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Environmental Geology of Grant County, Indiana—An Aid to Planning

By Edwin J. Hartke

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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Scope</td>
<td>1</td>
</tr>
<tr>
<td>Geography</td>
<td>1</td>
</tr>
<tr>
<td>Economy</td>
<td>1</td>
</tr>
<tr>
<td>Geology as related to land use</td>
<td>1</td>
</tr>
<tr>
<td>Sources of information</td>
<td>2</td>
</tr>
<tr>
<td>Illustrations</td>
<td>2</td>
</tr>
<tr>
<td>History and environment</td>
<td>2</td>
</tr>
<tr>
<td>Geology</td>
<td>4</td>
</tr>
<tr>
<td>Unconsolidated materials</td>
<td>4</td>
</tr>
<tr>
<td>Bedrock</td>
<td>7</td>
</tr>
<tr>
<td>Teays Valley</td>
<td>7</td>
</tr>
<tr>
<td>Water resources</td>
<td>10</td>
</tr>
<tr>
<td>Surface hydrology</td>
<td>10</td>
</tr>
<tr>
<td>Ground water</td>
<td>10</td>
</tr>
<tr>
<td>Unconsolidated system</td>
<td>11</td>
</tr>
<tr>
<td>Bedrock system</td>
<td>12</td>
</tr>
<tr>
<td>Water quality</td>
<td>12</td>
</tr>
<tr>
<td>Mineral resources</td>
<td>13</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>13</td>
</tr>
<tr>
<td>Crushed stone, building stone, and agricultural lime</td>
<td>13</td>
</tr>
<tr>
<td>Peat</td>
<td>13</td>
</tr>
<tr>
<td>Clay</td>
<td>13</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>13</td>
</tr>
<tr>
<td>Geologic considerations in land-use planning</td>
<td>15</td>
</tr>
<tr>
<td>Subsurface liquid-waste injection</td>
<td>17</td>
</tr>
<tr>
<td>Septic systems</td>
<td>18</td>
</tr>
<tr>
<td>Sanitary landfills</td>
<td>20</td>
</tr>
<tr>
<td>Liquid-waste storage lagoons</td>
<td>22</td>
</tr>
<tr>
<td>Literature cited</td>
<td>24</td>
</tr>
<tr>
<td>Other sources of information</td>
<td>25</td>
</tr>
</tbody>
</table>

## Illustrations

<table>
<thead>
<tr>
<th>Plate</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maps of Grant County, Indiana, showing bedrock topography and thickness of unconsolidated materials</td>
</tr>
<tr>
<td>Figure 1</td>
<td>Map of Indiana showing location of Grant County</td>
</tr>
<tr>
<td>2</td>
<td>Map of Grant County showing surficial geology</td>
</tr>
<tr>
<td>3</td>
<td>Map of Grant County showing bedrock geology</td>
</tr>
<tr>
<td>4</td>
<td>Generalized column showing lithologies and names of bedrock formations</td>
</tr>
</tbody>
</table>
## Illustrations

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Cross sections in Grant County showing surficial and bedrock topography, nature of unconsolidated materials, and potentiometric surfaces for the unconsolidated and bedrock aquifers</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Map of Grant County showing the potentiometric surface of the unconsolidated aquifer</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>Map of Grant County showing potential mineral resources</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>Map of Grant County showing areas of impermeable surficial materials, approximate depth to first permeable materials, wet areas of organic soils, and areas subject to periodic flooding</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>Map of Grant County showing relative suitability of geologic conditions for use of septic systems</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>Map of Grant County showing areas of relative suitability for sanitary landfills</td>
<td>21</td>
</tr>
<tr>
<td>11</td>
<td>Map of Grant County showing relative suitability of geologic conditions for waste-storage lagoons</td>
<td>23</td>
</tr>
</tbody>
</table>
Environmental Geology of Grant County, Indiana—An Aid to Planning

By EDWIN J. HARTKE

Introduction

SCOPE
This report is intended to provide general information on the geology of Grant County and to relate geology to the past, present, and future socio-economic development of the county. Emphasis is placed on mineral resources and waste disposal so that both can be managed with conservation and environmental protection foremost in mind.

GEOGRAPHY
Grant County lies in north-central Indiana (fig. 1) within the Wabash River drainage basin. It is a part of the physiographic unit known as the Tipton Till Plain (Wayne, 1956), which is a nearly flat to gently rolling glacial plain that encompasses the central third of Indiana from the Ohio border to the Illinois border. The climate is moderate; the winters are cool and the summers are warm. The mean temperature in January is about 30°F, and the mean temperature in July is about 76°F. Average annual precipitation is about 38 inches, relatively evenly spread throughout the year.

ECONOMY
Grant County is largely oriented toward agriculture. Business and manufacturing facilities are concentrated primarily in the Marion-Gas City-Jonesboro area. These are typical thriving, sprawling small cities that are spilling into surrounding farmland. They have common growth-related problems of water supply, mineral-resource and energy needs, sewage disposal, and solid-waste disposal.

GEOLOGY AS RELATED TO LAND USE
All of man's constructive activities on earth are directly affected by and affect geology. Therefore, geology should be a primary concern in planning any development.

The geologic setting of Grant County is stable, and there is low risk of landslide, earthquake, foundation instability, and other earth-movement related problems (Gray, 1973). The geologic setting also provides a
sound base for future development because essential construction-related resources (water, crushed stone, sand, and gravel) are readily available. Areas with geologic conditions suitable for waste disposal are a less obvious but most important resource. Preliminary investigations indicate that a relatively large part of the county may provide the geologic conditions required to qualify as a waste-disposal resource. Resource conservation and intelligent land use will still be required if the present standard of living is to be maintained or improved in the foreseeable future.

Hazards related to geology include potential flooding in low-lying areas along major streams, poor foundation conditions in areas underlain by muck and peat, slope-stability problems in specified areas, and potential ground-water and surface-water pollution where sanitary landfills, septic systems, and other waste-disposal facilities have been poorly sited. Knowledge and proper use of the geology and natural resources will promote the fullest economic and environmentally sound development of the county.

SOURCES OF INFORMATION
The information used in compiling this report was collected from (1) water-well records on file in the Department of Natural Resources, Division of Water; (2) oil-well records on file at the Indiana Geological Survey; (3) highway and bridge borings on file at the State Highway Department; (4) mapping done by the Indiana Geological Survey for Regional Geologic Map 5 (Burger and others, 1971); (5) new field and laboratory work; and (6) sources in the "Literature Cited."

