Suitability Assessment of Ohio's Soils for Soil-Based Wastewater Treatment[1]

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ABSTRACT. **Each of Ohio's 467 soil series was assessed to determine the depth of the soil to bedrock, the depth to a limiting soil condition, the depth to seasonal saturation, and the soil permeability. Each soil series was placed into one of three categories; suited for traditional leach fields or mound systems, suited for mound systems only, or not suited for soil-based treatment. In a mound system, a layer of sand is placed on top of the natural soil to augment its treatment capacity. Statewide only 6.4% of the land area is suited for soil absorption systems using traditional leach lines. This amounts to 1,680,020 acres of land. Soil series suited for mound systems are present in 25.4% of Ohio's land area accounting for 6,667,579 acres of land.**

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INTRODUCTION

In Ohio, almost one million homes are beyond the reach of community sewage systems (Bureau of Census 1990). Each year many more homes are built in rural Ohio and all must consider treating and disposing of wastewater on the lot.

The ability of the soil to purify wastewater has been recognized for decades. The goal in any sewage treatment system is to remove pollutants such as disease-causing organisms, ammonia, organic matter, and solids, before the wastewater reaches ground or surface water. Some naturally occurring soils have the capacity to accomplish pollutant removal to protect the water resource. While many soil processes assist in wastewater treatment, researchers recognize three properties as the most important; the depth of the soil column, its permeability, and aerobic (or unsaturated) conditions.

To renovate sewage effluents, soil must have several physical characteristics. Pores in the soil must be fine enough to trap suspended solids and disease-causing organisms. These same soils, however, must still have sufficient permeability to allow for the movement of air and water to accommodate the biological degradation of organic matter and ammonia by aerobic bacteria that colonize the soil matrix. Finally, the soil must have the capability to adsorb viruses and other water pollutants, like phosphorus.

Duncan and others (1994) found that fecal coliform bacteria were removed through a 45 cm column of unsaturated fine loamy soil. BOD_5 levels of septic tank effluent were reduced to less than 4.0 mg/l in the same columns. Phosphorus was undetectable after 15 cm. Widrig and others (1996) looked at BOD_5, total suspended solids, and ammonia removal from septic tank effluent through columns of sand. After moving through 45 cm of unsaturated sand, BOD_5, total suspended solids and ammonia-N were reduced to 31 mg/l, 25 mg/l and 0.89 mg/l, respectively. After 60 cm of unsaturated sand the BOD_5, total suspended solids and ammonia-N was further reduced to 20 mg/l, 16 mg/l and 0.39 mg/l, respectively.

In an extensive survey of the published literature, Gerba and others (1975) considered the removal of bacteria and viruses by soil. They found that the movement of bacteria through soil was related to its permeability. Bacteria moved as little as 60 cm downward through fine sandy loam but 180 cm downward through fine-grained sand. Bacteria were primarily removed by mechanical straining through mats of suspended solids and biological growth that occurs at the wastewater infiltration surface. Bacteria that move through this mat were then adsorbed onto clay minerals in the soil matrix.

Virus removal was found by Gerba and others (1975) to be more limited. Virus particles are very small and are difficult to filter. The primary mechanism of virus removal is adsorption onto clay minerals in the soil matrix. Viruses from sewage effluents were removed in soil columns ranging from 19 to 46 cm. Adsorption of viruses by soil is complicated, however, by the presence of organic matter in wastewater. Organic matter was found to interfere with virus adsorption. Soluble organic matter was found to compete for adsorption sites, decreasing virus removal and even causing the release of sorbed virus particles. To effectively remove viruses from sewage effluents, it is important to first remove and decompose the dissolved organic matter.

Gerba and other (1975) also reported on the movement of viruses through saturated soil. Viruses were found in wells 60 to 120 meters from the point where the viruses were introduced into saturated soils.

Figure 1 summarizes the findings of the various investigators. The figure shows the ranges of depths for soil types ranging from sands to loams.

Regulatory agencies often require unsaturated soil depths from 60 to 120 cm beneath the level of application to remove solids, BOD_5, ammonia and bacteria from sewage effluents. Depths of 120 cm or greater in sandy soils appear necessary to remove viruses. The Ohio Administrative Code (1977) requires a 120 cm deep soil layer between the bottom of a sewage leaching trench and a limiting soil condition.

