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COMPLETION REPORT

TECHNICAL AND REGULATORY STATUS OF THE PLACEMENT OF SANITARY LANDFILLS IN IOWA

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ABSTRACT

This project includes a "state of the art" summary of landfill placement in Iowa and an update of ground water monitoring for three upland sites in Iowa. Major conclusions include:

1. Current regulations favor upland placement of landfills, however, they occur in all topographic positions.
2. Pollution enclaves formed from floodplain sites are predictable and if this location is to be used the number in any one drainage basin must be considered to protect river water quality.
3. Pollution enclaves formed from upland sites are less predictable because of deeper penetration and larger number of geologic units encountered from source to sink. These sites may produce smaller volumes of leachate than flood plain sites.
4. 53.1% of all sites are in the uplands, 41.5% are located on valley walls or ravines and only 5.4% occur on flood plains.
5. Approximately 35% of permitted landfills have required monitoring. It is interesting to note that 26% of all landfills occur in the high hazard zones of the Iowa Geological Survey classification and only 52% of them are monitored and 33% occur in the no hazard zone and 23% of them are monitored.

6. A high correlation exists between area of each hazard zone and the percent of landfills found in each area. This suggests that factors other than geologic control their location.

Data gathered from three upland sites are somewhat limited but several conclusions can be reached.

1. Leachate concentrations are lower than those found in previous studies in Iowa on flood plain sites.
2. Because more activities of man can be encountered between the landfill and the ground water sink, the pollution enclave is more complex in its shape and direction of flow.
3. The production of leachate is more dependent on precipitation than flood plain sites. This means that the length of time over which leachate will be produced is lenthened.

Key words: ground water pollution, sanitary landfill, hydrogeology of landfills.

-- SUMMARY --

This project was divided into two parts, 1 to write a "state of the art" report on landfill placement in Iowa and, 2 to monitor the effect of placement of landfills on upland sites. These topics are written up as two separate reports and are also summarized separately.

"State of the Art" report -- An inspection of all permits provided the information for tabulation and analysis of all sites in Iowa relative to topographic position, monitoring programs, geographic distribution, geologic position, river basins, and Iowa Geological Survey hazard zones. The following conclusions can be drawn on placement of landfills in Iowa.

CONCLUSIONS

General

1. There are 3 types of water resources which need to be considered with respect to their potential to be polluted by the disposal of solid waste. They are 1) surface water, 2) water in shallow unconsolidated aquifers, and 3) water contained in deeper bedrock aquifers.
2. Current regulations favor the placement of sanitary landfills in upland sites.
3. A knowledge of the relationships between geologic materials and water flow characteristics may allow for the prediction of contamination patterns which develop from landfills placed in any one of the topographic positions.

4. Pollution enclaves are plume-shaped with the long axis parallel to ground water flow lines. Concentrations decrease both with distance along the axis and with distance radially away from it such that the enclave is entirely surrounded by uncontaminated water except at its source.

Floodplain sites

1. The pollution enclave's shape and position are highly predictable in the alluvial materials near rivers.
2. The area underlain by contaminated ground water can be minimized by placing disposal sites adjacent to a river in a groundwater flow regimen where the flow lines are oriented normal to the river.
3. Rivers act as boundaries for leachate migration and are areas of discharge for it. Dilution is the principle method of attenuation.
4. Depth of penetration of the pollution enclave is minimized in a floodplain position due to the short distance of flow to a discharge point.
5. Ground water flow is controlled much more by river stage than by local amounts of precipitation in an alluvial system.
6. Enclave size in alluvium reaches a maximum size quickly and then is maintained in a steady-state equilibrium condition.
7. Water quality data suggests that contaminated ground water does not significantly affect the surface water into which it discharges.

8. The aggregate effect of a number of landfills in floodplain positions within a single river basin must be considered. The cumulative amounts of pollution added should not increase pollution concentrations within the river beyond certain limits.

Upland Sites

1. The shape and position of pollution enclaves from upland disposal sites are more difficult to predict due to the natural variability of materials and the great distance to points of ground water discharge.
2. The area underlain by contaminated water, therefore, has the potential to be very large in upland sites.
3. The distance to points of discharge are greater, and consequently the processes of sorption, decay, and filtration have a greater chance to reduce the concentration of leachate from upland sites before it discharges into surface waters. Upland sites, however, are also regional and local recharge areas for bedrock aquifers.
4. The depth of penetration of the pollution enclave may be great and may reach into valuable bedrock aquifers.
5. Ground water flow is controlled by the amount of precipitation and the rate of infiltration in upland sites. The range of permeability of the various media present is also important in determining rates and direction of flow.

6. Because the available moisture depends on precipitation only, the enclave forms much more slowly than those which develop from disposal sites in floodplains.
7. Limited initial data from upland sites indicates that leachate concentrations are lower than those found in the floodplain. This may be due both to topographic position and the relative ages of the sites tested.
8. The long term effects of upland sites on water quality are not fully understood at this time.

Status of Iowa Landfills

1. The effects of current state regulations favoring the placement of sanitary landfills in upland positions is evident (only 5.4% occur in the floodplain and terrace positions combined).
2. Approximately 35% of the permitted landfills have required monitoring programs.
3. The percentage of the total number of landfills in the state occurring in any one IGS hazard zone is closely related to the area of that zone. This reflects both population distribution and the cost of transportation as an important economic variable in waste disposal.
4. Many sites having non-required monitoring are potential sites for special management practices.

Effect of Upland Sites on Ground Water Quality --

CONCLUSIONS

Although the data generated from the current upland site studies are somewhat limited, several conclusions can be reached:

1. The shape and position of pollution enclaves from upland disposal sites are more difficult to predict than flood plain sites due to the natural variability of materials and the large distance to points of ground water discharge. Other activities of man between an upland landfill and the ground water sink may also be responsible for the reduction of water quality.
2. The production of leachate in upland positions is dependent on the amount and distribution of precipitation. Enclaves from upland sites therefore form more slowly than those which develop from disposal sites in floodplains where groundwater flow is more continuous. Leachate production from upland sites should be periodic, with high concentrations associated with flushing following major precipitation events.
3. The theoretical depth of penetration of pollution enclaves from upland sites is greater than those associated with floodplains. The present data, in general, suggests that the concentration of leachate is greatest in the refuse and in nearby shallow materials. Water samples from deeper wells show that leachate concentrations decrease with distance away from the site and with increasing depth. This could be due to either a lack of production of significant amounts of leachate, or the attenuation of leachate as it moves through the ground.
4. Limited initial data from the three upland sites indicate that leachate concentrations are lower than those found in previous investigations on floodplain sites (Peckenpaugh,

1973; Stevens, 1974). This may be a direct result of the topographic position with its associated ground water regimen. The relative ages of the sites tested may also be important. All of the upland landfills which were studied are fairly new and have been operated as sanitary landfills since the deposition of wastes was begun on the sites. The floodplain sites which were tested were much older and had a complex history of open dumping.

PART ONE

TECHNICAL AND REGULATORY STATUS OF THE PLACEMENT OF SANITARY LANDFILLS IN IOWA

TECHNICAL AND REGULATORY STATUS OF THE PLACEMENT OF SANITARY LANDFILLS IN IOWA

INTRODUCTION

Iowa is an area of humid continental climate. The citizens and industry of the state depend on ground water obtained from both near surface and bedrock aquifers. Because precipitation exceeds evaporation at some time during a normal year, excess rainfall infiltrates the surface and becomes part of the ground water system taking into solution various chemicals from solid wastes which have been deposited on or within the ground. In this hydrogeologic environment critical decisions must frequently be made regarding the placement and operation of solid waste disposal sites. Special problems are often encountered at individual sites with respect to the maintenance of protective systems and the implementation of monitoring programs to protect valuable ground water resources near solid waste disposal sites.

The location of landfills in marginal wet areas such as floodplains is generally discouraged due to the operational problems associated with these areas. The use of large and heavy equipment near the water table necessitates a high level of maintenance to lower ground water and remove surface water during the operation of the landfill. A commitment to a high level of maintenance must also be continued following closure of the site to protect important water resources. Landfills located in upland areas generally require much less maintenance for their operation, but may pose special problems with respect to the protection of water quality.

RESULTS OF STUDIES

Past research of sanitary landfills in Iowa and the potential pollution of groundwater from these sites has lead to cooperation between the Iowa State Water Resources Research Institute (ISWRRI), Iowa Department of Environmental Quality (DEQ), and the Iowa Geological Survey (IGS). These efforts contributed to the formation of rules and regulations governing sanitary landfills, and more recently to the updating of these regulations. Studies conducted by ISWRRI have considered the pollution released from existing landfills located on floodplains as well as those located in upland sites.

The research on sanitary landfills located on floodplains lead to several conclusions relative to their placement in this position. The data obtained suggests that the pollution enclaves which develop in alluvium are plume-shaped with the long axis parallel to the ground water flow lines. Research by both Drake (1972) and Palmquist and Sendlein (1975) shows that the flow direction is generally directly from the landfill sites to the adjoining river. Decreasing concentrations were noted with distance along the axis. A general decrease in concentration both laterally and vertically away from the core of the enclave was also found. This means that an enclave is entirely surrounded by uncontaminated water except at its source.

An effort to use the electrical resistivity method to detect the pollution enclaves from floodplain landfills proved to be somewhat unsuccessful (Klefstad, 1973 and Klefstad, Sendlein and

Palmquist, 1975). As the inhomogeneity of the deposits in this topographic position increases, higher concentrations of ions in the leachate are needed for their detection because the natural scatter of resistivities due to the various media present mask the enclave anomaly. For this reason sample wells were installed with nests to achieve a vertical sampling distribution at each of the floodplain locations. The river stage was measured at each site, and groundwater evaluation and ion concentrations were tested for each well.

An analysis of the data obtained in this manner (Peckenpaugh, 1973 and Stephens, 1974) found:

1. Rivers act as boundaries for leachate migration and are areas of discharge for it.
2. Little mixing or dilution of leachate occurs after its initial introduction to the ground water.
3. The dominant control on concentrations is the water table condition and ground water flow.
4. Ground water flow is controlled much more by river stage than by precipitation.
5. Enclave size does not change in a uniform manner with time. Usually they achieve their maximum size quickly and then exist in a steady-state equilibrium condition.

The area underlain by contaminated ground water can be minimized by placing disposal sites adjacent to a river in a ground water regimen where flow lines are oriented normal to the river.

The water quality data (Palmquist and Sendlein, 1975) suggests that contaminated ground water does not significantly affect the surface water into which it discharges. Floodplain sites may be desirable in some cases where bedrock aquifers are vulnerable to contamination and are widely used as sources of water in the area. This is because of the predictability of the enclave shape and position in alluvium, the fact that floodplains are ground water discharge sites, and the low concentration of leachate formed in a high water table and high flow environment.

The initial study of upland sites as reported by Fenton (1973) proved to be inconclusive. In the spring of 1975 two new landfills in upland positions were instrumented by the ISU Geology group, one in Scott County and one in Fayette County. During the summer of 1976 an additional site in Cerro Gordo County was instrumented to monitor ground water quality. These three fills are currently being sampled on a monthly basis to evaluate their long term effects on ground water quality. Current regulations favor the placement of sanitary landfills in upland sites and these three sites represent this hydrogeologic condition. Data obtained from these sites is still somewhat limited, but to date the concentration of the leachate which has formed appears to be lower than that associated with floodplain sites. More time is needed for a final analysis to be made.

Theoretically the predictability of pollution from upland sites is less than that of floodplain sites. This is due to the increased complexity of materials as well as the greater horizontal and vertical distances to areas of discharge. The size and depth of penetration of the pollution enclave will be greater and it may extend into underlying bedrock aquifers. The increased distance and time of travel before surface discharge should allow for greater attenuation by the processes of soption, decay, and filtration. The presence of jointed and cavernous rocks near the surface will reduce the amount of attenuation which occurs.

Separate studies by Kunkle (1976) and Kaufman (1970a, 1970b) of landfills in upland areas developed in glacial till show that the effect of these systems on ground water quality is not fully understood and indicate that bedrock aquifers may be affected after just 3-5 years of landfill activity. It is apparent that the analysis of the effects of upland sites on groundwater quality should be continued. This research may lead to the re-examination of current governmental policy and provide a basis for recommending the revision of present regulations governing the placement of sanitary landfills.

The DEQ is responsible for issuing permits to agencies desiring to operate landfills in the state. The DEQ works in conjunction with the IGS to determine whether proposed sites meet current regulations and protect the natural resources and environment of the state. The applicant must provide detailed information regarding geology, ground and surface water hydrology, and plans for the design and operation of the site. The permit section reviews each application in cooperation with the IGS, which provides information relating to the geology and water use of the area.

The Iowa Department of Environmental Quality recognizes 5 general types of waste management sites in the administration of its permit program. They include sanitary landfills, construction and demolition debris sites, compaction and/or transfer stations, resource recovery units, and composting operations. Permits typically run for 3 years during which the DEQ continues to monitor the site in a surveillance program to insure that the original specifications of the permit are maintained. Special provisions can be included in granting a permit to require the monitoring of ground water quality in the area. Other management practices may also be required as a condition of the permit.

This report is an attempt to assemble the available information concerning the permitted landfills in Iowa and to analyze the effects of current governmental policy on their placement. The position of each landfill in terms of hydrogeologic environment is presented. Means of controlling landfill leachate production and the implementation of protective systems and monitoring programs in the state are also given.

METHOD OF STUDY

Data Source

During July and August of 1976 the DEQ permit files and engineering specifications were studied to obtain the information available at that time concerning the placement and operation of each landfill in Iowa. In June of 1977 the data was updated to include all permits granted by the DEQ since the inception of the permit program. An additional effort was made to classify each site with respect to topographic position, zone of hazard with respect to ground water contamination, and major drainage basin.

Topographic Classification

The topographic classification used in this report is based on research conducted during the past 15 years by a number of individuals. Toth (1963) analyzed the ground water flow of a local drainage basin. He found a local hydrologic system consisting of recharge points at minor topographic highs and discharge points at adjacent topographic lows. An intermediate hydrologic system consists of recharge and discharge points which are not necessarily adjacent to or at the extreme topographic positions. The regional flow system involves recharge at ground water divides with discharge into the bottom of the basin.

Using this model the groundwater flow of a region can be divided into three zones. The upper zone is active and consists of flow with a base level equal to the level of small streams. The middle zone is characterised by delayed flow which is subject to less climatic effect. Base level of this zone is equal to the bottoms of the largest rivers. A lower zone containing relatively stagnant water exists in a position beneath the level of the largest river (Figure 1).

LeGrand (1965) stated that an understanding of the relationships between geologic materials, ground water, and surface water could be used for the selection of landfill sites. He proposed the shape of a contamination enclave as a flame-shaped plume with its axis oriented parallel to the ground water flow lines (Figure 2). Palmquist and Sendlein (1975) noted that if a source of recharge by the infiltration of precipitation is considered, a zone of cleaner

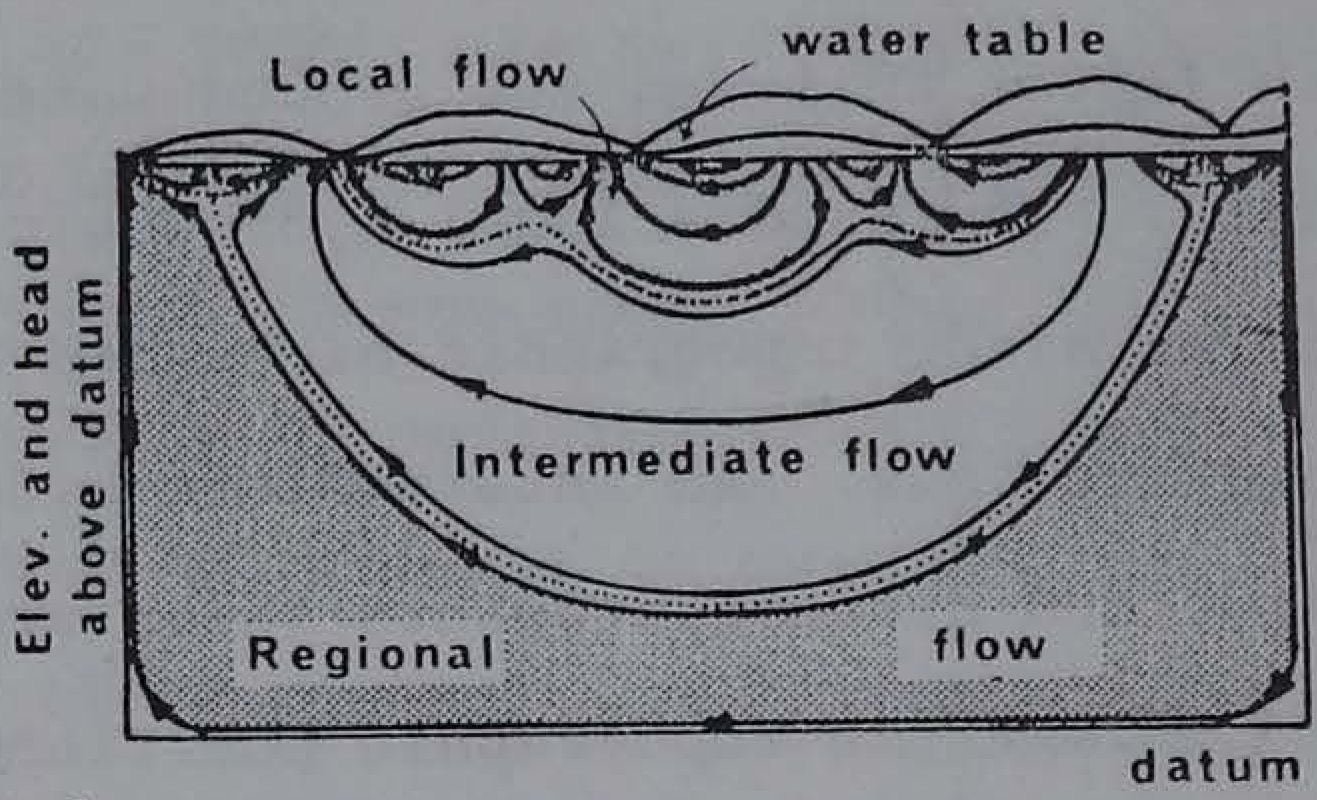


FIGURE 1. Idealized ground-water flow pattern through a homogeneous material (after Toth, 1963).

