fill buried channels and make up a significant portion of the fan deposit.

The upper portion of the Yellow River Basin occurs in the **Maxinkuckee Moraine** (figure 14) and ground moraine east of the moraine. The moraine consists of coalesced deposits of several glacial advances and is the most complicated terrain in the Kankakee River Basin. The deposits are uncommonly heterogeneous and are predominantly derived from a complex of outwash fans that drained eastward and southeastward. The moraine surface shows evidence of glacial stagnation that produced a mixture of deposits formed in outwash plains, collapsed drainage channels and lakes, till plains, and eolian plains.

The **Iroquois Moraine** is capped by thin *ablation* tills composed of moderately variable sandy or silty loams. Two major till sequences, thick lacustrine materials, and sand deposits lie beneath the ablation till. The upper till sequence is comprised of vertically uniform, silty loams having low areal variability. The lower till sequence is comprised of silty clay loams having low to moderate areal variability and no consistent vertical variability. Thick underlying lacustrine deposits are highly variable and have no consistent vertical variability. Sand deposits within the moraine are generally thin and are highly variable in occurrence.

The southern slope of the Iroquois Moraine is dominated by linear ridges, probably resulting from the Erie Lobe ice shearing up against the moraine which was formed earlier by the Michigan Lobe. The ridges are commonly sand-dominated and comprise some of the principle sand deposits of the moraine.

The **Iroquois Lowland**, consisting primarily of ground moraine, encompasses the floodplain of the Iroquois River and a major tributary, Sugar Creek. The lowland was formed during stagnation of the Erie Lobe. The Iroquois River Basin is coincident with the area where the Erie Lobe ice extended into the basin.

Low relief and subdued ice-disintegration features characterize the western part of the Iroquois Lowland. Features include broadly undulating topography, basins of internal drainage, and scattered linear sand ridges. The topography to the east is somewhat more rugged, and ice-disintegration features, especially ridge and trough systems, are better developed. The surficial cover in this eastern area is sand-dominated. Southeast of Rennselaer the sand has been remobilized into dunes.

A typical vertical sequence of deposits in the Iroquois Lowland consists of a thin upper unit of various ice-disintegration deposits overlying even thinner basal-ice deposits of silty loam till. These normally overlie a considerably thicker, older silty clay loam till which in turn rests either on lacustrine mud or bedrock.

Where deep bedrock valleys cross the area, the deposits in the valleys probably are tills and associated sand deposits. Some of the thicker sand accumulations may be alluvial channel fills.

There is relatively little sand throughout much of the volume of unconsolidated sediments in the Iroquois Lowland, and the sand that is present occurs at the surface or in deep bedrock valleys.

East of the Maxinkuckee Moraine the topography is dominated by features that are characteristic of ground-moraine deposits. The surface deposits are part of the **Nappanee Till Plain**. Numerous closed depressions form lakes or marshes covered by peat. The ground moraine of the Nappanee Till Plain is characterized by thick sequences of till which contain sand and gravel lenses of variable thickness and distribution.

A very broad apron of permeable sand and localized gravels characterizes the **Valparaiso Outwash Fan** east of the city of Valparaiso. A veneer of till caps the outwash on the moraine crest. The surface of the outwash fan is generally smooth, especially in the southern fan area. However, in the upper fan and locally in the mid-fan area, the topography is more irregular and is characterized by numerous muck and peat-filled basins of internal drainage.

West of Valparaiso, a narrow fringe of outwash drapes the southern margin of the moraine. Drilling information suggests that this sand deposit extends under the moraine and that it is continuous with sand deposits of the Kankakee River floodplain to the south. At the surface, however, the outwash sands are distinguished from those of the floodplain by a prominant erosional scarp as much as 50 feet high.

During the late Pleistocene Epoch the **Kankakee Floodbasin** was occupied by a broad low-gradient meltwater stream, which deposited a widespread sand sheet over lacustrine muds. During the subsequent Holocene Epoch the channel sands were mantled by fine-grained overbank *alluvium* and organic-rich muds deposited as the low-gradient, highly sinuous post-glacial Kankakee River migrated across the floodplain.

In the upper Kankakee River Basin in St. Joseph County, outwash deposits of the floodbasin are more complex than they are farther west. In upper reaches, outwash deposits are thicker, include many gravel

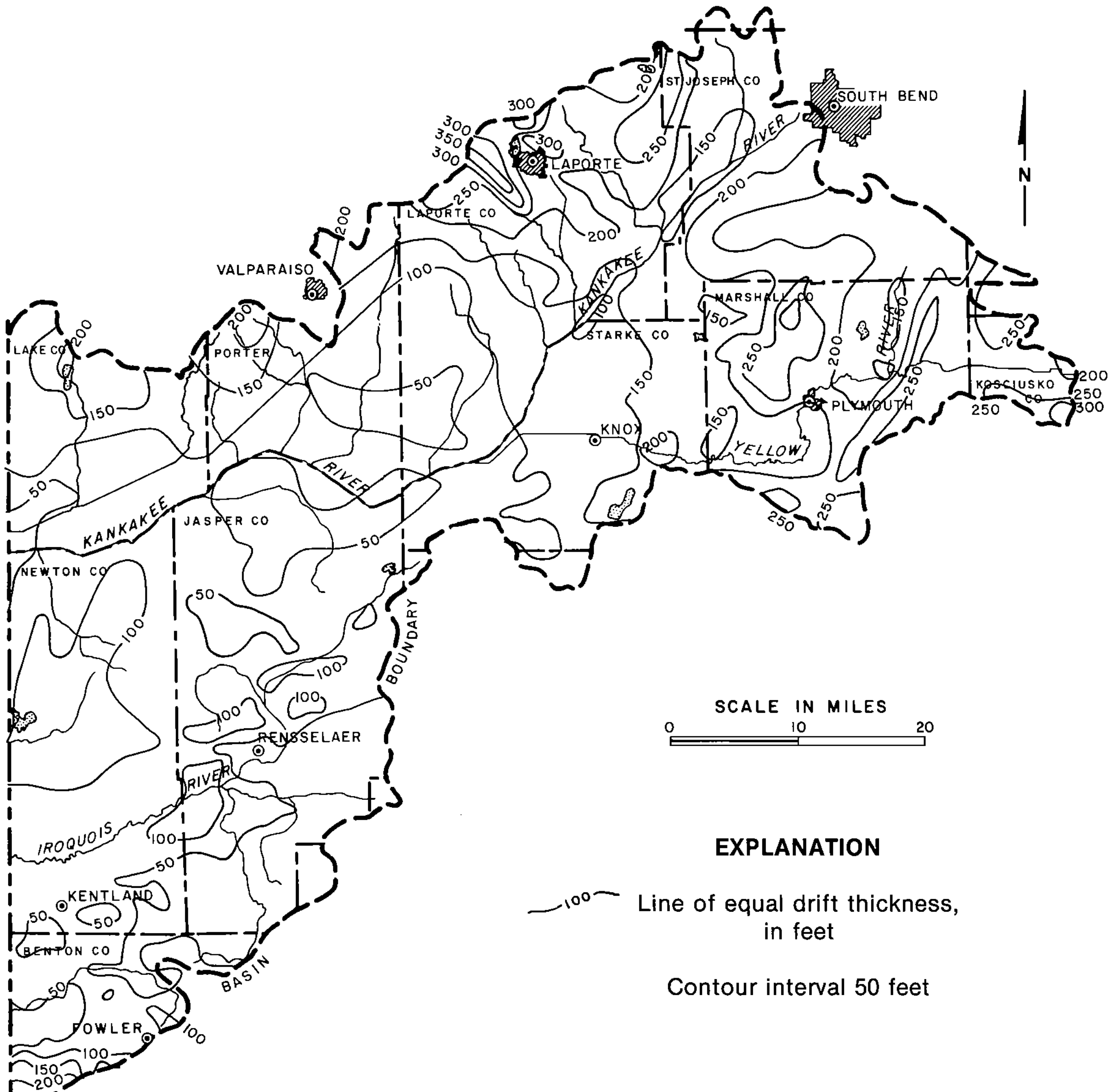


Figure 15. Thickness of unconsolidated deposits
(Adapted from Gray, 1983)

lenses, and appear to represent multiple stages of formation. The sediments in this area were deposited through interaction of processes that formed the Maxinkuckee and Valparaiso Moraines and the *fluvial* deposits in the St. Joseph River Basin.

The north margin of the floodbasin west of Kouts is characterized by a pronounced scarp which marks where the meltwater stream eroded the toe of the Valparaiso outwash apron and incised the modern floodplain.

**Eolian sands** (figure 14) occur primarily along the southern margin of the floodbasin where they form a broad plain. The sands are fine grained and well sorted and overlie heterogeneous material deposited in earlier glacial stages. In the Kankakee Floodbasin, dunes and sheets of eolian sand overlie fluvial sands or organic muds, whereas on the northern flank of the Iroquois Moraine, they overlie a mix of ice-contact gravels, organic mud and peat, and till. In the intermoraine lowland, the sand sheet and dunes overlie till.

### Unconsolidated thickness

The thickness of unconsolidated deposits in the Kankakee River Basin is related to the topography of the underlying bedrock and the types of glacial deposits. In general, unconsolidated deposits are thickest where moraines form topographic highs over bedrock valleys, and thinnest where a modern river valley overlies a bedrock high.

