

# Geologic Considerations in Planning Solid-Waste Disposal Sites in Indiana

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# Geologic Considerations in Planning Solid-Waste Disposal Sites in Indiana

By N. K. BLEUER

## Introduction

City and county officials and many industries throughout Indiana are faced with the immediate need to plan sanitary landfill facilities because open dumps will be illegal after January 1, 1971. The sanitary landfill method of solid-waste disposal, in most places the most economically feasible alternative to open dumping and burning, involves the planned and controlled disposal of waste, which is compacted and covered daily by a compacted layer of soil.

The well-run sanitary landfill eliminates many obvious problems associated with open dumps, such as breeding of rodents and insects and spontaneous or accidental burning. Solid waste becomes a part of the geologic environment, however, when it is deposited in the earth materials of a sanitary landfill, and it is then subject to such normal geologic processes as weathering and movement of water through waste. As a result of these natural processes, hidden and irreversible groundwater contamination or surface water contamination may result. Furthermore, short-sighted planning with respect to available cover material or general workability of materials can greatly affect the economics of the operation, which in turn can control the quality of the operation.

This report has been prepared as an aid to developers of municipal and private solid-waste disposal facilities in Indiana. It points out some of the geologic considerations involved in sanitary landfill site selection, and it emphasizes that general geologic and groundwater information should be obtained at the beginning of the site selection process and that detailed geologic information should be used in making the final site selection.

## Acknowledgments

Results of original research on refuse leachate and its relationship to geologic and groundwater parameters have been reported by workers in California, Illinois, Pennsylvania, and other states. This valuable work, combined with knowledge of the geology of the State of Indiana accumulated over many years by the Indiana Geological Survey, forms the basis of the following discussion.

## Indiana Refuse Disposal Act

The Refuse Disposal Act, as amended and adopted by the Indiana General Assembly (1969), stipulates:

Sec. 30. Open dumps are hereby declared to be inimical to human health, and as such are not suitable means of refuse disposal. Except as hereinafter provided, on or after January 1, 1971, disposal of garbage, rubbish, and refuse on lands in this state shall be made only through use of sanitary landfills or by means of incineration, composting, garbage grinding or other acceptable methods approved by the state board [of health].

Among the acceptable alternatives to open dumping and burning is disposal of wastes in sanitary landfills, which are subject to the following stipulation:

Sec. 3. (a) "Sanitary Landfill"—Where a sanitary landfill is to be employed, information necessary to evaluate the project shall be submitted to the state board for review and approval prior to purchase of land or equipment.

Finally:

Sec. 31. The state board may adopt reasonable regulations to carry out the provisions of this act.

Standards for sanitary landfills enforced by the State Board of Health pertain to the location of landfills with respect to ravines, low areas and standing water, floodways, and potential surface water and groundwater contamination. In order to evaluate potential site locations properly, the State Board of Health requires certain information on soil types, geology, groundwater levels, and the precautions being taken to prevent contamination.

## Aids in Planning Solid-Waste Disposal Sites

The primary purpose of sanitary landfills is to dispose of refuse safely. The purpose is not to fill existing depressions, such as quarries, gravel pits, or swamps, a practice that cannot be condoned in many parts of Indiana because of probable groundwater or surface water contamination. Intelligent selection of landfill sites on the basis of geologic information is therefore mandatory.