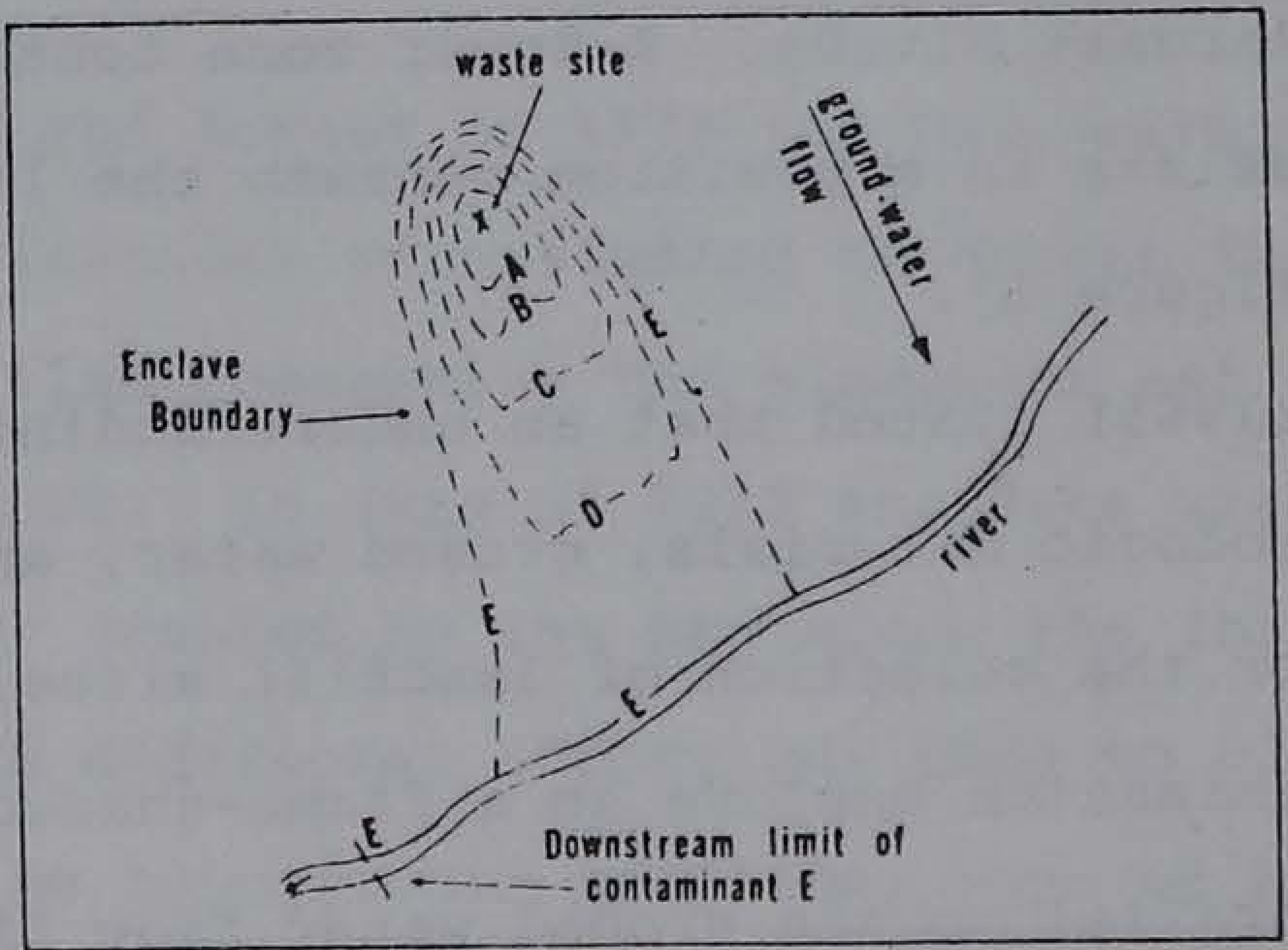


FIGURE 2. Plan view of a water table aquifer showing the hypothetical areal extent to which contaminants disperse and move to insignificant levels within the contamination enclave (after LeGrand, 1965).

water exists on top of the polluted water. Thus the contaminated ground water is a three-dimensional body formed at a source and extenting from it parallel to the flow pattern, through uncontaminated water, to a discharge point (Figure 3).

The topographic position when added to this information and considered in light of Toth's flow model may enable the prediction of the contamination pattern for landfills placed in any topographic position. A hydrogeologic model for this purpose has been proposed (Sendlein and Palmquist, 1973 and 1975). In this model the landscape was divided into seven positions: 1) floodplain, 2) terrace, 3) valleyside, 4) ravine, 5) convex crest, 6) upland valleyside, and 7) upland flat (Figures 4 and 5). This system was used to classify the topographic position of each of the permitted landfills in Iowa from the available data.

The current law in Iowa assumes that a sanitary landfill location which minimizes the flow of water through the refuse is prefered. Under these regulations the most suitable sites are the upland, crest, and upper gully. Using Toth's flow model it can be seen that the upland sites could have a high potential for contamination of major bedrock aquifers due to their location in local or regional recharge areas. The floodplain and river terrace sites may be more acceptable with respect to this criterion because they occur at discharge points where pollutants are rapidly released to the adjacent stream where they may be diluted to acceptable concentrations. In light of all of this information the landfills of Iowa were classified as to their topographic position.

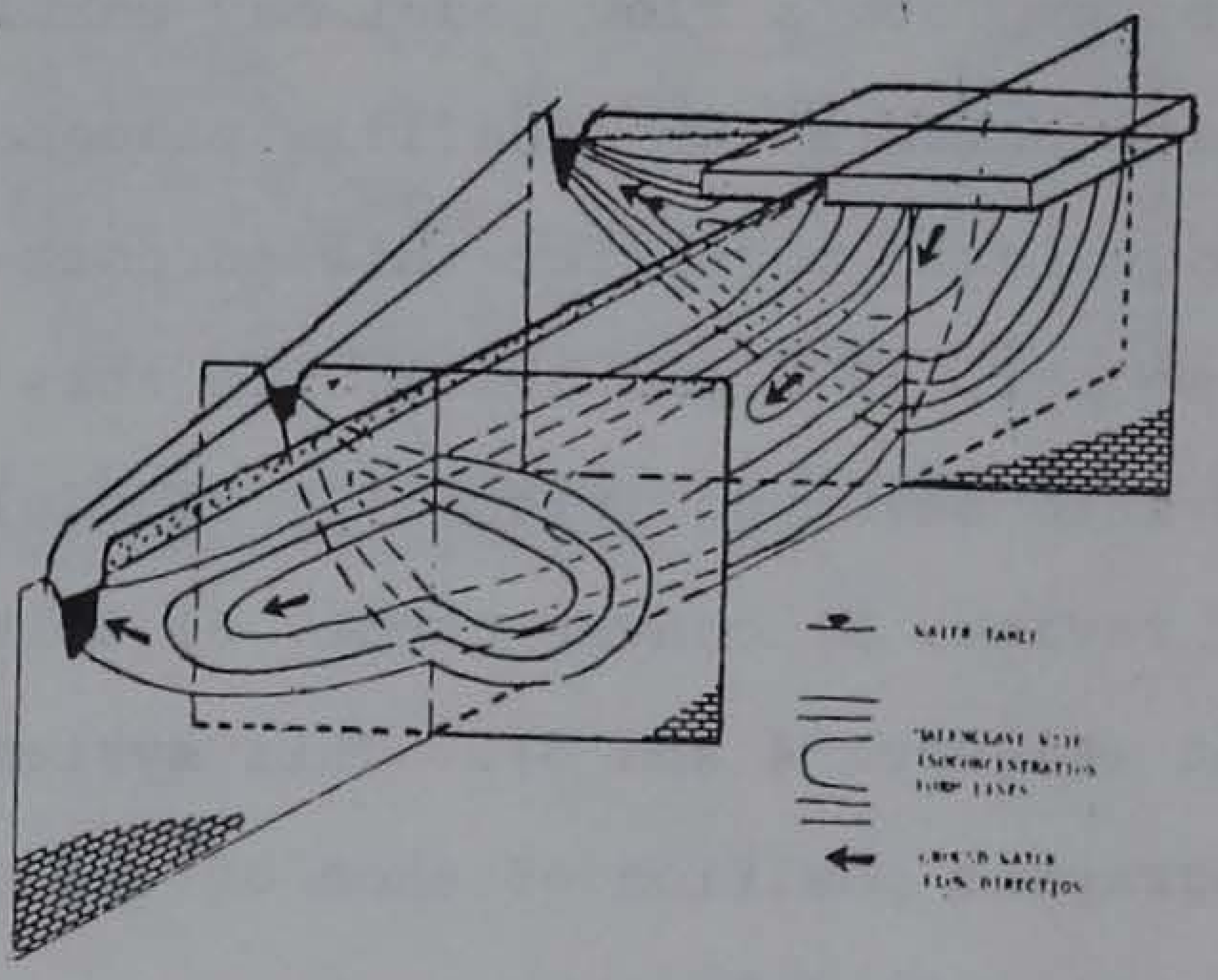


FIGURE 3. Idealized configuration of contamination enclave in alluvium (after Palmquist and Sendlein, 1975).

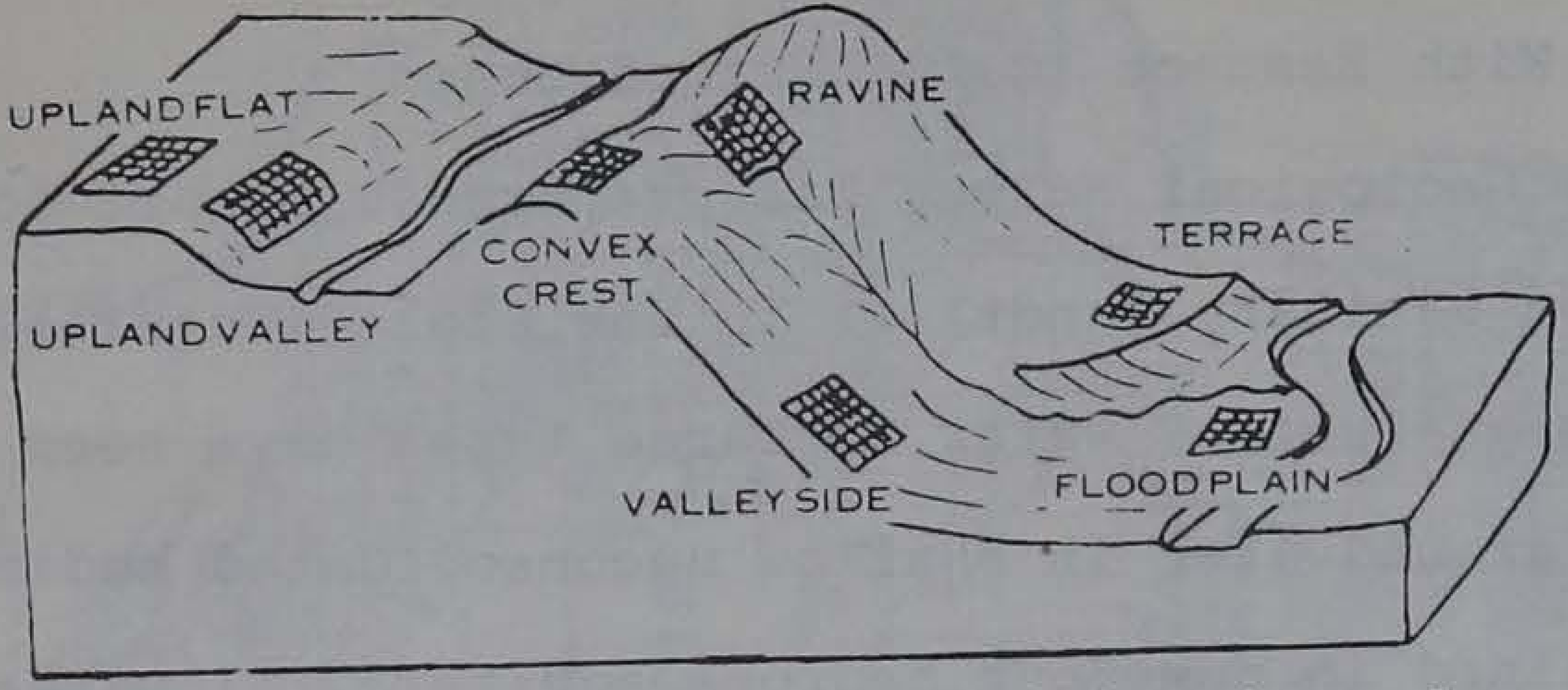


FIGURE 4. Topographic classification of potential disposal sites within a landscape (Sendlein and Palmquist, 1975).

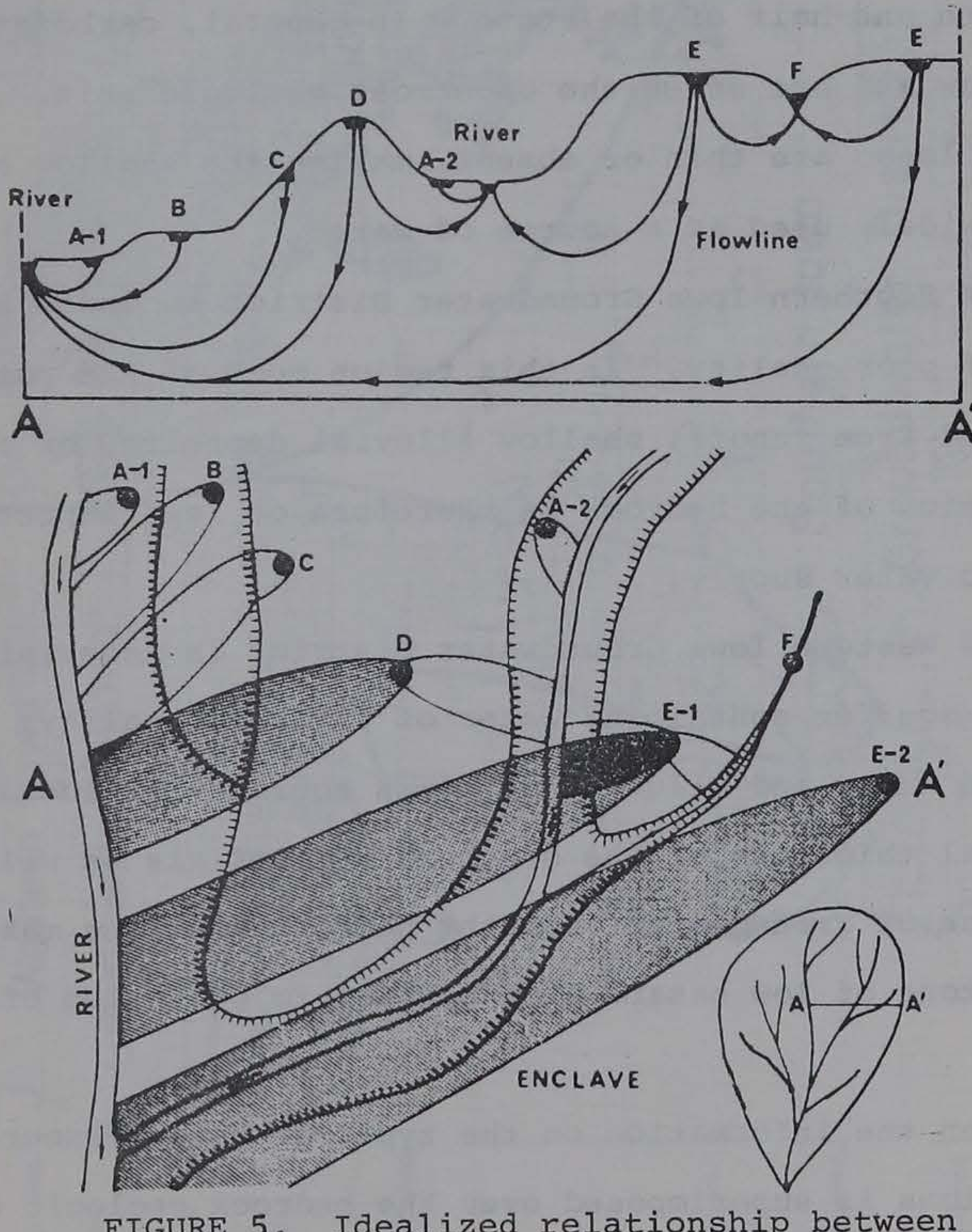


FIGURE 5. Idealized relationship between contamination enclaves and ground water flow pattern in a drainage basin (Based upon LeGrand, 1965; Toth, 1963).

Classification With Respect to IGS Hazard Zones

The Iowa Geological Survey has prepared a report concerning the placement of sanitary landfills in the state (Tuthill and others, 1972). In this analysis 3 water resource types have been recognized: surface water, groundwater in shallow unconsolidated sediments, and water contained in numerous bedrock aquifers. Iowa can be divided into 3 regions based on the similarities in use of their water resources (Figure 6).

The Eastern Iowa Groundwater District includes approximately the eastern one-half of the state. In general, carbonate aquifers are shallow and are often the uppermost geologic unit. Glacial drift and loess are thin or absent, making the shallow bedrock aquifers widely used as a source of water.

The Southern Iowa Groundwater District is underlain by bedrock sources of poor quality. In this region most of the potable water is obtained from runoff, shallow alluvial deposits, or surface water. Contamination of the bedrock is therefore of less importance with respect to water supply.

The Western Iowa Groundwater District is underlain by a sandstone aquifer containing water of variable quality. The use of surface water and alluvial or loess aquifers is locally important. The general thickness of the overburden materials as well as the limited use of groundwater from the bedrock aquifers makes this region a zone of low hazard with respect to pollution of the bedrock aquifer.

When the information on the types of water resources used in these regions is superimposed over the bedrock geologic map of the

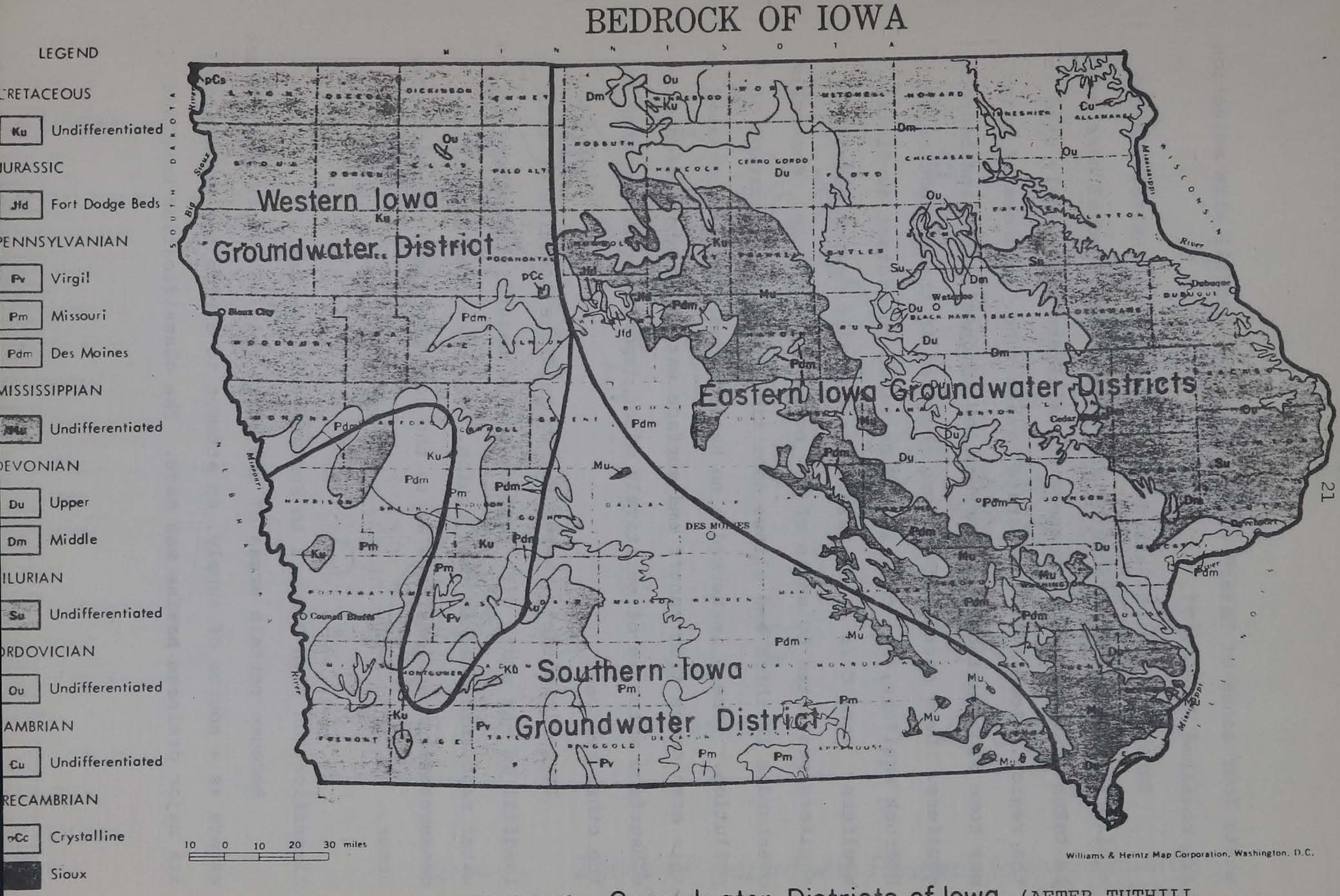


FIGURE 6. Groundwater Districts of Iowa (AFTER TUTHILL AND OTHERS, 1972)

state four zones of hazard with respect to landfill site selection are obtained (Figure 7).