Unconsolidated deposits typically are thinner in the lower Kankakee River Basin than in the upper basin (figure 15). Unconsolidated thickness generally ranges from 50 to 100 feet in the lower basin, and from 100 to 250 feet in the upper basin. Unconsolidated thickness exceeds 350 feet west of LaPorte where the Valparaiso Moraine forms a topographic high over a bedrock valley.

In the eastern part of the upper basin, the unconsolidated thickness is generally more than 150 feet in the Nappanee Till Plain. Beneath the Maxinkuckee Moraine, the thickness exceeds 300 feet in places.

### Bedrock geology

Bedrock of the Kankakee River Basin is Paleozoic sedimentary rock except for the very deep Precambrian *igneous* basement rocks. More than 4,000 feet of gently dipping sedimentary rocks were deposited in shoreline and near-shore environments as the level of ancient seas alternately rose and fell relative to the land surface. The box on the following page summarizes the major depositional environments found in the Kankakee River Basin during the Paleozoic Era.

The Kankakee River Basin lies across the crest of the Kankakee Arch, which is a broad upward bow of the bedrock surface (figure 16). A low area in the arch called the Jasper Sag occurs in Newton, Jasper and Starke Counties (Pinsak and Shaver, 1964). The Kankakee Arch extends into southeast Indiana, where it is known as the Cincinnati Arch.

The Kankakee Arch separates two large structural basins, the Michigan Basin to the northeast and the Illinois Basin to the southwest (figure 16). Formations dip from the crest of the arch toward the basins at about 35 feet per mile. The crest of the arch has been planed off by erosion, and as a result, the oldest rocks at the bedrock surface occur along the crest of the arch and younger rocks slope away from the arch into neighboring basins.

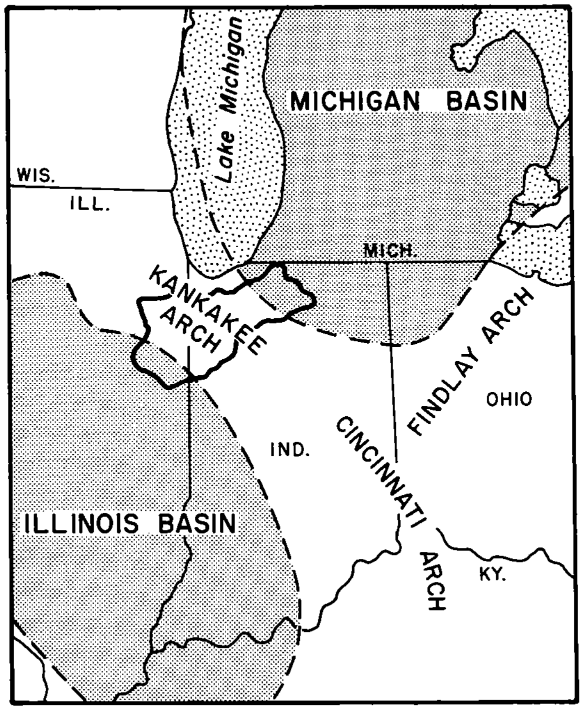


Figure 16. Regional bedrock structure

A major structural disturbance known as the Kentand Dome occurs near Kentland in south-central Newton County. The complexly folded, faulted, and truncated dome covers about 5 square miles, and is located on the extreme northeastern margin of the Illinois Basin. Within the anomalous structure, steeply dipping Ordovician and Silurian rocks have been uplifted more than 2,000 feet vertically from their normal stratigraphic position. Nearly horizontal Mississippian and Pennsylvanian rocks lie adjacent to the area (Gutschick, 1983).

Topographic differences in the bedrock surface in the Kankakee River Basin (figure 17) result from a combination of bedrock structure, differential erosion by streams and glaciers, and orientation and direction of glacial advances.

Bedrock surface elevations do not appear to be lithologically controlled. Bedrock highs are formed by different types of bedrock having differing ranges of resistance to erosion. The Borden Group siltstones, found in northern Benton County (figures 17, 18), form the highest bedrock elevations in the basin. The New Albany Shale forms an adjacent bedrock high in

## *History of bedrock deposition*

| ERAS | PERIODS | APPROXIMATE LENGTH IN YEARS | ROCK TYPES IN INDIANA |
|---|---|---|---|
| CENOZOIC | QUATERNARY (PLEISTOCENE EPOCH) | 1 MILLION | Glacial drift: *till, gravel, sand, silt (including loess), clay, marl, and peat* *(Till and gravel contain boulders of many kinds of sedimentary, igneous, and metamorphic rocks)* Thickness 0-500 ft. |
| CENOZOIC | TERTIARY | 60 MILLION | *Cherty gravels* *Sand and clay* — *Scattered deposits* |
| MESOZOIC | CRETACEOUS<br>JURASSIC<br>TRIASSIC | 70 MILLION<br>35 MILLION<br>30 MILLION | No deposits in Indiana |
| PALEOZOIC | PERMIAN | 25 MILLION | No deposits in Indiana |
| PALEOZOIC | PENNSYLVANIAN | 20 MILLION | *Shale (including carbonaceous shale), mudstone, sandstone, coal, clay limestone, and conglomerate* 1,500 ft. |
| PALEOZOIC | MISSISSIPPIAN | 20 MILLION | Upper Part: *alternating beds of shale, sandstone, and limestone* 500 ft. |
| | | | Middle Part: *limestone, dolomite; beds of chart and gypsum* 300 ft. |
| | | | Lower Part: *shale, mudstone, sandstone; and some limestone* 600 ft. |
| PALEOZOIC | DEVONIAN | 60 MILLION | Upper Part: *carbonaceous shale* 100 ft. |
| | | | Lower Part: *limestone, dolomite; a few sandstone beds* 40-80 ft. |
| PALEOZOIC | SILURIAN | 40 MILLION | *Dolomite, limestone, chert, siltstone, and shale* 100-300 ft. |
| PALEOZOIC | ORDOVICIAN | 70 MILLION | *Shale, limestone and dolomite* 700 ft. |
| | | | *Limestone, dolomite, and sandstone* — Not exposed at the surface in Indiana |
| PALEOZOIC | CAMBRIAN | 80 MILLION | *Sandstone and dolomite* — Not exposed at the surface in Indiana |
| | PRECAMBRIAN ERAS | 3 BILLION | *Granite, marble, gneiss, and other igneous and metamorphic rock types* — Not exposed at the surface in Indiana |

Deposition of the preserved sedimentary rocks began in the Late Cambrian Period as the sea invaded the area which is now the Kankakee River Basin. Beach sands derived by erosion from the igneous basement rocks were deposited to form the Mount Simon Sandstone. As sea level continued to rise through the Early Ordovician Period, the depositional environment shifted to one progressively favoring shale and limestone. Toward the end of the Lower Ordovician Period, the shallow sea began to retreat from the area and erosion removed the upper portion of the Knox Formation (Gutstadt, 1958).

Sea level again rose and reached its maximum known *transgression* upon the North American continent. The basal St. Peter Sandstone was deposited, followed by extensive and fairly uniform limestones. An abrupt change at the end of Trenton Limestone deposition marked the end of widespread carbonate deposition. Physical and biological environments changed rapidly as the shallow water in which the Maquoketa Group was deposited alternated between clear and muddy (Gutstadt, 1958).

A period of non-deposition and erosion occurred through the Late Ordovician and Early Silurian Periods. Land-locked reef-fringed basins developed in the region now occupied by the Great Lakes. As inland seas withdrew at the end of Early Paleozoic time, precipitation of evaporites such as salt and gypsum occurred within the basins (Levin, 1989). Traces of the evaporities extend into LaPorte County.

Deposition of Silurian and Devonian sediments was largely influenced by local conditions. The subsidence of the Michigan Basin and the expansion of reefs determined the local conditions under which the limestones and shales of the Silurian and Devonian Age were deposited (Pinsak and Shaver, 1964).

Predominant carbonate sedimentation gave way to shales in Middle and Late Devonian in the region east of the Mississipi Valley. The change to *clastic* deposition was a consequence of mountain-building in the Appalachians. Highlands formed during this time were rapidly eroded and *clastics* were transported westward to form an extensive apron of sediments (Levin, 1989).

Sediment that ultimately became black shale was deposited in a transgressing *epicontinental* sea that covered much of Indiana. Deoxygenated conditions caused by lack of water circulation between the epicontincental waters and the open ocean resulted in an accumulation of organic matter as an important part of the sediment.

A densely intertwined mat of floating algae is postulated as the source of much of the organic matter in the New Albany black shale. Such a mat may have aided in establishing *reducing* conditions by restricting wind-induced water circulation. Extensive disruption and/or destruction of the floating mat by storms or other cause resulted in deposition of extensive greenish-gray shale beds having little or no organic matter. Correlative rocks in the Michigan Basin sequence were continuous with the New Albany Shale before erosion removed upper Devonian rocks from the crest of the Kankakee Arch (Lineback, 1970).

The sea again invaded the land, shifting the depositional environment to one favoring carbonates. Carbonate deposition of the Mississippian sea was extensive and was the last of great Paleozoic flooding of the North American *craton*.

At the end of Mississippian time, seas finally left the craton and the exposed terrain was subjected to erosion that resulted in one of the most widespread regional unconformities in the world. Erosion not only was areally extensive, but also beveled entire systems of older rocks on arches and domes. Subsequent burial of the erosion surface by sedimentation during Pennsylvanian time created the regional Mississippian-Pennsylvanian unconformity.