Soil maps and interpretations, obtainable from

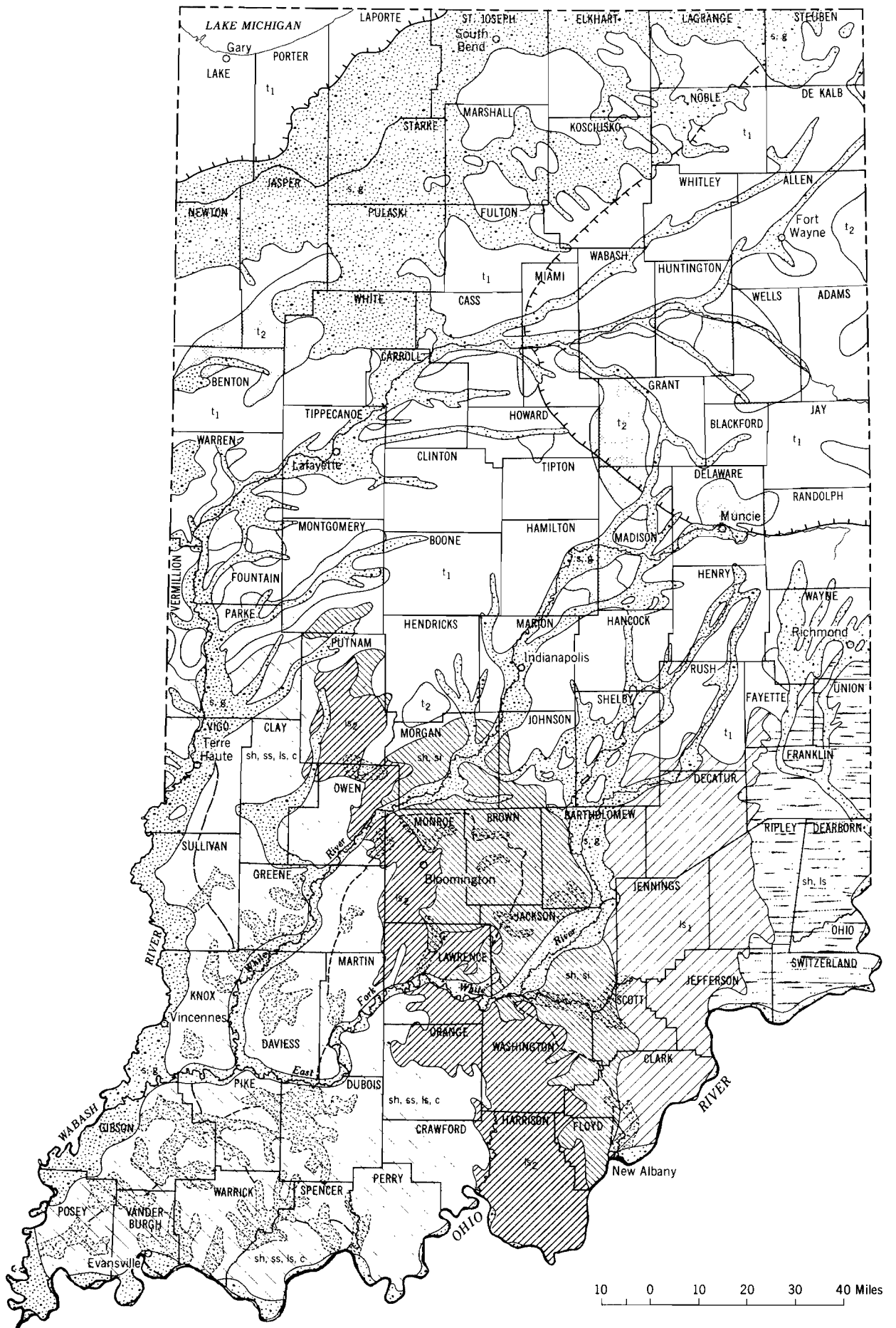


Figure 1. Map showing geologic limitations for solid-waste disposal sites in Indiana. Compiled from Gray, in preparation; Gray, Wayne, and Wier, 1970; Indiana Geological Survey, 1956; Wayne, 1956; and Wayne, 1958.

## EXPLANATION



Sand and gravel outwash of glacial origin and dune sand. Excellent essential aquifers are present in most areas, and contamination is a virtual certainty for normal operations. Little suitable cover material is available.



Cavernous jointed limestone bedrock. Subsurface drainage to wells and surface is common. Groundwater flow is unpredictable and water is easily contaminated. Bacterial pollutants are easily transmittable. Heavy clay surface soil is a poor cover material, but probably usable where thick enough.



