Environmental Geology and Land-Use Planning in Boone and Tippecanoe Counties, Indiana

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Abstract

Natural aspects of the land surface (surface drainage, geomorphology, surface and subsurface geology, and distribution of soils) must be considered in proper land-use planning. Boone and Tippecanoe counties lie within the Tipton Till Plain which is influenced by a combination of geologic and pedalogic factors and associated engineering characteristics. However, the two counties provided a contrast because of their different rates and extent of urban growth.

Large scale maps are needed to supply the required detail for land-use planning. Maps of the two counties were compiled at 1:24,000 scale (7½′ quadrangle) depicting the surface geology materials. Engineering interpretations are derived from such maps and used to aid site-selection.

Bedrock-elevation maps were prepared at 1:62,500 scale. Zones with thin glacial cover over bedrock extend across both counties. Tippecanoe County residents experienced problems in such bedrock areas involving septic tank emplacement, foundation excavation and ground water supply. Through proper consideration of the natural aspects, Boone County could benefit from this and other experience gained in Tippecanoe County during its rapid growth period.

Introduction

Natural factors contributing to land surface development must be considered when constructing a good land-use plan for a regional or county-wide area. Included are topography, surface drainage, soil development and surface and subsurface geology. Maps of surface materials and bedrock prepared at a sufficiently large scale to show the necessary detail, plus knowledge of the political-social aspects of a region must be available before a proper land-use plan can be developed.

Boone and Tippecanoe Counties, Indiana, represent an interesting comparison and contrast for land-use studies. Both lie within the same major physiographic province (Tipton Till Plain) and have similar geologic conditions. Tippecanoe County has experienced rapid population growth recently. With the close proximity of Marion County, Boone County likely will soon experience a marked population increase. Similarities in geologic conditions of the two counties provide an opportunity for Boone County planners to learn from the difficulties encountered in Tippecanoe County prior to the establishment of an area planning organization. Such comparison requires discussion of the natural factors in each county which are associated with proper land-use planning.

Methods

Information on surface materials is available for much of Indiana, which is important in land-use planning and space allocation. By presenting such information in map form, the patterns and distribution

of materials are well illustrated, making it easier to relate the importance of various components.

For land-use planning, the mapping should be prepared in sufficient detail to allow an accurate prediction of both beneficial and harmful aspects. In this study, the surface materials were mapped at a scale of 1:24,000 on 7½ minute topographic maps. The surface materials maps were compiled from: 1) agricultural soils maps (4, 9); 2) engineering soils maps (not available for Boone County) (17); 3) air photos; 4) Indiana Geological Survey 1° X 2°, geologic maps (12, 13); and 5) field investigations.

Soils information is of particular importance in regions of thick unconsolidated deposits, particularly in glaciated areas which pertains to the counties studied. McComas *et al.* (5) discussed the usefulness of surface geology and soil units in map preparation.

Bedrock maps were prepared at a scale of approximately 1 inch to 1 mile (1:62,500) from: 1) Indiana Geological Survey maps and reports (10, 11); 2) published ground water reports (2, 7); 3) well-log information on file at the Department of Natural Resources, Division of Water; and 4) files of the Indiana Geological Survey. The maps developed in this study include information concerning the depth to bedrock expressed as unconsolidated material thickness contours, using a 50-foot contour interval.

Results

Tippecanoe County

Tippecanoe County is characterized by flat to gently rolling ground moraine composed primarily of till. This material is the most extensive deposit in the county, although a sizeable portion has been shaped by the Wabash glacial sluiceway, trending northeast across the center of the county. Figure 1 shows the distribution of surface materials in Tippecanoe County. This map is based on published maps (12, 17) and recently completed studies at Purdue University (8, 16). Glacial melt water and the present-day Wabash River have deposited extensive volumes of sand and gravel in the form of terraces, outwash plains, and the river flood plain.

From an engineering standpoint the terrace and outwash deposits of greater Lafayette are excellent for most construction purposes; they contain abundant ground water and exhibit no major foundation problems. Within the past 10 years, however, growth has accelerated and the county population surpassed 100,000, with the major concentration near greater Lafayette. This rapid increase was due partly to the growth of Purdue University in West Lafayette, and partly to development of light and medium industry in Lafayette.

As a consequence of this growth and subsequent urbanization of surrounding areas, limited land-use planning, and lack of consideration for geologic factors, some adverse effects to the community developed.

The wooded, sloping terrain between the low-lying Wabash River floodplain and the upland glacial till plain provides an attractive area

for home sites. Residential development, however, is adversely affected by slope failure and soil creep. The residential area along Happy Hollow ravine in West Lafayette is a good example where slope failure has caused nuisance problems (16). Various methods of slope stabilization have been attempted by homeowners. Not all remedial constructions have been successful, and many through their unsightly design, reduce the beauty of the ravine.