This period of erosion removed progressively older Mississippian formations at increasing distances north of the Ohio River. In northern Indiana, the Mississippian-Pennsylvanian unconformity may represent as much as 8 million years of erosion. In southern Indiana that same unconformity may represent less than 3 million years of erosion. In the Kankakee River Basin, Pennsylvanian strata lie on rocks as old as Late Devonian. Rocks above the erosional hiatus differ markedly from those below (Droste and Keller, 1989).

It was not until near the beginning of Middle Pennsylvanian time that the seas were able to encroach onto the long exposed surface of the craton. The initial Pennsylvanian deposits, largely shales, were deposited over a *karst* topography developed on Mississipian limestone. One of the most notable aspects of Pennsylvanian sedimentation in the middle and eastern states is the repetitive alternation of marine and non-marine strata caused by minor oscillations in sea level. In Indiana, the deposits are approximately half marine and half non-marine. Vegetation accumulated in this coastal swamp condition producing coal deposits as a predominate feature of Pennsylvanian deposition. The bedrock was subsequently exposed to erosion for many years, thus allowing the existing bedrock surface topography to develop.

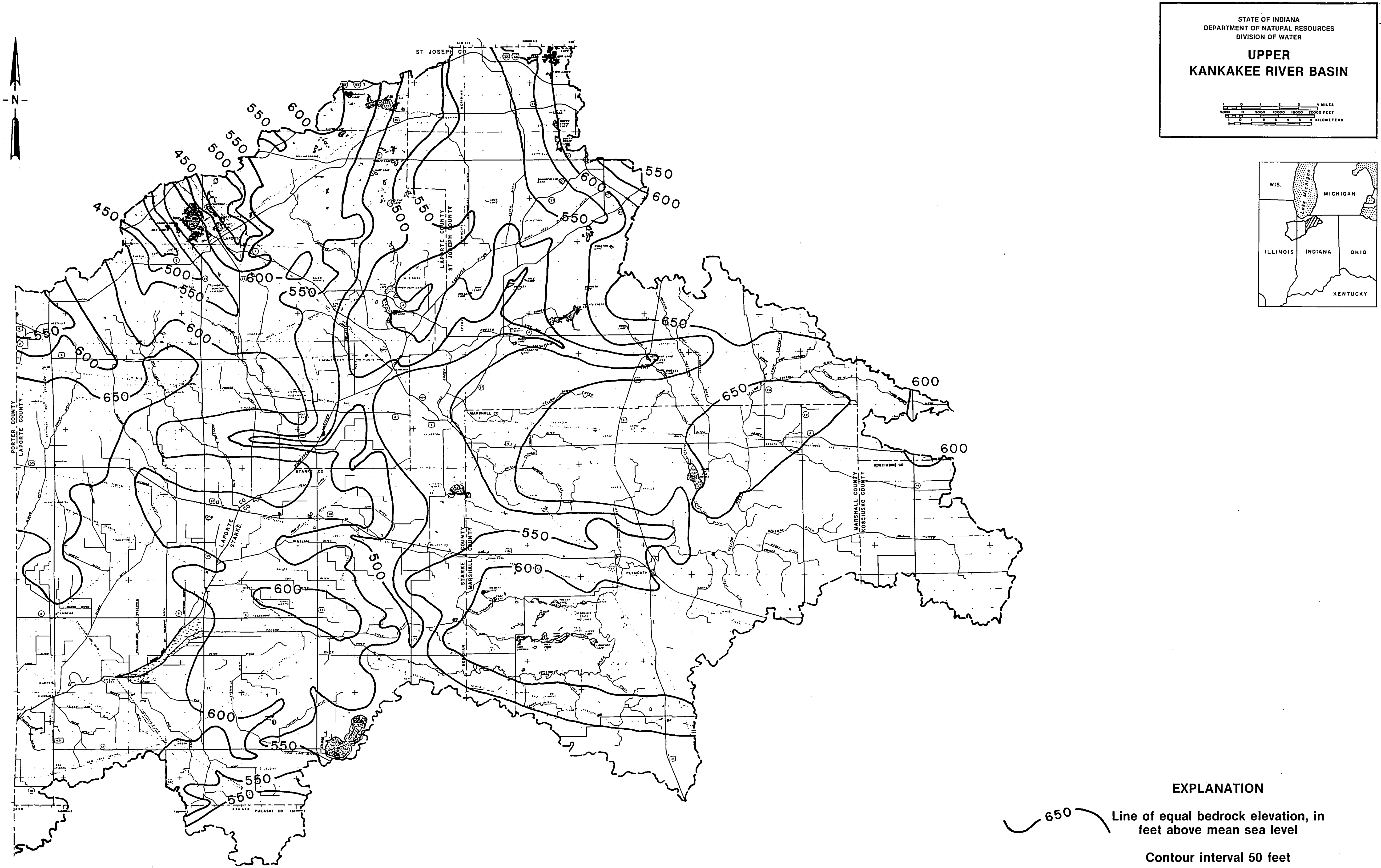


Figure 17a. Bedrock topography

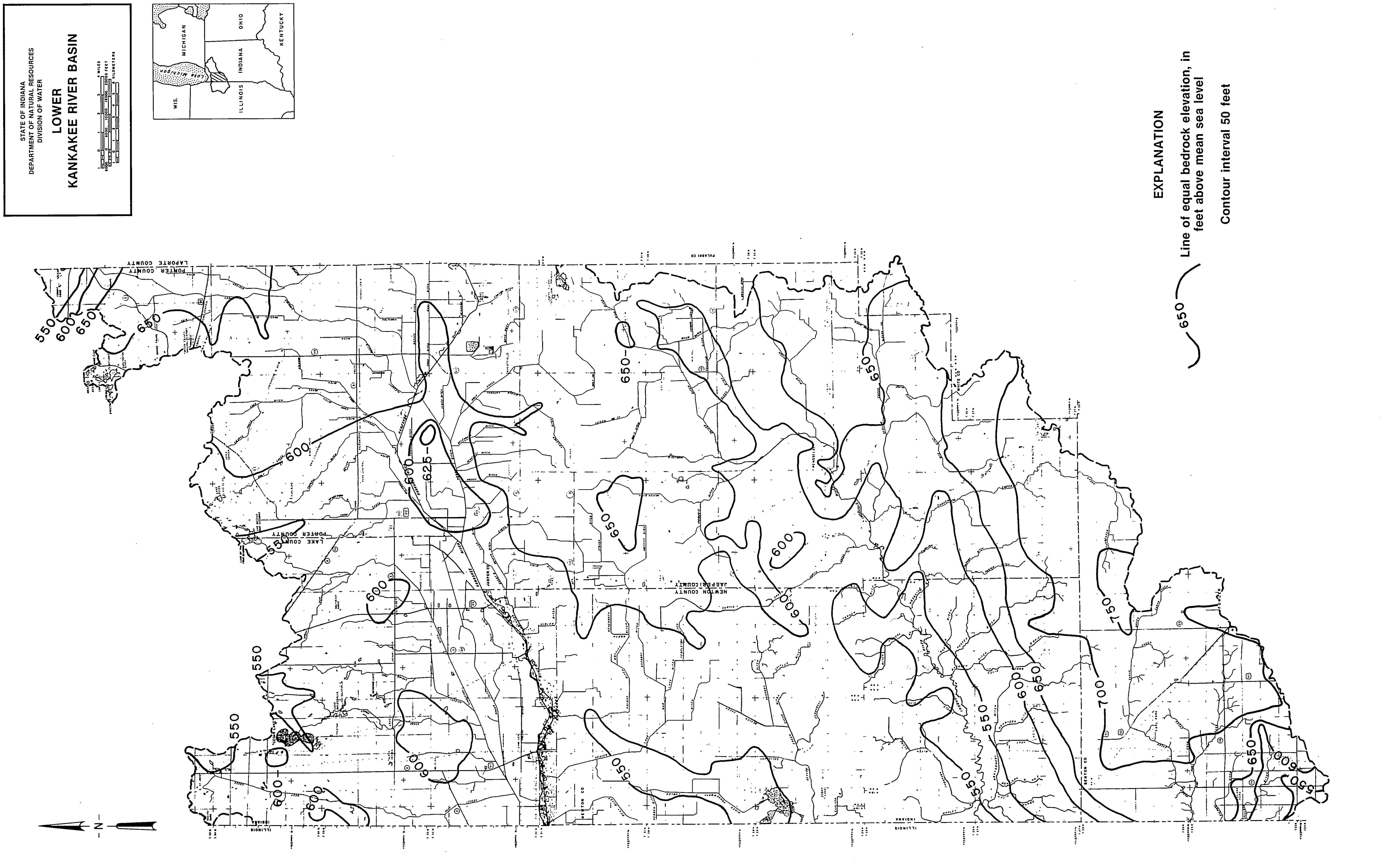


Figure 17b. Bedrock topography

southern Jasper County. Ellsworth Shale forms bedrock highs in northeastern Marshall County, southeastern St. Joseph County, and in an area southeast of Valparaiso in Porter and LaPorte Counties. Silurian and Devonian limestone and dolomite form bedrock highs on the crest of the Kankakee Arch.