Further information about various aspects of environmental geology can be obtained from the (1) Indiana Department of Natural Resources, Division of Water (ground-water and surface-water availability and management) and the Indiana Geological Survey (engineering geology and mineral-resource potential); (2) Indiana State Board of Health (waste-disposal requirements and permits); and (3) U.S. Department of Agriculture, Soil Conservation Service (soils information).

ILLUSTRATIONS
The maps and figures in this report are generalizations (boundaries represent gradational changes and categorized areas are not exclusive) because of the limited data used in compilation and because of the large scale of the project. They should therefore be used as guides in selecting sites for detailed study. Limiting exploration by use of these maps may save time and expense.

More detailed copies of the illustrations can be examined at the Indiana Geological Survey in Bloomington. Maps on a scale of 1 inch to 1 mile depicting bedrock topography, thickness of unconsolidated materials, relative suitability for sanitary landfills and septic systems, and mineral-resource potential can also be examined in the county planner's office in Marion.

History and Environment
Grant County was covered by a thick mature forest before the first white settlers arrived. In this largely hardwood forest, oak trees commonly reached a diameter of 5 feet (Phinney, 1884). One particularly healthy specimen measured 9 feet in diameter at a height of 4 feet above the ground (Whitson, 1912). Bears, panthers, wolves, and their prey vied with human competitors, Indians, for their daily existence in this lush setting without upsetting the balance of nature.

Upon their arrival, the first white settlers, Quakers from North Carolina, began to modify the natural environment. They cleared the forests, thereby altering the hydrologic, biologic, and botanic regimes with little consideration for the effect on the environment. Natural resources were thought to be inexhaustible. Most of the trees cut during clearing operations for agriculture were burned because the wood was a nuisance. Loss of this valuable resource was felt by the logging industry as early as the 1870's, when lumber exporting became big business. It was also apparent as early as the 1870's that deforestation introduced troublesome side effects. The most serious effect was the alteration of the hydrology and an attendant increase in erosion and streamflow fluctuations.
The next obstacle overcome during the establishment of an agricultural economy was the control of erosion and drainage. Drainage was improved by tiling fields, ditching, and straightening and dredging existing streams. The resulting improvement, however, reduced surface-water and shallow ground-water retention and storage. The improved surface drainage also had the undesired effect of producing more rapid and extreme fluctuations in stream discharge and a decrease in base flow. A graphic example of the effect of surface modifications on areal hydrology is that before modifications the Mississinewa River was a navigable stream during most of the year. Flatboats large enough to carry three or four freight cars were floated downstream to the Wabash River region (Phinney, 1884). Shipping down the river was reduced and finally discontinued in the late 1800's because base flow in the Mississinewa ultimately decreased as the forests were removed and swamps and bogs were drained.

Destruction of the forest and drainage of the bogs were soon followed by overtillage and loss of soil fertility. Overuse of the land was a serious problem in the early 1900's. Land that was among the richest in Indiana was tilled so extensively that its nutrients were exhausted. The soil has been rehabilitated by the extensive use of fertilizers. Fertilizers, however, are an environmental hazard because if applied improperly they become a source of ground-water and surface-water contamination.

In the late 1880's Grant County had an oil boom occasioned by the discovery in parts of Indiana and Ohio of what was then the world's largest oil and gas field (the Trenton Field). The northeast quarter of the county was riddled with holes a thousand feet deep. In fact, more than 4,000 wells were drilled in the county between 1880 and 1910. Regulatory laws for controlling oil and gas production were not introduced until the late 1890's, and then the laws were not vigorously enforced. And so conservation and the future well-being of the area were not given due consideration during development of the Trenton Field. Many unproductive holes were improperly plugged or were not plugged at all; gas was vented or burned as waste, and oil was overproduced. Therefore, the oil boom brought with it harmful environmental impact: (1) salt water produced in large quantities with the oil was released on the surface and allowed to contaminate streams; (2) unplugged wells permitted salt water from the oil-producing zones to rise and contaminate shallow ground-water supplies; (3) gas was vented to the atmosphere and burned, which caused air pollution; (4) gas, a limited natural resource, was wasted; and (5) oil, also a limited resource, was lost from production because of poor development and management.

Only about 10 percent of the oil in the Trenton Field was recovered (Stanley J. Keller, oral communication, 1977). Normally, between 20 and 30 percent primary recovery is possible in a properly managed oil field, but secondary recovery is not feasible because of the haphazard nature of the field's development and its eventual abandonment.

Early economic development, other than that resulting from the short-lived oil boom, was based on agriculture and the timber industry. Coordinated with this economic growth, numerous small sand and gravel pits were opened to supply materials for roads and general construction; crushed stone was quarried along the Mississinewa River, where it was exposed at the surface just north of Marion; stone from these quarries was also used for foundations and other building purposes; and brick and tile were produced for local use from glacial till (Whitlatch, 1933) near Sweetser. And so all basic construction materials that have low unit costs but high bulk and therefore high transportation costs were readily available for facilitating development in the county.

The growth of Grant County has been steady and strong except for the spurt prompted by the local oil and gas industry. Abundant energy readily available during the oil boom attracted industry and caused rapid growth of some small towns. Much of this industry remained after the local oil and gas supply was exhausted, and the county continued to prosper because of agriculture and industry. Pressures on the environment,
however, accompany growth. These pressures are related to constructive land use for building, agriculture, mineral-resource recovery, recreation, and waste disposal. These pressures were not serious in the early history of the county when the population and standard of living were much lower than at present. Now, however, environmental considerations are critical to continued development.

Geology
The geologic materials of Grant County are of two principal kinds: unconsolidated materials (fig. 2), deposited during the Ice Age and more recently, and consolidated bedrock materials (fig. 3), deposited more than 400 million years ago. Each of these basic material types affects and is affected by man's activities on or in them. This report is most concerned with the components of the unconsolidated materials because they are the dominant surface materials in the county. Bedrock is exposed naturally only in limited areas along the Mississinewa River.

UNCONSOLIDATED MATERIALS
The unconsolidated materials (fig. 2) consist of clay, silt, sand, gravel, peat, and muck deposited by ice, water, and wind during the Ice Age and by water, wind, and mass wasting of slopes following the Ice Age. These materials were deposited on an eroded limestone and dolomite bedrock surface. They range from 0 to more than 425 feet in thickness (pl. 1).

Materials formed during the Ice Age consist primarily of: (1) glacial till (a heterogeneous mixture of clay, silt, sand, and some gravel) deposited directly by melting ice; (2) outwash (a mixture of sand and gravel) deposited in glacial river valleys by meltwater; (3) lacustrine material (clay and silt) deposited by standing water; and (4) peat and muck (organics, clay, and silt) deposited in closed depressions. Till is predominant, and it is characteristically relatively stable, dense, and stiff and has low permeability. Outwash is present in terraces along the Mississinewa River and some of its tributaries. Lacustrine material is found principally in an ancient lakebed west of Marion. Muck and peat deposits occur in isolated, closed, or poorly drained depressions throughout the county.