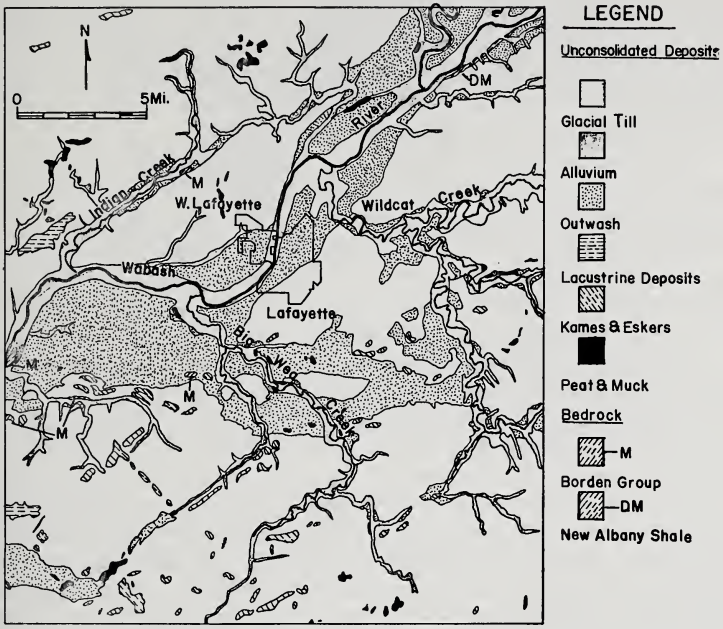

FIGURE 1. *Surface materials map of Tippecanoe County, Indiana.*

The gravel-rich terrace deposits along the Wabash River are a valuable mineral resource, and are mined in several locations. Immediately south of the Purdue University airport, mining of sand and gravel has left an extensive void in the landscape. Sequential land-use should incorporate reclamation, perhaps for recreational purposes.

An apartment complex, located on the floodplain in West Lafayette, was constructed on hydraulic fill material dredged from the river. Although the building site was elevated about 10 feet in the process, during times of flooding, the basement apartments may be flooded. Construction upon floodplain reduces the cross sectional area of the waterway, thus changing its capacity to carry flood water and encouraging erosion downstream. Care must be taken when constructing on a floodplain to prevent any constriction of floodwater.

Greater Lafayette has three sanitary landfills (two now abandoned) located in permeable deposits adjacent to the Wabash River. Serious problems may develop if landfill leachate migrates with ground water

toward the river or pollutes adjacent sand and gravel aquifers. One abandoned landfill is located south of the Purdue University airport on river terrace deposits in depressions resulting from previous sand and gravel operations. Few homes exist in the area, but the steep ground water gradient toward the Wabash River encourages leachate movement.

A second landfill was located on the north side of Lafayette near the Harrison Street bridge. This landfill, which operated until recently, employed hydraulic fill from the Wabash River to cover the layers of refuse (1). It was located near the river, on the floodplain, and relatively close to the Lafayette municipal water-well field. Leachate from a previous unsupervised open dump has caused the city to abandon one well which became contaminated.

The currently-active landfill site services the greater Lafayette region. It is located north of Lafayette and US 52 By-Pass on the floodplain about 1 mile east of the river. The ground water gradient is sufficiently low that pollution of the river is not an immediate problem, but ground water contamination adjacent to the site is inevitable. Future landfills would function better on the upland till plain in impermeable materials at a safe distance from drainage ways.

Rapid population growth in the Lafayette area has expanded home building into the surrounding countryside beyond the services of city water supply and sanitary sewerage. To illustrate, the Klondike area is located 5 miles northwest of West Lafayette. Here the bedrock rises sufficiently close to the surface to cause serious concern for residential developers (16). The bedrock high trends northeast across Tippecanoe County. The rock unit is a siltstone within the Borden group and is impermeable and non-water bearing. Where this siltstone lies within a few feet of the surface, it is expensive to excavate for full basements. Problems in obtaining ground water occur in adjacent areas where less than 100 feet of glacial drift (mostly till) overlies the siltstone (15). In one subdivision, residents were forced to locate a community well about 1,000 feet away, in unconsolidated materials sufficiently thick to supply ground water. A third associated problem, caused by the impermeability of the rock, involved sewage removal. Septic tank fields do not function where the siltstone lies close to or at the surface and residents were required to install a small sewage treatment facility for waste disposal. These factors have caused inconveniences to the residents resulting in expensive adjustments during and after construction. The engineering problems are illustrated in plan and cross section in Figure 2.