Bedrock valleys radiate away from the crest of the Kankakee Arch following the regional dip of the bedrock. The valleys were incised into the bedrock during the long period of erosion following the Pennsylvanian Period.

The most well developed bedrock valley system trends north-south through eastern LaPorte and Starke Counties (figure 18). The elevation of the main valley is 500 feet m.s.l. Tributary valleys branch east and west from the main valley.

Equally deep but less developed valleys radiate from the basin of Lake Michigan southward to the Valparaiso Moraine. These valleys may have been enlarged or deepened by the Lake Michigan Lobe when it advanced southward.

Another large bedrock valley lies beneath the Iroquois River and extends from the town of Mt. Ayr into eastern Illinois. This valley has a moderately well-developed drainage network.

Rocks in the Kankakee River Basin which occur at the bedrock surface represent a veneer of the 4,000 feet of sedimentary rock covering the granitic basement (figure 19). Most of the sedimentary rock is Cambrian and Ordovician in age. Rocks at the bedrock surface range from Silurian to Pennsylvanian in age. Details of stratigraphy, structure, and sedimentology of the basin may be obtained from Becker (1974), Doheny and others (1975), Droste and Shaver (1982), and other references cited in the text.

**Silurian**-Age rocks are the oldest rocks at the bedrock surface in the Kankakee River Basin. Gray and others (1987) identify these rocks as members of the Wabash Formation, which consists of dolomite, dolomitic limestone, and limestone. Shaver and others (1986) describe four principal lithologies that intergrade and replace one another spatially within the Wabash Formation.

Rocks of **Devonian** Age are found at the bedrock surface in much of the basin (figure 18). The oldest of the Devonian rocks in the basin belong to the Muscatatuck Group. The Muscatatuck Group consists of limestone, dolomite, and perhaps evaporite deposits in its lower part. Common lithologies are described by Shaver and others (1986).

The upper Devonian Antrim Shale lies above the Muscatatuck Group on the northern slope of the Kankakee Arch. The Antrim Shale consists mainly of brown to black non-calcareous shale. However, calcareous shale, limestone and sandstone are reported in the lower parts of the unit in some areas in LaPorte County (Shaver and others, 1986).

In the Illinois Basin, the **Upper Devonian** to **Lower Mississippian** New Albany Shale overlies the Muscatatuck Group. The New Albany Shale consists of brown to black carbonaceous shale, green to gray shale, and minor amounts of dolomite and sandstone. The New Albany Shale is largely correlative with the Antrim Shale of the Michigan Basin (Shaver and others, 1986).

The **Devonian** and **Mississippian**-Age Ellsworth Shale occupies a large area of the bedrock surface in the northern part of the Kankakee River Basin (figure 18). The Ellsworth Shale is characterized by gray-green shale having limestone or dolomite lenses in the upper part and alternating beds of gray-green shale and brown-black shale in the lower part. The boundary between the Antrim Shale and the Ellsworth Shale is *conformable* and marked by the lowest green-gray shale bed.

The **Mississippian** Rockford Limestone conformably overlies the New Albany Shale in the Illinois Basin. Limestone is the predominant lithology, but shale, siltstone, and dolomite also occur. The limestone is usually gray, fine grained, *ferruginous*, and slightly *fossiliferous*. It may be dolomitic and *argillaceous*, having thin gray-green shale zones interbedded in the limestone.

The Mississippian Borden Group makes up the bedrock surface in the southwest part of the basin (figure 18). The Borden Group mainly consists of gray argillaceous siltstone and shale interbedded with limestone lenses.

Small *outliers* of **Pennsylvanian** Age rocks occur in southwest parts of the basin (figure 18), including the area known as the Kentland Dome. These rocks are of the lower Pennsylvanian Raccoon Creek Group, which consists of sandstone, shale, and minor amounts of limestone and coal.

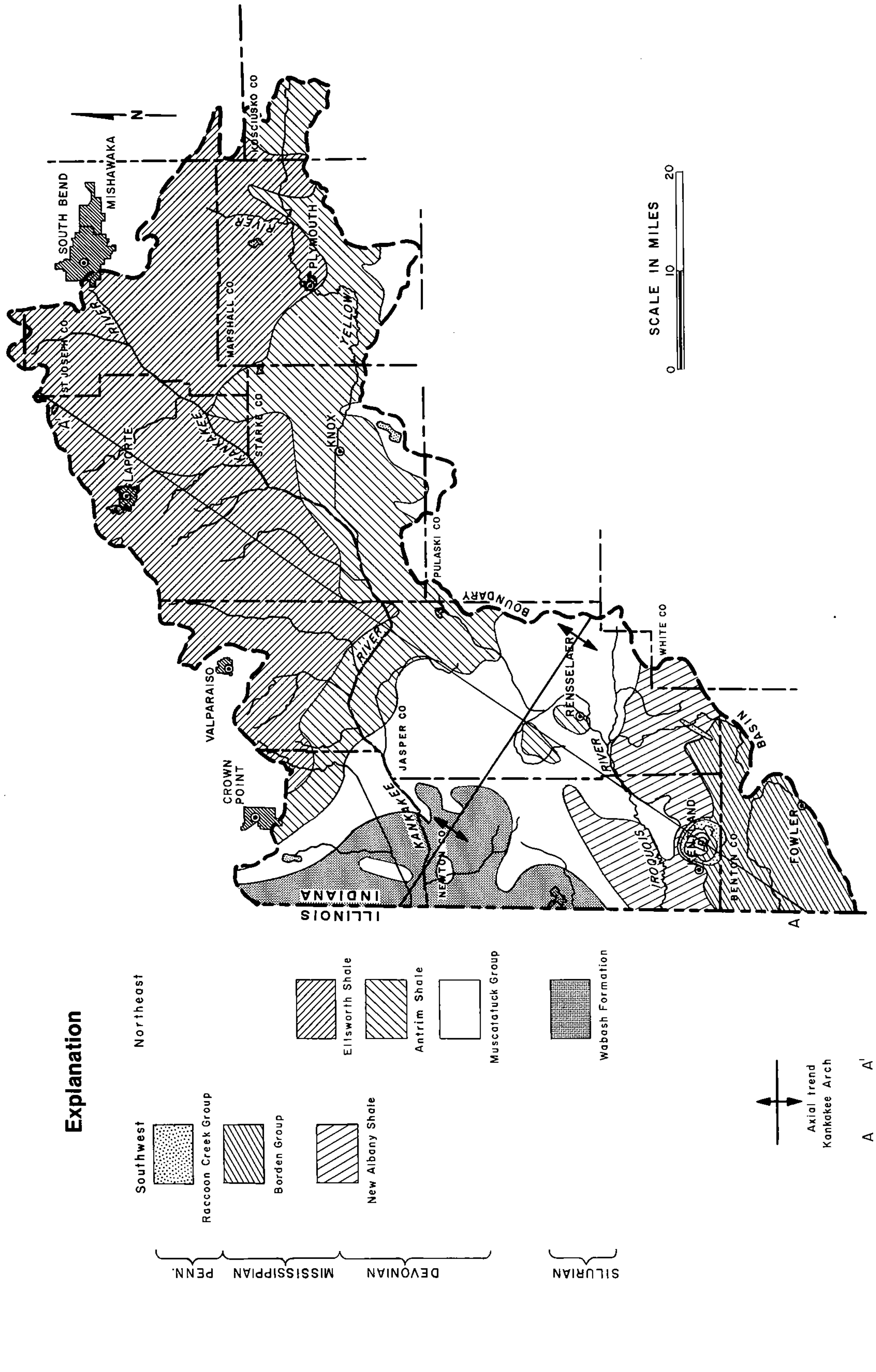


Figure 18. Bedrock Geology
(Adapted from Gray and others, 1987)