Sandy loams, loams, silt loams, and clay loam till of glacial origin. Scattered essential aquifers are present as interstratified sands and gravels. Sufficient thickness of slowly permeable material may be present above aquifers. Abundant cover material available.



Interbedded shale, sandstone, limestone, and coal bedrock. Scattered essential aquifers are present in sandstone and limestone. Locally high degree of dissection, relief, and slope present surface drainage and general feasibility problems, particularly in the east. Locally thicker glacial materials toward the west may be adequate for cover.



Same as  $t_1$ , but less than 50 feet drift over bedrock. Possibly insufficient thickness to guarantee noncontamination of interstratified sand and gravel aquifers or underlying limestone bedrock aquifers. Abundant cover material available.



Clay to silt loam of glacial lake origin. Material is very slowly permeable and might be an excellent refuse receptacle, but might be hard to work, might be an unsatisfactory cover material, and might be subject to ponding.



Shale and limestone bedrock. This material is very slowly permeable and aquifers in it are uncommon. Likelihood of contamination of subsurface water is slight. Locally thicker glacial materials may provide adequate cover material.



Limits of clay loam to silty clay loam glacial till



Interbedded limestone and dolomite bedrock that commonly is an aquifer in the upper 20 feet. Locally thicker glacial materials may provide adequate cover material.



Southern limit of upland glacial material



Shale and siltstone bedrock. No likelihood of contamination of subsurface water exists. The highly dissected and sloping terrain in the slowly permeable material may present surface drainage problems, and adequate cover material is scarce.



Eastern limit of thick upland silt of windblown origin. Material is similar to glacial lake materials, but less clayey, more workable, and better drained, and might provide excellent receptacles.

county Soil and Water Conservation District offices or the U.S. Department of Agriculture, Soil Conservation Service, and geologic information and groundwater information, obtainable from the Division of Geological Survey and the Division of Water of the Indiana Department of Natural Resources (see "Sources of Information"), are essential in the initial search for a sanitary landfill site. Soil scientists study weathered earth materials to a maximum depth of 6 feet or so, geologists study all that material below the soil, and groundwater geologists study the water contained in the pore spaces of all these materials.

Soils information gives insights into the workability, permeability, soil wetness and flooding hazard, shrink-swell potential, compressibility, erodibility, and water runoff yield of a soil. Further, soil maps on an aerial photograph base provide information on the slope and shape of land surfaces as well as the relationship of soil areas to natural land features and cultural features.

Geologic and groundwater information gives insights into the workability and permeability of underlying geologic materials, their topographic expression, their sequence and lateral variation, including the nature and distribution of subsurface water-bearing and nonwater-bearing formations, the position of the water table, the nature of groundwater movement, and the likelihood of groundwater or surface water contamination from proposed sanitary landfill operations. Such geologic and water-contamination problems are the primary concern in this report.

### **Groundwater**

All bedrock and unconsolidated surficial materials have pores, that is, open spaces not occupied by mineral matter. At some depth below the earth's surface these pores are completely filled with water, and the material is said to be saturated. The upper surface of the saturated zone is called the water table, and its depth changes seasonally because of the effect of rainfall on the amount of water moving through the soil and geologic materials. Such materials as most silt, clay, and glacial till (hardpan), although having high percentages of pore space capable of being filled by water, do not allow water to flow through rapidly; that is, they are relatively impermeable. Sand, gravel, and fractured or cavernous bedrock, however, have large interconnected void spaces and typically are highly permeable. Those materials that allow the contained water to flow through freely are called aquifers.

In uniform materials, water derived from precipitation or other forms of recharge moves downward

through pore spaces in geologic materials to the water table, or the zone of saturation, whereupon much of it moves down gradient, or in the direction of the slope of the water table, to points of local discharge. Some of it, however, enters a larger, regional flow system. Inhomogeneities in the stratified geologic materials greatly affect the speed and direction of water movement within this system and may result in perched water tables above the permanent zone of saturation or in confined artesian aquifers.