Materials deposited after the glacier retreated are: (1) alluvium (silt, sand, and clay) deposited in present stream valleys; (2) loess (silt and sand) deposited as a thin cover on nearly all upland surfaces; and (3) colluvium (heterogeneous mixture of soil material) deposited at the base of present slopes.

Glacial till, which covers about 90 percent of the county, is in two forms: (1) ground moraine consisting of rock debris that was carried within and dragged beneath the glacier and deposited in thin, fairly even layers with a gently rolling surface and (2) end moraine consisting of rock debris that was deposited irregularly at the front of a glacier so as to give shape to an elongate, rolling, and elevated area. The positions of the two types of till (fig. 2) are evident primarily because of the surface expressions of the end moraines in the northeast (Mississinewa Moraine) and in the southwest (Union City Moraine). Ground moraine dominates the surface west of the Mississinewa River except for the small southeast-northwestward-trending belt of end moraine (Union City Moraine) in the extreme southwestern tip of the county. Ground moraine is also found in the northeast corner of the county.

There are two tills of different ages in the county. Each has its own lithologic identity. An eastern till, which is more than 40 feet thick east of the Mississinwa River, thins and may be absent in places west of the river. This till, which is the younger of the two, comprises both the Mississinewa and Union City Moraines and the ground moraine between these two end moraines. It is distinguished by its high clay and low sand and silt content. A western till is at the surface west of the Union City Moraine and underlies the eastern till throughout the rest of the county. It differs from the eastern till in that it is sandy and silty and has fairly abundant pebbles and cobbles.

The till surface, particularly in the area of the Mississinewa Moraine, is dotted with small lakes and bogs that formed in kettle holes (depressions produced by late-melting ice blocks buried within the drift). Stream valleys dissecting the till surface are filled with
Mainly ground moraine, clay rich in east but silty and sandy in west; level to slightly rolling (less than 2-percent slope)

Mainly end moraine; eastern moraine is clay rich and rolling topography (2-8-percent slope); western moraine is clay and silt rich with gently rolling topography (2-percent slope)

Clay-rich lacustrine material with 0-percent slope

Paludal and lacustrine material with 0-percent slope

Alluvial, colluvial, and paludal material in troughs on till surface with less than 2-percent slope

Mostly alluvium with less than 2-percent slope

Valley-train materials with less than 2-percent slope

Bedrock exposures

Figure 2. Map of Grant County showing surficial geology. Modified from Burger and others (1971).
EXPLANATION

- **Silurian rocks**
  - Limestone, dolomitic limestone, dolomite, and some shale

- **Ordovician rocks**
  - Shale

- **S**
  - Structure contour on base of Waldron Formation
  - Datum is mean sea level

- **W**
  - Base of Waldron Formation

- **M**
  - Base of Mississinewa Shale Member (Wabash Formation)

- **LC**
  - Base of Liston Creek Limestone Member (Wabash Formation)

Figure 3. Map of Grant County showing bedrock geology.
GEOLOGY

alluvial material and in some examples are terraced by outwash deposits. Modern surface features created by man are also present. These include farm ponds and reservoirs, sand and gravel pits, clay pits, quarries, and peat mines.

BEDROCK

The bedrock on which the glacial materials were deposited is composed of sedimentary rocks of Silurian and Ordovician age. These overlie rocks of Cambrian age that are not at the bedrock surface within the county. The total thickness of the layered sequence of sedimentary rocks (fig. 4) is about 3,500 feet. Beneath this sequence lies igneous (granitic) Precambrian rocks called the basement complex. Bedrock is exposed at the surface (fig. 2) along the Mississinewa River north of Marion and in stone quarries in the county.

The youngest part of this sedimentary sequence forms several distinct rock units (fig. 4) that belong to the Silurian System. The lithology of these units—composed of limestone, shale, dolomitic limestone, dolomite, and reef rock—indicate deposition in a quiet shallow marine environment. Ordovician rocks, which are at the bedrock surface only in a deeply buried valley in northeastern Grant County (fig. 3), were also deposited in a shallow marine environment. The Ordovician sequence consists of shale, limestone, dolomite, and sandstone. Sandstone, which is present only in Middle Ordovician and older rocks, indicates a shoreline depositional environment. Rocks of both Silurian and Ordovician age are or were sources of important mineral resources, but the Cambrian and older rocks have no known economically recoverable mineral resources.

Lying beneath the Ordovician and making up the basal part of the sedimentary sequence is the Cambrian System of rocks. Carbonate rocks (limestone and dolomite) and fine-grained clastics (shale and siltstone) are the primary rock types at the top of the Cambrian, and coarse-grained clastics (sandstones) are the predominant rock type in the lower 700 feet of the system. This Cambrian sequence of sedimentary rock was deposited on the eroded surface of granitic basement rock.

The relief on the bedrock surface (pl. 1) is more pronounced than that of the present land surface and is not reflected by the present surface. The most significant erosional feature of the bedrock surface is the Teays Valley. This is a preglacial river valley, as much as 450 feet deep, that was filled with glacial debris.

TEAYS VALLEY

The Teays Valley was the route of an ancient river, carved deeply into the bedrock surface, that drained much of the area now encompassed in the Ohio River drainage basin. Its source was in the Piedmont of South Carolina. From there the river meandered northwestward through West Virginia, Ohio, and into Indiana. Entering Indiana in Adams County, it turned westward and exited the state through Benton County. The Teays turned southwestward in Illinois, where it connected with the ancestral Mississippi River. During the Ice Age the channel of the Teays was blocked by ice and glacial drift, and its drainage was eventually diverted southward into the Ohio River system.

