EVALUATING SANITARY LANDFILL SITES IN ILLINOIS

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INTRODUCTION

Open dumping and open burning of refuse have been illegal in Illinois since the promulgation of "Rules and Regulations for Refuse Disposal Sites and Facilities" by the Illinois State Department of Public Health in April 1966. The only practical methods for disposal of large quantities of refuse, therefore, are incineration or burial in a sanitary landfill. The landfill method requires daily covering of refuse with a compacted layer of at least 6 inches of earth materials.

A principal concern of the Illinois Department of Public Health, the regulatory agency for refuse disposal sites in the state, is the potential contamination of ground water and surface water at landfill sites. The need for evaluation of physical conditions at the many refuse disposal sites in the state has resulted in steadily increasing activity for the staffs of both the Department of Public Health and the Illinois State Geological Survey, which advises the Department on such matters.

Putrescible refuse when saturated, even intermittently, produces a leachate that usually has a high concentration of dissolved minerals. The leachate also acts as an agent for transporting bacterial pollutants. The Department of Public Health regulations therefore stipulate that landfills should be located in areas where there is reasonable assurance that leachate from the landfill will contaminate neither the ground water nor surface water in the area. The topography of the landfill area should be such that surface runoff will not flow into or through the fill. Operations that will result in refuse disposal below or near the highest known water-table elevation may be required to include corrective or preventive measures to protect the ground water. No refuse disposal is permitted in standing water (Ill. Dept. Public Health, 1966, p. 3, 6-7).

These regulations are the criteria for geologic investigation of sanitary landfill sites. Locations where disposal can take place above the water table are relatively rare in Illinois. In some cases, although disposal
did take place above the water table, ground-water mounds have reportedly
developed at the site, resulting in permanent saturation of the refuse. In
addition to the desirability of disposal above the water table, the convention
in Illinois is to have a minimum of 30 feet, and preferably 50 feet, of relo-
tively impermeable material between the base of the landfill and the shallowest
underlying water-yielding formation (aquifer).

This note discusses the principles of ground-water geology and
hydrology that relate to the location and the effects of landfills, the prin-
ciples on which the Department of Public Health regulations are based. A
systematic approach to investigating the geologic factors that influence
ground-water occurrence and movement at a landfill site is suggested so that
municipal officials, landfill operators, consultants, and health officers can
make preliminary evaluations of proposed sites, and, we hope, eliminate from
consideration the more obviously unsuitable ones.

MOVEMENT OF GROUND WATER

Subsurface water is usually considered to occur in two zones—the
zone of aeration where the pores of the soil or rock are filled with both
air and water, and the zone of saturation where the pores are entirely filled
with water. The upper surface of the zone of saturation is frequently called
the water table. Technically, ground water is water that occurs below the
water table (i.e., water in the zone of saturation).

Considerable quantities of water may be present in the zone of
aeration. Some water is held in this zone by attractive forces acting between
soil particles and water. Water in excess of the amount that can be held by
these forces moves downward under the influence of gravity. The amount of
water in the zone of aeration depends upon the precipitation pattern of the
area, vegetative cover, the depth to the water table, and the type of earth
materials and their particle arrangement.

Materials in the zone of saturation will supply water to wells if
there are enough connected pore spaces to allow water to move fairly rapidly
from one point to another. Permeability is the term used to describe the
capacity of earth materials to transmit fluids. It is dependent upon the
size and shape of the pores and the extent of their interconnection. Coarse
sands and gravels have large pores that are extremely well interconnected,
and they therefore have high permeabilities. Fine silts and clays have
fairly high percentages of pore space, but the pores and their interconnecting
openings are so small that fluids can move through them only very slowly.
They therefore have low permeabilities.

Joints or fractures can occur in the rigid rocks such as limestones,
shales, dense sandstones, and granites, and even in tough clay and glacial
till. Water moves along these fractures rather than through the small pores
between mineral grains. Solution of limestone or dolomite by water often
produces cavities and fissures that are capable of transmitting large quanti-
ties of water.
In the zone of aeration, water movement is generally downward towards the water table. If the materials underlying the top layers have lower permeability and occur above the water table (such as the clay layer in figure 1), the downward movement of the water may be partly deflected.