Contaminants may enter water supplied in leachate derived from decomposing landfill refuse. These contaminants include bacteria, dissolved mineral matter, and gases in concentrations as much as 100 times stronger than in raw sewage (Emerich and Landon, 1969) and may also include inadvertently dumped highly toxic solid and liquid chemicals.

Contaminants entering the groundwater flow system move in the same direction as the groundwater and do not mix substantially with the groundwater elsewhere in the system. Little dilution of these contaminants occurs, as compared with the amount of dilution of contaminants entering a large, turbulent flowing stream (Cartwright and Sherman, 1969, p. 3). Therefore, an improperly located landfill could introduce contaminants into the groundwater that might not be detected immediately. Furthermore, concentrations of contaminants might not be lowered until long after the abandoned landfill has stabilized.

### **Geology of Solid-Waste Disposal Sites**

The following discussion considers the relationship of sanitary landfill placement to geology and to the groundwater resource. Because the community and regional planner must consider potential but untapped water-bearing formations as no less important than formations that are presently in production, these considerations are applicable whether or not existing water wells may be affected by proposed landfilling.

The ideal landfill has the following characteristics: First, disposal should be above the zone of saturation and below relatively slowly permeable cover, so that conditions are so dry that little water moves through the refuse, little leachate is produced, and maximum renovation of leachate is possible (Hughes, 1967, p. 10). Thus, refuse certainly should not be deposited below the level of the water table, as in standing water, surface runoff should not be allowed to enter or to leave the site, and buried refuse should still be above the highest seasonal level of the water table after final covering of the site. Because water levels are high throughout much of Indiana, special engineering techniques may be necessary to protect water supplies.

Second, disposal should be in slowly permeable materials, such as most glacial till, glacial lake silt and clay, shale, or siltstone. These materials allow partial renovation of leachate through various processes and "minimize the rate at which contaminants could be introduced into a potable water supply" (Hughes, 1967, p. 10).

Third, "movement of contaminants along lines of flow...[should be] such that either they could not reach a useful ground water or surface water reservoir, or their attenuation to acceptable levels...[should occur] before they reached such a water resource" (Hughes, 1967, p. 10-11). These last-stated conditions may be difficult to define but can usually be considered in general terms.

Fourth, available cover material should be workable and compactable at all times of the year and, as mentioned above, should be relatively impermeable. Furthermore, it should not crack excessively upon drying. Peat, muck, incinerator residue and fly ash, and coarse-grained geologic materials, such as gravel, sand, and loamy sand, either are not sufficiently compactable to provide an adequate landfill cover or are not sufficiently impermeable to assure a slow water buildup toward field capacity in the refuse. Fine-grained geologic materials, such as clay and clay loam, may be difficult to work when extremely wet or dry and may crack excessively when dry, especially if compacted.

### Geologic Considerations in Indiana

Geologic factors applicable to the selection of sanitary landfill sites in Indiana include the nature of ground-water supplies, the thickness of glacial drift over bedrock aquifers, and the character and sequence of the surficial or bedrock materials and the aquifers therein. The discussion that follows is meant only to clarify the types of problems to be encountered in Indiana and to guide planners to consideration of areas where the probability of finding a suitable site is high. More detailed geologic information, available from the Division of Geological Survey and the Division of Water, should be studied prior to the selection of potential sites. Potential sites should then receive more detailed geologic study before selection of the final site.

#### UNCONSOLIDATED MATERIALS

Sand and gravel deposits (s, g fig. 1) occur throughout Indiana. During the Ice Age these were deposited from glacial meltwaters in outwash terraces and outwash plains and in some places have been reworked by wind into dunes. These materials are generally ill

sited for waste disposal operations. Because of the extremely high permeability of these deposits, leachate moves freely and will invariably contaminate contained waters. In many examples these materials constitute essential high-yield aquifers which are an invaluable future, as well as present, resource. Even if local deposits are thin or if for other reasons the materials are not important aquifers, leachate could rapidly migrate to other aquifers or to points of surface discharge. Under few circumstances are large gravel deposits suitable for waste disposal, regardless of the tempting convenience of existing abandoned pits.