Zone A is a high hazard zone underlain by shallow bedrock aquifers which may be fractured and cavernous. Special care must be taken in this area to protect the aquifers most widely used in the region. Zone B is a moderate hazard zone. Sources of water may come from surface water or shallow unconsolidated and bedrock aquifers. Less care is therefore required in the protection of bedrock aquifers, but care should be taken to protect surficial aquifers. Zone C is a low hazard zone usually having bedrock aquifers protected by units of low permeability shale. Generally overburden is thick and allows some time for the attenuation of pollution. Zone D is termed a no hazard zone. Most water used in this area comes from runoff and surface waters so protection of subsurface water is of relatively minor importance as compared to the other regions.

It is important, therefore, to know the position of each landfill in the state with respect to the hazard it produces to the water resources used in that region. The permitted landfills consequently are classified as to the zone of hazard in which they occur.

Classification With Respect to Surface Drainage Basin

Because certain areas of the state rely on runoff and surface waters as a source of supply, an attempt to divide the state into its major drainage basins was made. The classification used was

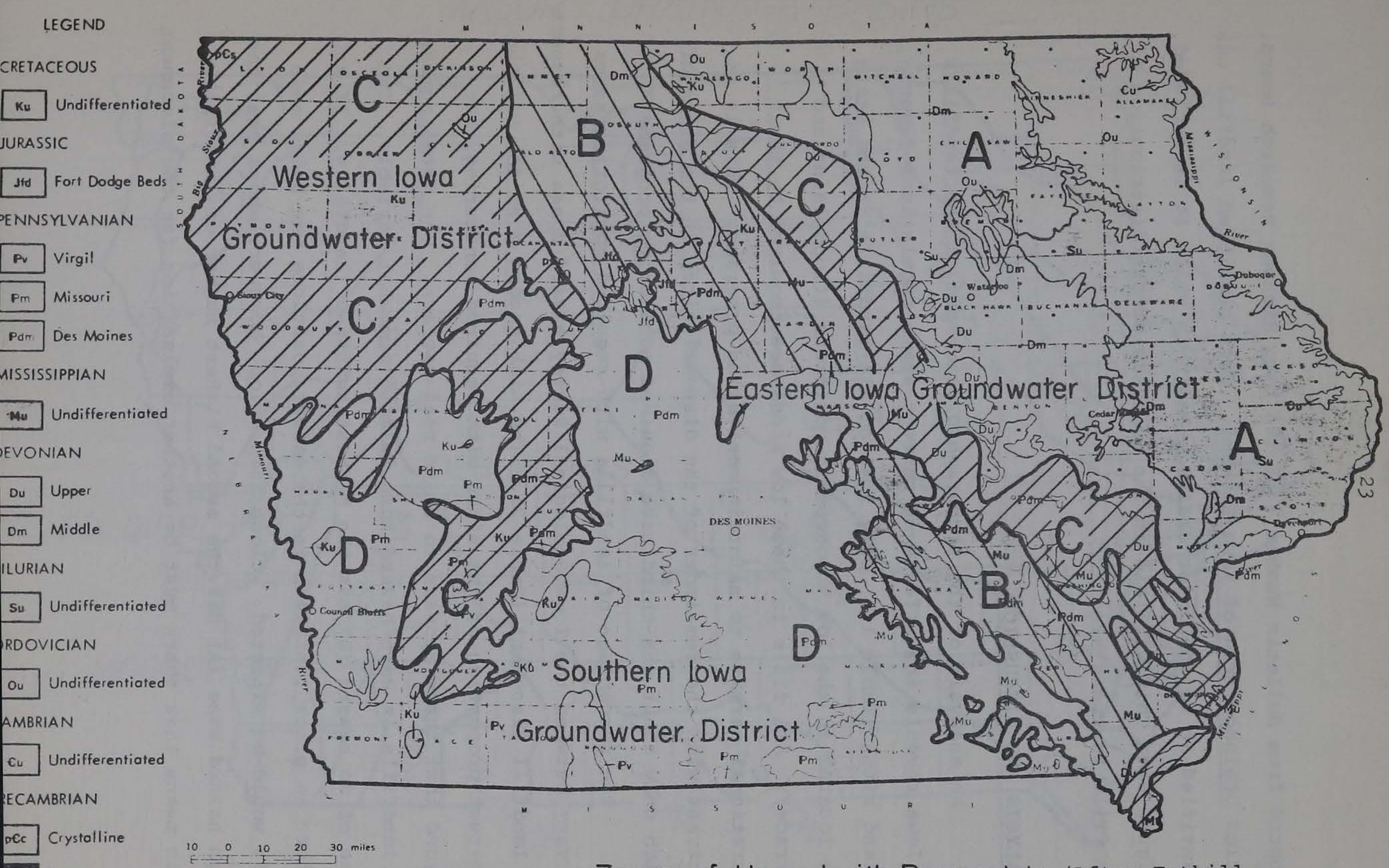


FIGURE 7. Zones of Hazard with Respect to Landfill Site Selection. (After Tuthill and others, 1972)

adopted from Bulletin Number 7 of the Iowa Highway Research Board, titled Drainage Area of Iowa Streams. Each permitted landfill was classified as to the major drainage basin in which it is included (Figure 8). This will aid in the analysis of the distribution of landfills in the state.

ANALYSIS AND DISCUSSION

An analysis of the topographic placement of the landfills in Iowa reveals the effects of current state regulations favoring upland sites (Table 1). Only 5.4% of all landfills in the state are located in the low topogrpahic positions (floodplains and terrace). All fills in these low areas are required by their operational permits to maintain monitoring programs. This is in contrast with the remainder of the disposal sites in the state of which only about one-third have required monitoring programs.

The percentage of landfills with required monitoring seems to vary between the Iowa Geological Survey hazard zones with respect to landfill placement (Table 2). The high hazard zone (A) has the greatest proportion of its sites with required monitoring, but beyond that there appears to be no real pattern. The total number of landfills in each hazard zone is also somewhat variable. The zone of no hazard (D) has the highest number of landfills. If an effort to place landfills in the safest positions was being made this would be expected. Close inspection, however, shows that the high hazard zone (A) has the second highest number of landfills. This means that there must be another explanation for the placement

MAJOR DRAINAGE BASINS

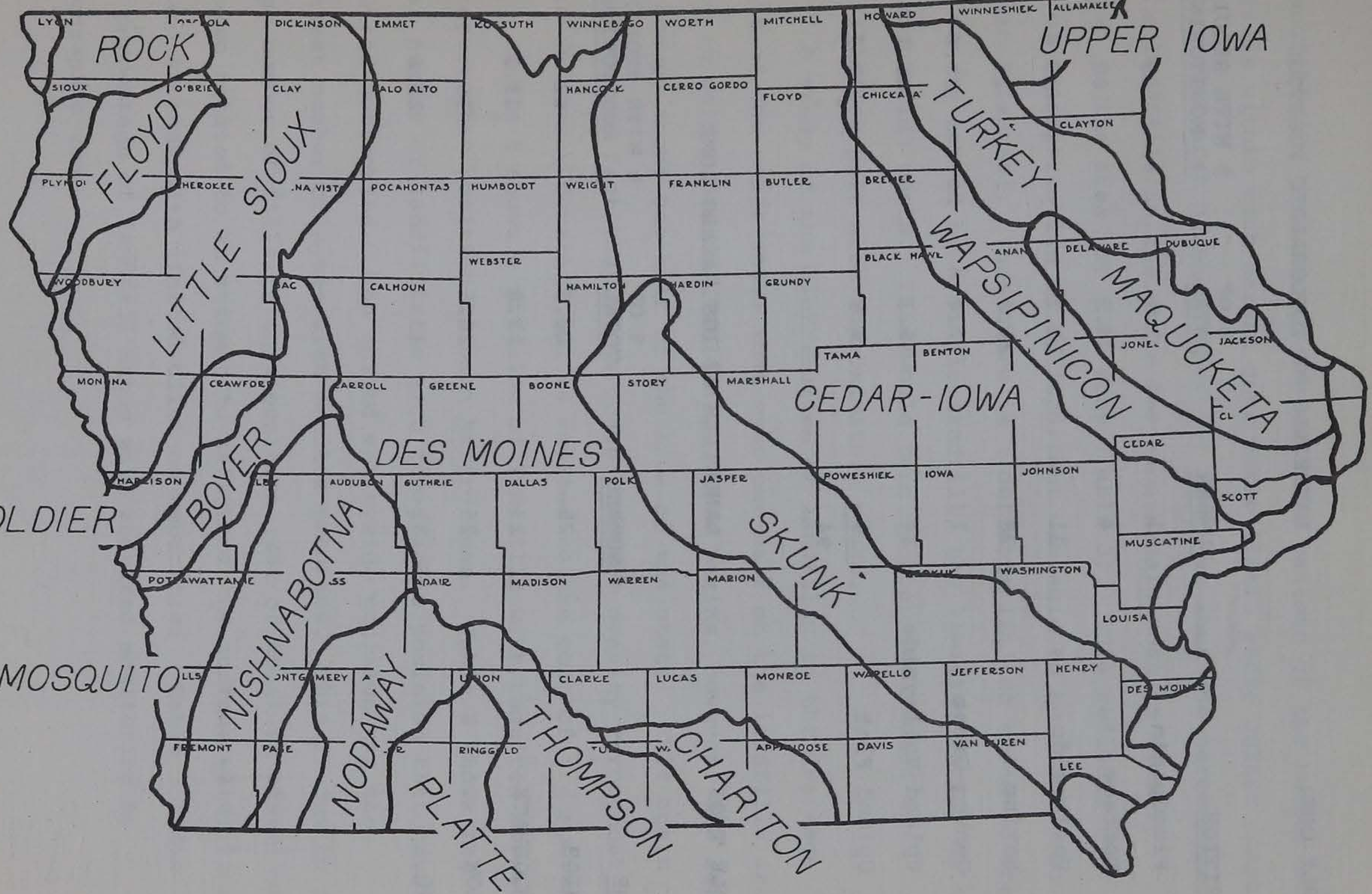


FIGURE 8. (After Iowa Highway Research Board, Bulletin No. 7)

TABLE ONE: LANDFILLS BY TOPOGRAPHIC POSITION

POSITION	NUMBER	% OF TOTAL	% WITH REQUIRED MONITORING
1. Floodplain	1	1.1	100
2. Terrace	4	4.3	100
3. Valleyside	11	11.7	36.4
4. Ravine	28	29.8	25
5. Convex Crest	7	7.4	28.6
6. Upland Valleyside	34	36.2	41.2
7. Upland Flat	9	9.6	22.2
	94		

TABLE TWO: LANDFILLS BY IGS HAZARD ZONE

ZONE	NUMBER	% OF TOTAL	% WITH REQUIRED MONITORING
A HIGH	25	26.6	52
B MODERATE	13	13.8	23.1
C LOW	25	26.6	36
D NO	31	33	22.6

of landfills in the state. The variable pattern of the number of landfills within each hazard zone makes little sense unless compared to the total area of each zone. It is clear that the percentage of the landfills in the state for each hazard zone is closely related to the area of that zone (Table 3). This reflects the cost of transportation as an important variable to be considered in waste disposal. Thus there is a definite limited economic area that can be served by a single landfill, the limiting factor being transportation costs. This would tend to keep the number of landfills per unit area approximately equal.

A study of the distribution of landfills in the drainage basins of the state shows that over one-half of the landfills are found in only 3 basins (Table 4). These basins, however, are large and occupy about one-half of the area of the state. This again points to the fact that the average landfill density throughout the state is nearly constant and is related to the cost of transportation.

Table 5 shows a division of landfills with required monitoring by topographic position in each hazard zone. Table 6 shows the total number of landfills in each topographic position that have required monitoring. The upland valleyside position has the greatest number of sites with monitor programs. This is due to the large number of fills in this position (36% of total in state) and is also related to an attempt to safeguard the surface water in small upland streams with limited dilution capacities. Table 7 shows the percentage of landfill sites with required monitoring by topographic zone.

TABLE THREE: AREA OF IGS HAZARD ZONES (approximate)

ZONE	% OF AREA OF STATE	% OF TOTAL LANDFILLS
A HIGH	27	26.6
B MODERATE	16	13.8
C LOW	27	26.6
D NO	30	33.0

TABLE FOUR: SANITARY LANDFILLS BY DRAINAGE BASIN

RIVER BASIN	NUMBER IN BASIN
Des Moines (and Raccoon)	23
Cedar (Fox, Iowa, & English)	19
Skunk	9
Nishnabotna	5
Missouri	5
Turkey	4
Little Sioux	4
Maquoketa	3
Wapsipinicon	3
Platte	3
Thompson	2
Boyer	2
Nodaway	1
Chariton	1
Soldier	1
Rock	1
Mosquito	1
Floyd	1
Upper Iowa	1
UNKNOWN	1

TABLE FIVE: TOPOGRAPHIC POSITION OF REQUIRED MONITORING BY HAZARD ZONE

ZONE A (HIGH HAZARD)

Position	Number Required
1. Floodplain	1
3. Valleyside	1
4. Ravine	1
5. Convex Crest	2
6. Upland Valleyside	5
7. Upland Flat	3
	13

(One demolition debris site in this zone is also required to have monitor wells.)

ZONE B (MODERATE HAZARD)

4. Ravine	1
6. Upland Valleyside	2
	3

ZONE C (LOW HAZARD)

2. Terrace	1
3. Valleyside	1
4. Ravine	4
6. Upland Valleyside	3
	9

ZONE D (NO HAZARD)

2. Terrace	2
3. Valleyside	2
4. Ravine	1
6. Upland Valley	2
	7

TABLE SIX: REQUIRED MONITORING BY TOPOGRAPHIC POSITION

POSITION	NUMBER REQUIRED
1. Floodplain	1
2. Terrace	4
3. Valleyside	4
4. Ravine	7
5. Convex Crest	2
6. Upland Valleyside	12
7. Upland Flat	3
	33

TABLE SEVEN: % OF LANDFILLS WITH REQUIRED MONITORING BY TOPOGRAPHIC ZONE

TOPO ZONE	% WITH REQUIRED MONITORING
Lowland (floodplain and terrace)	100
Valleyside (and ravine)	28.2
Uplands (crest, valley, flat)	34

Some disposal sites have required monitoring, but no well monitoring network is used. These areas generally have surface water or existing wells and tile systems which are required to be monitored and are listed in Table 8. Some landfills in the state are not required to carry on monitoring programs, but have the capability to do so. Three permitted fills are included in this category and are shown in Table 9.

Only one landfill in the state of Iowa was constructed using the synthetic lining system. This fill is used for the disposal of foundry wastes from the John Deere plant in Dubuque. The area of the landfill is underlain by high permeability loess over carbonate bedrock. With the use of this synthetic liner (produced by B. F. Goodrich under the trade name "Flexseal") leachate is collected and used for spray irrigation during the summer months. During the remainder of the year lechate is collected and taken to a wastewater treatment plant. This permit is shown in Table 10.

Many of the fills in the state have management systems which may lend themselves to future leachate collection and treatment. Generally these sites have some type of ground water interceptor tile. These tile lines may be very useful in the future if a serious leachate problem develops. The landfills with tile lines proposed or in operation are listed in Table 11.

The DEQ also grants permits for alternative types of waste handling procedures. Other activities controlled by the sanitary landfill permit system include transfer stations, incinerators, recycling centers, construction and demolition debris disposal sites, and garbage composting facilities. The agencies permitted to

TABLE EIGHT: OTHER REQUIRED MONITORING

COUNTY	PERMIT NUMBER	TYPE OF MONITORING
Appanoose	4-SDP-1-76P	Existing pond and sludge drying lagoon
Cedar	16-SDP-1-76P	Existing pond
Clinton	23-SDP-1-74P	Existing well plus three new ones
Clinton	23-SDP-2-74P	Existing bedrock wells in Galena Formation
Crawford	24-SDP-1-73P	Existing tile system
Iowa	48-SDP-1-75P	Existing tile system
Mahaska	62-SDP-1-74P	Existing wells

TABLE NINE: LANDFILLS WITH NON-REQUIRED MONITORING

Des Moines	29-SDP-1-76P	Two wells fitted with perforated PVC
Hamilton	40-SDP-2-75P	One well in
Van Buren	80-SDP-1-75P	Two wells fitted with perforated PVC

TABLE TEN: LANDFILLS WITH LINERS

Debuque (John Deere)	31-SDP-1-75P	B. F. Goodrich "Flexseal" liner; Leachate collection for summer spray irrigation and winter sewage treatment.

TABLE ELEVEN: LANDFILLS WITH LEACHATE MANAGEMENT POTENTIAL

COUNTY	NUMBER	MANAGEMENT CAPABILITY
Benton	6	Tile collection
Black Hawk	7	Berm for collection
Boone	8	Diversion tile
Calhoun	13	Tile collection
Cerro Gordo	17	Tile collection
Crawford	24	Tile collection
Dallas	25	Slurry trench
Dubuque	31.2	Tile collection
Franklin	35	Tile collection
Greene	37	Dam to catch surface seeps
Grundy	38	Underground slurry trench
Iowa	48	Tile collection
Jackson	49	Cut-off dikes for surface runoff
Jones	53	Berm to control leachate
Lee (Fort Madison)	56.1	Dam at end of ravine to collect surface water
Madison (Rice)	61.1	Tile collection
Marshall	64.2	Ground water interceptor
Muscatine	70.2	Subsurface dike to control leachate migration
Polk (Metro West)	72.2	Berm keyed to till
Webster	94	Collection plan

perform these activities in the state of Iowa are listed in Table 12.