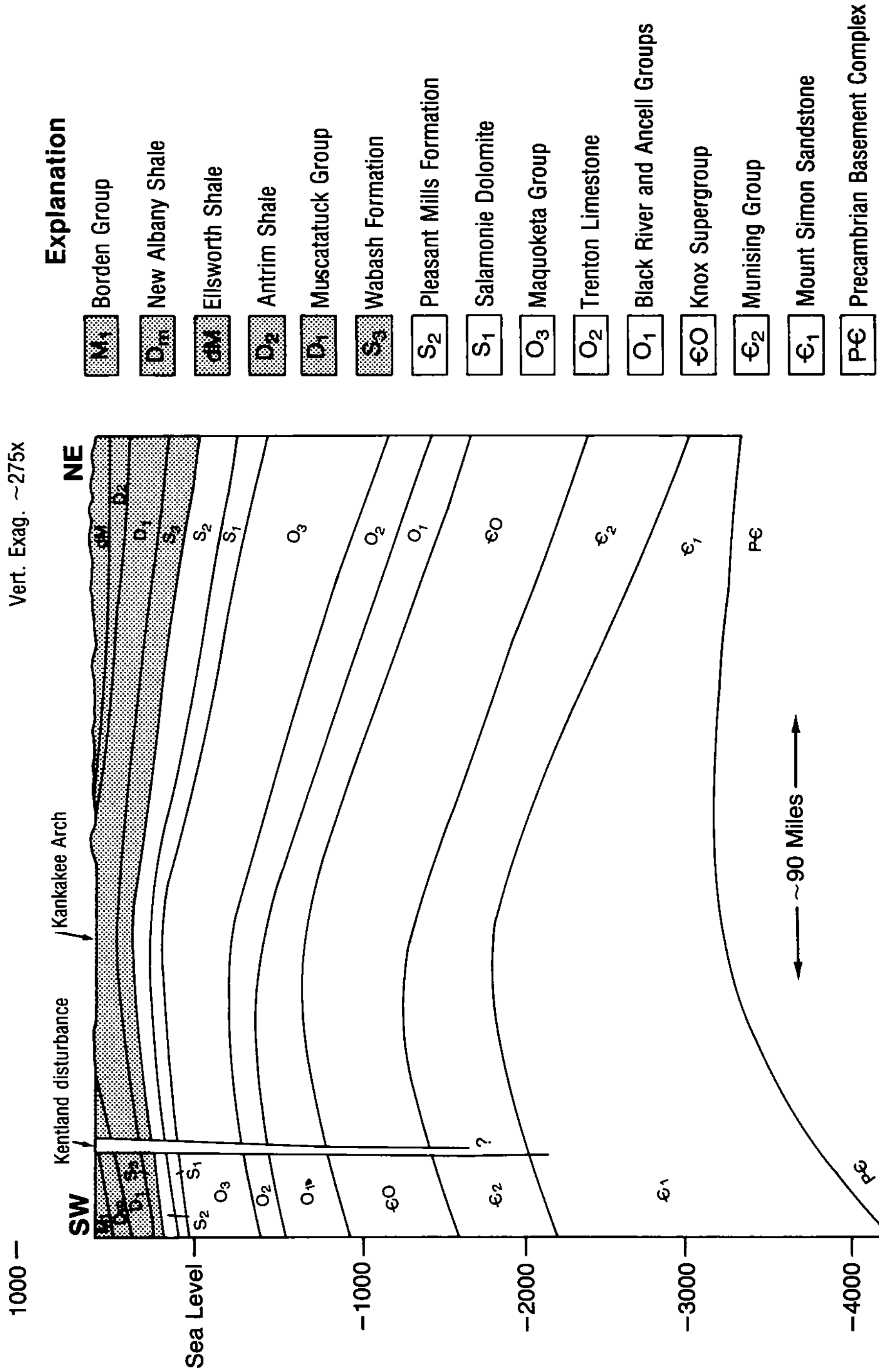


Figure 19. Generalized cross section of bedrock structure

## SOILS

Soil is the end-product of various agents acting on glacial and bedrock deposits. The properties of different soils are determined by chemical, physical and biological processes acting on soil *parent materials* over long periods of time (see box below).

Soil properties influence the generation of surface-water runoff and help determine the suitability of an area for crops, pasture, woodland, wildlife habitat, recreational facilities, buildings, highways and other uses. The type of land use can directly or indirectly modify hydrology, which in turn can further influence land and water development.

Soil data and basic information on the economy, land use and water resources of major basin counties and two adjoining Illinois counties are presented in soil survey reports (Persinger, 1972; Benton, 1977; Paschke, 1979; Smallwood, 1980; Furr, 1981, 1982; Barnes, 1982, 1989, [in press]; Kiefer, 1982; and Smallwood and Osterholz, 1990). Soil maps and related data found in these reports can be used for general planning purposes. The following discussions are based on generalized maps which provide an even broader overview of basin soils.

### Soil associations and hydrologic soil groups

Soils can be classified according to similarities of parent materials, texture, *horizon* characteristics, topography, natural drainage, and special features. A soil series, the most common category used in county soil surveys, allows detailed evaluations of specific tracts of land. For generalized applications, however,

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#### *Factors affecting soil formation*

Soil is produced by chemical, physical and biological processes acting on glacial or bedrock deposits. The characteristics of soil at any given location are determined by 1) the physical and mineralogical composition of the parent material, 2) the past and present climate, 3) the plant and animal life on and in the soil, 4) the relief, or topography, and 5) the length of time the forces of soil formation have acted on the soil material.

The properties of soils in the Kankakee River Basin vary greatly, sometimes within small areas, depending on how the **parent materials** were deposited. The main parent materials in the basin were deposited as glacial outwash, lacustrine material, organic material, alluvium, and glacial till.

*Outwash* was deposited by water flowing from melting glaciers. Outwash deposits generally consist of layers of coarse particles, such as sand and gravel. Tracy soils are an example of soils that formed in outwash deposits.

*Lacustrine* material settled out of still or ponded glacial meltwater. Because the coarser fragments drop out of moving water to form outwash, only the finer particles, such as very fine sand, silt, and clay remain to settle out in ponded water as lacustrine deposits. Rensselaer soils are an example of soils that formed in lacustrine material.

*Organic* deposits consist of partially decomposed plant materials. The remains of grasses, sedges, and water-tolerant trees accumulated in wet depressional areas of outwash, lake, and till plains. In some areas, the plant residues subsequently decomposed; in other areas, the material has changed little since deposition. Houghton soils are an example of soils that formed in organic material.

*Alluvium* was deposited by streams in geologically recent time. The texture of the alluvium depends on the flow rate of the water from which it was deposited. The alluvium deposited along the relatively swift Yellow River is coarser-textured than that deposited along the slower moving Kankakee River. Genessee soils are an example of soils that formed in alluvial deposits.

Glacial *till* was laid down directly by glaciers with a minimum of water action. Till consists of particles of different sizes mixed together. Soils in the basin that have developed on till typically have a well-developed structure. Riddles and Morley soils are examples of soils that formed in glacial till.

**Climate** determines the kinds of plants and animals on and in the soil. Climate also determines the amount of water available for weathering minerals and transporting soil material. Through its influence on soil temperature, climate also determines the rate of physical and chemical reactions in the soil.

The chief contribution of **plants and animals** to soil formation is the addition of organic matter and nitrogen. The kind of organic material in the soil depends mainly on the kinds of plants that grow on the soil. Soils that developed under dominantly forest vegetation generally have less total accumulated organic matter than soils in the basin that developed under predominantly grassy vegetation. Many soils in the Iroquois River Basin and developed under prairie grasses.

**Relief**, or topography, has a marked influence on soils through its influence on erosion, plant cover, soil temperature, soil moisture and natural drainage. For example, slight topographic differences produce soil-moisture differences, and thereby influence soil development.

Runoff of water is greatest on steep slopes, in contrast to runoff in low areas, where water often is temporarily ponded. Water and air move freely through soils that are well drained, but slowly through soils that are very poorly drained. Oshtemo soils are an example of well-drained, well-aerated soils, whereas Brookston soils are very poorly drained and poorly aerated.

Long periods of **time** usually are required for distinct soil horizons (layers) to form in parent material. The differences in length of time that parent materials have been in place commonly are reflected in the degree of development of the soil profile. Moreover, some soils develop rapidly and others develop slowly because of differences in positions on the landscape.

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a soil association is a commonly used category.

A soil association is a landscape having a distinctive pattern of soil series in relation to similar parent materials, landforms and slopes. Within a given soil association, each soil series occupies a characteristic position on one of three major landform types; namely, 1) hillslopes, *swells*, or depressions within broad uplands, 2) terraces, outwash plains, or lacustrine plains, and 3) floodplains or bottomlands (Galloway and Steinhardt, 1984).

A soil association is composed primarily of two to four major soils and a few minor soils, and is named for the major soils. The soils in one association may occur in another, but in a different pattern.

A total of 108 soil associations were identified in a series of generalized county soil maps developed in 1970 by the U.S. Department of Agriculture's Soil Conservation Service and Purdue University's Agricultural Experiment Station. A few of the general soil maps were revised slightly when they were later printed with supplementary data tables and a user's guide in 1975 (U.S. Department of Agriculture, 1971; Galloway and others, [1975]).

Appendix 3 presents the general soil maps for nine major counties of the Kankakee River Basin, as compiled from the 1971/1975 series. The map units outlined in black show broad areas that have a distinctive pattern of soils, relief, drainage, and parent materials. The colors represent the potential response of soils to irrigation, which will be discussed in the final chapter of this report in the section entitled ***Water Use and Projections***.

It should be emphasized that the maps in appendix 3, compiled from the comprehensive 1971/1975 county map series, differ from general soil maps included in detailed county soil survey reports referenced on the previous page. Moreover, general soil maps in survey reports, unlike those in the 1971/1975 series, may not always join with maps for adjacent counties. The differences in mapping are the result of several factors, including changes in concepts of soil series and differences in grouping detailed soil map units into general areas.

In 1977, the Soil Conservation Service and Purdue University combined the 1971/1975 series of general soil maps to produce a 1:500,000-scale map of Indiana showing major soil associations on a broad basis. Figure 20, adapted from a 1982 revision of the state map (U.S. Department of Agriculture, 1982), shows the location of major soil associations in the Kankakee River Basin. The table accompanying figure 20 lists, for the basin region only, the relation between numbered soil associations of the 1971/1975 generalized county maps and alphanumeric groupings of the 1982 state map.

Figure 20 also shows the regions of similar parent materials into which the major associations are grouped. It should be noted that Region 3 along rivers is characterized by both glacial outwash and recent alluvial parent materials.

The maps in figure 20 and appendix 3 can be useful in relating basin soils to surficial geology, topography and vegetation types (see explanatory text accompanying figure 20). A report by Galloway and Steinhart (1984) discusses the influences of geology, physiography and climate on the formation of soil associations, and summarizes the relations among associations occupying specific landscape positions.