Once water, or leachate from a landfill, reaches the zone of saturation it moves with the ground water. Two flow systems frequently influence the eventual path of this water. One is a local flow system that usually involves a fairly short journey, in the direction of the slope of the water table, to the nearest discharge point (e.g., the nearest swamp, pond, or surface stream). In general, the direction of this flow is the same as the slope of the land surface. However, some of the water may continue to percolate downward and enter the regional flow system, which is usually at greater depths, passing under local discharge points toward major points of discharge (e.g., movement under a small stream toward a larger one; see fig. 2).

In porous material, ground water moves fairly predictably toward discharge areas, that is, in the direction of the water-table gradient. Detailed drilling and mapping of the subsurface materials and the water table provide the information needed for reasonably accurate predictions about the ground-water flow system. Jointed or fissured material permits rapid movement of water along paths that, in general, are unpredictable. Only limited inferences can be made about ground-water movement in such material, because the exact location of subsurface joints or fissures generally cannot be predicted.

Water-table elevations are lowered in the vicinity of pumping wells. This area of lowered water levels resembles a cone and is therefore called a cone of depression. When wells are closely spaced, individual cones of depression may merge into a large cone. The water-table gradient is unusually steep in the pumping cone area, causing ground water to move toward the well with greater velocity. Pumping can modify, and in some cases reverse, the natural ground-water flow system.

NATURAL PURIFICATION OF REFUSE LEACHATE

Dilution and dispersion are effective mechanisms for reducing the concentration of contaminants in surface waters. In contrast to the usually turbulent flow of surface water, ground-water flow is almost always in smooth, parallel lines. Dilution and dispersion of refuse leachate in ground water is therefore usually a slow, ineffective process.

The porous rocks act as bacterial filtering agents of the water that moves through them. Filtering effectiveness is directly related to the size of the intergranular openings. A clean gravel (one containing very little sand, clay, or silt) with large pores will be a poor filter, whereas a fine-grained material with small pores is a more effective one. Although filtering may remove bacterial contaminants, it does not affect dissolved chemical contaminants.

Clays probably reduce the concentrations of some of the objectionable substances in a landfill leachate through ion exchange. Much like a household
Fig. 1 - Infiltration toward the water table, with some diversion along a clay layer of low permeability.

Fig. 2 - Regional and local ground-water flow patterns.
water softener, these fine-grained materials are capable of exchanging ions with the ground water. Because this is an exchange process, the amount of total dissolved solids will not change greatly.

Recent investigations in northeastern Illinois suggest that in some cases clay layers may act as semipermeable membranes that restrict the passage of dissolved ions (Hughes et al., 1968). The applicability of this mechanism to landfill leachate is as yet unproved.

Aquifers in which the movement of ground water or leachate is through joints or fissures have little or no attenuating effect upon either chemical or bacterial contaminants. Extreme caution is therefore necessary in evaluating a potential landfill site in an area where creviced limestones are used as a source of water.

The practice of requiring at least 30 feet of relatively impermeable material between the base of a landfill and any aquifer has been followed for many years in Illinois. Although the origin of this practice is not known, recent research (Hughes et al., 1968) and concepts of ground-water movement suggest that it is a reasonable though perhaps conservative requirement.

SOURCES OF GROUND WATER

There are two main sources of ground water in Illinois, the unconsolidated sand and gravel deposits of the glacial drift and river valleys and the sandstone and limestone formations within the bedrock. Fresh water occurs in these strata from depths of only a few feet to as much as 2000 feet in some parts of Illinois. Strata capable of storing and transmitting water to a well in usable quantities are called aquifers.

Most of the unconsolidated deposits, which attain a maximum thickness of about 600 feet (Piskin and Bergstrom, 1967), were left by glaciers that overrode parts of Illinois during the major stages of ice advance. At its maximum, the ice covered Illinois as far south as Carbondale, leaving only the southern tip of the state, the northwest corner (Jo Daviess County area) and a small portion of western Illinois (Calhoun County) unglaciated. River deposits along the major and some secondary streams are the only other significantly thick unconsolidated material.

Yields of wells in unconsolidated sands and gravels vary from one or two gallons per minute (gpm) for household supplies to several thousand gpm for industrial or municipal supplies. In areas of thick drift, sand and gravel may be extensive and deeply buried. Sand and gravel most commonly occur near the base of the drift and in ancient buried valleys cut into the bedrock surface; however, they can occur anywhere within the drift section from the land surface down. Shallow sand and gravel is most common in river valleys. In areas where the drift is thin, only scattered sand and gravel deposits generally are present. Modern day streams commonly flow along partially filled ancient valleys, especially in areas of thin drift.