Table 13 is a list of all permitted waste handling facilities in the state of Iowa. Those landfills with required monitoring are included in Table 14.

CONCLUSIONS

General

1. There are 3 types of water resources which need to be considered with respect to their potential to be polluted by the disposal of solid waste. They are 1) surface water, 2) water in shallow unconsolidated aquifers, and 3) water contained in deeper bedrock aquifers.
2. Current regulations favor the placement of sanitary landfills in upland sites.
3. A knowledge of the relationships between geologic materials and water flow characteristics may allow for the prediction of contamination patterns which develop from landfills placed in any one of the topographic positions.
4. Pollution enclaves are plume-shaped with the long axis parallel to ground water flow lines. Concentrations decrease both with distance along the axis and with distance radially away from it such that the enclave is entirely surrounded by uncontaminated water except at its source.

TABLE TWELVE: SPECIAL PERMITS

TRANSFER STATIONS

COUNTY	PERMIT NUMBER
Clay	21-SDP-1-76P
Palo Alto	74-SDP-1-76P
Pocahontas	76-SDP-1-75P
Polk	77-SDP-5-75P
Polk (fairgrounds compactor)	77-SDP-6-75P
Polk (Public Service Trucking)	77-SDP-8-75P
Polk (Metro Transfer Station)	77-SDP-10-76P
Scott	82-SDP-1-75P
INCINERATORS	
Johnson	52-SDP-2-76P
Story (heat recovery)	85-SDP-2-75P
RECYCLING	
Des Moines (Pak-A-Way)	29-SDP-2-76P
Linn	57-SDP-2-74P
Polk (Metro Recycling)	77-SDP-3-73P
CONSTRUCTION AND DEMOLITION DEBRIS	
Linn	57-SDP-1-72P*
Marshall	64-SDP-1-75P*
Muscatine	70-SDP-1-74P
Muscatine	70-SDP-3-76P
Polk (J. C. White-Ovid)	77-SDP-7-75P*
Polk (J. C. White-Market)	77-SDP-9-75P*
Story	85-SDP-3-75P
DIGESTER	
Polk (Enviro-Systems Ltd.)	77-SDP-4-74P

* Required Monitoring

GUIDE TO TABLES 13 & 14

The data in Tables 13 and 14 are arranged in the following way. The first column contains numbers corresponding to the county names arranged alphabetically. The second column has the permit number of each landfill within a given county arranged chronologically, the first permit granted having the number 1. Permit numbers issued by the DEQ are in the following format:

County Number-SDP-Fill Number-Issue Year P

Column 3 is the name of the river basin in which the landfill occurs. If monitoring is required by the DEQ, the word "yes" appears in column 4. The final column is the topographic position in which each fill occurs. A key to the method used is shown below:

1-floodplain

2-terrace

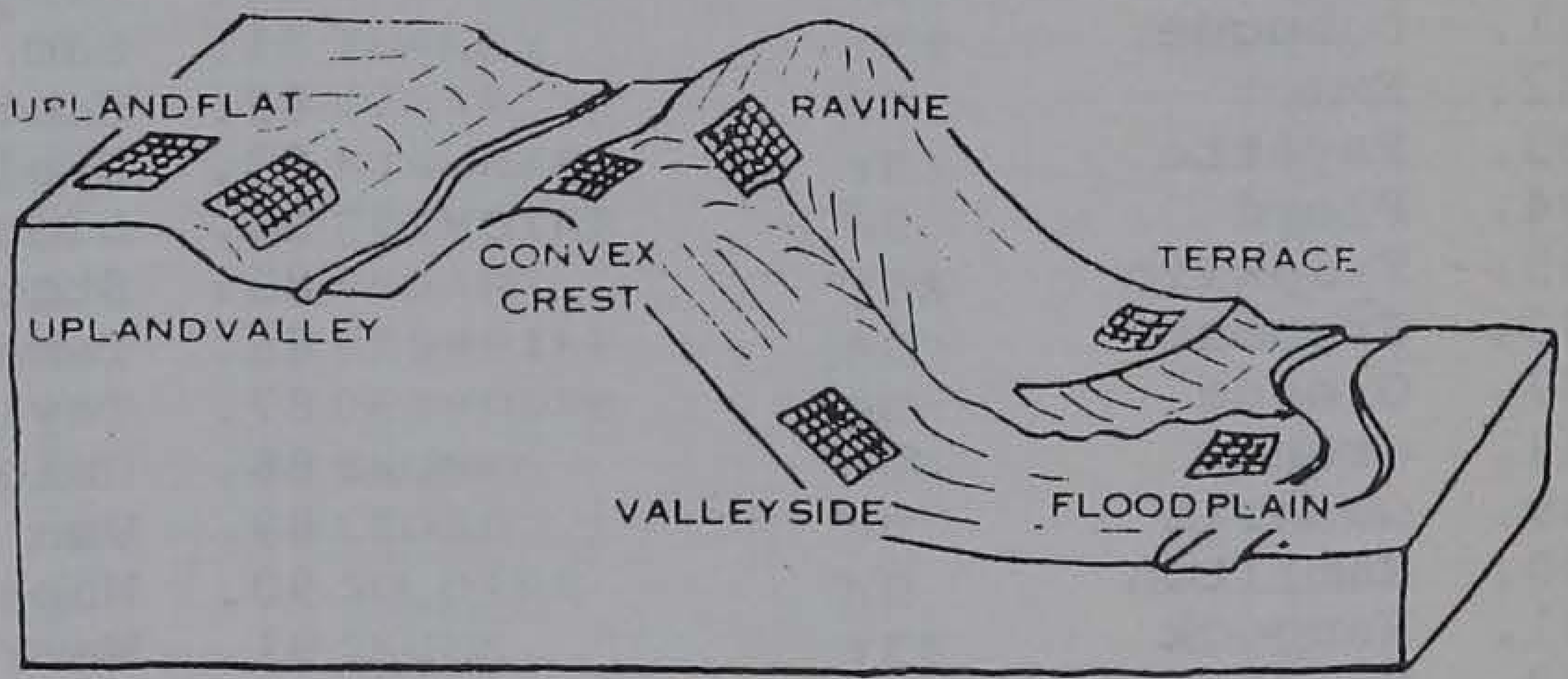
3-valleyside

4-ravine

5-convex crest

6-upland valley

7-upland flat



ALPHABETICAL LIST OF COUNTY NAMES

1. Adair
2. Adams
3. Allamakee
4. Appanoose
5. Audubon
6. Benton
7. Blackhawk
8. Boone
9. Bremer
10. Buchanan
11. Buena Vista
12. Butler
13. Calhoun
14. Carroll
15. Cass
16. Cedar
17. Cerro Gordo
18. Cherokee
19. Chickasaw
20. Clarke
21. Clay
22. Clayton
23. Clinton
24. Crawford
25. Dallas
26. Davis
27. Decatur
28. Delaware
29. Des Moines
30. Dickinson
31. Dubuque
32. Emmet
33. Fayette
34. Floyd
35. Franklin
36. Fremont
37. Greene
38. Grundy
39. Guthrie
40. Hamilton
41. Hancock
42. Hardin
43. Harrison
44. Henry
45. Howard
46. Humbolt
47. Ida
48. Iowa
49. Jackson
50. Jasper
51. Jefferson
52. Johnson
53. Jones
54. Keokuk
55. Kossuth
56. Lee
57. Linn
58. Louisa
59. Lucas
60. Lyon
61. Madison
62. Mahaska
63. Marion
64. Marshall
65. Mills
66. Mitchell
67. Manona
68. Monroe
69. Montgomery
70. Muscatine
71. Obrien
72. Osceola
73. Page
74. Palo Alto
75. Plymouth
76. Pocahontas
77. Polk
78. Pottawatomie
79. Poweshiek
80. Ringgold
81. Sac
82. Scott
83. Shelby
84. Sioux
85. Story
86. Tama
87. Taylor
88. Union
89. Van Buren
90. Wapello
91. Warren
92. Washington
93. Wayne
94. Webster
95. Winnebago
96. Winneshiek
97. Woodbury
98. Worth
99. Wright

TABLE 13. LANDFILLS IN IOWA

OBS	1 COUNTY	2 FILL	3 HAZARD	4 BASIN	5 MONITOR	6 POSITION
1	1	1	D	NODAWAY	YES	6
2	4	1	D	CHARITON	NO	3
3	5	1	C	NISHNABO	NO	6
4	6	1	A	CEDAR	NO	4
5	7	1	A	CEDAR	YES	6
6	8	1	D	DESMOINE	NO	4
7	9	1	A	TURKEY	YES	3
8	10	1	A	WAPSIPIN	YES	6
9	11	1	C	DESMOINE	YES	2
10	12	1	A	CEDAR	NO	7
11	13	1	D	DESMOINE	NO	7
12	14	1	D	DESMOINE	NO	6
13	15	1	C	NISHNABO	YES	6
14	16	1	A	CEDAR	NO	4
15	17	1	A	CEDAR	YES	6
16	18	2	C	LTLSIOUX	NO	6
17	19	1	A	WAPSIPIN	NO	3
18	20	1	D	DESMOINE	YES	4
19	20	2	D	THOMPSON	YES	2
20	23	1	A	MISSISSI	NO	4
21	23	2	A	WAPSIPIN	NO	5
22	24	1	C	BOYER	NO	4
23	25	1	D	DESMOINE	YES	3
24	27	1	D	THOMPSON	NO	5
25	28	1	A	MAQUOKET	YES	5
26	29	1	C	MISSISSI	NO	4
27	30	1	C	LTLSIOUX	NO	6
28	31	1	A	TURKEY	NO	4
29	31	2	A	TURKEY	NO	4
30	32	1	B	DESMOINE	NO	6
31	33	1	A	TURKEY	YES	7
32	35	1	C	CEDAR	NO	6
33	36	1	D	NISHNABO	YES	6
34	37	1	D	DESMOINE	NO	4
35	38	1	C	CEDAR	YES	6
36	39	1	C	DESMOINE	NO	6
37	40	1	B	DESMOINE	NO	7
38	40	2	B	SKUNK	NO	6
39	42	1	B	CEDAR	NO	7
40	43	1	D	SOLDIER	NO	6
41	44	1	B	SKUNK	YES	4
42	46	1	B	DESMOINE	NO	6
43	47	1	C	LTLSIOUX	NO	6
44	48	1	C	CEDAR	NO	4
45	49	1	A	MAQUOKET	NO	4
46	50	1	D	SKUNK	NO	3
47	52	1	C	CEDAR	YES	4
48	53	1	A	MAQUOKET	NO	4
49	54	1	B	SKUNK	NO	4
50	55	1	B	DESMOINE	NO	6
51	56	1	C	SKUNK	YES	4
52	56	2	B	SKUNK	NO	5
53	56	3	C	MISSISSI	NO	4
54	57	3	A	CEDAR	YES	1

TABLE 13. LANDFILLS IN IOWA (continued)

OBS	1 COUNTY	2 FILL	3 HAZARD	4 BASIN	5 MONITOR	6 POSITION
55	58	1	C	CEDAR	YES	4
56	60	1	C	ROCK	NO	6
57	61	1	D	DESMOINE	NO	6
58	61	2	D	DESMOINE	NO	6
59	62	1	B	SKUNK	YES	6
60	63	1	D	DESMOINE	NO	2
61	64	2	D	SKUNK	NO	4
62	65	1	D	MOSQUITO	NO	7
63	66	1	A	CEDAR	YES	7
64	67	1	C	LTLSIOUX	NO	4
65	68	1	D	DESMOINE	NO	3
66	69	1	D	NISHNABO	NO	6
67	70	1	A	CEDAR	NO	4
68	70	2	A	CEDAR	YES	4
69	73	1	D		NO	6
70	74	2	B	DESMOINE	YES	6
71	75	1	C	FLOYD	NO	6
72	77	1	D	DESMOINE	YES	3
73	77	2	D	DESMOINE	NO	5
74	79	1	C	CEDAR	NO	6
75	81	1	D	BOYER	NO	4
76	82	2	A	MISSISSI	YES	6
77	82	3	A	MISSISSI	YES	5
78	83	1	D	NISHNABO	NO	5
79	84	1	C	MISSOURI	YES	6
80	84	2	C	MISSOURI	NO	3
81	85	2	D	SKUNK	YES	2
82	86	1	C	CEDAR	YES	3
83	87	1	D	PLATTE	NO	6
84	88	1	D	PLATTE	NO	4
85	88	2	D	PLATTE	NO	6
86	89	1	B	DESMOINE	NO	3
87	90	1	D	DESMOINE	NO	3
88	94	1	D	DESMOINE	NO	4
89	95	1	A	DESMOINE	NO	7
90	96	1	A	UPIOWA	YES	6
91	97	1	C	MISSOURI	YES	4
92	97	2	C	MISSOURI	NO	4
93	98	1	A	CEDAR	YES	7
94	99	1	B	CEDAR	NO	7

TABLE 14. LANDFILLS WITH REQUIRED MONITOR WELLS

OBS	1 COUNTY	2 FILL	3 HAZARD	4 BASIN	5 MONITOR	6 POSITION
1	1	1	D	NODAWAY	YES	6
2	7	1	A	CEDAR	YES	6
3	9	1	A	TURKEY	YES	3
4	10	1	A	WAPSIPIN	YES	6
5	11	1	C	DESMOINE	YES	2
6	15	1	C	NISHNABO	YES	6
7	17	1	A	CEDAR	YES	6
8	20	1	D	DESMOINE	YES	4
9	20	2	D	THOMPSON	YES	2
10	25	1	D	DESMOINE	YES	3
11	28	1	A	MAQUOKET	YES	5
12	33	1	A	TURKEY	YES	7
13	36	1	D	NISHNABO	YES	6
14	38	1	C	CEDAR	YES	6
15	44	1	B	SKUNK	YES	4
16	52	1	C	CEDAR	YES	4
17	56	1	C	SKUNK	YES	4
18	57	3	A	CEDAR	YES	1
19	58	1	C	CEDAR	YES	4
20	62	1	B	SKUNK	YES	6
21	66	1	A	CEDAR	YES	7
22	70	2	A	CEDAR	YES	4
23	74	2	B	DESMOINE	YES	6
24	77	1	D	DESMOINE	YES	3
25	82	2	A	MISSISSI	YES	6
26	82	3	A	MISSISSI	YES	5
27	84	1	C	MISSOURI	YES	6
28	85	2	D	SKUNK	YES	2
29	86	1	C	CEDAR	YES	3
30	96	1	A	UPIOWA	YES	6
31	97	1	C	MISSOURI	YES	4
32	98	1	A	CEDAR	YES	7

Floodplain sites

1. The pollution enclave's shape and position are highly predictable in the alluvial materials near rivers.
2. The area underlain by contaminated ground water can be minimized by placing disposal sites adjacent to a river in a groundwater flow regimen where the flow lines are oriented normal to the river.
3. Rivers act as boundaries for leachate migration and are areas of discharge for it. Dilution is the principle method of attenuation.
4. Depth of penetration of the pollution enclave is minimized in a floodplain position due to the short distance of flow to a discharge point.
5. Ground water flow is controlled much more by river stage than by local amounts of precipitation in an alluvial system.
6. Enclave size in alluvium reaches a maximum size quickly and then is maintained in a steady-state equilibrium condition.
7. Water quality data suggests that contaminated ground water does not significantly affect the surface water into which it discharges.
8. The aggregate effect of a number of landfills in floodplain positions within a single river basin must be considered. The cumulative amounts of pollution added should not increase pollution concentrations within the river beyond certain limits.

Upland Sites

1. The shape and position of pollution enclaves from upland disposal sites are more difficult to predict due to the natural variability of materials and the great distance to points of ground water discharge.
2. The area underlain by contaminated water, therefore, has the potential to be very large in upland sites.
3. The distance to points of discharge are greater, and consequently the processes of sorption, decay, and filtration have a greater chance to reduce the concentration of leachate from upland sites before it discharges into surface waters. Upland sites, however, are also regional and local recharge areas for bedrock aquifers.
4. The depth of penetration of the pollution enclave may be great and may reach into valuable bedrock aquifers.
5. Ground water flow is controlled by the amount of precipitation and the rate of infiltration in upland sites. The range of permeability of the various media present is also important in determining rates and direction of flow.
6. Because the available moisture depends on precipitation only, the enclave forms much more slowly than those which develop from disposal sites in floodplains.
7. Limited initial data from upland sites indicates that leachate concentrations are lower than those found in the floodplain. This may be due both to topographic position and the relative ages of the sites tested.

8. The long term effects of upland sites on water quality are not fully understood at this time.

Status of Iowa Landfills

1. The effects of current state regulations favoring the placement of sanitary landfills in upland positions is evident (only 5.4% occur in the floodplain and terrace positions combined).
2. Approximately 35% of the permitted landfills have required monitoring programs.
3. The percentage of the total number of landfills in the state occurring in any one IGS hazard zone is closely related to the area of that zone. This reflects both population distribution and the cost of transportation as an important economic variable in waste disposal.
4. Many sites with non-required monitoring have a potential for special management practices.

RECOMMENDATIONS

1. Floodplain sites may be desirable in some cases where bedrock aquifers are vulnerable to contamination and are widely used as sources of water (such as in IGS zone A). An option for the use of these sites should be available in certain situations.

2. Further studies to determine the long term effects of upland disposal sites on the quality of ground and surface water should be started.

PART TWO

THE EFFECT OF UPLAND SANITARY LANDFILL SITES ON GROUND WATER QUALITY

THE EFFECT OF UPLAND SANITARY LANDFILL SITES ON GROUND WATER QUALITY

REVIEW OF UPLAND SITES

Introduction

The pollution potential of the leachate that is naturally produced in the stabilization of solid wastes depends on many diverse factors including the type and nature of the waste, the rate and amount of infiltration, temperature, and the hydrogeology of the disposal site (Clark, 1975). The nature of the waste depends on local industry and the types of activities performed in the region. In general, the amount of water available for infiltration and the temperature depend on local climate. This leaves the location and therefore the hydrogeology of the site as the only variable which can be chosen to fit optimum conditions within a local area.

For the most part, regulations governing the operation of disposal sites favor locations on the uplands rather than on the floodplain or terrace. The reason for this is that upland areas generally have a low water table, good surface drainage, and low permeability materials. It is thought that refuse placed in an upland site will remain relatively dry so that the amount of leachate which develops will be minimal. Upland sites are therefore considered more likely to protect the quality of both the ground water and surface water of the surrounding region.

Precipitation, however, does occur over upland landfills. Some water infiltrates the surface of the fill, and after passing through the refuse a liquid with high concentrations of both organic and inorganic matter may be formed. Because upland areas are local and regional ground water recharge sites this contaminated water can be very important.