Limiting conditions are considered to be soil or geologic layers that are either insufficiently or excessively

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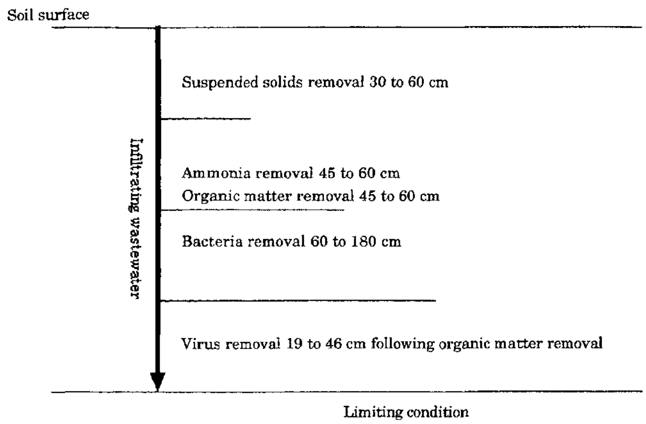

FIGURE 1. Range of removal depths of pollutants in wastewater as infiltrating through unsaturated soil. Removal depth is influenced by soil permeability.

permeable. In Ohio, limiting conditions include ground or perched water tables, hard, unfractured bedrock, dense glacial till, compacted zones, dense clays, pans such a fragipans, sand, gravel and fractured rock.

Converse (1978) presented an onsite wastewater treatment system design that could be used in areas with shallow soil depths to a limiting condition. Known as a mound system, a layer of sand is placed on top of the natural soil to augment its treatment capacity. The sand layer of up to 60 cm acts to reduce suspended solids, BOD_5, and ammonia with continued removal, along with bacteria and virus removal in the underlying soil. Converse found that with sand augmentation, onsite wastewater treatment systems could be used in areas with more slowly permeable soils, with permeabilities as low as 0.5 inches per hour. Widrig and Mancl (1990) adapted the concept of a mound presented by Converse to apply to Ohio's soil conditions and regulatory requirements.

A comprehensive program to describe, classify, map and interpret Ohio's soils began in 1899. The program has involved cooperation between the United States Department of Agriculture – Soil Conservation Service (now the Natural Resources Conservation Service), together with state agencies and The Ohio State University. Soil survey information is available for all 88 Ohio counties, each with a range of characteristics. Each soil is described in terms of sequences of layers, called horizons, that have developed through time from a variety of parent materials, under the influence of climate, living organisms and the position of the soil on the landscape. Each soil horizon and each integrated soil profile presents a unique set of conditions for effluent treatment.

Of course, as pointed out by Miller and Wolf (1975), soil is not present in the landscape in discrete units, but rather as a continuous spectrum of soil associations and geologic conditions with varying capabilities to renovate sewage effluents. The soil maps, therefore, serve as a guide to help assess the extent and diversity of the soil resource.

The objective of this study was to estimate the extent of Ohio's land area that is suited to soil-based wastewater treatment. Both soils with the capability to treat wastewater through traditional leach lines as soil absorption systems and soils which can be augmented with a layer of sand, to utilize mound systems, were considered in this assessment.

METHODS

Each of Ohio's 467 soil series characterized by National Cooperative Soil Survey (1960-2000) were tabulated and assessed to determine the depth of the soil to bedrock, the depth to a limiting soil condition, the depth to seasonal saturation, and the soil permeability. Each soil series was placed into one of three categories; suited for traditional leach fields or mound systems, suited for mound systems only, or not suited for soil-based treatment. The criteria used to distinguish soil series is listed in Table 1.

TABLE 1

Soil characteristic to determine suitability for soil-based wastewater treatment.

Characteristic	Traditional leach lines soil absorption system	Mound soil absorption system augmented with suitable sand
Depth to bedrock	at least 4 feet	at least 2 feet
Depth to restrictive layer	at least 4 feet	at least 2 feet
Depth to seasonal high water table	at least 4 feet	at least 2 feet
Soil permeability at 18 inch depth	between 1 in/hr and 20 in/hr	—
Soil permeability at soil surface	—	between 0.5 in/hr and 20 in/hr

Each county soil survey contains a table listing the acreage and proportionate extent of the soils in that county. All 88 tables were reviewed to determine the extent of each soil category by county.