The Teays Valley and its tributaries are significant at present because this system is a potential source of ground water. The Teays is not, as is commonly thought, an underground river with rapidly flowing water. It is, instead, a deep bedrock trench filled with unconsolidated material. Where significant sections of this material are coarse grained and permeable (fig. 5), the Teays is a productive aquifer. The two cross sections in figure 5 show considerable coarse-grained material, but data are too limited to ascertain continuity. It does appear, however, that the upper layer of coarse-grained material, which averages somewhat less than 50 feet in thickness and lies anywhere between about 60 and 150 feet beneath the surface, is continuous as is the layer in the base of the channel. Some wells, however, have been reported by water-well drillers to penetrate to the valley floor and to show no significant sand or gravel. It therefore appears that the Teays was a general dumping ground for the glaciers. Outwash, till, and lacustrine deposits seem mostly to be indiscriminately mixed, but exceptions as noted above do exist.
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>ROCK UNITS</th>
<th>DOMINANT LITHOLOGY</th>
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<td></td>
<td></td>
</tr>
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<td>Mississinewa Shale Mbr.</td>
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</tr>
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<td>Limestone and dolomite</td>
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</tr>
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Figure 4. Generalized column showing lithologies and names of bedrock formations.
Figure 5. Cross sections in Grant County showing surficial and bedrock topography, nature of unconsolidated materials, and potentiometric surfaces for the unconsolidated and bedrock aquifers.
Water Resources

SURFACE HYDROLOGY

The surface-water hydrology of Grant County reflects the moderate to low topographic relief of the county and its humid temperate climate. Most streams maintain their flow throughout the year as a result of abundant and well-distributed precipitation and of soil and topography that deter runoff. The average annual precipitation in Grant County is about 38 inches; two-thirds is lost through runoff or evapotranspiration and one-third infiltrates the soil (standard assumption for this climatic-vegetative-geologic zone by the American Society of Civil Engineers, 1957). The low to moderate topographic relief of the area also reduces the rate and amount of runoff. This effect has been modified by the extensive ditching used by farmers to facilitate drainage of their fields. The area most extensively ditched is the flat-lying area west of the Mississinewa River. The area of moderate relief east of the river is also dissected by ditches but to a lesser extent. Most ditches are in the courses of old poorly developed streams that have been dredged and straightened.

Grant County lies in the Wabash River drainage basin. The Mississinewa River, a major tributary of the Wabash, provides drainage for most of the county. Pipe and Grassy Creeks drain the western part and Black Creek the northeastern part. The southern tip of the Mississinewa Reservoir, a flood-prevention and recreation facility located primarily in Wabash County and fed by the Mississinewa River, extends into Grant County. At maximum flood stage (779 feet above mean sea level), the upper reach of the reservoir is just north of Marion (U.S. Geological Survey, 1975). Since 1923, when regular recordkeeping began, flow extremes in the Mississinewa River have ranged from a maximum 25,000 cfs to a minimum 3.4 cfs. Maximum recorded flood stage was reached in 1913, when floodwater rose to an elevation of about 800 feet MSL at the point where Boot Creek crosses Fourth Street in Marion. The areas of Marion lying below 800 feet MSL and in the Mississinewa River flood plain should therefore be considered susceptible to flooding. The Mississinewa River poses the major flood threat in Grant County because it flows through heavily populated areas. The smaller streams, although also subject to flooding, are not major problems because their flood plains are small and they flow through agricultural areas.

Surface water was once used as a source of power and a mode of transportation but is now used solely to dilute and transport liquid wastes, primarily municipal sewage.

GROUND WATER

Ground water is water that is below the earth's surface in the zone of saturation. Ground water and surface water in Grant County are parts of one rather complex system except in isolated areas where certain lakes may be perched on impervious material. The ground-water level (water table) is indicated by the level of base flow in the perennial streams and by the free surface-water level in excavations (gravel pits, quarries, borrow pits, etc.) and in marshy areas. The water table reflects, although in subdued form, the surface topography. In the low, relatively flat-lying area west of the Mississinewa Moraine, the potentiometric surface (height to which water will rise in a well in a confined aquifer)—there is no readily definable water table in this area—is nearly horizontal and relatively shallow (fig. 6). On the higher rolling Mississinewa Moraine, however, the potentiometric surface reflects the surface topography to a limited extent. The potentiometric surface is much deeper below the surface of the hills of the moraine (recharge area) than it is below the flood plains of the stream valleys (discharge area). In the area of the Mississinewa Moraine, the potentiometric surface is generally lower in bedrock than it is in unconsolidated rocks, but east of the moraine the levels in each kind of material are nearly identical.

Where the pore spaces in the soil or rock beneath the zone of saturation are large and interconnected, as they are in sand, gravel, or jointed limestone, water moves freely. If the porous and permeable material is a formation of significant vertical and lateral extent, the formation is an aquifer. Two aquifer systems are in use in Grant County: (1) the unconsolidated system and (2) the bedrock system.
UNCONSOLIDATED SYSTEM
The unconsolidated system is composed of lenses and layers of sand and gravel interspersed in the till and of layers of sand and gravel exposed on flood plains and outwash plains. The till aquifers are generally confined within the low-permeability till. The flood-plain and outwash aquifers are generally unconfined (water-table) aquifers.

Figure 6. Map of Grant County showing the potentiometric surface of the unconsolidated aquifer.
The most significant of the aquifers in the unconsolidated system are the glacial outwash terraces in the flood plain of the Mississinewa River and the thick sand and gravel lenses in the buried Teays Valley and its tributaries. The shallow outwash aquifers are recharged directly by precipitation and are generally connected hydraulically to the river. They are unconfined and are directly affected by droughts and periods of high rainfall. Because they are shallow water-table aquifers, they are also highly susceptible to contamination from surface sources. The deeper buried sand and gravel aquifers in the till are confined and are affected only by extended periods of drought. The till aquifers are recharged over large areas by infiltration through the slowly permeable till. They therefore have much more storage capacity and are much less subject to contamination from the surface.

Domestic and agricultural supplies of water are largely obtained from sand and gravel lenses in the till east of the Mississinewa River, where the unconsolidated material is thick (Heckard, 1968). Large municipal supplies for Marion, Gas City, and Jonesboro are obtained from an extensive sand and gravel aquifer in a Teays tributary. Van Buren and Upland draw on what appear to be isolated sand and gravel aquifers in the till.

BEDROCK SYSTEM
The upper 200 feet of bedrock is considered here to be the bedrock aquifer system (Capps, 1910). Porosity and permeability generally decrease below 200 feet. Porosity and permeability in the carbonate bedrock are generally secondary and are caused by solution widening of joints, bedding planes, and fractures. Because solution activity tends to decrease with depth, the opportunities for finding producing zones decrease with depth.

The bedrock system is confined by and receives recharge from the till above. It is generally a good aquifer capable of supplying water for domestic and limited industrial needs. Because the bedrock system is relatively deeply buried, it is not directly affected by short-term changes in precipitation or by surface contamination.

Wells are generally completed in the bedrock system west of the Mississinewa River, where the glacial till is relatively thin. The bedrock aquifer extends throughout the entire county but is used little in the east, where it is deeply buried and shallower water is available from the unconsolidated system. Bedrock is used for all or part of the supply for Marion, Fairmount, Upland, Van Buren, and Swazee.