The current analysis of flow patterns (Toth, 1963; LeGrand, 1965; Sendlein and Palmquist, 1975) shows that upland sites have outward flow of both ground and surface water. Because these sites are recharge areas the greatest potential for extensive contamination of bedrock aquifers exists. The long horizontal and vertical distances to zones of discharge allow a much larger and deeper enclave to develop than those of floodplain sites. If the natural attenuation processes are not sufficient to reduce the concentration of the leachate to acceptable levels as it moves through the ground, regional bedrock aquifers may be threatened. For this reason it was decided that more information was needed from landfills in upland positions.

Method of Study

During the spring of 1975 two new landfills in upland sites were instrumented by the Iowa State University Geology Group. One of these landfills was in Scott County and the other one was located in Fayette County. In the summer of 1976 an additional site in Cerro Gordo County was instrumented to monitor ground water quality (Figure 9). All of these sites represent upland areas, but a wide variety of geologic conditions exist. All of the upland sites currently being studied have been operated as sanitary land-

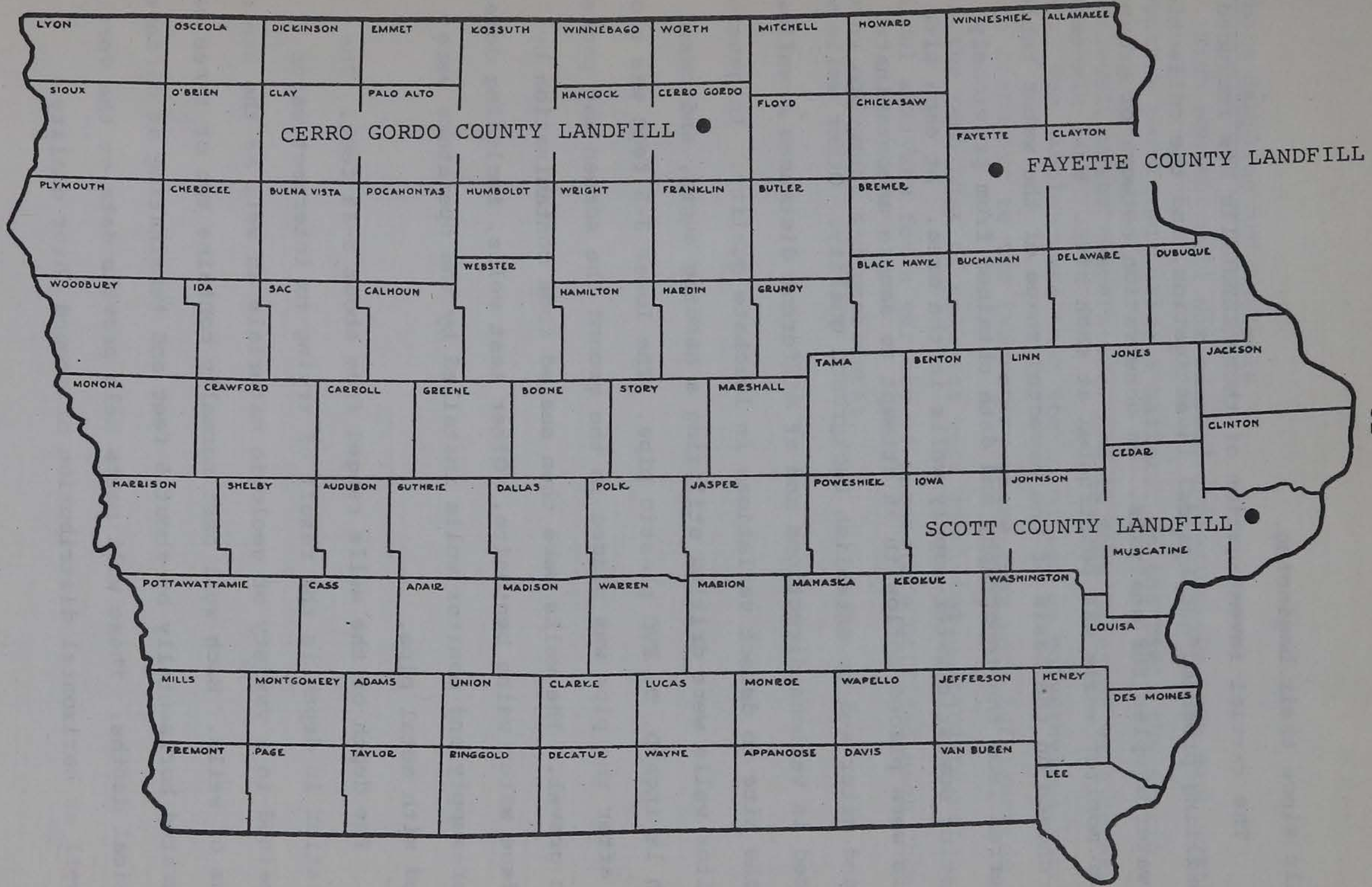


Figure 9. LOCATIONS OF CURRENT MONITORING PROGRAMS ON UPLAND SITES

fills since their beginning.

The initial investigation of these landfills has included a drilling program, geophysical investigation, and the collection of water samples for analysis. An observation network of ground water monitor wells was constructed at each site. Well placement was chosen on the basis of the expected shape of the water table inferred from the topography and data obtained from previously existing domestic water-supply wells in the area. At each site wells were placed upflow in an attempt to sample uncontaminated ground water and to establish background quality. Other wells were placed in various directions and at different distances downflow of the site to detect variations in leachate quality. In general, monitor wells were drilled utilizing a hardzog auger, and cased with 1½ inch O. D. PVC plastic pipe. The lower 3-5 feet was slotted and after the pipe was placed in the ground the screen was packed with gravel. The wells were then sealed from contamination by surface water using bentonite. Other test wells, including domestic water-supply and monitor wells installed by the operators were cased with metal pipe.

The depth of the wells ranged from about 5-45 feet. The variation in depth is the result of trying to intersect water contained in a variety of geologic materials as well as the use of nests of wells. Each well nest normally contains two or three wells seperated horizontally by about 5 feet and terminating at different vertical depths. These well nests help provide data on the vertical as well as horizontal distribution of ground water quality.

Leachate Sampling and Analysis

Each monitor well was sampled approximately once each month, as weather permitted, using a bailer. In the field the static water level, water temperature, and in some cases pH were determined. The samples were then stored on ice in polyethylene bottles during transport to the laboratory where they were refrigerated until the remainder of analyses were completed. Standard wet chemical analyses for a variety of parameters utilized Hach Chemical Company equipment and procedures.

SCOTT COUNTY SITE (SE¼, NE¼, Sec. 34, T78N, R3E)

The Scott County Landfill is located near the Brady Street exit on Interstate 80 in Davenport, Iowa. It is an upland site in an area of loess-mantled topography (Figures 10& 11), and occupies a position adjacent to a small stream which runs to the east and south of the area (Figure 12). This stream normally flows throughout the year, but during the fall of 1976 it completely dried up due to the extreme lack of precipitation. Several small gullies also border the site.

Currently 17 monitor wells and 2 stream samples are being collected monthly for analysis. Well 8 was the original background well, but preliminary tests indicated high concentrations of some chemical species. Well 9 was then located as a second background well. This well shows a high concentration of Cl^- which is undoubtably related to de-icing on the adjacent exit ramp of I-80. Well 10 was drilled as a soil test well to the west of the initial fill area, but it was cased and is used as a sample well. Filling has now progressed to the area surrounding well 10 and will continue until the closure of the site. Future analysis should show the change in quality of the ground water caused by the disposal of refuse. The remainder of the wells are placed in an attempt to intercept leachate migration from the landfill to the adjacent small stream (Table 15).

Both wells 1 and 2 penetrate the refuse disposed in the landfill. Well number 1 has slots open into the garbage and water samples from this well should give an indication of the concentration of the leachate as it leaves the site before any significant attenuation occurs. Well 2 is slotted only into the till beneath the refuse. Water samples from this well indicate the quality of water beneath the site and show the attenuation that is occurring in the underlying till.

Data from this site (Table 16) are still somewhat preliminary and no effort has been made to do a detailed analysis at this time. In general, however, it appears that the quality of water recovered from the shallow wells (those with a "b" suffix) is lower than the water obtained from the adjacent deeper wells. Most of the shallow wells terminate within the loess above the loess-till interface. The presence of leachate with higher ion concentrations in the shallow wells may be due to a channelization of ground water flow in the loess above the less permeable till. It may also be an indication of the increased attenuation ability offered by the till in which the deeper wells are completed.

FIGURE 10. SCOTT COUNTY LANDFILL

Generalized North-South Cross Section

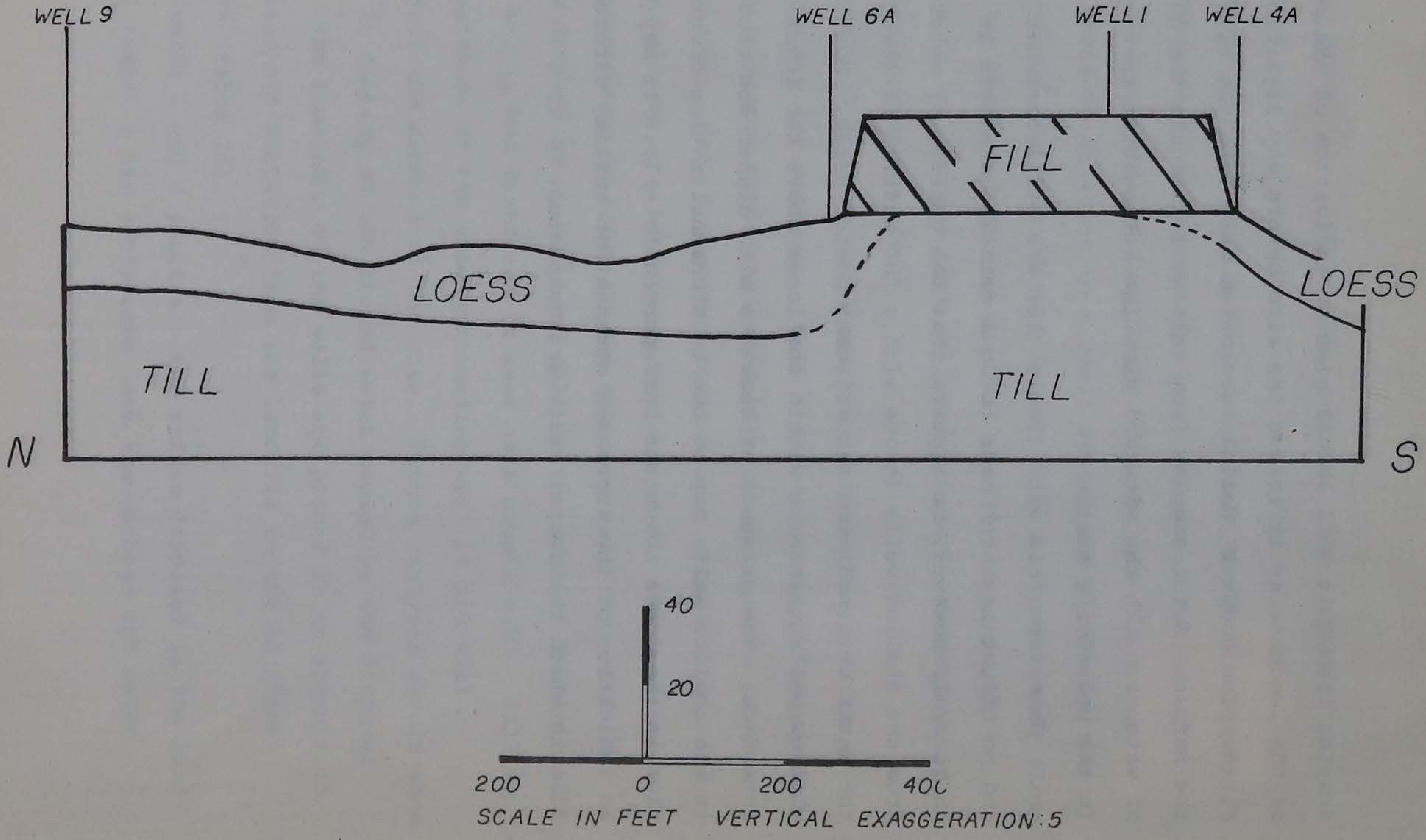
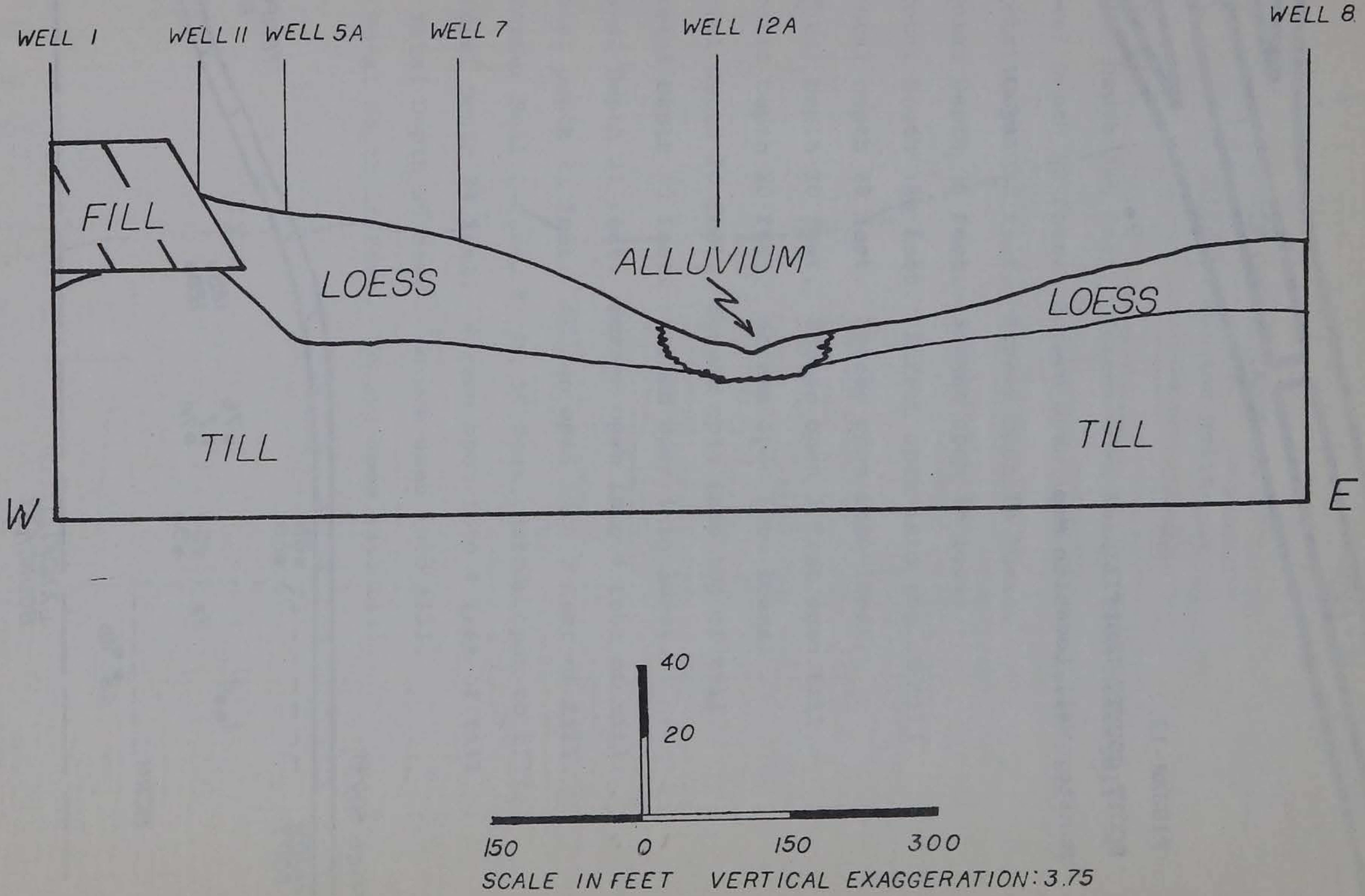


FIGURE 11. SCOTT COUNTY LANDFILL

Generalized West-East Cross Section



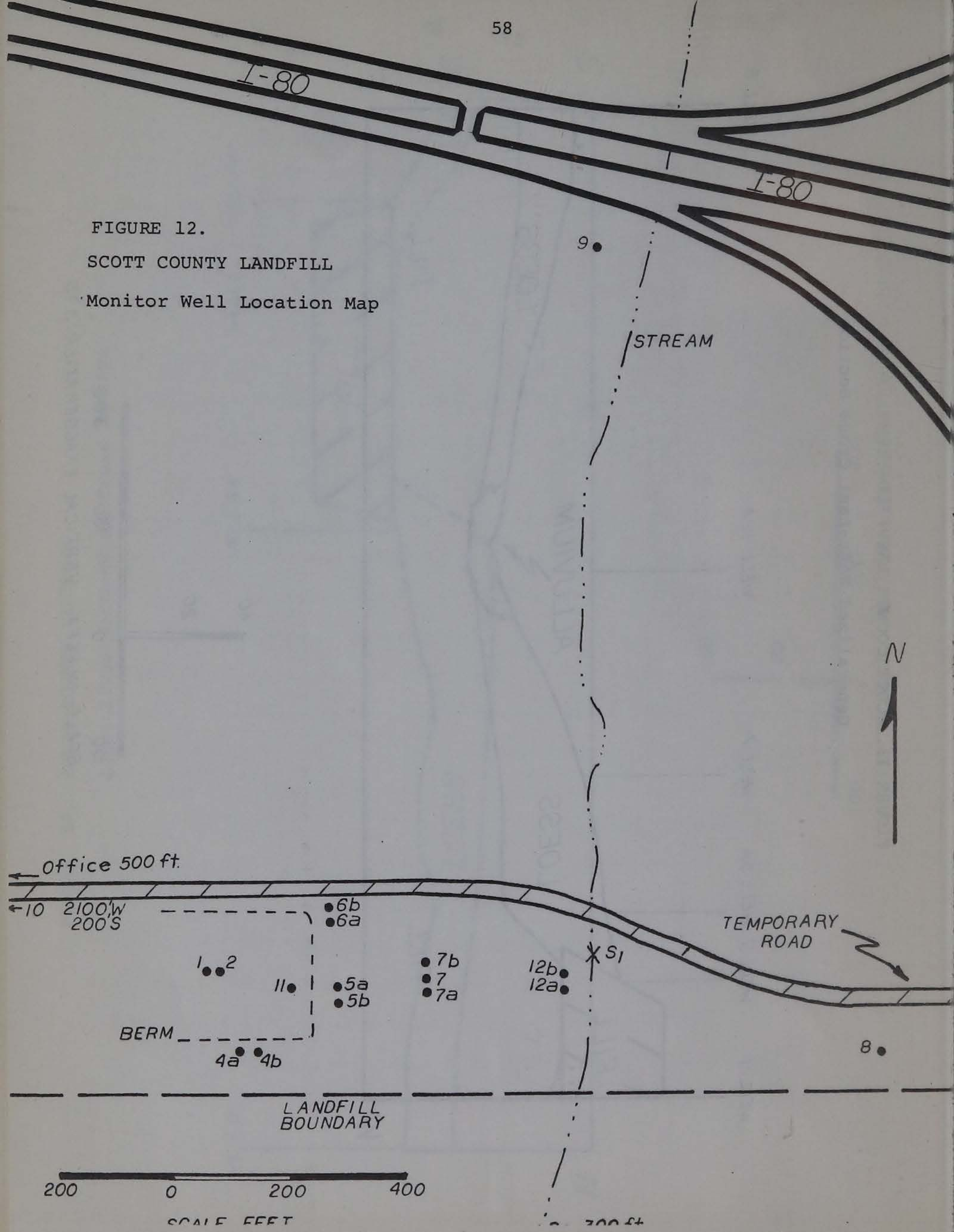


FIGURE 12.