Soil survey reports (referenced on the previous page) contain detailed descriptions of soil properties that affect land use, and include tables which outline the potentials and limitations of individual soils for cultivated crops, woodland, urban and recreation uses. Although the maps in figure 20 and appendix 3 are too generalized for such detailed land-use planning, they can be used to compare the suitability of large areas for general land uses. A few examples are given in the box on page 56.

In addition to their utility in assessing general land uses, the maps in figure 20 and appendix 3 also can be helpful in examining, on a broad basis, the role of soils in the generation of surface-water runoff. The Soil Conservation Service has classified soils into four hydrologic groups (A, B, C, D) according to the soil's ability to absorb rainfall and thereby reduce runoff. Classifying bare soils on the basis of their minimum *infiltration rate* after an extended period of wetting reflects the properties of both the surface and underlying soil horizons.

Soils in hydrologic group A have high infiltration rates even when thoroughly wetted, and consist chiefly of deep, well to excessively drained sands and gravels. These soils also have high *transmission rates*. Plainfield soils, which are found on sand ridges and *knolls* (association F2 in figure 21), are the only major soils in the Kankakee River Basin that naturally fall into hydrologic soil group A. Maumee, Houghton and Adrian soils, found primarily in the Kankakee River valley (associations B1 and B2), may be classified into

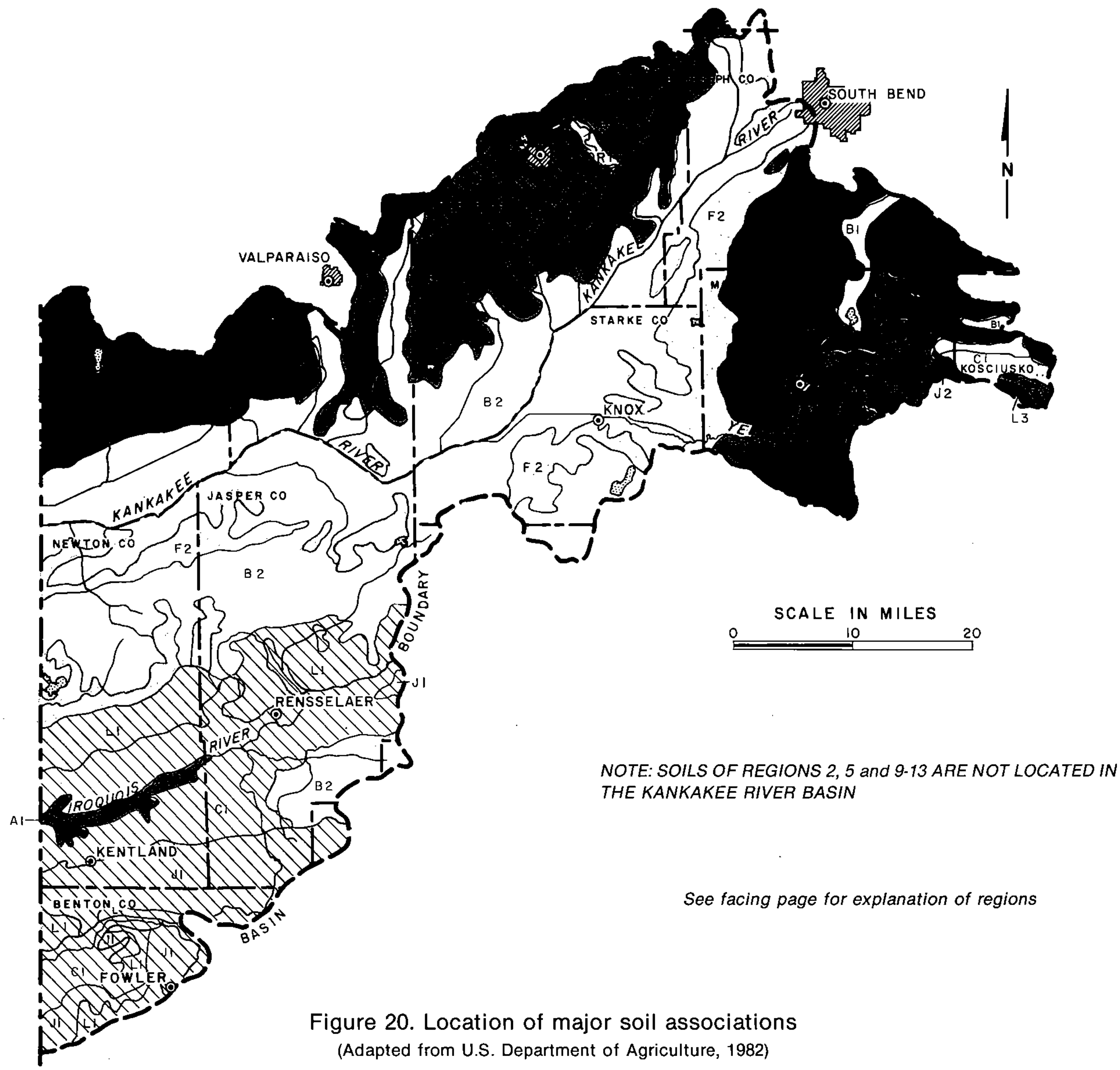


Figure 20. Location of major soil associations
(Adapted from U.S. Department of Agriculture, 1982)

hydrologic soil group A after artificial drainage measures have improved their ability to absorb rainfall and reduce runoff.

Soils in hydrologic group B have moderate infiltration and transmission rates. Well-drained soils that typify this soil group include those that have formed on outwash-plain deposits, such as soils of the Tracy-Door-Lydick association (E1). Other soils classified into hydrologic soil group B include those that have formed on outwash deposits in Marshall County (associations E3 and E4), on alluvial deposits of the lower Iroquois River valley (association A1), and on loess-covered, loamy glacial till deposits of the Iroquois River Basin (associations J1 and L1).

Soils in hydrologic group C have slow infiltration and transmission rates. These soils consist chiefly of soils with a layer that impedes downward movement of water, or soils having a moderately fine to fine texture. In the Kankakee River Basin, these soils are found primarily on the Valparaiso Moraine (associations M1 and M2), where the soils have formed on clayey glacial till deposits. Other areas of C-group soils are found

## Explanation To Figure 20

### *REGION 1 — SOILS FORMED IN SANDY AND LOAMY LACUSTRINE AND OUTWASH DEPOSITS AND EOLIAN SAND DEPOSITS*

The nearly level, very poorly drained soils of the **Maumee-Gilford-Sebewa** association (B2) developed on the broad lacustrine and outwash plains found primarily in the main valleys of the Kankakee River and its major tributaries. Parent materials range from sand to loam in texture. Native vegetation was grasses and water-tolerant mixed hardwoods.

The nearly level, very poorly drained soils of the **Houghton-Adrian** association (B1) formed in organic materials deposited in ancient lakes, and developed under a cover of trees, shrubs and sedges. Because these soils occur as relatively small muck pockets scattered throughout the main Kankakee River Valley, they are not mapped.

Loamy soils in the **Rensselaer-Darroch-Whitaker** association (C1) predominate on the nearly level lacustrine plains of the Iroquois River Basin. The very poorly drained Rensselaer soils occur in swales and broad, flat areas. Somewhat poorly drained Whitaker and Darroch soils are found on convex swells in the lake plain. Whitaker and Rensselaer soils formed under a cover of mixed hardwoods, whereas Darroch soils developed under prairie grasses.

### *REGION 3 — SOILS FORMED IN ALLUVIAL AND OUTWASH DEPOSITS*

Soils of the **Genesee-Eel-Shoals** association (A1) developed on *calcareous* loamy alluvium found along the nearly level floodplain of the lower Iroquois River. Native vegetation included a large variety of hardwood species such as beech, maple, oak, elm, sycamore and buckeye. Genesee is well drained; Eel is moderately well drained; and Shoals is somewhat poorly drained.

Well-drained soils of the **Tracy-Door-Lydick** association (E1) occupy the pitted *outwash fan* which extends from eastern Porter County to northwest St. Joseph County. The parent materials are loamy and sandy outwash deposits that were high in sulfur-containing shale particles and which weathered to form acid soils. The native vegetation on Tracy soils was mainly oak; on Door it was prairie grasses; and on Lydick, it was a mixture of the two vegetation types. Tracy soils are found on 0 to 12 percent slopes. Lydick and Door soils are mainly on 0 to 2 percent slopes.

Soils of the **Oshtemo-Fox** (E3) and **Fox-Ockley-Westland** (E4) associations are found on undulating *outwash plains* and *moraines* in Marshall County. Parent materials are loamy, sandy and gravelly drift. Native vegetation was mixed hardwoods, especially beech, maple, white oak and hickory. Except for the very poorly drained Westland soils found in nearly level drainageways and swales, these soils are well drained and are located mainly on 0 to 6 percent slopes.

### *REGION 4 — SOILS FORMED IN EOLIAN SAND DEPOSITS*

Soils of the **Plainfield-Maumee-Oshtemo** association (F2) developed in the *eolian* sands and sandy outwash deposits located primarily south and east of the Kankakee River. Well-drained Plainfield soils have a fine sand texture throughout and typically are found on 2 to 12 percent slopes on sand dunes, where the native vegetation was mainly white and black oak. Very poorly drained Maumee soils, which are fine sand or loamy fine sand throughout, occupy the level, low-lying areas around the dunes. Oshtemo soils, located on outwash plains, are well drained and are comprised of loamy sands or sandy loams.