WATER QUALITY
Little water-quality information is available for Grant County. Data that are available point to a problem concerning the contamination of surface water by human or animal wastes. The total coliform count is particularly high (annual average 24,000) in the Mississinewa River at a sampling point near the Highland Avenue bridge (Indiana State Board of Health, 1975). Coliform bacteria indicate the presence of human or animal excrement. Chemical quality of the surface water is about average compared with other surface water in the state.

Ground water in Grant County is generally hard to very hard (greater than 350 ppm (parts per million) as CaCO₃). Hardness might be called the soap-wasting property of water, because no suds will be formed until the minerals producing the hardness are removed by the soap. The resulting mineral-soap combination is an insoluble scum. Hardness is produced mainly by mineral salts of calcium and magnesium, major components of both the unconsolidated and bedrock aquifers. Hard water is particularly troublesome because it requires excessive amounts of soap, leaves an insoluble scum, and forms incrustation on pipes and boilers.

Less frequent but troublesome problems of ground-water quality are hydrogen sulfide and iron. Hydrogen sulfide, a gas, is formed by sulfate-reducing bacteria in the absence of oxygen. Hydrogen sulfide is objectionable because it has an offensive odor and because it forms a weak acid in water. This acid attacks iron pipe and forms a scale that may restrict or close the pipe. Iron may be present in the ground water or may be dissolved from the plumbing by corrosive water. Iron in water causes staining and incrustation when it is in concentrations greater than 0.5 ppm. None of these are particularly health hazards,
although large concentrations cause untreated water to become objectionable for use.

Most organic contaminants in water are related to the activities of man. Examples are sewage and industrial wastes in streams and septic effluent and sanitary-landfill leachate in ground water. These are not serious problems at present in Grant County, but they should be carefully guarded against, particularly in the water table and shallow confined aquifers.

Mineral Resources
The economic mineral resources in Grant County are derived from unconsolidated sediments and from bedrock. Sand and gravel, lake clays, clay-rich tills, and peat are obtained from unconsolidated sediments. Limestone and oil and gas are obtained from bedrock.

SAND AND GRAVEL
Grant County has a relatively large supply of sand and gravel. Deposits of these materials are primarily in glacial outwash in the flood plain of the Mississinewa River. Lesser quantities of outwash are in the lower reaches of the flood plain of Walnut Creek just north of Gas City. There are large gravel pits northwest and just southeast of Marion and also a small but expanding pit southwest of Upland.

CRUSHED STONE, BUILDING STONE, AND AGRICULTURAL LIME
Stone is a quarriable resource only in a limited area of the county because of the thick cover of glacial drift. Drift thickness exceeds 100 feet over most of the county (pl. 1). Only in the western third of the county, where much of the drift is less than 25 feet thick, is surface mining an economic matter. Both reef rock and interreef rock of the Liston Creek Limestone Member of the Wabash Formation are mined at two locations in Grant County (fig. 7). The older Pipe Creek Quarry, near Sweetser, produced primarily road ballast and riprap. The newer Pipe Creek Jr. Quarry, north of Point Isabel, produces primarily agricultural limestone. Smaller quarries scattered around the eastern part of the county have been abandoned. Building stone, primarily for foundations, was cut from thin-bedded Liston Creek Limestone in now-abandoned quarries north of Marion in the Mississinewa River flood plain. One quarry was at the site of the Marion City Park and another at the Marion sewage-disposal plant.

PEAT
Small peat deposits are scattered throughout the county. The largest deposits and greatest density of deposits are on the Mississinewa Moraine and in the area immediately to the southwest (fig. 7). The most extensive of these deposits, 3 miles east and half a mile north of Fairmount, presently supports a small commercial operation. This particular deposit appears to contain a large quantity of usable peat. The peat is 50 feet thick (operator, oral communication, 1977), is one of the thickest deposits in Indiana, and is part of a linear system of parallel bogs (fig. 2) in troughs that are several miles long.

CLAY
Clay was once mined on a small scale from pits in various parts of the county. Most of the clay from these pits was used to produce drain tile, but some was used in bricks for local construction. The largest known clay operation was at the south edge of Sweetser, where a nearly pebble-free glacial till provided the clay that was fired in local kilns (Whitlatch, 1933). Clay mining ceased when plastic tile supplanted the less convenient clay tile.

OIL AND GAS
The oil and gas boom in the Trenton Field of east-central Indiana brought an influx of people, businesses, prosperity, and pollution to Grant County in the late 1800's. The boom ended with the depletion of the oil and gas in the early 1900's. Production reached a peak in 1904 (Carpenter and others, 1975) and dropped off rapidly thereafter. Today only minor amounts of gas are being produced for local domestic or farm use.

The Trenton Field was so named because oil and gas were produced from the Trenton Limestone. The top of the Trenton Limestone lies at an average depth of about 950 to 1,050 feet below the land’s surface, and the formation has an average thickness of about
Good potential for sand and gravel production in outwash materials

Some potential for limited sand and gravel production in alluvial materials

Potential for crushed-stone production
Bedrock 25 feet or less beneath the surface

Active sand and gravel pit

Inactive sand and gravel pit

Active limestone quarry

Inactive limestone quarry

Peat pit

Inactive clay pit

Figure 7. Map of Grant County showing potential mineral resources.
175 feet. Oil and gas were generally produced from the dolomitized upper 75 feet of the formation.

About 105 million barrels of oil and a trillion cubic feet of gas were produced from the Trenton Limestone. A substantial part of this was produced from the more than 4,000 wells in Grant County. With modern drilling and recovery procedures and environmental controls, production could have been more than doubled (Carpenter and others, 1975).

The gas supply in the Trenton has essentially been depleted except for some minor pockets that, as mentioned above, have sufficient pressure to provide for the limited needs of an individual homeowner or farmer. An appreciable amount of oil remains within the formation, but production is prohibitively expensive because as many as 1,000 barrels of brine is produced for each barrel of oil.

Other potential oil-producing bedrock units in Grant County are the Black River Limestone and the Knox Dolomite. Small quantities of oil and gas have been found in each of these units in northeastern Indiana, but neither has been explored extensively (Gutstadt, 1958). The top of the Black River, which lies immediately below the Trenton, is about 1,100 to 1,150 feet beneath the surface (fig. 4). The Black River is primarily a dense impermeable 300-foot-thick limestone with a few porous and permeable dolomitized zones. These dolomitized zones are the potential oil and gas reservoirs. The top of the Knox Dolomite, which lies immediately below the Black River, is about 1,450 feet beneath the surface. The Knox consists of limestone and dolomite and is about 800 feet thick. The dolomite is porous and is therefore a potential hydrocarbon reservoir. Future price increases for oil and gas may justify exploration of these units.