SCOTT COUNTY LANDFILL

Monitor Well Location Map

TABLE 15.

SCOTT COUNTY LANDFILL

Guide to Monitor Wells

Well 1 - Total Depth 38½ feet. Screen open into filled material.

Well 2 - Total Depth 60 feet. Screen open into till beneath fill.

Well 4a - Total Depth 30 feet. Screen open in loess.

Well 4b - Total Depth 20 feet. Screen open in loess.

Well 5a - Total Depth 38½ feet. Screen open into top of till.

Well 5b - Total Depth 28 feet. Screen open into loess.

Well 6a - Total Depth 30 feet. Screen open 2 feet into till.

Well 6b - Total Depth 20 feet. Screen open into loess.

Well 7 - Total Depth 20 feet. Screen open into top of till.

Well 7a - Total Depth 40 feet. Screen open into loess.

Well 8 - Total Depth 21 feet. Screen open into 4 feet of till.

Well 9 - Total Depth 21 feet. Screen open into 2 feet of till.

Well 10 - Former Soil Boring, T. D. 50 feet. Screen open to till.

Well 11 - Total Depth 34 feet. Screen open into 4 feet of till.

Well 12a - Total Depth 25 feet. Screen open into till.

Well 12b - Total Depth 16 feet. Screen open into till.

TABLE 16. Water Quality at Scott County Landfill

WELL	PARAM	LO	HI	AVE
1	PH	6.00	7.58	6.89
	SPECCOND	200.00	2250.00	1418.00
	DO	0.00	31.40	7.68
	ALK	240.00	1120.00	560.93
	CAHRD	135.00	1385.00	532.57
	MGHRD	22.00	1635.00	454.64
	CA/MG	0.22	47.27	4.69
	FE	0.04	16.00	3.25
	SO4	0.00	58.00	9.86
	CL	20.00	1220.00	543.50
	NO3	0.31	3.90	1.26
	MN	0.20	7.00	3.96
2	PH	6.67	8.54	7.34
	SPECCOND	180.00	455.00	339.71
	DO	7.36	34.20	15.81
	ALK	215.00	536.00	420.41
	TTLHRD	180.00	2450.00	500.94
	CAHRD	105.00	1710.00	325.88
	MGHRD	50.00	740.00	175.06
	CA/MG	.	.	2.03
	FE	0.02	4.10	0.99
	SO4	0.05	22.50	5.58
	CL	15.00	50.00	22.68
	NO3	0.00	1.75	0.29
4A	PH	6.73	8.58	7.65
	SPECCOND	85.00	340.00	244.41
	DO	10.60	39.60	20.14
	ALK	120.00	450.00	337.56
	TTLHRD	100.00	450.00	304.60
	CAHRD	30.00	305.00	193.06
	MGHRD	60.00	177.00	111.56
	CA/MG	0.43	3.59	1.77
	FE	0.02	0.72	0.16
	SO4	0.00	32.50	4.92
	CL	4.00	20.50	7.14
	NO3	0.09	1.55	0.52
	MN	0.00	0.65	0.28
4B	PH	6.80	8.49	7.56
	SPECCOND	100.00	390.00	278.24
	DO	11.50	35.00	19.21
	ALK	105.00	444.00	305.22
	TTLHRD	86.00	684.00	360.67
	CAHRD	55.00	360.00	248.39
	MGHRD	25.00	414.00	112.28
	CA/MG	0.39	9.40	2.98
	FE	0.01	0.49	0.14
	SO4	16.00	72.00	49.44
	CL	5.00	17.50	9.44
	NO3	0.12	1.10	0.51
	MN	0.00	1.30	0.34
5A	PH	6.87	8.48	7.65
	SPECCOND	150.00	450.00	319.59
	ALK	148.00	483.00	382.11
	TTLHRD	168.00	559.00	412.00

TABLE 16. (Continued)

WELL	PARAM	LO	HI	AVE
	CAHRD	35.00	355.00	266.94
	MGHRD	71.00	232.00	145.06
	CA/MG	0.26	3.82	2.00
	FE	0.00	1.38	0.18
	SO4	10.00	57.00	33.13
	CL	6.50	22.00	13.03
	NO3	0.10	2.10	0.53
	MN	0.10	3.00	0.82
5B	PH	6.48	8.44	7.12
	SPECCOND	195.00	775.00	508.71
	DO	8.70	29.00	16.70
	ALK	156.00	1018.00	654.06
	TTLHRD	236.00	1050.00	712.06
	CAHRD	46.00	765.00	462.67
	MGHRD	105.00	400.00	249.39
	CA/MG	0.24	4.10	2.00
	FE	0.05	1.88	0.48
	SO4	47.50	130.00	90.08
	CL	5.00	9.50	7.47
	NO3	0.05	0.65	0.28
	MN	0.00	4.65	1.12
6A	PH	6.95	8.40	7.55
	SPECCOND	120.00	380.00	283.53
	DO	11.04	36.80	17.27
	ALK	170.00	455.00	348.56
	TTLHRD	140.00	505.00	336.89
	CAHRD	60.00	345.00	213.72
	MGHRD	73.00	206.00	123.17
	CA/MG	0.47	4.26	1.86
	FE	0.01	0.65	0.13
	SO4	0.00	36.50	8.49
	CL	5.00	11.00	6.86
	NO3	0.06	1.13	0.46
	MN	0.00	2.80	0.99
6B	PH	6.68	8.45	7.31
	SPECCOND	205.00	530.00	379.41
	DO	9.20	39.40	17.72
	ALK	162.00	640.00	496.33
	TTLHRD	275.00	789.00	543.28
	CAHRD	125.00	497.00	349.28
	MGHRD	95.00	342.00	194.00
	CA/MG	0.66	4.75	1.98
	FE	0.01	0.64	0.25
	SO4	11.50	100.00	51.75
	CL	4.50	16.00	8.33
	NO3	0.01	1.23	0.29
	MN	0.00	0.75	0.25
7A	PH	7.23	8.04	7.92
	SPECCOND	135.00	365.00	295.83
	DO	7.40	19.78	10.30
	ALK	153.00	450.00	342.57
	TTLHRD	140.00	432.00	332.14
	CAHRD	50.00	280.00	203.72
	MGHRD	70.00	161.00	128.43

TABLE 16. (Continued)

WELL	PARAM	LO	HI	AVE
	CA/MG	0.56	2.22	1.56
	FE	0.01	1.24	0.24
	SO4	1.00	28.40	10.41
	CL	5.00	18.50	9.64
	NO3	0.10	0.62	0.31
	MN	0.10	1.20	0.40
7	PH	7.00	8.52	7.67
	SPECCOND	120.00	352.00	244.00
	DO	10.10	32.60	17.62
	ALK	150.00	433.00	320.78
	TTLHRD	140.00	517.00	313.83
	CAHRD	50.00	350.00	201.94
	MGHRD	26.00	180.00	111.89
	CA/MG	0.52	9.81	2.16
	FE	0.01	0.87	0.13
	SO4	0.00	12.40	6.86
	CL	5.00	13.50	8.08
	NO3	0.10	1.22	0.50
	MN	0.02	0.30	0.13
7B	PH	6.77	8.40	7.72
	SPECCOND	205.00	365.00	287.14
	DO	10.60	24.38	15.07
	ALK	300.00	420.00	371.88
	TTLHRD	325.00	421.00	378.25
	CAHRD	195.00	286.00	246.87
	MGHRD	95.00	163.00	131.38
	CA/MG	1.44	2.99	1.93
	FE	0.02	0.46	0.13
	SO4	2.00	33.00	26.44
	CL	5.00	10.00	8.56
	NO3	0.12	0.60	0.27
	MN	0.00	0.25	0.06
8	PH	6.83	8.58	7.55
	SPECCOND	42.00	375.00	260.83
	DO	11.50	54.60	19.33
	ALK	62.00	470.00	324.39
	TTLHRD	55.00	480.00	345.28
	CAHRD	30.00	395.00	239.00
	MGHRD	25.00	180.00	106.28
	CA/MG	0.55	5.89	2.47
	FE	0.00	0.45	0.09
	SO4	0.00	56.00	29.08
	CL	5.00	15.00	10.36
	NO3	0.15	1.50	0.65
	MN	0.00	0.30	0.12
9	PH	7.00	8.60	7.68
	SPECCOND	160.00	410.00	298.85
	DO	10.60	40.40	19.20
	ALK	124.00	365.00	267.93
	TTLHRD	180.00	472.00	330.57
	CAHRD	107.00	337.00	228.64
	MGHRD	25.00	184.00	101.93
	CA/MG	1.11	9.57	3.00

TABLE 16. (Continued)

WELL	PARAM	LO	HI	AVE
	FE	0.03	2.60	0.31
	SO4	13.00	44.00	31.69
	CL	12.50	75.00	47.08
	NO3	0.07	1.60	0.50
	MN	0.00	0.80	0.30
10	PH	7.11	8.55	7.75
	SPECCOND	140.00	350.00	268.00
	DO	14.30	25.40	19.44
	ALK	180.00	828.00	325.06
	TTLHRD	180.00	410.00	336.88
	CAHRD	90.00	390.00	242.63
	MGHRD	20.00	135.00	44.25
	CA/MG	1.00	19.50	3.67
	FE	0.00	3.04	0.24
	SO4	16.00	56.00	37.28
	CL	4.00	16.50	8.70
	NO3	0.05	0.72	0.35
	MN	0.00	2.00	0.08
11	PH	6.49	8.10	7.24
	SPECCOND	320.00	665.00	523.00
	DO	11.50	17.02	15.69
	ALK	290.00	875.00	617.50
	TTLHRD	581.00	961.00	719.00
	CAHRD	133.00	644.00	434.17
	MGHRD	232.00	354.00	284.83
	CA/MG	0.45	2.16	1.55
	FE	0.02	0.80	0.24
	SO4	81.00	130.00	105.00
	CL	8.00	12.50	10.08
	NO3	0.13	1.23	0.43
	MN	0.10	2.80	0.92
12A	PH	6.92	8.73	7.94
	SPECCOND	69.00	425.00	219.25
	DO	4.60	17.48	12.33
	ALK	85.00	394.00	279.50
	TTLHRD	90.00	688.00	294.50
	CAHRD	42.00	395.00	179.50
	MGHRD	48.00	293.00	115.00
	CA/MG	0.88	2.68	1.60
	FE	0.01	0.46	0.21
	SO4	0.00	79.50	13.10
	CL	5.50	20.00	9.13
	NO3	0.10	0.28	0.16
	MN	0.00	0.65	0.15
12B	PH	7.38	8.67	8.00
	SPECCOND	67.00	385.00	250.00
	DO	6.90	20.24	13.81
	ALK	63.00	378.00	273.38
	TTLHRD	65.00	428.00	302.13
	CAHRD	30.00	307.00	179.38
	MGHRD	30.00	200.00	122.75
	CA/MG	0.26	2.54	1.48
	FE	0.01	1.96	0.29

TABLE 16. (Continued)

WELL	PARAM	LO	HI	AVE
	SO4	10.00	63.50	34.69
	CL	7.50	15.50	10.68
	NO3	0.02	1.15	0.24
	MN	0.00	2.00	0.35
S1	PH	7.25	8.53	7.98
	SPECCOND	75.00	400.00	294.07
	DO	8.70	32.00	19.93
	ALK	100.00	318.00	218.67
	TTLHRD	170.00	413.00	310.20
	CAHRD	107.00	362.00	222.13
	MGHRD	45.00	134.00	88.07
	CA/MG	1.26	7.11	2.88
	FE	0.00	0.14	0.06
	SO4	21.50	72.00	47.37
	CL	16.50	182.50	59.87
	NO3	0.02	43.50	3.46
	MN	0.00	0.10	0.03
S2	PH	7.38	8.78	8.06
	SPECCOND	155.00	395.00	280.29
	DO	9.20	58.60	21.78
	ALK	80.00	320.00	200.13
	TTLHRD	155.00	400.00	292.80
	CAHRD	95.00	358.00	194.27
	MGHRD	32.00	175.00	98.53
	CA/MG	0.66	11.18	2.52
	FE	0.00	0.41	0.08
	SO4	19.00	69.00	45.07
	CL	13.50	114.00	52.63
	NO3	0.04	42.00	4.64
	MN	0.00	0.25	0.08

FAYETTE COUNTY SITE (NW¼. Sec. 21, T93N, R8W)

The Fayette County Landfill is located northwest of Fayette, Iowa on property owned by the County Farm. The site is an upland area of loamy soils developed on glacial till (Figures 13 & 14). A small stream runs approximately one-half mile west of the landfill and is the local sink to which leachate migration is expected (Figure 15).

Currently 30 wells are available for water sampling. Wells 4-15 are domestic water-supply wells that were in operation before use of the site for waste disposal began. The remainder of the wells were placed for the current ground water monitoring program. Samples from the wells and a surface water sample from the stream are collected approximately once each month for analysis (Table 17).

The investigation at this site is complicated by the presence of animal feedlots near many of the domestic supply wells. The entire area surrounding the disposal site is being used for agricultural crop production making the presence of fertilizer and pesticide residuals possible. The sewage treatment lagoon for the Fayette County Home is also located on the southwest of the landfill in the general direction that leachate is expected to migrate toward the stream.

Data from the site are still somewhat preliminary (Table 18). The pattern of shallow wells having higher leachate concentrations than nearby deep wells is not as well expressed at this site as at Scott County. Well nests 2 and 3 do show this general trend, however.

This may be an indication of the movement of leachate in the general direction of these well nests. The well nest down gradient from the sewage lagoon (21) has lower concentrations of dissolved oxygen than the rest of the wells. Other parameters, however, are much like those for other wells in the vicinity. It should be noted that well nests 21, 22, and 23 were placed during November of 1976 and the short period of time since emplacement and the general low level of precipitation may not have allowed these wells to fully stabilize at this time.

FIGURE 13.

FAYETTE COUNTY LANDFILL Generalized North-South Cross Section

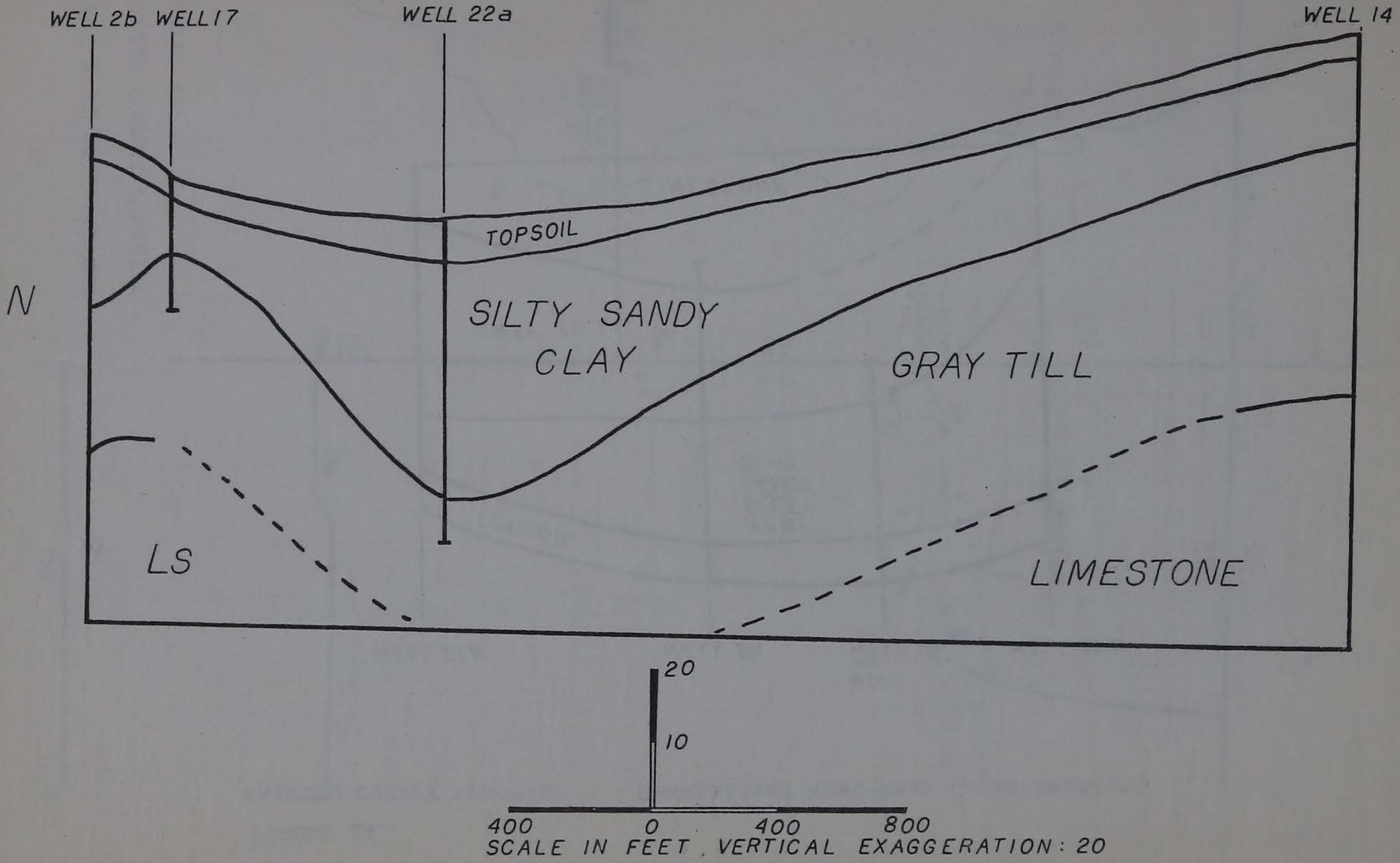
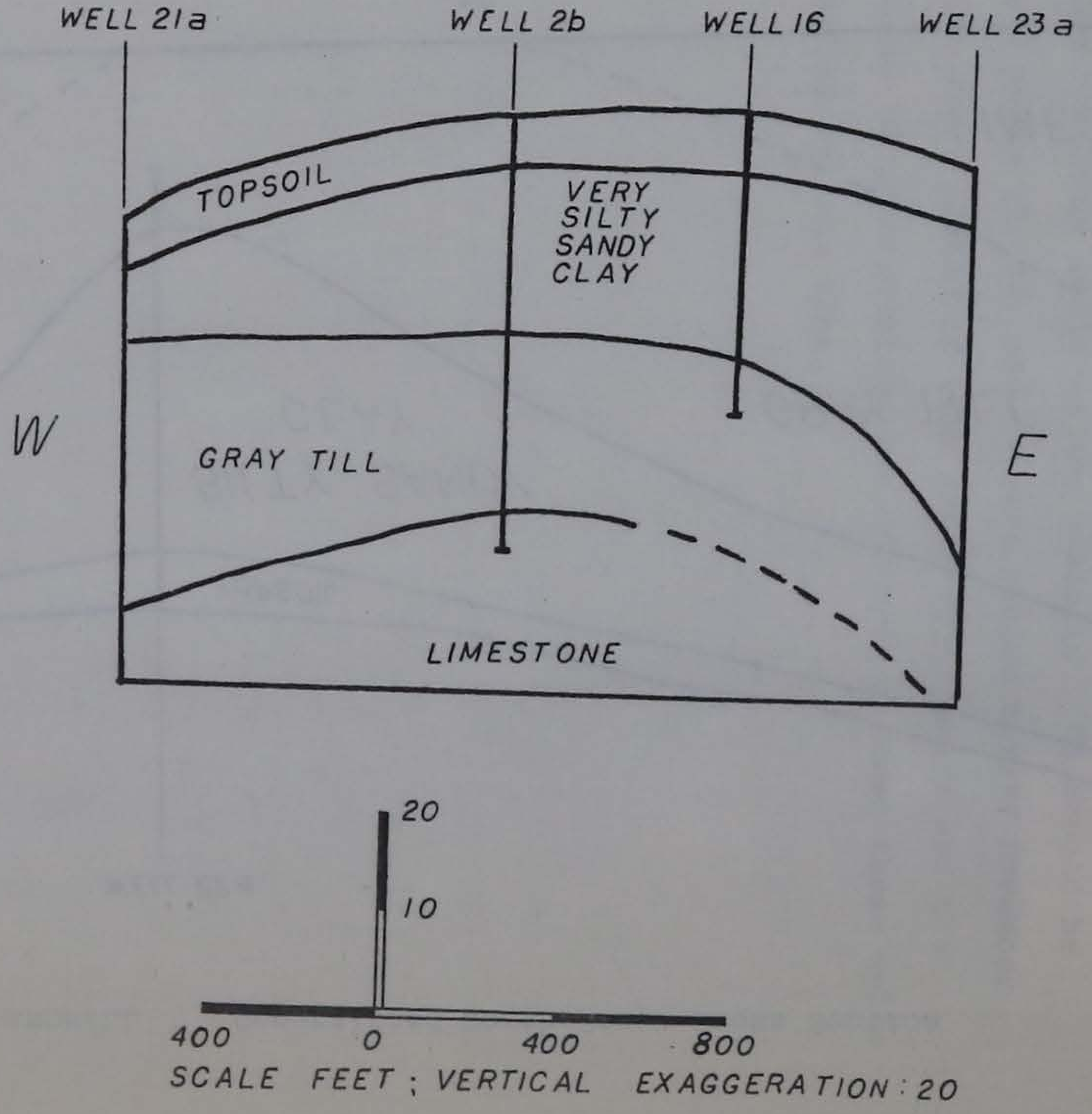