RESULTS

Eighty-four soil series were considered suited for traditional leach lines or mound systems in Ohio. These soils are deep, well drained and are listed in Table 2. Figure 2 presents a cross-section of one of these soil series. Figure 3 shows where these 84 soil series occur in Ohio. Most are present along a band from northeastern to southwestern Ohio. Only small areas of these soils occur in northwest Ohio.

One hundred and sixty-eight soil series were considered suited for mound systems only in Ohio. These soils are shallower and less permeable than those suited for soil absorption systems and are listed in Table 3. Figure 4 presents a cross-section of one of these soil

TABLE 2

Soil series suited for traditional leach line systems or mound systems.

Alford	Hazelton	Shelocta
Allegheny	Hennepin	Sisson
Ashton	Hickory	Spargus
Beasley	Kanawha	Sparta
Belmore	Leoni	Spinks
Birkbeck	Lumberton	Tyner
Bionnell	Lybrand	Uniontown
Boyer	Martinsville	Watertown
Brownsville	Mechanicsburg	Waupecan
Cedarfalls	Mentor	Wea
Chavies	Mertz	Wellston
Chenango	Negley	Westmore
Chili	Nineveh	Westmoreland
Cidermill	Oakville	Wheeling
Clymer	Ockley	Williamburg
Colonie	Oshtemo	Zurich
Conotton	Otisville	
Crider	Parke	
Donnelsville	Pike	*May be subject*
Duncannon	Plattville	*to flooding*
Elkinsville	Princeton	Chagrin
Frankstown	Riddles	Cuba
Fredricktown	Rigley	Genesee
Gallia	Rossburg	Gessie
Gallman	Rush	Haymond
Grayford	Russell	Jules
Hackers	Saylesville	Landes
Hartshorn	Scioto	Pope
Hayter	Sewell	Ross

series indicating the presence of the limiting condition. Figure 5 shows where these 168 soil series occur in Ohio. Their occurrence mirrors the soils suited for traditional leach lines, with only small areas of these soils occurring in northwest Ohio.

The remaining 215 soil series are not suited for soil-based sewage treatment. These soils are identified in Table 4 along with a major reason they were considered unsuited. Soils may not be appropriate for soil-based wastewater treatment systems because they are hydric, are shallow to water table or a restrictive layer, are subject to frequent flooding or are very slowly permeable. It is important to note that some of these soils may be unsuited for more than one reason. Figure 6 presents a cross-section of one of these soil series indicating the depth of the limiting condition.

Statewide only 6.4% of the land area is suited for soil absorption systems using traditional leach lines. This amounts to 1,680,020 acres of land. Soil series suited for mound systems are present in 25.4% of Ohio's land area accounting for 6,667,579 acres of land. The overall occurrence of soils suited to soil-based treatment through traditional leach lines and mound systems is presented in Figure 7.

CONCLUSIONS AND RECOMMENDATIONS

Soil absorption systems and mound systems are important tools in enabling homes to be built beyond the reach of sewer systems while still protecting the public health and the environment. Care in evaluating sites must be practiced to ensure that ground and surface waters are not contaminated and that untreated sewage does not surface in yards or seep into ditches.

Soil maps, while important useful tools, do not guarantee the presence of the soil series mapped at every spot identified. Soil maps indicate the predominant soil type in an area. Small inclusions of contrasting soils are often present within mapping units. Also many soils throughout Ohio have been disturbed and eroded. Individual site assessment to determine suitability is always necessary before designing and constructing a soil absorption system or mound.

Soils in Ohio suited for traditional leach lines are rare and valuable, because of the soil's ability to easily and inexpensively renovate sewage to protect ground and surface water. These deep, well-drained soils are also valuable agricultural soils and are well suited for construction projects. The most highly settled areas of Ohio also have the largest acreages of deep, well-drained soils. Much of this soil has already been disturbed. The remaining areas should be identified and protected from damage caused by construction, excavation or filling. It has taken natural processes thousands of years to create these soils. They can be quickly destroyed if not recognized and guarded.

Larger land areas in Ohio are suited to mound systems only. A survey conducted by Mancl (1999) revealed little use of mound systems throughout Ohio. The findings of this study indicate that mounds should receive greater consideration with Ohio's large areas of shallow soils to seasonal water tables and restrictive layers. The use of mound systems can greatly impact rural development and environmental and public health protection in counties. For example, in Clermont County less than 10% of the land area is suited for soil absorption systems but over 40% of the land area is suited for mound systems.