Geologic Considerations in Land-Use Planning

The term land usability in this report refers to the effect that geologic conditions have on land use and the effect that land use has on the geologic setting. These effects have seldom been given due consideration in past planning efforts. A significant part of land-use policies has been based primarily on convenience, economics, and politics. Now, because of the ever-increasing pressure placed on land, land usability must be one of the prime land-use planning factors. Land should be used to its greatest practical potential, whether that use is a waste-disposal site, housing area, farm, mineral-extraction site, waste-injection well, or natural area.

Grant County is a part of Indiana's most productive agricultural region. Therefore, due consideration should be given to the preservation of the rich cropland of the county. Urban-industrial development that removes cropland from production should be directed toward the less productive agricultural areas. Mineral resources also require protection if they are to be available for future use. Deposits of sand and gravel and areas underlain by minable limestone and dolomite are the two mineral resources that may be most seriously affected by development in Grant County. Both of these resources are vital elements for the construction industry and therefore essential for continued economic growth. Construction of homes or industrial plants on the land surface above these resources precludes development of the resources, at least in the near future.

Land suitable for disposal of waste materials should also be considered as a natural resource. No satisfactorily economical alternative to land disposal of wastes has yet been developed. Therefore, it is vital to protect from loss to some other preemptive use those areas in which geologic conditions ensure that toxic wastes are confined or rendered harmless by biochemical or physical activity before reentering the environment. Geologic conditions directly affect land suitability. Some adverse geologic features that are related to construction in Grant County are flood plains, steep slopes, and swamps and bogs.

Flood plains are natural physical features that serve periodically to carry flow in excess of what the stream channel itself will conduct. Floodwater, because of its high energy level, carries a heavy load of freshly eroded sediment that is deposited as flooding subsides. Flood plains, therefore, are composed largely of rich silty organic soils. The rich soil of the flood plains enhances their
Areas with 25 feet or more of low permeability, predominantly fine-grained material above the first significant (5-foot minimum) layer of permeable material.

Areas with 10-25 feet of low permeability, predominantly fine-grained material above the first significant (5-foot minimum) layer of permeable material.

Areas with less than 10 feet of low permeability, predominantly fine-grained material above the first significant (5-foot minimum) layer of permeable material.

Areas of highly variable layered and intermixed fine- and coarse-grained materials deposited in flood plains; parts of this area are subject to periodic flooding and most of the area is wet much of the year; a zone of ground-water discharge.

Areas of largely organic and/or fine-grained materials deposited in depressions; may be 50 feet thick or more; generally in closed depressions and wet.

Figure 8. Map of Grant County showing areas of impermeable surficial materials, approximate depth to first permeable materials, wet areas of organic soils, and areas subject to periodic flooding.
desirability for agricultural use, but only if occasional flood damage to crops is acceptable. Recreational areas or game preserves are perhaps the best possible uses for flood plains. If a flood plain is preserved as a natural or recreational area, little or no restructuring is required, because the flood-damage problem is alleviated.

Two problems that must be faced when building on a flood plain are: (1) structures are susceptible to flood damage and (2) structures can impede flow and increase flood levels upstream. Flood plains, therefore, should be recognized and their associated hazards respected before they are put to some unnatural use. The areas in Grant County subject to periodic flooding (fig. 8) are the flood plain of the Mississinewa River and the lower reaches of its major tributaries. Flooding has occurred in the southeastern part of Marion as discussed under the heading "Surface Hydrology." This part of Marion and the westernmost part of Gas City are the two developed areas most susceptible to flooding.

Highly organic soils, such as muck and peat, present an environmental hazard for nearly any type of construction because they are soft and generally wet. Organic soils are readily compressible because of their high porosity and are subject to rapid changes in water content because of their high porosity and permeability. Muck and peat also have little shear strength and generally have poor bearing capacity. Structures constructed on organic soils, therefore, require special foundation treatment. Evidence of the hazards of building on organic material can be observed in Grant County where State Road 26 crosses a trough of muck and peat just west of Barren Creek. The roadway in this location buckled because of the effect of differential loading on the soft pliable peat. Areas that are hazardous because of organic-rich soils (fig. 8) are the two parallel 3- to 4-mile-long elongate depressions that extend southwestward and northeastward between Fairmount and Fowler and the many smaller bogs in the depressions on the Mississinewa Moraine.

Slope failure that results from such alterations as overloading, oversteepening, or oversaturating is another geologic hazard that must be considered in Grant County. Slopes of less than 8 percent are generally thought to present minor problems for most types of construction, and most slopes in the county fall in this category. There are, however, slopes greater than 8 percent, particularly along the valley walls of the Mississinewa River, Sugar Creek, and the western margin of the Mississinewa Moraine. These slopes have reached stability in their natural state, but the addition of weight or moisture or any other physical alteration may result in slope failure.

Subsurface Liquid-Waste Injection

Subsurface liquid-waste injection is the injection of liquid wastes, under pressure, deep into the subsurface for the intended purpose of permanent storage. Liquid-waste injection wells are typically used by the oil industry, the chemical industry, steel mills, and the food-processing industry to dispose of materials not suitable for disposal on land or in surface water. The reappearance of these wastes at the ground surface, in potable ground water, or in a mineral resource is a real threat to the environment. Selecting a geologically suitable site is therefore critical to the success of an injection well.

Geologic criteria for an environmentally safe injection well are: (1) a permeable rock zone of sufficient porosity, permeability, thickness, areal extent, and storage capacity to accept the waste without overpressurization, (2) impermeable rock layers above and below the injection zone that will contain the liquid, (3) injected liquid that will not react with the rock to reduce permeability, and (4) injected liquid that is compatible with the resident fluid.

Normally, the deeply buried porous and permeable rock layers in Indiana already are saturated with saline or brackish water. The waste liquid must therefore displace this resident liquid. Displacement normally occurs through movement of the liquid, by compression of the resident fluid, by joint or pore expansion in the skeletal structure of the rock, and by compression of the grains of the solid formation material. Displacement is induced by an increase in pore pressure as liquid wastes are injected into the receptor.
formation. Therefore, the injection zone must be sandwiched between impermeable layers of rock to provide for vertical containment of the liquid. Layers of nearly impermeable shale provide the best sealing, and jointed and fractured limestone and porous poorly cemented coarse-grained sandstone provide the optimum for an injection zone.