FIGURE 14.

FAYETTE COUNTY LANDFILL Generalized West-East Cross Section



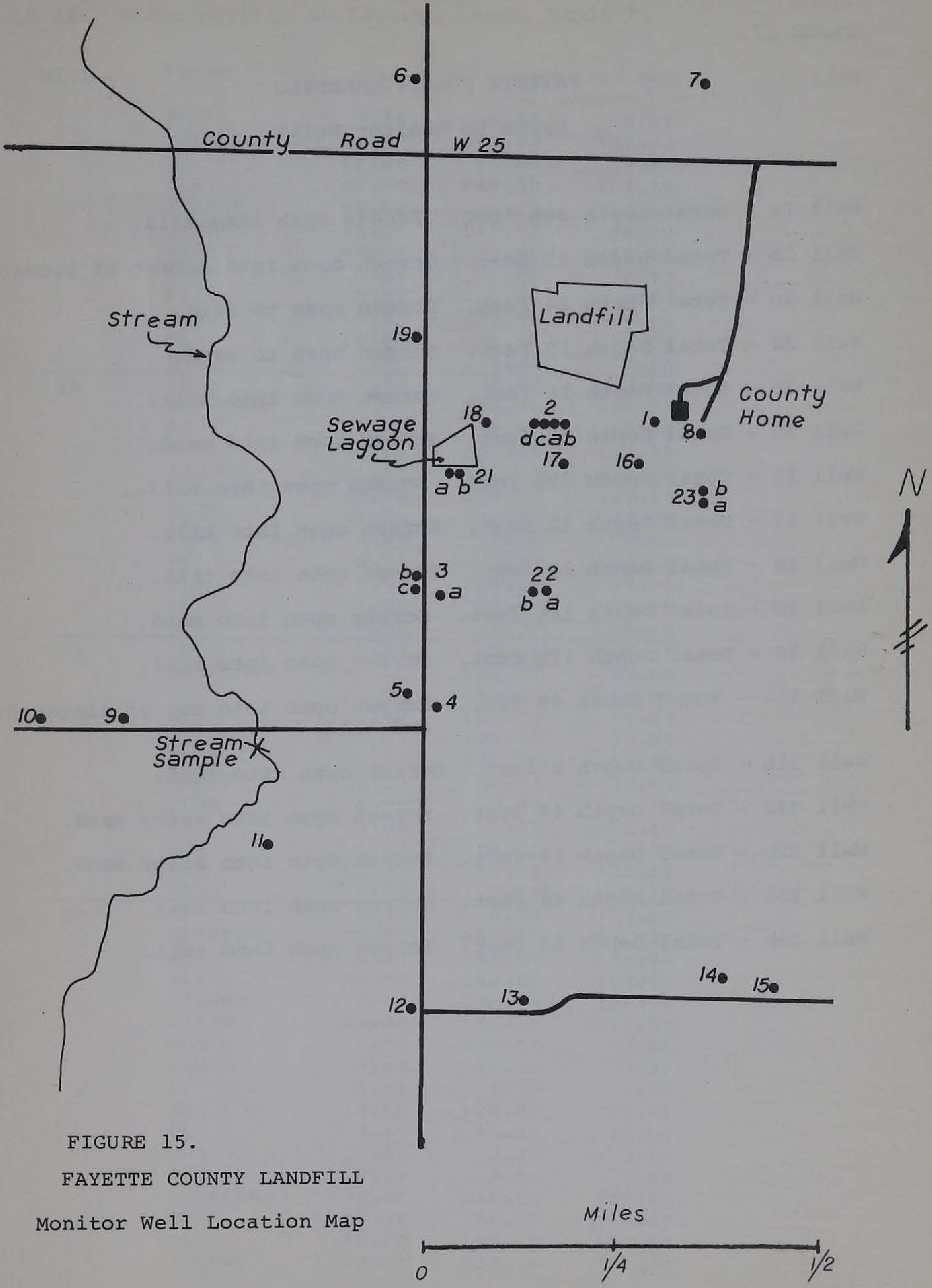


FIGURE 15.

FAYETTE COUNTY LANDFILL

Monitor Well Location Map

TABLE 17.

FAYETTE COUNTY LANDFILL

Guide to Monitor Wells

Well 2a - Total Depth 38½ feet. Screen open into till.

Well 2b - Total Depth 45 feet. Screen open into 3 feet of limestone.

Well 2c - Total Depth 24 feet. Screen open to sand.

Well 2d - Total Depth 15 feet. Screen open to sand.

Well 3b - Total Depth 16 feet. Screen open into till.

Well 3c - Total Depth 4½ feet. Screen open into sand.

Well 16 - Total Depth 29½ feet. Screen open into till.

Well 17 - Total Depth 18 feet. Screen open into till.

Well 18 - Total Depth 19 feet. Screen open into till.

Well 19 - Total Depth 16½ feet. Screen open into sand.

Well 20 - Total Depth 17½ feet. Screen open into till.

Well 21a - Total Depth 48 feet. Screen open into top of limestone and till.

Well 21b - Total Depth 8 feet. Screen open into sand.

Well 22a - Total Depth 44 feet. Screen open into silty sand.

Well 22b - Total Depth 17 feet. Screen open into silty sand.

Well 23a - Total Depth 48 feet. Screen open into till.

Well 23b - Total Depth 38 feet. Screen open into till.

TABLE 18. Water Quality at Fayette County Landfill

WELL	PARAM	LO	HI	AVE
1	PH	7.34	8.88	8.47
	SPECCOND	81.00	875.00	182.75
	DO	12.88	25.80	17.37
	ALK	80.00	240.00	107.25
	TTLHRD	89.00	168.00	118.83
	CAHRD	35.00	110.00	56.75
	MGHRD	49.00	77.00	62.08
	CA/MG	0.54	1.90	0.93
	FE	0.02	0.77	0.23
	SO4	10.80	37.00	19.59
	CL	10.00	22.50	14.00
	NO3	0.00	0.35	0.18
2A	PH	7.16	8.58	7.92
	SPECCOND	125.00	300.00	227.22
	DO	13.40	24.60	17.68
	ALK	40.00	250.00	179.33
	TTLHRD	121.00	335.00	231.22
	CAHRD	85.00	239.00	157.13
	MGHRD	36.00	120.00	72.25
	CA/MG	0.83	3.56	2.44
	FE	0.11	2.00	0.65
	SO4	0.00	125.00	37.75
	CL	21.00	50.00	32.61
	NO3	0.02	1.50	0.46
2B	PH	7.43	9.12	8.47
	SPECCOND	62.00	160.00	93.80
	DO	11.00	38.00	18.26
	ALK	0.47	166.00	77.70
	TTLHRD	45.00	127.00	76.50
	CAHRD	20.00	100.00	44.50
	MGHRD	16.00	56.00	32.00
	CA/MG	0.55	3.70	1.57
	FE	0.02	0.45	0.10
	SO4	1.00	28.00	9.04
	CL	12.00	55.00	23.15
	NO3	0.08	0.28	0.17
2C	PH	6.99	8.54	7.65
	SPECCOND	75.00	245.00	150.27
	DO	13.30	41.00	18.33
	ALK	64.00	195.00	153.00
	TTLHRD	102.00	336.00	168.00
	CAHRD	39.00	186.00	114.55
	MGHRD	10.00	159.00	53.45
	CA/MG	0.62	12.90	3.71
	FE	0.01	1.38	0.52
	SO4	0.05	105.00	24.91
	CL	7.50	25.50	15.09
	NO3	0.01	2.70	0.49
	PH	6.99	8.54	7.65
	SPECCOND	75.00	245.00	150.27
	DO	13.30	41.00	18.33
	ALK	64.00	195.00	153.00
	TTLHRD	102.00	336.00	168.00

TABLE 18. (Continued)

WELL	PARAM	LO	HI	AVE
	CAHRD	39.00	186.00	114.55
	MGHRD	10.00	159.00	53.45
	CA/MG	0.62	12.90	3.71
	FE	0.01	1.38	0.52
	SO4	0.05	105.00	24.91
	CL	7.50	25.50	15.09
	NO3	0.01	2.70	0.49
2D	PH	7.38	8.00	7.69
	SPECCOND	155.00	250.00	202.50
	DO	18.80	36.60	27.70
	ALK	190.00	350.00	246.33
	TTLHRD	153.00	350.00	256.00
	CAHRD	100.00	210.00	170.00
	MGHRD	53.00	150.00	86.00
	CA/MG	1.33	3.82	2.35
	FE	0.30	2.55	1.11
	SO4	37.00	43.00	40.33
	CL	8.00	24.50	17.67
	NO3	1.19	4.80	2.40
3A	PH	7.72	9.04	8.66
	SPECCOND	35.00	150.00	78.23
	DO	11.96	57.00	19.68
	ALK	15.00	54.00	43.31
	TTLHRD	30.00	129.00	79.31
	CAHRD	20.00	98.00	49.00
	MGHRD	10.00	46.00	30.31
	CA/MG	1.00	3.16	1.71
	FE	0.01	0.18	0.07
	SO4	0.00	33.00	9.00
	CL	16.00	45.00	30.65
	NO3	0.00	0.60	0.16
3B	PH	7.20	8.52	8.01
	SPECCOND	145.00	255.00	196.43
	DO	16.60	22.50	18.25
	ALK	110.00	244.00	139.75
	TTLHRD	159.00	305.00	211.88
	CAHRD	116.00	227.00	154.88
	MGHRD	40.00	78.00	57.00
	CA/MG	1.88	3.68	2.82
	FE	0.09	3.74	1.20
	SO4	22.30	70.00	38.67
	CL	15.00	26.00	20.00
	NO3	0.25	1.20	0.61
3C	PH	6.94	7.24	7.08
	SPECCOND	125.00	255.00	175.00
	DO	16.10	20.70	18.67
	ALK	110.00	237.00	173.50
	TTLHRD	135.00	298.00	191.67
	CAHRD	100.00	220.00	144.33
	MGHRD	29.00	78.00	47.33
	CA/MG	2.82	3.90	3.19
	FE	0.00	0.42	0.17
	SO4	17.00	39.00	24.93

TABLE 18. (Continued)

WELL	PARAM	LO	HI	AVE
	CL	7.50	13.00	9.30
	NO3	0.41	6.10	2.31
4	PH	6.64	7.61	7.12
	SPECCOND	325.00	590.00	500.42
	DO	3.22	42.00	17.72
	ALK	123.00	461.00	392.25
	TTLHRD	413.00	660.00	593.08
	CAHRD	249.00	572.00	472.33
	MGHRD	47.00	167.00	121.16
	CA/MG	1.52	12.17	4.56
	FE	0.00	0.45	0.17
	SO4	63.50	140.00	119.46
	CL	41.50	121.00	94.88
	NO3	1.30	11.60	5.97
5	PH	7.05	8.52	7.84
	SPECCOND	80.00	310.00	224.85
	DO	12.88	43.00	20.60
	ALK	65.00	436.00	230.00
	TTLHRD	80.00	490.00	287.00
	CAHRD	55.00	380.00	217.92
	MGHRD	25.00	110.00	69.08
	CA/MG	1.65	11.83	3.57
	FE	0.01	0.78	0.12
	SO4	11.30	39.50	28.98
	CL	15.00	45.00	23.69
	NO3	0.06	0.47	0.26
6	PH	7.05	8.70	7.92
	SPECCOND	87.00	220.00	180.00
	DO	13.80	35.00	19.96
	ALK	82.00	245.00	213.50
	TTLHRD	150.00	250.00	215.43
	CAHRD	56.00	184.00	154.86
	MGHRD	40.00	90.00	60.57
	CA/MG	0.67	4.48	2.79
	FE	0.00	0.53	0.27
	SO4	3.00	16.00	5.96
	CL	2.00	15.00	5.48
	NO3	0.01	0.66	0.22
8	PH	7.08	8.52	7.98
	SPECCOND	80.00	250.00	195.83
	DO	10.12	20.20	15.22
	ALK	68.00	265.00	206.33
	TTLHRD	147.00	327.00	249.17
	CAHRD	92.00	236.00	184.00
	MGHRD	40.00	91.00	65.17
	CA/MG	1.67	5.25	2.93
	FE	0.02	0.98	0.19
	SO4	10.80	44.00	29.56
	CL	5.00	15.00	10.54
	NO3	0.03	0.27	0.16
9	PH	7.21	8.52	7.88
	SPECCOND	135.00	265.00	216.43
	DO	9.66	47.00	17.82

TABLE 18. (Continued)

WELL	PARAM	LO	HI	AVE
	ALK	90.00	334.00	275.57
	TTLHRD	120.00	307.00	264.36
	CAHRD	80.00	237.00	181.79
	MGHRD	40.00	138.00	82.57
	CA/MG	0.99	3.39	2.28
	FE	0.01	0.65	0.13
	SO4	0.00	10.00	7.29
	CL	1.80	9.50	5.49
	NO3	0.12	0.83	0.46
10	PH	7.61	8.39	7.92
	SPECCOND	165.00	240.00	191.67
	DO	15.00	33.40	22.67
	ALK	109.00	298.00	228.33
	TTLHRD	168.00	276.00	209.67
	CAHRD	87.00	189.00	126.00
	MGHRD	81.00	87.00	83.67
	CA/MG	1.07	2.17	1.49
	FE	0.00	0.79	0.39
	SO4	9.00	12.00	10.33
	CL	3.50	9.50	6.17
	NO3	0.12	0.71	0.38
11	PH	6.99	8.48	7.66
	SPECCOND	130.00	380.00	311.46
	DO	12.00	45.60	16.54
	ALK	85.00	545.00	294.08
	TTLHRD	125.00	435.00	362.92
	CAHRD	115.00	310.00	259.23
	MGHRD	10.00	140.00	103.69
	CA/MG	1.86	11.50	3.22
	FE	0.07	2.50	0.40
	SO4	19.00	98.00	59.81
	CL	25.00	70.00	33.27
	NO3	1.65	9.80	4.52
12	PH	6.99	8.45	7.64
	SPECCOND	165.00	340.00	227.22
	DO	12.70	24.20	16.54
	ALK	60.00	253.00	193.67
	TTLHRD	180.00	304.00	244.33
	CAHRD	105.00	230.00	164.67
	MGHRD	40.00	177.00	79.67
	CA/MG	0.67	5.75	2.61
	FE	0.00	0.33	0.08
	SO4	20.00	38.00	27.44
	CL	10.50	22.50	15.50
	NO3	0.04	3.60	1.11
13	PH	7.05	8.31	7.69
	SPECCOND	130.00	240.00	191.43
	DO	11.50	20.20	16.59
	ALK	211.00	235.00	223.71
	TTLHRD	220.00	268.00	239.71
	CAHRD	144.00	200.00	172.14
	MGHRD	52.00	103.00	67.57
	CA/MG	1.60	4.00	2.74

TABLE 18. (Continued)