Most of Ohio's land area is not suited to soil-based treatment. Construction of homes without sewer service in these areas must proceed cautiously. While technologies exist to treat and dispose of wastewater onsite, such as sand bioreactors (Mancl and Rector 1999) and reuse of treated wastewater through irrigation (Mancl and Rector 1997), these approaches have limitations. They are more expensive than soil-based treatment and require more maintenance. Also at least a 30 cm depth of unsaturated soil is needed to accommodate onsite irrigation of treated wastewater. Many soils, including Ohio's 92 hydric soil series, would require subsurface drainage to lower a seasonal high water table to below 30 cm before treated wastewater could be irrigated.

As Ohio communities begin to plan for the future, they need to consider how best to provide sewage treatment services. Through careful use of soil-based sewage treatment and disposal systems, homes can be

a) Description of a single example profile:

Horizon	Depth Inches	Color	Texture	Structure	Consistence	Redox	Perm. In/hr
Ap	0-10	brown (10YR4/3)	silt loam	weak fine granular	friable		0.6-6
E	10-14	yellowish brown (10YR5/4)	silt loam	weak medium and fine subangular blocky	friable		0.6-6
Bt	14-34	dark yellowish brown (10YR4/4)	silty clay loam	moderate medium subangular or angular blocky	firm		0.6-2
BC	34-58	light yellowish brown (10YR6/4)	very fine sandy loam	weak coarse subangular blocky	firm		0.6-2
2BC2	58-60	dark brown (7.5YR4/2)	very gravelly sandy loam	very weak coarse subangular blocky	friable		0.6-2
3C	60-72	dark grayish brown (10YR4/2)	stratified very gravelly sand				6-20

b) Composite profile showing common range of depths for horizons

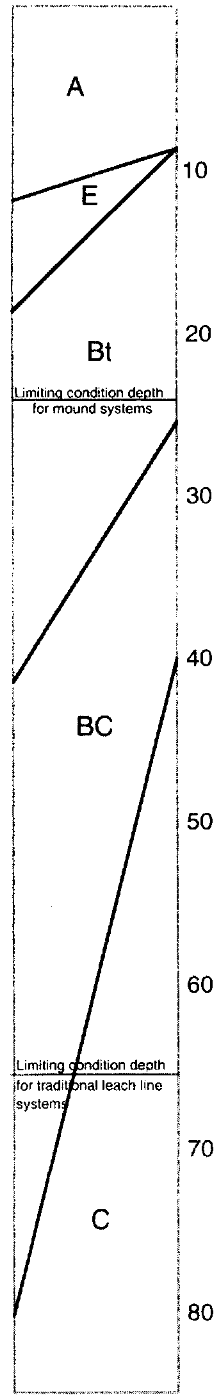

FIGURE 2. Soil suitable for traditional leach line system – Wheeling Series.

constructed in rural Ohio while still protecting the public health and Ohio's valuable water resources.

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LITERATURE CITED

Bureau of Census. 1990. Detailed housing characteristics, Ohio. Structural characteristics. US Dept of Commerce. p 81.

Converse JC. 1978. Design and construction manual for Wisconsin mounds. Small Scale Waste Management Project 15.5. Univ of Wisconsin, Madison, WI. 80 p.

Duncan CS, Reneau RB, Hagedorn C. 1994. Impact of effluent quality and soil depth on renovation of domestic wastewater. Proceedings of the 7th International Symposium on Individual and Small Community Sewage Systems. ASAE, St. Joseph, MI. p 219-28.

Gerba CP, Wallis C, Melnick JL. 1975. Fate of wastewater bacteria and viruses in soil. J Irrigation and Drainage Division ASCE 101(IR3):157-73.

Mancl K. 1999. Survey of approved practices for onsite sewage treat-

FIGURE 3. Percent of land area, by county, suited to traditional leach lines or mounds.

ment systems in Ohio. Ohio J Sci 99(3):38-43.

Mancl K, Rector D. 1997. Reuse of reclaimed wastewater through irrigation for Ohio communities. Ohio State Univ Extension Bull 860. Columbus, OH. 33 p.

Mancl K, Rector D. 1999. Sand bioreactors for wastewater treatment in Ohio communities. Ohio State Univ Extension Bull 876. Columbus, OH. 20 p.

Miller FP, Wolf DC. 1975. Renovation of sewage effluents by the soil. Second National Conference on Individual Onsite Wastewater Systems. NSF, Ann Arbor, MI. p 87-101.