A monitoring system should be an integral part of any injection-well program. The well should be monitored both at the surface and in the subsurface. Surface monitoring should include consideration of injection pressure, leakage testing, and injection-fluid chemistry. Subsurface monitoring can be accomplished through the installation of observation wells that monitor liquid pressure and chemistry near the area of injection and at various distances away. Observation wells should also be established above and below the injection horizon to monitor possible vertical movement of toxic liquids. It should be mentioned here that the resident fluid in the injection horizon is also probably toxic. In nearly all places where waste injection is feasible, the resident fluid contains a high concentration of dissolved solids and salts. In some places the resident fluid may be more toxic than the waste liquid that is displacing it. It is therefore critical that the resident fluid as well as the injection fluid be confined.

In Grant County four rock units appear to be capable of accepting liquid wastes. These units are the Mount Simon Sandstone, the Knox Dolomite, the Black River Limestone, and the Trenton Limestone. Only the Mount Simon Sandstone, however, meets all requirements for satisfactory liquid-waste storage. Each of the other units has at least one geologic deficiency.

The properties that qualify the Mount Simon (ORSANCO, 1976) as a suitable storage unit for liquid wastes are: (1) pore space that, on the basis of porosity of 5 to 10 percent, is sufficient to accept liquid; (2) two confining units, the Eau Claire Formation, which provides a 600-foot-thick layer of impermeable material above, and impermeable granitic basement-complex material below; (3) sufficient thickness (more than 500 feet) and depth (about 3,000 feet); and (4) a saline resident liquid (more than 50,000 ppm NaCl). Other factors, such as the compatibility of the injected and resident liquids and the effect of the injected liquid on the formation material, must be determined on a case-by-case basis.

Liquid-waste injection, or deep-well disposal as it is sometimes called, can be satisfactory for storing wastes that cannot be handled by any other means. Careful control and professional handling are required to ensure that no environmental harm results. In Indiana liquid-waste injection is controlled by permit from the Water Pollution Control Section of the Indiana State Board of Health.

**Septic Systems**

Septic systems are designed and used to process and disseminate small amounts of domestic liquid wastes. The septic system is composed of a holding tank and a tile field, each buried just beneath the earth’s surface. They are limited in capacity and function by the on-site geology, the infiltrative capacity of the soil, the nature of the liquid, the system design, the soil moisture content, and the size of the area available for tile-field installation.

Septic systems are designed to remove liquid waste from purview of the senses of sight and smell, but, most importantly, they serve to purify wastes through physical, chemical, and biologic activity.

Septic systems disseminate liquid waste most readily into such permeable coarse-grained materials as sand. Sand is, however, not the earth material best suited for purifying waste. Both chemical and biologic contaminants may travel great distances in a permeable coarse-grained medium with little attenuation. Fine-grained materials (clay and silt), however, act through mechanical filtration, adsorption, and ion exchange to cleanse the liquid of contaminants. Where clay and silt are the predominant size fraction, movement of liquid from the tile field into the soil may be extremely slow. If the field is too small, liquid may back up and may even seep out at the surface. Proper design can alleviate or minimize the infiltration problem. For example, field size should be controlled by the anticipated liquid load and by permeability of the geologic material in which the tile field is installed. In many installations
Figure 9. Map of Grant County showing relative suitability of geologic conditions for use of septic systems.
the size of the tile field needed for proper function of the septic system dictates the minimum lot size for home construction.

Geologic conditions that support proper functioning of septic systems are: (1) soil thickness of more than 10 feet between the base of the tile field and the water table, (2) sufficient distance between the bottom of the tile field and the bedrock surface (more than 5 feet), (3) earth material that consists largely of silt and clay, (4) an area not subject to flooding, (5) a tile-field size based on permeability, and (6) a relatively flat-lying tile field. (Less than 8-percent slope is best, and greater than 15-percent slope is unacceptable.) On the basis of these criteria, large areas of Grant County (fig. 9) are potentially suitable for the use of septic systems.

The primary areas of concern in Grant County are: (1) areas with excessively permeable surficial materials (primarily sand), (2) areas with excessively tight surficial materials (primarily clay), (3) flood plains, in which the water table is high and flooding is a hazard, (4) depressional wet areas where the water table is high, and (5) the steep slopes of the Mississinewa River. Particular care should be used in locating the tile field on the basis of location and depth of water-supply wells. Because the nature of geologic materials in Grant County is varied and relatively unpredictable, each installation requires separate study.

If the situation demands, a septic system can be designed to function acceptably even in adverse geologic conditions. Installation of a specially designed system, however, is usually prohibitively expensive. Specially designed systems may also require more frequent and expensive maintenance. Most sites that are not suitable for use of septic systems are also poorly suited to housing development, especially high-density housing.

Sanitary Landfills

A sanitary landfill is defined as an engineering method of land waste disposal that creates no nuisances or hazards to public health or safety (American Society of Civil Engineers, 1959). The sanitary-landfill concept of solid-waste disposal by land burial was devised to overcome the environmental hazards inherent in the open dump. Open dumps create visual scars, air pollution, and surface-water and ground-water pollution and are breeding grounds for disease-carrying rodents and insects. Burial in nearly any geologic setting alleviates most of these problems. But contamination of surface water and ground water by leachate is not so easily controlled. Leachate is a highly toxic liquid created by the reaction of water with soluble materials in the waste. Leachate control requires a special set of geologic conditions (Bleuer, 1970; Bleuer and Hartke, 1971). These conditions are not met in most readily available manmade excavations, such as gravel pits and stone quarries. In fact, areas most suitable for farming and housing development are generally also most suitable for sanitary landfills.

Geologic conditions for the siting of environmentally acceptable sanitary landfills are: (1) a thick surficial layer of tight low-permeability material, (2) a water table well below the proposed base of the landfill, (3) good surface drainage, (4) an abundant supply of tight low-permeability cover material, and (5) freedom from flooding. Each of these conditions is equally important and should be given due consideration in searching for an environmentally suitable site. The map showing sanitary-landfill suitability (fig. 10) is based on these environmentally protective considerations.

The sanitary-landfill concept is a reasonable alternative approach to solid-waste disposal in that it replaces the open-burning dump with a covered and generally more effectively managed operation. As noted above, however, sanitary landfills present their own human health and welfare hazards. Conditions within the landfill are generally anaerobic. Decomposition of the wastes is therefore slower, but the leachate is more concentrated than that formed under the aerobic conditions of the open dump. Geologic conditions must therefore be such that leachate production is minimized or that leachate is retained within the landfill or is purified before entering underground or surface water.

Methane, a highly flammable gas produced by organic decomposition within the landfill, is another environmental hazard. The same geologic conditions that help contain leachate
SANITARY LANDFILLS

Figure 10. Map of Grant County showing areas of relative suitability for sanitary landfills.