Much of Indiana is covered with glacial till ( $t_1$  fig. 1), an unstratified material of sandy loam to clay loam texture that was directly deposited by glaciers during the Ice Age. Till, sand, and gravel together are generally referred to as glacial drift. Glaciers invaded Indiana at various times and advanced and retreated irregularly, so that many bodies of glacial till occur within the glacial drift. These are separated by layers of outwash sand and gravel, many of which are important aquifers. Most glacial tills, where not deeply jointed, are sufficiently impermeable that flow of refuse leachate is retarded, but where aquifers occur within the till and sufficiently close to the surface, contamination can result.

Outside the hachured line in figure 1, the till is a sandy loam to loam—material that would be suitable for the landfill and its cover. Within the hachured line, however, the surface till is a silty clay loam to clay, although the clayey till is only a thin cover over the sandier till in a few places. The clayey till is ideally suited for refuse receptacles, but it may be hard to work, may be susceptible to ponding, and may crack objectionably if used as a cover. Many acceptable sites for refuse disposal probably exist in this area, but great care must be taken in location planning.

South of the limit of thick, more recently deposited glacial till ( $t_1$ ) the bedrock formations are generally at or near the surface. In places are areas of older glacial till that may be sufficiently thick to protect underlying bedrock aquifers or to contain sand or gravel aquifers themselves. In the extreme southwestern part of the state thick deposits of windblown silt cap the bedrock, and throughout the area are scattered deposits of stratified silts and clays that were deposited in lakes during the Ice Age. These are highly impermeable, yield no water, and where thick enough are excellent refuse receptacles, but they may be wet and hard to work, may be susceptible to ponding, and may be inferior cover material.



#### THICKNESS OF UNCONSOLIDATED MATERIALS

"A minimum of 30 feet of relatively impermeable material is [customarily] required between the base of a landfill and the shallowest aquifer" in Illinois. "In general, this means that approximately 50 feet of favorable material is needed for a satisfactory site. A thickness of 50 feet permits trenching to a depth of 20 feet, with 30 feet of material still in place for aquifer protection. If the refuse is to be covered at the land surface, without excavation, then 30 feet of relatively impermeable material could be satisfactory" (Cartwright and Sherman, 1969, p. 7).

Thus far in Indiana, minimum thicknesses of relatively impermeable unconsolidated material between the base of a landfill and the shallowest aquifer of 10 to 25 feet have been suggested. Although any such standards must be flexible enough to be applicable to local conditions, a 20- to 30-foot minimum thickness is suggested here for general use. Thus, a 50-foot thickness of relatively impermeable unconsolidated material would allow for trench-method landfilling to a depth of 20 feet. Proportionately less material would be required where trenches are to be less than 20 feet deep.

Within the area of generally thick glacial materials are areas where the drift is less than 50 feet thick ( $t_2$  fig. 1). In these areas any sand or gravel aquifer within the glacial materials or a bedrock aquifer might not have the necessary thickness of protective cover of slowly permeable material. Even where the drift is greater than 50 feet thick, the first potential aquifer within the drift might be much nearer the surface.

#### CONSOLIDATED MATERIALS

Bedrock formations beneath the glacial drift in the central and northern parts of Indiana are primarily limestone and shale. Where thin drift overlies a bedrock aquifer as mentioned above (fig. 1), prior detailed geologic and groundwater study should assure that groundwater will not be contaminated by a landfill operation.

