almost all lakes are used for recreation. Except in a few cases, the lake levels are not controlled and water flows downstream over the uncontrolled spillway.

With regard to erosion and sedimentation, the major problems facing Illinois lakes are excessive sedimentation rates, degradation of lake water quality, and wave erosion of the lake shores. The physical, geological, and land use character of the lake watershed and the physical characteristics of the lake contribute significantly toward the input and output of sediment to and from this system.

An example of the interactions in this model would be as follows: trap efficiency (Box 452) is impacted by imported material (Box 194) and lake morphology (Box 218), whereas trap efficiency (Box 452) impacts sedimentation, sediment storage (Box 352,359), which in turn impacts exported material (Box 122) through bed load, bed material, adsorbed material (Box 40,41,7). The other interactions can easily be traced by following the arrows shown for any component.

Comments Related to Level II Models

It is important to recognize the significance of the models discussed so far since the remaining portions of the report are based on these diagrams. The models represent in diagrammatic format the interaction of erosion and sedimentation processes with other processes in Illinois at a useful intermediate level of detail. As such, they explicitly describe the most important interactions of the erosion and sedimentation processes. Furthermore, the existing literature is organized according to these models. Thus, the reader can examine the models, find topics of interest, identify the model components and interactions which describe the topics of interest, and then quickly search the bibliography for information which addresses the topics of interest. Finally, the models also have assisted in identifying gaps in our knowledge and priorities for research relating to soil erosion and sedimentation.

WORKSHOP

After the models were in draft form and the literature search was nearly complete, a two-day workshop was convened in July 1983 to review the project. Twenty-nine individuals from fourteen agencies provided excellent assistance in refining the models, suggesting important literature citations, identifying information gaps, and recommending high priority research needs. A roster of workshop attendees is provided in the appendix.

INFORMATION GAPS AND RESEARCH NEEDS

A comprehensive attempt to identify information gaps and high priority research needs was one of the major goals of the present project. These gaps were identified through reviews of the literature as related to the models, through interviews with agencies, and through discussions at the workshop. The following list shows the topics recognized to be those of greatest importance for future research efforts, subdivided under the following subtitles: data needs, erosion, habitats, management, methods, outreach, sedimentation, sediment transport, and water quality.

Data Needs

- Collection of instream sediment data from benchmark stations
- Determination of lake sedimentation rates
- Identification of suitable reservoir sites
- Sediment data on all phases of erosion and sedimentation

Erosion

- Measurement of erosion rates in relation to the erosion cycle
- Rainfall-runoff relationships for regional watersheds
- Impact of flow velocities, stages, water level fluctuations, waves, and geological conditions on stream bank erosion
- Characterization of wind erosion in Illinois
- Relationship between soil erosion and agricultural practices
- Methods of reducing sheet and rill erosion
- Evaluation of selectivity and sorting processes in interrill areas
- Effect of soil erosion on productivity and the time requirement for topsoil formation
- Quantification and mitigation of erosion from construction sites

Habitats

- Impact of sediment on aquatic habitats, including wetlands, lakes, streams, and rivers
- Susceptibility of wetland types to changes in water level, sediment load, and water quality

Effects of sediment on toxicity levels of pollutants
Effects of sediment on structure of aquatic communities
Status of identified natural areas in relation to erosion and sedimentation

Management

Methods for reduction of sedimentation in backwater lakes
Techniques for dredging backwater lakes
Impacts of stream channelization
Effects of conservation tillage techniques on wildlife habitat and water quality
Physical and biological impacts of lakes and dams on the Illinois and Mississippi Rivers and their relationships to water management
Possibilities for thalweg disposal of dredged materials
Sediment control from surface-mined areas
Reclamation of highly eroded land
Development of regulatory laws on soil erosion

Methods

Relationship between the Universal Soil Loss Equation and sediment load of receiving streams
Adequacy of existing sediment data and their application
Application of modified ANSWERS model to simulate watershed erosion
Development of linear programming models for soil erosion, crop productivity, and wildlife habitat values

Outreach

Methods of educating landowners about erosion and sedimentation
Transfer of technical results to direct application, specifically for small watersheds
How to meet T-values by the year 2000

Sedimentation

Impact of sediment loads from small but steep-gradient watersheds
Trap efficiencies of Illinois lakes
Sediment and dredging requirements on the Illinois and Mississippi Rivers
Sources and rates of sedimentation within a basin and in wetlands, lakes, streams, and rivers

Sediment Transport

Sediment transport characteristics of streams and rivers including Mississippi, Illinois and Ohio Rivers
Mathematical modeling of sediment movement for large and small rivers
Determination of the resuspension, lateral movement and pulse input of sediment to backwater lakes due to river traffic
Instream sediment load during storm events

Water Quality

Role of sediment in transporting pollutants and in affecting water quality
Identification of streams, lakes, and watersheds that could have a great effect on water quality due to increased erosion and sediment load
Quantification of water quality improvement resulting from a reduction of soil erosion due to agricultural and construction practices
Impact of sedimentation on water quality and lakes
Water quality improvement from a reduction in sheet, rill, and stream bank erosion
Determination of water quality variabilities in streams during storm events

CONCLUDING REMARKS

Volume I has presented a broad outline of this fairly extensive and detailed project. The project objectives, literature review, agency survey and responses, development of the conceptual models (including a brief description of the models), the interagency workshop, and the significant gaps in information and data have been described in this volume. Volume II includes detailed descriptions of the models and model interactions, as well as the bibliography.

REFERENCE

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. *Classification of Wetlands and Deep Water Habitats of the United States*. U.S. Department of Interior, Fish and Wildlife Service, Biological Services Program, FWS/OBS-79/31.

APPENDIX - LIST OF WORKSHOP PARTICIPANTS

Names (in alphabetical order)	Affiliations
Nani G. Bhowmik	Illinois State Water Survey
Nancy R. Black	Illinois State Geological Survey
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Leon Follmer	Illinois State Geological Survey
Jonathan Goodwin	Illinois State Geological Survey
Julia B. Graf	U.S. Geological Survey
David L. Gross	Illinois State Geological Survey
Marvin E. Hubbell	Illinois Department of Agriculture
Louis Iverson	Illinois Natural History Survey
William A. Jansen	Illinois Department of Conservation
George Johnson	U.S. Army Corps of Engineers, Rock Island District
J. Kent Mitchell	Agricultural Engineering, University of Illinois
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Bill Rice	Illinois Environmental Protection Agency
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