Ohio Administrative Code. 1977. Chapter 3701-29.

National Cooperative Soil Survey. 1960 – 2000. Soil surveys for counties in Ohio. 88 different volumes with one for each Ohio county. Can be obtained through the Soil and Water Conservation District office in each county.

Widrig D, Mancl K. 1990. Mound systems for on-site wastewater treatment. . . siting, design and construction in Ohio. Ohio State Univ Extension Bull 813. Columbus, OH. 20 p.

Widrig D, Peeples J, Mancl K. 1996. Intermittent sand filtration for domestic wastewater treatment: Effects of filter depth and hydraulic parameters. Applied Engineering in Agriculture 12(4):451-9.

TABLE 3

Soil series suited for mound systems only.

Aaron	Crane	Jeneva	Pacer	Tiro
Alexandria	Cruze	Jessup	Parr	Trappist
Amanda	Culleoka	Jimtown	Perrin	Tremont
Ava	Cygnet	Johnsburg	Pierpont	Tuscola
Bepre	Dana	Kane	Pinegrove	Upshur
Berks	Darroch	Keene	Plainfield	Vandalia
Bixler	Dekalb	Kelloggs	Plumbbrook	Vandergrift
Blairton	DelRay	Kendallville	Prout	Vaughnsville
Bogart	Digby	Kensington	Rainsboro	Wakeman
Boston	Dunbridge	Ladig	Raub	Warsaw
Braceville	Edenton	Lakin	Rawson	Waynetown
Brady	Elba	Libre	Reesville	Weinbach
Bratton	Eldean	Licking	Richland	Wernock
Brecksville	Elliott	Lily	Rittman	Westgate
Brenton	Ellsworth	Lordstown	Rodman	Wharton
Bronson	Ernest	Loudon	Rossmoyne	Whitaker
Brooke	Faywood	Loudonville	Sardinia	Woodsfield
Brookside	Fincastle	Lowell	Savona	Woolper
Broughton	Fitchville	Lykens	Schaffenaker	Wooster
Brushcreek	Fox	Markland	Sciotoville	Wyatt
Cambridge	Gallipolis	Miami	Sees	Wynn
Cana	Geeburg	Miamian	Seward	Xenia
Caneadea	Germano	Milton	Shawtown	Zanesville
Canfield	Gilpin	Mitiwanga	Shinrock	
Captina	Glenford	Monongahelia	Sleeth	
Cardinal	Gosport	Morley	St.Clair	
Casco	Guernsey	Morrisville	Steinsburg	*May be subject*
Castalia	Haney	Muse	Stringley	*to flooding*
Celina	Hanover	Muskingum	Summitville	Lobdell
Centerburg	Harbor	Nicholson	Switzerland	Medway
Cincinnati	Heverlo	Odell	Tarhollow	Nolin
Clarksburg	Homer	Ogontz	Tarlton	Sligo
Coblen	Homewood	Omulga	Teegarden	Tioga
Corwin	Ionia	Ottokee	Tilsit	
Coshocton	Iva	Otwell	Tippecanoe	

a) Description of a single example profile:

Horizon	Depth Inches	Color	Texture	Structure	Consistence	Redox	Perm. In/hr
Ap	0-9	brown (10YR4/3)	silt loam	moderate medium subangular blocky parting to weak fine granular	friable		0.2-0.6
Btl	9-12	dark yellowish brown (10YR4/4)	clay loam	moderate medium subangular blocky	friable		0.2-0.6
Bt2	12-18	dark yellowish brown (10YR4/4)	clay loam	moderate medium subangular or angular blocky	firm		0.2-0.6
Bt3	18-26	yellowish brown (10YR5/4)	clay	weak medium prismatic parting to strong medium subangular and angular blocky	firm		0.2-0.6
BCt	26-33	yellowish brown (7.5YR4/2)	loam	weak coarse subangular blocky	firm	few fine prominent strong brown (7.5YR5/8) iron accumulations	0.2-0.6
Cd	33-80	yellowish brown (10YR5/4)	loam	massive	very firm	few prominent strong brown accumulations	0.2-0.6