The materials that do not yield water to wells (nonaquifers) consist of pebbly clay (glacial till), lake deposits consisting mainly of silt, wind-
blown silt (loess), and residual soils. All of these materials retard the movement of water into and between aquifers. Tills are by far the most common and thickest nonaquifers pertinent to sanitary landfill siting. Although the particle sizes in individual till units are fairly consistent, size distributions vary greatly from one till unit to another. Units can vary from having more than 50 percent clay-size particles to having almost no clay. Lake deposits that formed behind ridges of glacial deposits (moraines) and in ice-clogged river valleys consist primarily of silts and clays, but, as in Kankakee County, may include sand. Loess consists mostly of silt, but may locally contain some very fine sand- or clay-size particles. Residual soils are generally clayey, but are not often of sufficient thickness and extent to be of much consequence in Illinois.

Ground-water conditions in the bedrock vary considerably in the state. However, bedrock formations are more consistent in character and better known than drift deposits. Predictions of depth and water-yielding character of the bedrock, therefore, can often be made with some certainty. Bedrock formations dip into the Illinois Basin, an oval, spoon-shaped structural depression, the deepest part of which is in Hamilton, Wayne, Edwards, and White Counties. As water moves through the formations toward the deep part of the basin, it becomes more saline. Therefore, the rock units that produce potable water in northern Illinois to a depth of 2000 feet lie at much greater depths in the Illinois Basin and contain brine. At somewhat shallower depths, potable water can usually be found in the southern and western parts of the state. In south-central Illinois, saline water occurs near the surface.

Permeable limestones, dolomites, and sandstones underlie the unconsolidated material in the northern quarter and along the western and southern edges of the state (Willman and others, 1967). In those areas the shallow bedrock forms one of the principal aquifers, supplying water for domestic, municipal, and industrial uses; yields of over 1000 gpm can sometimes be obtained from the creviced limestones and dolomites of the northern third of Illinois. In the remainder of the state, the Pennsylvanian rocks underlie the unconsolidated materials. Aquifers in these rocks are of minor importance, generally being limited to a few thin sandstones of low permeability and an occasional fractured limestone or shale. Their yields are low, rarely more than enough for a small domestic supply, although yields of over 50 gpm have been reported. In all areas of the state, crevicing and fracturing are best developed in the uppermost 50 or 75 feet of the bedrock, just below the unconsolidated deposits.

GEOL OGY FOR LANDFILL SITES

Silts and tills in the unconsolidated deposits and shales in the bedrock retard the movement of water and pollutants into aquifers. Where the bedrock aquifers are shallow and the unconsolidated deposits are thin, satisfactory landfill sites will be difficult or impossible to locate. In areas of thick drift (except river valleys) or areas of shale bedrock, satisfactory landfill sites that meet the existing hydrogeologic and ground-water pollution criteria should be readily available.

Landfills should be located so that ground-water contamination does not occur. Because refuse should be disposed of above the water table and
30 to 50 feet of fine-grained material generally is required between the refuse and underlying aquifers, limestone quarries and gravel pits are rarely, if ever, acceptable refuse disposal sites from the hydrogeologic standpoint. Some gravel pits that have high clay and silt contents probably would be usable if other conditions were met.

A map of Illinois in three sections (figures 3A, 3B, and 3C) shows areas with the greatest likelihood of furnishing satisfactory sites for refuse disposal. This does not mean that all sites in the areas marked favorable are good, nor that all sites in the unfavorable areas are poor; it is merely a probability map. The map was compiled from a bedrock geology map (Willman and others, 1967), a drift thickness map (Fiskin and Bergstrom, 1967), and a surficial deposits map (Thornburn, 1960). Regions marked as unfavorable are areas where there is less than 50 feet of unconsolidated material overlying permeable bedrock or where large aquifers are known to exist near the surface. Conversely, marked as favorable are areas where 50 feet or more of unconsolidated material (principally clayey or silty) overlies the bedrock, and areas in which the bedrock is impermeable and no extensive, near-surface aquifers are known to be present in the drift. The regions marked locally favorable are areas in which the shallow aquifer conditions are variable.