### *REGIONS 6-7 — SOILS FORMED IN LOAMY OR CLAYEY GLACIAL TILL*

Soils of the **Crosier-Brookston** (J2) association and **Miami-Crosier-Brookston-Riddles** (L3) association are found in St. Joseph and Marshall Counties on *till plains* with swell-and-swale topography, on rolling areas near streams *dissecting* the till plain, and on end moraines. The parent material is calcareous loam till, covered on the till plain by up to 20 inches of loess. Native vegetation was mainly oak, beech and maple forests.

Well-drained Miami and Riddles soils are located on 2 to 12 percent slopes. Somewhat poorly drained Crosier soils are found on toe slopes and on nearly flat areas of swells. The very poorly drained Brookston soils are located in drainageways and swales.

Soils of the **Markham-Elliott-Pewamo** (M1) and **Morley-Blount-Pewamo** (M2) associations are found on the Valparaiso Moraine in Lake, Porter and western LaPorte Counties. The parent material is calcareous silty clay loam or clay loam till. Soils of the Markham-Elliott-Pewamo association developed under prairie grasses, whereas soils of the Morley-Blount-Pewamo association formed under beech, oak and maple forests.

Well-drained Markham and Morely soils are found on 2 to 12 percent slopes. The somewhat poorly drained Elliott and Blount soils occupy nearly level areas. Very poorly drained Pewamo soils are found in drainageways and swales.

### *REGION 8 — SOILS FORMED IN THIN LOESS OVER LOAMY GLACIAL TILL*

Soils of the **Brookston-Odell-Corwin** association (J1) are located in the Iroquois River Basin on the nearly level till plains having swell-and-swale topography. Soils of the **Parr-Brookston** association (L1) are found on end moraines and on rolling areas near streams that dissect the till plain. Most soils in these associations formed in loess. Soils of both associations formed under native prairie grasses.

The somewhat poorly drained Odell soils are found on swells, moderately well-drained Corwin soils are found on 2 to 6 percent slopes, and well-drained Parr soils are found on 2 to 12 percent slopes. The very poorly drained Brookston soils are located in swales.

**Predominantly prairie soils**

### *RELATION BETWEEN SOIL MAP UNITS*

{Major soil associations on the state map (U.S. Department of Agriculture, 1982; see facing page) represent clusters of soil associations on county general soil maps (U.S. Department of Agriculture, 1971; see appendix 3).}

| State | County | State | County |
|---|---|---|---|
| B1 | *108* | | |
| B2 | *13, 23, 24* | L3 | *63, 78, 79* |
| C1 | *10, 37, 47, 48, 49* | J2 | *58* |
| A1 | *4* | M1 | *65* |
| E1 | *14, 15, 51* | M2 | *61* |
| E3 | *35* | J1 | *59, 88* |
| E4 | *27* | L1 | *69, 70, 89* |
| F2 | *39, 40, 41, 42* | L2 | *12* |

### *General land-use considerations for major soil associations*

In outwash areas of the upper Kankakee River Basin, nearly level to gently sloping soils of the **Tracy-Door-Lydick** association (E1 in figure 21) are fairly well suited for cultivated crops, pasture, woodland, recreation areas and urban development. A few soils located on steep slopes, however, are better suited for woodland uses because they tend to be droughty and are subject to wind erosion if not protected by plant cover.

Considerable residential and urban development occurs on swells of the **Markham-Elliott-Pewamo** (M1) and **Morley-Blount-Pewamo** (M2) associations on the Valparaiso Moraine. Nearly level soils are poorly suited for sanitary facilities and building-site development, however, because of slow to moderately slow *permeability*. Some flat areas are well suited for cultivated crops, particularly if depressional areas are drained. Erosion, sedimentation, and drainage are major farm management concerns.

Soils of the **Maumee-Gilford-Sebewa** association (B2), found primarily in the Kankakee River valley, are well suited for cultivated crops if adequately drained by artificial means such as deep ditching, supplementary tiling, and *water-table control structures*. Subsurface and sprinkler irrigation are used during the summer to increase crop yields. In contrast to their high agricultural value, these intensively cropped soils generally are unsuitable for building-site development and sanitary facilities because of wetness, ponding, poor filtering qualities and frost action. Wind-erosion control is a major farming concern.

Depressional areas of the Kankakee River valley containing mucks and peats of the **Houghton-Adrian** association (not mapped in figure 20) are subject to ponding, wetness, flooding, and instability of organic matter. In their natural state, these soils are poorly suited for building-site development, sanitary facilities, recreation areas and cultivated crops, and are better suited for wetland plants or fish and wildlife habitat. Much of the acreage that has been artificially drained can be cultivated, and the larger muck areas with intensive water-management systems produce valuable vegetable and mint crops.

The irregular topography and large number of soils within the **Parr-Brookston** association (L1) make this only a moderately productive area for crop production (Galloway and Steinhardt, 1984). In the nearly flat lacustrine plain to the south, however, soils of the **Rensselaer-Darroch-Whitaker** association (C1) are well suited for crop production, although improved drainage is needed on most farms to increase crop yields. Alluvial bottomland soils of the **Genesee-Shoals-Eel** association (A1), found along the lower Iroquois River floodplain, are subject to overflow during floods, and excess water often limits crop production. Most bottomland soils are well suited for woodland and wildlife uses.

on lacustrine deposits of the Iroquois River Basin (association C1).

Soils in hydrologic group D have very slow rates of infiltration and transmission. In the Kankakee River Basin, this soil group consist chiefly of soils having a permanent high water table and clay soils having a high swelling potential, or soils having a clay layer at or near the surface. Undrained tracts dominated by Maumee, Houghton or Adrian soils (associations B1 and B2) are included in this hydrologic soil group. Undrained depressional areas dominated by Pewamo or Brookston soils also are classified in soil group D. Undrained Pewamo and Brookston soils commonly are found in *swales* and drainageways on the Valparaiso Moraine (assocations M1 and M2) and on the rolling morainal areas of St. Joseph and Marshall Counties (associations L3 and J2).

## Drainage and erosion

**Soil drainage** is a major problem in much of the Kankakee River Basin. Reports by the U.S. Department of Agriculture (1958, 1962, 1963) are among a large number of publications by various agencies which address drainage problems in the basin.

Most soils in the basin that have poor natural drainage are drained artificially to allow or enhance agricultural cultivation. In many drained areas, however, wetness, ponding and flooding can continue to pose moderate to severe limitations.

Some soils cannot be adequately or economically drained because of the difficulty in obtaining a sufficient drainage outlet. Undrained tracts primarily are located in depressional areas having Houghton, Adrian, Gilford and Edwards soils. In these low-lying areas, wetland or fish and wildlife uses may be more appropriate than attempted cultivation.

Some sandy soils having a high water table do not have adequate drainage outlets. Open ditches constructed in these sandy soils often are not stable and tend to become filled with sand within a few years. When these ditches are filled, the capacity of the open ditch and the drains discharging water into them is severely restricted.

Some organic soils have special drainage problems. When the pore spaces of organic soils are filled with air, the soils oxidize and compact, causing surface subsidence. Special drainage systems therefore are needed to control the depth and period of draining. Maintaining the water table below the ground surface during the crop-growing season and raising the water table to at or near the surface during the rest of the year minimizes the oxidation and subsidence of these organic soils.

Subsurface drainage is usually not considered feasible in soils that are muck over marl, such as Edwards and Martisco soils. In contrast, overdrainage is a possibility in soils that are muck over sand, such as Houghton and Adrian mucks. Overdrainage can lead to rapid oxidation and surface subsidence of the organic material. *Water-table control structures* are commonly used to maintain a high water table during the fall and winter to help limit oxidation and subsidence.

The design of both surface and subsurface drainage systems varies with the kind of soil. In general, drains need to be more closely spaced in slowly permeable soils than in rapidly permeable soils. A combination of surface and subsurface drains and pumping systems is needed in most areas of very poorly drained soils that are used for intensive row cropping. Information on drainage designs for specific soils is available from the Purdue University Cooperative Extension Service, the IDNR Division of Soil Conservation, and local offices of the USDA Soil Conservation Service.

**Soil erosion** is the detachment and movement of soil particles by natural forces, primarily water and wind. In general, there is a potential for water erosion where the land slope is at least 2 percent. Sandy or organic soils can be susceptible to wind erosion during certain times of the year, particularly when the soil surface is dry and when vegetative or surface cover is minimal.

Excessive erosion can reduce the soil's inherent productivity, whereas the associated sedimentation can damage young plants and fill drainage ditches, lakes and streams. These erosive processes can reduce farm income by decreasing crop yields and increasing maintenance costs for drainage systems. Additional erosion damages in both rural and urban areas include reduced property values, deteriorated water quality, and increased costs of removing sediment from roadways, roadside ditches, and surface-water supplies.

Compared to other *major land resource areas* of Indiana, the two areas encompassing the Kankakee River Basin have a low overall erosion rate, primarily because of their low relief, permeable soils and low runoff rates. Within the two designated areas, estimated soil losses on cropland by *sheet* and *rill* erosion in 1982 averaged 2.8 to 3.3 tons per acre, which was considerably less than than the state average of 6.1 tons per acre (U.S. Department of Agriculture, 1987a).