EXPLANATION

- **Unsuitable**: Extreme preparatory and operational adjustments are required; stream valleys contain permeable surficial materials and are subject to flooding.
- **Potentially suitable**: Requires precautionary measures; generally 10 to 25 feet of impermeable material above a potential aquifer.
- **Unsuitable without modification**: Closed depressions with generally high organic or clay content; difficult to work; may have less than 10 feet of impermeable material above a potential aquifer (shown by diagonal lines).
- **Suitable**: Generally thick section of impermeable material, low water table, and well above flood level.
within the fill also cause gas to be confined. Pressure builds because gas is constantly being produced. Pressure is released when the gas escapes along paths of least resistance. The direction of escape is generally upward through cracks or other conduits in the cover material. Escape routes either can be planned to allow controlled escape or can be permitted to develop randomly and therefore to allow uncontrolled and potentially hazardous escape.

The most unsatisfactory areas for establishing sanitary landfills in Grant County are the stream valleys in which the materials are quite permeable, the water table is near the surface, and flood potential is high. The flood plains of the Mississinewa River and Sugar Creek are particularly hazardous because they contain substantial amounts of highly permeable glacial outwash. Other areas of particular concern are the isolated wet depressional areas. The bogs and swampy areas, largely associated with the Mississinewa Moraine, are hazardous because they are wet and poorly drained. Two relatively large areas, one north of Herbst and the other between Marion and Gas City, have little cover over the bedrock (generally less than 10 feet). These areas are hazardous because little protection is provided for the ground water in the shallow bedrock and because material available for cover is limited.

The most satisfactory areas for sanitary landfills in Grant County are the high areas on the Mississinewa Moraine and the areas of glacial till in which a thick clay layer (fig. 8) lies at the surface and in which the water table lies well below the surface. Significant areas suited for establishing sanitary landfills also exist west of the Mississinewa River, but they are discontinuous because of variations in drift thickness. Areas too small to map exist within the areas mapped as suitable and may prove to be unacceptable for sanitary landfilling. For example, small stream valleys or isolated bogs are basically unacceptable sites for landfills. On the basis of information compiled from the data gathered for this report, reasonably good prospects exist for locating satisfactory sanitary landfills close to the population center of the county (fig. 10).

Information provided by the map showing areas of relative suitability for sanitary landfills (fig. 10) is meant to be used as a guide in searching for suitable sites. Exploration in areas designated as suitable should prove more fruitful than searches in marginal or poor areas. In any event, detailed site studies must be completed according to the requirements of the State Board of Health (Indiana Stream Pollution Control Board, 1974) before proceeding with site purchase and construction.

**Liquid-Waste Storage Lagoons**

Liquid-waste storage lagoons are an inexpensive and relatively efficient natural biologic and physical means for storing and treating liquid wastes. They can be constructed and used in harmony with the environment if simple precautions regarding geologic and engineering design are taken. Liquid-waste storage lagoons are used as (1) settling ponds to allow precipitation of soluble salts, solids, and colloids; (2) aeration lagoons to decrease BOD (biochemical oxygen demand) and to facilitate removal of bacteria and viruses; and (3) holding ponds that serve as storage for liquid wastes awaiting treatment or dispersal. Lagoon design and size depend on the geologic material, waste composition, and volume of waste. Normally, optimum depth for lagoons is about 10 feet. If aerated lagoons are used, depth can be increased to 15 to 20 feet while still maintaining the desired aerobic surface conditions (Olson, 1974). If an aerated lagoon is to be used for biologic treatment, however, a second lagoon may be needed to facilitate removal of solids.

Four examples of facilities that can use lagoons profitably are: (1) animal feedlots, (2) municipal sewage-treatment plants, (3) food-processing plants, and (4) chemical-manufacturing plants. For the first three examples, biologic treatment is the primary concern, and an anaerobic settling pond, an aeration pond, and a polishing pond are generally required to produce the desired results. Chemical plants use storage lagoons to hold chemical wastes for treatment before disposal or reuse. If storage is the sole function, a single lagoon is usually sufficient.

The discussion of uses suggests the environmental hazard posed by a faulty
LIQUID-WASTE STORAGE LAGOONS

Figure 11. Map of Grant County showing relative suitability of geologic conditions for waste-storage lagoons.
waste-storage lagoon. In each kind of use a potentially harmful liquid waste is placed in an open pond. Haphazard site selection and poor management can result in serious contamination of surface water and ground water. The primary environmental concern, therefore, is the need to choose a geologically suitable site. Geologic conditions at nearly all types of potential sites may be altered through careful engineering, thereby producing an acceptable situation. The best and least expensive way to achieve an acceptable level of environmental protection, however, is to use the best available natural geologic conditions.

Ideal geologic requisites for sewage-lagoon siting are: a substantial section of low-permeability clay-loam soil (extending at least 20 feet beneath the base of the lagoon), a minimum distance of 20 feet between the bottom of the pond and the water table, a flat surface in an area with little relief, little organic matter in the soil, and location above the maximum expected flood level. Surficial inspection, water-well logs, highway borings, and Indiana Geological Survey auger-hole samples were used to delineate general areas of suitability (fig. 11) for storage-lagoon construction in Grant County.

On the basis of the above-mentioned criteria, the most suitable areas for waste-storage lagoons are (1) east of the Mississinewa River on the Mississinewa Moraine and (2) in the northwest corner of the county. The suitable areas on the Mississinewa Moraine are restricted to the level or nearly level uplands. All geologic factors are positive on the level uplands: the thick surficial material is clay-rich till, the water table is depressed (generally more than 25 feet below the surface), and bedrock is also well below the surface. Other areas that appear to be suitable (fig. 11) are the extreme northeast corner of the county and relatively large but isolated sections of till west of the Mississinewa River.

The areas that are unacceptable (fig. 11) are readily identifiable on a topographic map. These areas include flood plains, marshes, and valley walls and hillsides. Others are not acceptable, primarily in the western part of the county, because of a shallow water table, shallow bedrock, or insufficient thickness of surficial clay.

The map showing relative suitability of geologic conditions for waste-storage lagoons provides only a generalized picture because of the variability of the glacial materials. It can be used successfully, however, to eliminate some areas and recommend others for further study if a waste-storage lagoon is needed.

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OVERSIZED DOCUMENT

The following pages are oversized and need to be printed in correct format.
MAPS OF GRANT COUNTY, INDIANA, SHOWING BEDROCK TOPOGRAPHY AND THICKNESS OF UNCONSOLIDATED MATERIALS

By Edwin J. Hartke

1982