The bedrock formations exposed in southern Indiana are of several types. In two areas the rock is generally suitable for sanitary landfills. In the southeast corner are interbedded shale and limestone (sh, ls fig. 1) and in the south-central part are shale and siltstone (sh, si fig. 1) which yield little water and into which leachate movement would be very slow. Excellent disposal sites can be found in these materials provided surface water runoff is controlled. However, heavy ripping equipment may be required for excavation, suitable cover material may be scarce, and steep slopes, particularly in "sh, si," may preclude

operation of heavy equipment over large parts of these areas.

Between these two areas is an area of limestone or thin shale over limestone ( $ls_1$  fig. 1) bedrock. Although the groundwater supply from these rocks is small, the rocks are highly permeable to refuse leachate. Below thin glacial materials the upper 20 feet is commonly fractured, which allows rapid water movement to wells or to the surface.

In the southwestern part of the state the bedrock consists of interbedded shale, sandstone, limestone, and coal (sh, ss, ls, c fig. 1). Scattered small but important groundwater supplies are derived from sandstone and limestone, and aquifers could be harmed by refuse leachate, but in general groundwater pollution is not a serious problem. Conditions are generally unfavorable in the eastern part of this area because of steep slopes and high relief. Cover material may be scarce throughout much of the area. Abandoned coal strip mines present special problems involving surface water discharge and the nature and workability of disturbed overburden, and they must be considered on an individual basis.

The limestone belt ( $ls_2$  fig. 1) of south-central Indiana is characterized by subterranean drainage through solutionally enlarged joints and bedding planes in the carbonate strata. Although the integrated network of cave streams and smaller channels carry underground waters in the sense that they are subterranean, these streams are little different from surface streams in that they are part of the natural drainage of the area. Although the subterranean channels are hidden, they transmit pollutants rapidly to wells and discharge them through springs into surface streams. In places where thick clay and silt cover the limestone, areas might be found for sanitary landfill operations, although the clay is generally a poor cover material, and careful study must be made before a site is chosen.

Many other geologic factors must be considered as well. For instance, abandoned underground coal mines in southwestern Indiana or abandoned, poorly plugged oil and gas wells in northeastern Indiana might offer leachate quick access to subsurface water supplies. Some areas, mapped as floodplains by geologists and soil scientists, are periodically subjected to flooding. Areas affected by such problems preclude landfilling unless drastic engineering precautions are planned.

Thus it is clear that diverse geologic conditions within the State of Indiana must be considered in the planning of solid-waste disposal sites. These conditions govern the acceptability of the site from an engineer-

ing standpoint and the ultimate effect of a landfill at the site on groundwater and surface water resources.

## Conclusion

The most important element involved in planning surface refuse disposal sites is not convenience but regard for the protection of the groundwater resource and regard for the engineering practicality of maintaining minimum landfill standards. To encourage intelligent planning, generalized information is presented here to alert planners to the particular problems that may be encountered in any one area. Where an obvious choice is involved, an area with fewer or more easily surmountable problems can be chosen on the basis of these data.

The most important geologic requirements for a sanitary landfill site, as summarized from this report, are:

1. The base of a proposed landfill should be in relatively fine-grained material and more than 20 to 30 feet above the shallowest aquifer. Sites should not be located in abandoned sand and gravel pits or limestone quarries for this reason.

2. The base of a proposed landfill should be above the highest seasonal level of the water table.

3. A proposed site should not be subject to flooding. Sites should not be located on river floodplains for this reason.

4. Adequate medium-textured cover material must be available near a proposed site.

More detailed geologic and groundwater data regarding particular areas and regarding these suggested requirements are available from the Division of Geological Survey and the Division of Water of the Department of Natural Resources (see "Sources of Information") and should be sought prior to detailed planning. Individual site examination by qualified geologists, soil scientists, and soils engineers, possibly including an exploratory drilling program, and approval by the State Board of Health are necessary.

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## Sources of Information

Indiana State Board of Health  
Division of Sanitary Engineering  
1330 West Michigan Street  
Indianapolis, Indiana 46206

Department of Natural Resources  
Geological Survey  
611 North Walnut Grove  
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