b) Composite profile showing common range of depths for horizons

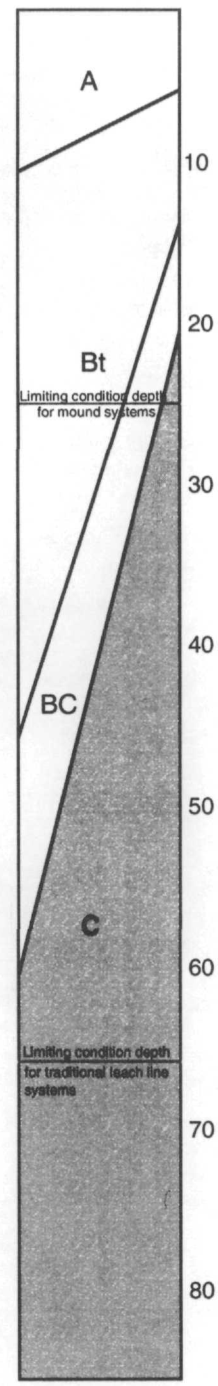

FIGURE 4. Soil suitable for mound system – Miamian Series.

TABLE 4

Soil series not suited for soil-based wastewater treatment.

Depth to Restrictive Layer	*Depth to Water Table*		*Flooding*	*Hydric Soils*	
Bethesda	Aetna	Mahoning	Clifty	Adrian	Mermill
Biglick	Algansee	McGary	Flatrock	Allis	Milford
Channahon	Algiers	Mespo	Harrod	Alvada	Millgrove
Colyer	Atlas	Metamora	Hartshorn	Atherton	Milldale
Enoch	Aurand	Minoa	Huntington	Beaucoup	Miner
Fairmount	Avonburg	Mortimer	Kinn	Blanchester	Montgomery
Fairpoint	Bennington	Nappanee	Knoxdale	Bonnie	Muskego
Farmerstown	Blount	Newark	Lanier	Bono	Olentangy
Gasconade	Canal	Painesville	Lindside	Brookston	Olmsted
Lewisburg	Cardington	Pekin	Moshannon	Canadice	Pandora
Lorenzo	Cavode	Platea	Orrville	Carlisle	Patton
Marblehead	Ceresco	Pyront	Philo	Clermont	Paulding
Morristown	Claverack	Randolph	Sarahsville	Cohoctah	Peoga
Opequon	Claysville	Rarden	Senecaville	Colowood	Pewamo
Richey	Coolville	Ravenna	Skidmore	Condit	Pinnebog
Strawn	Crosby	Red Hook	Stonelick	Conneaut	Piopolis
Titusville	Crosier	Remsen		Damascus	Purdy
Tuscarawas	Darien	Rimer		Drummer	Ragsdale
Weikert	Defiance	Schaffer		Edwards	Rensselaer
	Dixboro	Shoals		Frenchtown	Risingsun
	Doles	Smothers		Fries	Rockmill
Very slowly	Dubois	Stafford		Gilford	Rollersville
permeable	Eel	Stanhope		Ginat	Romeo
Eden	Elnora	Stendal		Glendora	Roundhead
Lawshe	Fulton	Stone		Granby	Sandusky
Lucas	Galen	Taggart		Holly	Saranac
Pate	Gavers	Tedrow		Hoytville	Sebring
Roselms	Glynwood	Thackery		Ilion	Secondcreek
	Gresham	Thrifton		Joliet	Sheffield
	Haskins	Tiderishi		Kerston	Sloan
	Haubstadt	Tygart		Killbuck	Swanton
	Henshaw	Tyler		Kingville	Tawas
	Holton	Vanlue		Kokomo	Toledo
	Hornell	Venango		Kyger	Treaty
	Houcktown	Wadsworth		Lamson	Trumbull
	Hyatts	Wakeland		Latty	Wabasha
	Jenera	Wallington		Lenawee	Wallkill
	Jonesboro	Waphani		Linwood	Warners
	Kibbie	Westboro		Lippincott	Washtenaw
	Lamberjack	Wilbur		Lorain	Wauseon
	Latham	Williamson		Luray	Wayland
	Lockport			Mahalasville	Westland
				Marengo	Wetzel
				Martinisco	Weyers
				McGuffey	Willette
				Melvin	Zipp