WELL	PARAM	LO	HI	AVE
	FE	0.03	0.52	0.18
	SO4	8.00	21.00	15.67
	CL	5.00	10.00	7.71
	NO3	0.12	6.00	1.10
14	PH	7.30	10.47	8.23
	SPECCOND	175.00	258.00	230.43
	DO	34.60	14.26	20.81
	ALK	260.00	278.00	268.57
	TTLHRD	240.00	315.00	288.86
	CAHRD	175.00	237.00	209.71
	MGHRD	65.00	102.00	79.14
	CA/MG	2.09	3.69	2.85
	FE	0.02	0.21	0.06
	SO4	11.50	19.00	15.81
	CL	15.00	31.00	19.00
	NO3	0.06	0.39	0.22
15	PH	7.14	8.68	7.93
	SPECCOND	275.00	625.00	425.42
	DO	5.98	19.40	12.51
	ALK	280.00	525.00	394.42
	TTLHRD	75.00	194.00	144.33
	CAHRD	40.00	140.00	84.33
	MGHRD	35.00	82.00	60.00
	CA/MG	0.87	2.69	1.43
	FE	0.14	2.75	1.26
	SO4	18.00	67.00	30.71
	CL	26.50	57.50	39.91
	NO3	0.82	52.00	11.79
16	PH	7.57	8.76	8.11
	SPECCOND	155.00	245.00	216.00
	DO	7.36	20.70	13.99
	ALK	110.00	225.00	180.30
	TTLHRD	250.00	287.00	266.10
	CAHRD	163.00	218.00	187.20
	MGHRD	37.00	108.00	78.90
	CA/MG	1.66	5.89	2.62
	FE	0.02	0.55	0.16
	SO4	44.00	80.50	63.55
	CL	11.00	44.50	18.05
	NO3	0.02	0.48	0.16
17	PH	7.24	8.44	7.90
	SPECCOND	130.00	255.00	193.43
	DO	6.90	37.40	15.93
	ALK	90.00	217.00	186.21
	TTLHRD	140.00	280.00	221.21
	CAHRD	85.00	244.00	162.71
	MGHRD	30.00	157.00	58.50
	CA/MG	0.69	7.18	3.33
	FE	0.00	0.58	0.09
	SO4	8.00	90.00	36.62
	CL	8.50	15.00	11.21
	NO3	0.02	1.52	0.40
18	PH	7.10	8.15	7.60

TABLE 18. (Continued)

WELL	PARAM	LO	HI	AVE
	SPECCOND	190.00	295.00	229.44
	DO	6.00	41.00	19.34
	ALK	130.00	213.00	167.78
	TTLHRD	205.00	275.00	236.13
	CAHRD	160.00	218.00	192.25
	MGHRD	17.00	70.00	43.88
	CA/MG	2.93	12.80	5.21
	FE	0.02	0.75	0.15
	SO4	16.00	125.00	65.44
	CL	15.00	25.50	19.11
	NO3	0.11	0.80	0.34
19	PH	7.19	8.74	7.82
	SPECCOND	155.00	315.00	239.62
	DO	6.00	31.60	16.64
	ALK	174.00	316.00	266.92
	TTLHRD	20.00	375.00	294.15
	CAHRD	140.00	295.00	219.92
	MGHRD	25.00	161.00	74.23
	CA/MG	0.96	10.60	3.89
	FE	0.03	0.23	0.09
	SO4	19.00	150.00	42.44
	CL	8.50	19.50	11.54
	NO3	0.00	0.68	0.26
21A	PH	.	.	8.20
	SPECCOND	280.00	220.00	250.00
	DO	11.50	11.04	11.27
	ALK	180.00	216.00	198.00
	TTLHRD	240.00	253.00	246.50
	CAHRD	165.00	147.00	156.00
	MGHRD	75.00	106.00	90.50
	CA/MG	1.39	2.20	1.80
	FE	0.11	0.14	0.13
	SO4	50.00	70.00	60.00
	CL	43.00	52.50	47.75
	NO3	0.08	0.20	0.14
21B	PH	.	.	8.00
	SPECCOND	230.00	265.00	247.50
	DO	5.06	14.72	9.89
	ALK	154.00	214.00	184.00
	TTLHRD	200.00	232.00	216.00
	CAHRD	165.00	175.00	170.00
	MGHRD	35.00	57.00	46.00
	CA/MG	3.07	4.71	3.89
	FE	0.04	0.08	0.06
	SO4	52.00	57.00	54.50
	CL	30.00	37.00	33.50
	NO3	0.24	0.45	0.35
22A	PH	.	.	7.65
	SPECCOND	295.00	305.00	300.00
	DO	8.28	17.02	12.65
	ALK	216.00	283.00	249.00
	TTLHRD	330.00	380.00	355.00
	CAHRD	250.00	280.00	265.00

TABLE 18. (Continued)

WELL	PARAM	LO	HI	AVE
	MGHRD	72.00	100.00	86.00
	CA/MG	2.80	3.58	3.19
	FE	0.18	0.21	0.20
	SO4	29.00	42.00	35.50
	CL	30.00	52.00	41.00
	NO3	0.06	0.08	0.07
22B	PH	.	.	8.05
	SPECCOND	150.00	210.00	180.00
	DO	6.90	10.58	8.74
	ALK	130.00	270.00	200.00
	TTLHRD	160.00	277.00	218.50
	CAHRD	120.00	275.00	197.50
	MGHRD	2.00	40.00	21.00
	CA/MG	3.00	137.50	70.25
	FE	0.15	0.72	0.44
	SO4	17.00	48.00	32.50
	CL	7.50	35.00	21.25
	NO3	0.05	0.11	0.08
23A	PH	.	.	7.85
	SPECCOND	220.00	230.00	225.00
	DO	4.14	8.74	6.44
	ALK	187.00	187.00	187.00
	TTLHRD	244.00	253.00	248.50
	CAHRD	179.00	197.00	188.00
	MGHRD	56.00	65.00	60.50
	CA/MG	2.75	3.52	3.14
	FE	0.05	0.11	0.08
	SO4	32.00	53.00	42.50
	CL	22.50	25.00	23.75
	NO3	0.13	0.20	0.17
23B	PH	.	.	8.16
	SPECCOND	190.00	205.00	197.50
	DO	4.60	5.98	5.29
	ALK	186.00	203.00	194.50
	TTLHRD	220.00	226.00	223.00
	CAHRD	157.00	171.00	164.00
	MGHRD	63.00	55.00	59.00
	CA/MG	2.49	3.11	2.80
	FE	0.09	0.28	0.19
	SO4	28.00	30.00	29.00
	CL	12.50	14.00	13.00
	NO3	0.16	0.24	0.20
STREAM	PH	6.65	8.69	7.88
	SPECCOND	90.00	270.00	205.00
	DO	6.44	34.40	20.03
	ALK	70.00	233.00	142.83
	TTLHRD	100.00	360.00	215.67
	CAHRD	75.00	275.00	157.00
	MGHRD	25.00	85.00	58.67
	CA/MG	1.67	4.29	2.83
	FE	0.00	0.09	0.03
	SO4	8.00	86.00	36.95
	CL	20.00	39.50	29.38

TABLE 18. (Continued)

WELL	PARAM	LO	HI	AVE
STREAM	NO3	0.15	8.85	1.86

CERRO GORDO COUNTY SITE (E½, Sec. 22, T96N, R21W)

The Cerro Gordo County Landfill near Mason City, Iowa is constructed adjacent to a small upland stream named Crane Creek which runs to the west and north of the site. The surficial material at the site consists of glacial till (silty and sandy clay). This glacial till is normally 20-50 feet thick and contains at least one known lense of sand. The uppermost bedrock unit is the Cerro Gordo Limestone which is rarely used as a source of significant water. The Juniper Hill Shale is approximately 50 feet thick and probably protects the Cedar Valley Limestone, a major regional aquifer (Figure 16).

During the summer of 1976 eight monitor wells were placed on the landfill property. The locations of these wells is shown in Figure 17. Wells cg5a and cg5b serve as background quality wells and should measure the quality of the ground water before it reaches the landfill. Monitor wells down gradient from the fill include cg1a, cg1b, cg2, cg3a, cg3b, and cg4. Two stream samples are also collected and analyzed to test the quality of the surface water.

The data collected to date tend to indicate that any leachate plume that may be developing does not extend to the monitor network at this time (Table 19). It could be that the dry climate conditions and the short period of time since operations were begun have not been sufficient for the development of a leachate plume. If the sand lense beneath the site begins to act as a conduit for leachate migration the current monitor network should intercept the plume.

During June 1977 a bedrock monitor well was placed into the upper bedrock unit (Cerro Gordo Limestone) to test the quality of water in that horizon. No data is presently available from this new well. A proposed production well for use at the landfill will also serve as a monitor for the Cedar Valley Limestone in the future.

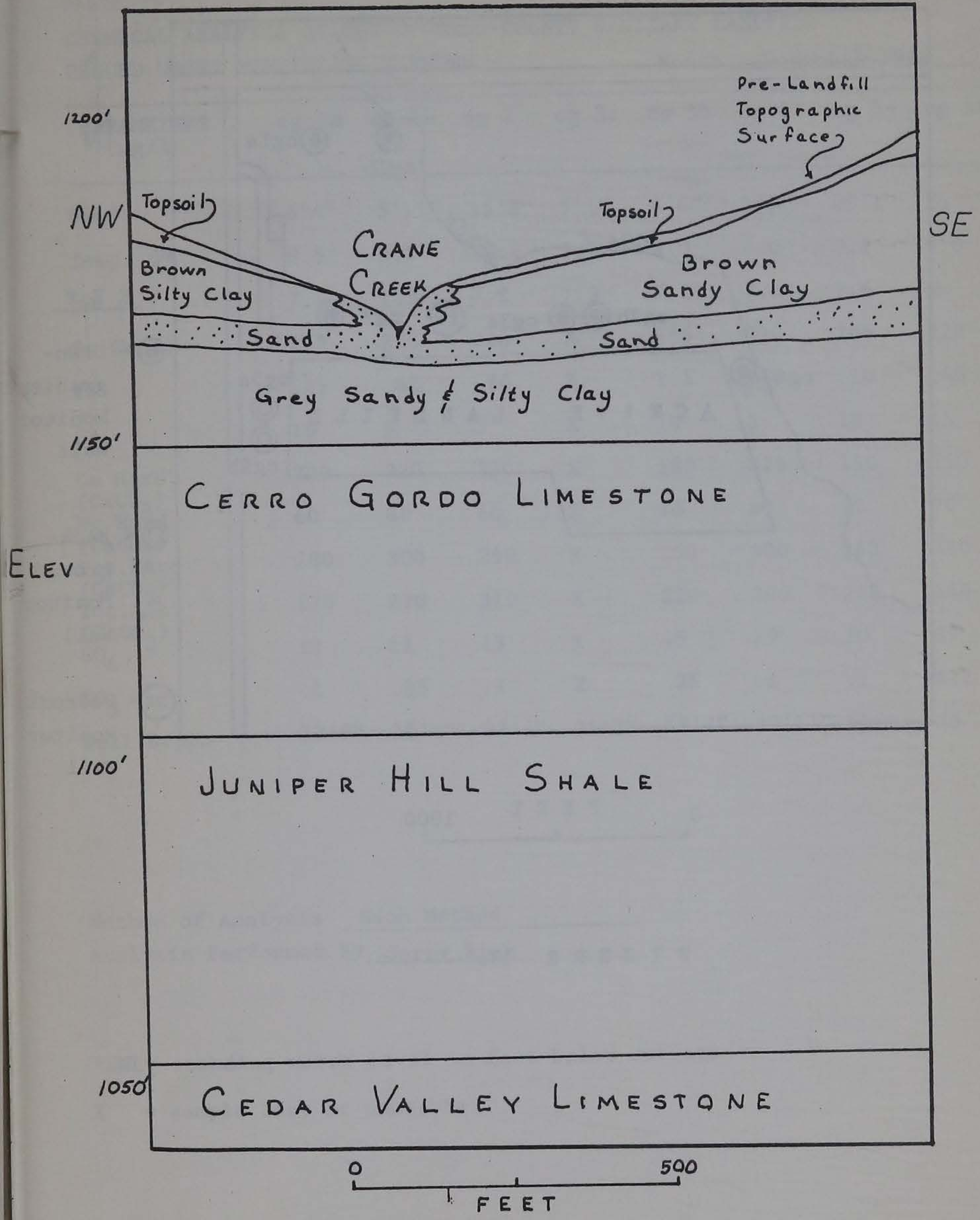
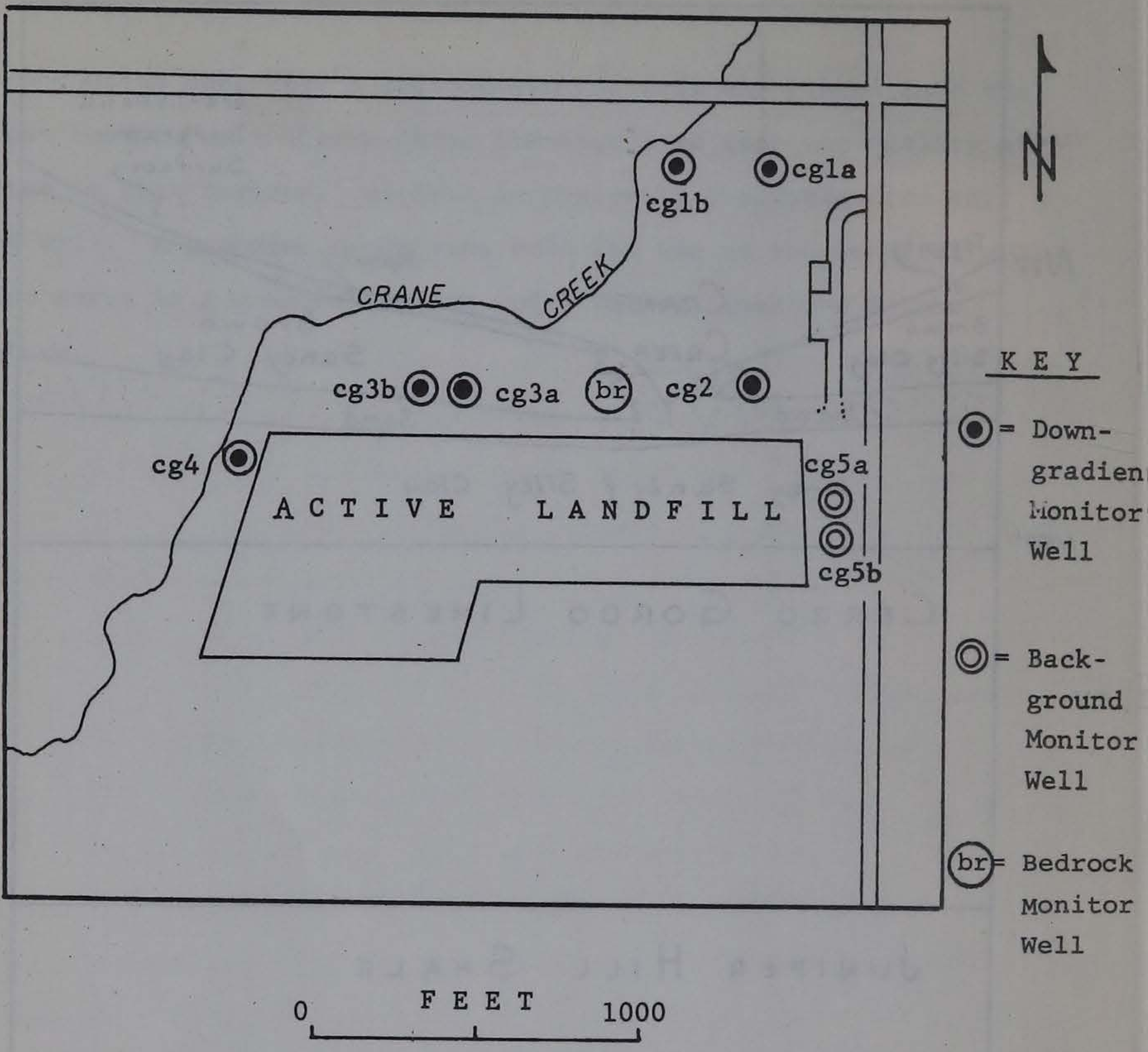

1200'
NW
Topsoil
Brown Silty Clay
Sand
Crane Creek
Pre-Landfill Topographic Surface
Topsoil
SE
Brown Sandy Clay
Sand
Grey Sandy & Silty Clay
1150'
Cerro Gordo Limestone
Elev
1100'
Juniper Hill Shale
1050'
Cedar Valley Limestone
0
500
FEET

FIGURE 16.


CRANE CREEK
cg1b
cg1a
cg2
br
cg3a
cg3b
cg4
cg5a
cg5b
ACTIVE LANDFILL
K E Y
◉ = Down-gradien Monitor Well
◎ = Back-ground Monitor Well
br = Bedrock Monitor Well
0 FEET 1000

F I G U R E 17.

TABLE 19

CHEMICAL ANALYSIS OF CERRO GORDO COUNTY SANITARY LANDFILL GROUND WATER MONITORING NETWORK

Month December 1976

PARAMETERS mg/1	cg 1a	cg 1b	cg 2	cg 3a	cg 3b	cg 4	cg 5a	cg 5b
SWL*	6'4"	5'11"	15'8"	5'1"	4'6"	1'9"	29'1"	26'8"
Temp. C^{o}	9.5	8.2	10.2	7.0	8.0	6.0	9.2	9.0
pH	7.4	7.3	7.2	7.3	7.1	7.2	7.6	X
Sp.Cond.	215	220	220	X	205	210	205	220
Fe	.25	.42	.60	X	1.1	.40	.10	.40
Cl	10	5	5	X	10	5	10	15
Ca Hard ($CaCO_3$)	220	220	230	X	180	220	190	250
Mg Hard ($CaCO_3$)	60	80	60	X	70	80	70	70
Tot.Hard ($CaCO_3$)	280	300	290	X	250	300	260	320
Tot.Alk. ($CaCO_3$)	270	270	310	X	220	280	260	250
SO_4	18	11	13	X	45	29	20	39
NO_3	.1	.35	.1	X	.25	.1	.1	2.2
Well Depth	17'9"	25'1"	27'6"	31'7"	18'7"	23'11"	54'	35'

Method of Analysis Hach Method

Analysis Performed By Jerry Rick

*SWL= standing water level in feet below surface

X = sample lost or unusable

Conclusions

Although the data generated from the current upland site studies are somewhat limited, several conclusions can be reached:

1. The shape and position of pollution enclaves from upland disposal sites are more difficult to predict than flood plain sites due to the natural variability of materials and the large distance to points of ground water discharge. Other activities of man between an upland landfill and the ground water sink may also be responsible for the reduction of water quality.
2. The production of leachate in upland positions is dependent on the amount and distribution of precipitation. Enclaves from upland sites therefore form more slowly than those which develop from disposal sites in floodplains where ground water flow is more continuous. Leachate production from upland sites should be periodic, with high concentrations associated with flushing following major precipitation events.
3. The theoretical depth of penetration of pollution enclaves from upland sites is greater than those associated with floodplains. The present data, in general, suggests that the concentration of leachate is greatest in the refuse and in nearby shallow materials. Water samples from deeper wells show that leachate concentrations decrease with distance away from the site and with increasing depth. This could be due to either a lack of production

of significant amounts of leachate, or the attenuation of leachate as it moves through the ground.

4. Limited initial data from the three upland sites indicate that leachate concentrations are lower than those found in previous investigations on floodplain sites (Peckenpaugh, 1973; Stevens, 1974). This may be a direct result of the topographic position with its associated ground water regimen. The relative ages of the sites tested may also be important. All of the upland landfills which were studied are fairly new and have been operated as sanitary landfills since the deposition of wastes was begun on the sites. The floodplain sites which were tested were much older and had a complex history of open dumping.

Recommendation

The present study of upland landfills should be continued. An effort to determine the long term effects of these sites on the quality of ground and surface water in the surrounding regions should be made. It should be recognized that leachate production in upland sites is dependent on precipitation and therefore may be periodic. Longer periods of study may be necessary to generate the data needed for a proper evaluation of the use of upland sites for waste disposal.

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