Compressible peat and muck deposits occur sporadically throughout Tippecanoe County and complicate construction of roads and building foundations. Most occurrences have been recognized and adequate precautions taken. Shallow deposits are excavated before construction begins, however, for thicker accumulations, the site is avoided or special construction techniques are employed. Thick peat and muck deposits are a good source of organic material and can be regarded as a natural resource.

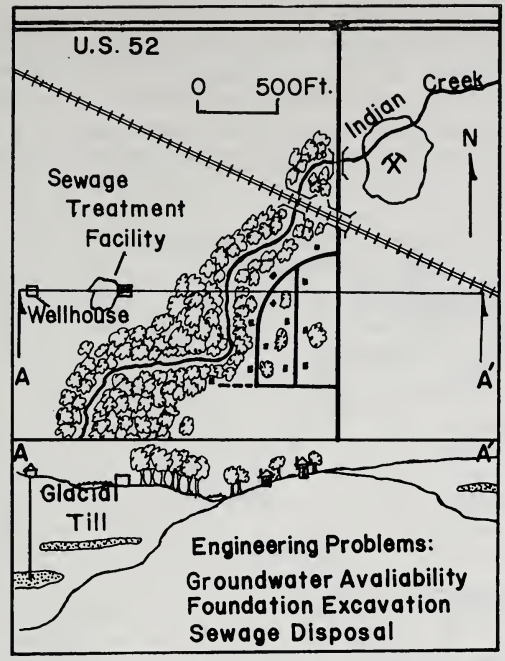

FIGURE 2. *Plan and cross sectional view of bedrock high in Klondike area.*

Boone County

Boone County, a predominantly agricultural area, is located northwest of Marion County. The current population of about 30,000 represents an increase of only 10,000 people in the past 100 years. During the past 5 years, however, the county has experienced rapid population growth in the Zionsville area resulting from an overflow of people from the Marion County region and an "out to the country" popularity among homebuilders. Two other factors will facilitate population growth: 1) the rapid transportation systems of Interstates 65, 74 and 465; and 2) Old Indiana, a large amusement center proposed for construction along Sugar Creek, northwest of Lebanon. This facility could attract millions of people to the county every year. In view of the possibility of urban expansion at the expense of productive farmland, a land-use plan utilizing geologic considerations for man/earth harmony should be established. Balance between the growing numbers of people and conservation of agricultural resources would thus be provided.

Surface Materials, Landforms and Land-Use Potential. Distribution of surface materials in Boone County is shown in Figure 3. Ground moraine is the most extensive feature present. The maximum thickness is 350 feet, in an area immediately south of Lebanon. These gently rolling, unconsolidated deposits are composed of boulder-clays which are generally poorly drained and have high seasonal perched

water tables. These regions are good for farming and location of sanitary landfills, but present somewhat of a problem for residential development. As this material is impermeable, particularly in the depression areas, septic tank effluent from homes is not readily accepted, and corrections must be made. The ground moraine is a somewhat reliable source of water as thick deposits contain occasional sand and gravel lenses.

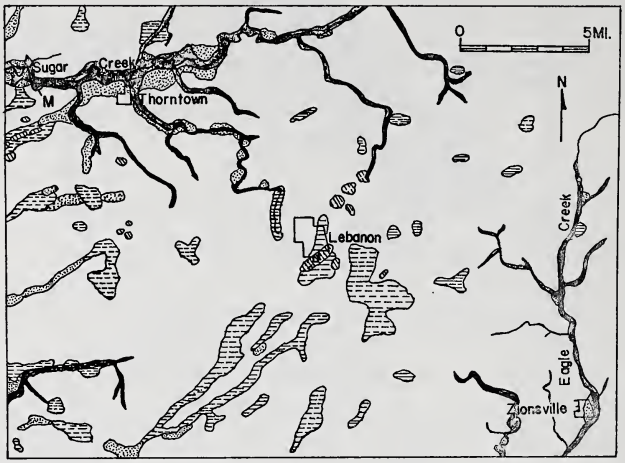

FIGURE 3. *Surface materials map of Boone County, Indiana. (See Figure 1 for legend.)*

Alluvium and floodplain deposits occupy areas associated with the drainageways of Sugar Creek and Eagle Creek. Ideally, these areas should be reserved for agriculture or recreation, but if development prevails, the cross sectional area of the water way should not be reduced. Alluvium provides moderate supplies of water and limited quantities of sand and gravel.

Outwash (valley train) deposits in Boone County are primarily restricted to Sugar Creek and its lower tributaries to the lower segments of Big Racoon and Big Walnut Creeks, and to patches along Eagle Creek. The thickness of sand and gravel is in excess of 100 feet in places. These regions may be a major natural resource for construction materials, and are favorable areas for ground water recharge and withdrawal. They should be outlined and their extent and potential made known to planners. However, outwash is an excellent material for supporting foundations of residential and industrial development. Therefore the quality of the gravel and associated economic factors should be considered along with the ground water potential and possible site development in the determination of the optimum land-use for the area.