Soil losses by wind erosion, however, are higher in northwestern Indiana, including the Kankakee River Basin, than in other regions. Average wind erosion on cropland in 1982 was estimated to be 3.0 tons per acre in large parts of the basin, and 1.9 tons per acre or less in remaining portions (U.S. Department of Agriculture, 1987a).

A special study of soil erosion and land-treatment needs in the Kankakee River Basin in Indiana and Illinois was conducted in the early 1980s by the U.S. Department of Agriculture in cooperation with the State of Indiana, State of Illinois, and Soil and Water Conservation Districts (U.S. Department of Agriculture, 1986). The purpose of the study was to provide alternatives for the land-treatment element of a previous Kankakee River Basin study (U.S. Department of Agriculture, 1976).

The 1986 study identified major erosion problems on more than 1.4 million acres of cropland in eight Indiana counties and three Illinois counties. These areas are characterized by a predominance of land that is eroding substantially in excess of rates at which long-term crop productivity can be maintained.

Major erosion areas in the Indiana part of the study region where water erosion was identified as the dominant form of soil loss include parts of Marshall and St. Joseph Counties and the end moraines in central Lake, Porter, LaPorte, Newton and Jasper Counties. Wind erosion was identified as the dominant form of erosion in much of the main Kankakee and lower Yellow River valleys, particularly in Starke County, southwest LaPorte, and northern Newton and Jasper Counties. Erosion in Benton County was not examined in the study.

In major erosion areas of the Kankakee River Basin study region in Indiana where sheet and rill erosion by water was identified as the dominant problem, soil loss from all sources was estimated to be about 3 million tons per year, or roughly 5.9 tons per acre per year. In areas where sheet erosion by wind is the dominant problem, total sheet erosion by wind was estimated to be about 3.6 million tons per year, or 7.1 tons per acre per year.

As part of the Kankakee River Basin soil erosion study, three alternative management plans were developed for each county (U.S. Department of Agriculture, 1986). Each alternative would reduce soil loss from sheet and rill erosion by both water and wind action to three different levels. Alternative 2, the most cost-effective alternative, would reduce soil loss to the tolerable limit (T), or the maximum annual rate of soil erosion at which a high level of crop productivity can be sustained economically and indefinitely. Alternative 1 would reduce soil loss to 2T, and Alternative 3 would reduce soil loss to 1/2T. In each alternative, *gully* erosion and *ephemeral gully* erosion would be controlled to aid in localized erosion reduction.

Major management practices that can be used to reduce wind and water erosion include conservation tillage, contour farming, diversion terracing, grassed waterways, grade stabilization structures, and water- and sediment-control basins. Additional soil conservation measures include the use of crop residues, green-manure crops, and winter cover crops.

Since the completion of the basin erosion study (U.S. Department of Agriculture, 1986), additional studies have been completed in adjoining areas of northern and central Indiana (U.S. Department of Agriculture, 1988a, 1990). These reports present data and management alternatives similar to those described in the 1986 Kankakee River Basin report.

In 1987, the Division of Soil Conservation was established within the Department of Natural Resources. This division is responsible for administering the state's accelerated soil erosion/sedimentation reduction program. The goals of the program include 1) reducing erosion on all land to at least the tolerable limit, and 2) applying the best practical technology to control off-site sedimentation by the year 2000 (Governor's Soil Resources Study Commission, 1985).

Major projects implemented jointly by the division, county Soil and Water Conservation Districts, and the U.S. Department of Agriculture's Soil Conservation Service in the Kankakee River Basin have included erosion-control projects at Koontz Lake and Lake of the Woods, and the installation of erosion-control structures on seriously eroding cropland.

A variety of programs administered by public and private agencies encompass research projects, education programs, technical assistance, and cost-share financial assistance for erosion control. Other major agricultural programs intended to reduce soil erosion include the 1985 Food Security Act, commonly known as the Farm Bill. The act sets forth mandatory conservation plans by the year 1990 on lands classified as *highly erodible*.

Under the act's conservation reserve program, financial incentives are provided to farmers who remove highly erodible land from production for a minimum of 10 years. In 1987, an average of 0.4 percent of farmland in the Kankakee River Basin was placed in the program (see U.S. Bureau of the Census, 1989). In Starke County, where wind erosion is the dominant form of soil loss, conservation reserve lands totaled about 2 percent of all farmland.

### Stream sedimentation

Sediment is inorganic and organic material that is transported by, suspended in, or deposited by streams. Sediment load, which is the quantity of sediment transported by a stream, is a function of stream discharge, soil and land-cover features, meteorological conditions, land-use activities, and many other factors.

Sediment load can be divided into two components on the basis of the mode of sediment transport. **Suspended sediment** consists of silt- and clay-size particles held in suspension by turbulence in flowing water. **Bedload sediment** consists of larger particles which slide, roll or bounce along the streambed by the force of moving water.

Much of the sediment load carried by the Kankakee River appears to be moving as suspended load. Moreover, most of the suspended load is transported during flood events, although the largest suspended sediment discharges are not necessarily associated with the largest water discharges.

Reports by Bhowmik and others (1980) and DeMissie and others (1983) concluded that the watershed of the Iroquois River in Indiana and Illinois contributes more suspended load per square mile of drainage area than the watershed of the mainstem Kankakee River. In addition, the suspended load carried by the Iroquois River is composed primarily of fine materials, mostly silts and clays, whereas the Kankakee River carries substantial amounts of sand, particularly during high stream discharges. These particle-size differences can be attributed largely to the predominance of silty, clayey soils in the Iroquois River watershed, in contrast to the predominance of sandy streambed materials and basin soils in the Kankakee River watershed (Gross and Berg, 1981).

Sediment yield is the total quantity of sediment transported from a drainage basin at a given location in a given period of time. A study by Crawford and Mansue (1988) concluded that suspended sediment yields and concentrations for streams in the Northern Lake and Moraine Region, which encompasses the Kankakee River Basin (figure 13), are notably less than values for streams in other parts of Indiana. The median suspended-sediment yield computed for the northern region was 68 tons per square mile per year, in contrast to 195 tons per square mile per year for the rest of Indiana.

The low suspended sediment yields in northern Indiana, including the Kankakee River Basin, can be largely attributed to the region's low erosion rate. In most areas, the low relief and permeable soils help limit the availability of eroded material from within watersheds. Moreover, fairly low stream velocities help limit the sediment-transport capacities of streams, and significant amounts of *base flow* are available for dilution of suspended sediment concentrations.

Although sediment yields in the Kankakee River Basin are fairly low, changes in land use, stream-flow characteristics and drainage patterns can alter the natural sedimentation rate. For example, the conversion of wetlands or woodlands to cropland can increase soil erosion and the associated sedimentation in streams. Activities that increase stream slope and velocity can increase the stream's erosive capacity and sediment-transport capability. Construction projects within or adjacent to streams, particularly activities that disturb the streambed and streambanks, can contribute to sedimentation problems, primarily by dislodging or exposing soils and sediments.

Sedimentation problems along streams of the Kankakee River Basin often are caused by the erosion of unstable agricultural ditch banks and adjacent cropland. Windblown soil particles also contribute to sedimentation problems and associated water-quality problems through the deposition of sediment-borne pollutants into ditches, streams and rivers. Unstable spoil banks along newly excavated ditches and unvegetated portions of existing spoil banks can be a source of excessive streambank erosion and its associated sedimentation.

Excessive amounts of sediment resulting from natural or man-made causes can result in the destruction of aquatic habitat and a reduction in the diversity and abundance of aquatic life. A study in Illinois (Brigham and others, 1981) concluded that if the amount of sand and silt moving downstream in the Kankakee River in Illinois were to increase and subsequently cover cobble, gravel and rock substrates with substrates chiefly composed of sand, the diversity and population size of fish species, mussels and benthic macroinvertebrates associated with the coarse substrates would be greatly reduced. Where sand substrates have historically predominated, however, increased sand deposition may have little detrimental impact on sand-associated aquatic life.

Excessive amounts of suspended sediment cause the water to be cloudy (turbid). Increased turbidity affects the growth of algae and aquatic plants, which adversely affects the entire aquatic *ecosystem*. Moreover, increased turbidity decreases the water's aesthetic appeal and the enjoyment of recreational activities. In addition, some metal ions, pesticides, and nutrients may adhere to sediment particles and be transported downstream (Crawford and Mansue, 1988).

A report by Bhowmik and others (1980) suggested preventive measures for reducing excessive sediment load in a river. The measures included 1) the proper repair and maintenance of drainage ditches and levees, 2) minimal disturbance of the riverbanks, 3) avoidance of structural disturbance of the river, 4) reduction of sediment excesses arising from construction activities, 5) application of artificial and natural means for preventing erosion, and 6) the use of proper land and water management practices on the watershed. These preventive measures were preferred over remedial measures, which included 1) construction of detention reservoirs, sedimentation ponds, or settling basins, 2) development of side-channel flood-retention basins, and 3) removal of deposited sediment by dredging.

A draft report by the Indiana Nonpoint Source Task Force (1989) outlines recommendations for protecting water quality through erosion control. Several recommendations involve regulatory measures associated with current Indiana and federal statutes administered by the state Departments of Natural Resources, Environmental Management, and Highways, and the U.S. Army Corps of Engineers. These laws provide some consideration of erosion and sedimentation control along streams and lakes during flood-control, drainage, highway, bridge, and other stream-related construction projects.