The map is intended solely as a guide to areas where conditions for refuse disposal are most favorable, and does not show the potential for pollution at individual sites. No attempt was made to consider the exact physical character of the unconsolidated material or of the bedrock formations in each area. Ground-water flow conditions in an area were considered only in the very broadest sense.

**SITE EVALUATION**

Sanitary landfills should be located in relatively impermeable, or slowly permeable, material so that movement of refuse leachate will be retarded. Clay, shale, silt, and glacial till are the most common materials with low permeability in Illinois. They are also the most effective materials for filtering out the biologic organisms of leachate. Sites where sand and gravel occur are generally unsuitable for refuse disposal because of their high permeability.

A minimum of 30 feet of relatively impermeable material is usually required between the base of a landfill and the shallowest aquifer. 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 land surface, without excavation, then 30 feet of relatively impermeable material would be satisfactory.

In areas where the glacial drift or other unconsolidated deposits are less than 30 feet thick, the nature of the underlying bedrock must be considered in appraising a landfill site. If the bedrock is one of the relatively thick shale formations that occur widely in Illinois, landfill operations might be permissible. If the bedrock is creviced limestone or porous
sandstone, both of which serve as aquifers for shallow wells, a sanitary landfill in the thin overburden would not be considered advisable.

Viewed strictly from the ground-water contamination standpoint, no unconsolidated cover material would be required at a site where the bedrock was thick shale. Operationally, however, the requirement of daily covering, the usual need for trenching, and the rapidity with which water moves across bedrock surfaces may preclude the selection of many sites that do not have 10 to 20 feet of unconsolidated material above the bedrock.

Obtaining as much information as possible about any existing wells near the prospective landfill site serves two purposes. First, it is an excellent way to obtain information about the depths of aquifers and the types of material underlying the land surface. Second, it provides information helpful in predicting the potential for contamination of existing water supplies. If only large diameter dug wells are present in the area, for instance, it is likely that shallow permeable aquifers are absent, and the area could be favorable for waste disposal if the landfills are located at least 500 feet away from the dug wells (American Public Works Assn., 1966, p. 125). Driven wells (well points) or shallow drilled wells are normally found in areas where shallow aquifers occur. Their presence suggests that ground-water contamination could be considered likely if waste disposal were permitted near by.

The operational method (area fill or trenching) to be used at a landfill depends upon the topography of the site. Topography also is important in the over-all evaluation of a landfill site. Sites near surface water should be studied to determine whether the landfill would be free from flooding and whether refuse leachate would travel adequate distances through the ground before discharging into the surface water. Both flooding and discharge, or unattenuated leachate, could cause surface-water contamination, and normally would preclude approval of such sites.

Rough, irregular topography usually is favorable for area fill operations. However, any water moving through or accumulating in low areas should not be allowed to come in contact with the refuse.

It is advisable to commence refuse disposal operations at the head of a gully or drainageway, thereby eliminating much of the surface-water problem. Trenching into the banks of large gullies or depressions is an alternate approach. Diverting or draining these waters is a good solution but is usually expensive.

Most flat upland areas where trenching can take place cause few operational problems, and surface-water problems are virtually eliminated.

The following criteria provide a basis for preliminary investigations of the ground-water pollution potential at proposed or existing sanitary landfill sites. The conventional basis for landfill site investigations is the requirement that 30 feet of relatively impermeable material is necessary between the base of the landfill and the shallowest aquifer.
Generally unfavorable, thin cover over shallow aquifer
Locally favorable, aquifer conditions variable
Generally favorable, shallow aquifers rare

Figs. 3B and 3C - Geologic conditions relating to feasibility of sanitary landfills in southern two-thirds of Illinois. Patterns indicate chances of success in locating a suitable site for refuse disposal.
1) Type of unconsolidated material:
   Favorable - glacial till, lake silts and clays, windblown silt (loess)
   Unfavorable - sand, gravel

2) Thickness of unconsolidated material:
   Favorable - 50 feet or more (30 feet if no trenching is proposed)
   Unfavorable - less than 50 feet (30 feet if no trenching is proposed)

3) Type of bedrock:
   Favorable - shale
   Unfavorable - sandstone, fissured limestone or dolomite
   Questionable - limestone or dolomite not known to be fissured