Lacustrine plains are regions of flat topography and are composed of stratified silts and clays. One major lake plain occurs in Boone County. It originates in the Lebanon area and "funnels" southwest-

ward. Other patches of lacustrine slack water deposits occur in the western part of the county in association with outwash materials. Agricultural potential is generally promising and residential development may proceed if the land is properly drained.

Thin loess, or wind blown silt, covers the whole county. In the western portion, accumulations in excess of 6 feet are widespread. The distribution is southwest of a northwestward trending moraine. These thick deposits were derived from a local source of outwash and flood plain materials along Sugar Creek. The moraine may have acted as a barrier creating a "wind tunnel" effect thus channeling the deposits to the southeast. Loess provides the best farmland in the county and ideally should be the last areas removed from agricultural production. However, if residential development occurs here, special problems will be encountered. When saturated, loess has a low bearing strength, and structures built on it may settle.

Slope, topography, and other soil forming factors play a role in modifying the glacial drift to produce the well-drained Miami Soil series. The distribution follows a pattern closely associated with the major drainageways and their associated tributaries. These well-drained materials also occupy remnants of the northwestward trending morainal ridge. Numerous kames are included in this group. These areas have a strong potential for residential and some industrial development. Foundation support is good. Septic tanks respond favorably but precautions should be taken because of closeness to surface drainageways.

Bedrock Effects. Bedrock is exposed along Sugar Creek from about 1 mile west of Thorntown to the county line; these outcrops were not previously recognized in the geologic studies of Boone County by Gorby and Lee (3) and Brown (2). This rock is a non-calcareous argillaceous, fine-grained, jointed, thinly-bedded siltstone. It is likely the Carwood formation of the Borden Group (N. M. Smith, pers. comm.), and it presents stratigraphic as well as potential land-use problems. The outcrop occurs too far east for its position in the Borden Group. This area of shallow glacial cover is included within the potential growth region of the county. If development occurs, land-use complications similar to those experienced in the bedrock-associated area in Tippecanoe County may be expected.

Bedrock at depths of less than 100 feet occurs primarily south and west of the buried Knobstone Escarpment which trends northwest through the center of the county. There are a few isolated buried outliers to the north. Bedrock depths in the eastern part of the county, near Whitestown, are in places less than 25 feet. The probability of obtaining ground water in these shallow ($<$100 feet) bedrock regions decrease proportionately, particularly when the underlying rock is impermeable.

Conclusions

Work is continuing on environmental geology and land-use studies in both Boone and Tippecanoe Counties. The final objective is to

construct county-wide land-use plans based on the topographic and geologic factors. These plans will depict the beneficial and problematic aspects of an area relative to proposed land-use functions. For those areas in which problems are anticipated, remedial or corrective measures will be suggested, thus providing a positive solution to siting rather than an entirely restrictive approach in which only the "good" sites are acceptable. This additional contribution falls within the traditional area of engineering geology.

The study to date has enumerated several engineering aspects which require consideration in the two counties, as follows:

1) Slope stability along actively downcutting streams
2) Siting of sanitary landfills
3) Septic tank percolation fields
   a. Impermeable soils
   b. High, seasonal, perched water tables
4) Preservation of natural construction materials (sand and gravel, stone, borrow materials)
5) Foundation excavation in bedrock areas
6) Compressible, organic soils
7) Foundation in loessal and lacustrine deposits
8) Ground water supply
9) Prevention of ground water pollution
10) Storm runoff and local flooding
11) Constriction of waterways by construction in flood plains
12) Erosion control
13) Siltation and sediment transport
14) Performance of soils as road subgrades

These 14 items represent a relatively small percentage of the possible geologic hazards that could be compiled on a national scale or to some extent even on a state-wide basis (problems in limestone bedrock areas, for example). The list does focus on the local problems, which is an objective of this study.

A primary purpose of this report was to summarize both existing and new information available on Boone County. Tippecanoe County enjoyed a much greater wealth of compiled geologic information than did Boone County, primarily because Boone County has a smaller population and a lack of obvious, valuable mineral resources.

Compilation of available data is an important beginning for environmental geology land-use applications. Without a careful job here, the succeeding work is rendered inaccurate at best and possibly may be greatly misleading. Geologic information is used to construct the land-use plan. This can be accomplished through the use of overlays (McHarg, 6) and other techniques (Batelle report, 14). For Boone and Tippecanoe Counties, this final work is yet to be performed but the geologic data have been amassed and work is progressing toward development of information for regional land-use planning.

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