4) Local sources and potential sources of water:
   Favorable - deep bedrock wells, sand and gravel wells with logs showing
   thick impermeable cover over aquifer, dug wells if 500 feet
   or more from the site
   Unfavorable - shallow bedrock wells (particularly in fissured limestone),
   sand and gravel wells with logs showing thin cover over
   aquifer

5) Site topography:
   Favorable - flat upland areas, heads of gullies and ravines, dry strip
   mines
   Unfavorable (require operational engineering) - depressions where water
   accumulates, lower reaches of gullies, stream floodplains,
   other sites near surface water areas where leachate might
   discharge into the water

If 1, 2, 4, and 5, or 1, 3, 4, and 5 are favorable, there is little probability
that ground-water contamination will occur.

Information about both the type and thickness of bedrock and unconsol-
solidated material is obtainable from various sources. In many cases a
specific source of information may supply data concerning several facets of
the site investigation.

The map accompanying this note indicates areas where the probability
of locating favorable sites is good, bad, and intermediate. Slightly more
detailed information, but still regional in character, is found in the
regional ground-water reports published by the Illinois State Geological
Survey (listed at the end of the references). These reports indicate areas
where sand and gravel aquifers probably occur, as well as areas where water
is obtainable from the bedrock. More detailed reports for some smaller areas,
such as counties, within the state also have been published. The Bibliography
and Index of Illinois Geology (Willman et al., 1968) is a good source book
for locating publications that include such information.

Information about the thickness and character of the unconsolidated
materials at specific localities is frequently difficult to obtain without
test drilling. General information can be obtained from the drift thickness
map of Piskin and Bergstrom (1967), and Thornburn's (1960) surficial materials map. The bedrock topography map (Horberg, 1950, 1957), when used in conjunction with topographic quadrangle maps, also is a useful source of information concerning drift thickness. More detailed information can sometimes be obtained from sand and gravel resource reports published by the Illinois State Geological Survey (see Willman et al., 1968). A careful examination of road and stream cuts in the area frequently will provide considerable insight into the nature of the unconsolidated material. Thousands of driller's logs on file at the Geological Survey Offices in Urbana give the thickness and character of the various units encountered during drilling.

The driller's logs also describe or identify the bedrock wherever it was encountered. Another more regional source of information about the distribution of the types of bedrock in the state is the geologic map compiled by Willman and others (1967). Many well owners and most local well drillers know what the local bedrock is and how far into it one must go to obtain water.

The Illinois State Water Survey has published detailed descriptions, including well logs if available, of most public ground-water supplies in the state (Hanson, 1950, 1958, 1961). Topographic quadrangle maps have been published for the entire state, and geologic quadrangle maps are available for many areas in the state.

If available data are inadequate for evaluation of a site, or if the evaluation shows it to be a marginal case, test borings may be required of the prospective landfill operator by the Department of Public Health. The number of borings required will depend upon the size of the area concerned and the complexity of its geology. In some places one boring is adequate, but more than a dozen might be necessary. These borings should be made to at least 30 feet below maximum depth of refuse burial (50-foot total depth is adequate for most sites). Drilling should be done by an experienced driller, who should make an accurate drilling log and carefully collect samples, both of which should be submitted to the Illinois Department of Public Health. In addition, the depth to the top of the zone of saturation (if possible) and the static water level after completion of drilling should be determined.

**SUMMARY**

Limestone or dolomite quarries and most sand and gravel pits make poor landfill sites because these materials are usually good aquifers. Swampy areas also make poor sites unless they are properly drained to prevent disposal into standing water. Strip mines, clay pits, and gravel pits containing gravel with a high percentage of natural clay binder (the type that is often used for grading county roads) do make good disposal sites if kept dry. Flat upland areas also are good potential sites if the required natural clay barrier is present above any aquifer. The careful selection of a landfill site will result in a minimum of operating problems and little, if any, danger of ground-water or surface-water pollution.

The investigative procedures outlined in this report are the steps currently followed by the Illinois State Geological Survey for the reconnaissance evaluation of the landfill sites, made at the request of the Illinois
Department of Public Health. These steps are based on fundamental concepts of ground-water geology and seem a reasonable approach for reconnaissance investigations. Where hydrogeologic conditions are not known, the Illinois Department of Public Health may require the person or organization requesting approval for a site to arrange for a detailed site investigation. Such an investigation usually includes test drilling.

REFERENCES


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