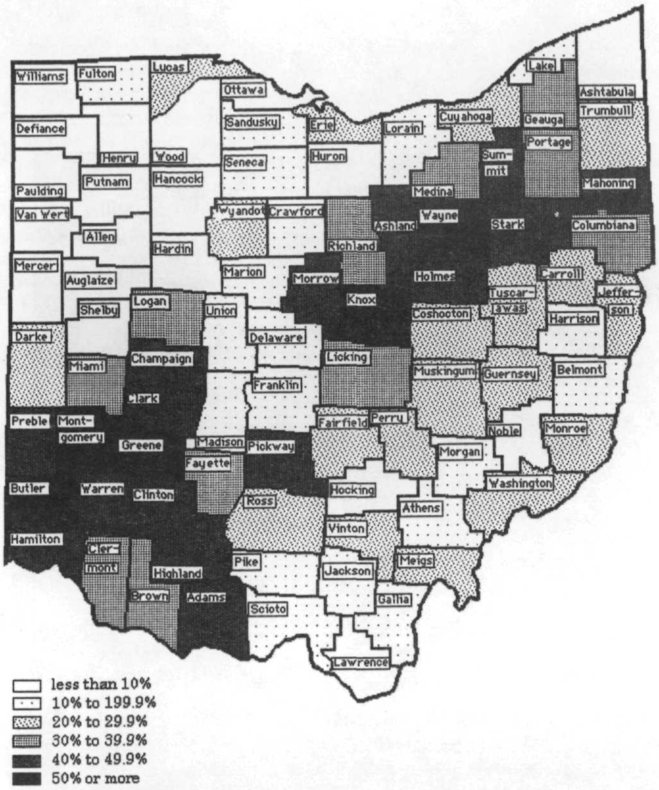

FIGURE 5. Percent of land area, by county, suited to mound systems only.

(Note: See next page for Figure 6.)

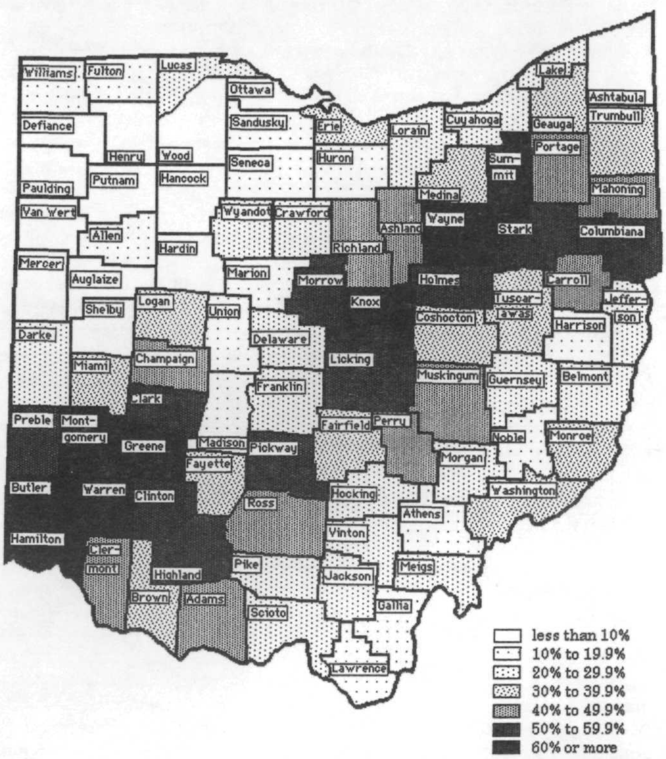

FIGURE 7. Percent of land area, by county, suited to soil-based wastewater treatment.

a) Description of a single example profile:

Horizon	Depth Inches	Color	Texture	Structure	Consistence	Redox	Perm. In/hr
Ap	0-9	very dark gray (10YR3/1)	silty clay loam	weak fine and medium granular	friable		0.6-2
A	9-16	black (10YR2/1)	silty clay loam	moderate fine and medium angular blocky	firm		0.6-2
Btg1	16-31	dark gray (5YR4/1)	silty clay loam	moderate medium and fine subangular and angular blocky	firm	common medium distinct dark yellowish brown (10YR 4/4) and few medium prominent yellowish brown (10YR 5/6) iron oxide masses	0.2-0.6
Btg2	31-50	olive gray (5YR5/2)	silty clay loam	moderate coarse subangular blocky	firm	common coarse prominent strong brown (7.5YR5/6) and yellowish brown (10YR 5/8) iron oxide masses	0.2-0.6
2C	50-64	brown (10YR5/3)	loam	massive	friable		0.2-0.6

b) Composite profile showing common range of depths for horizons

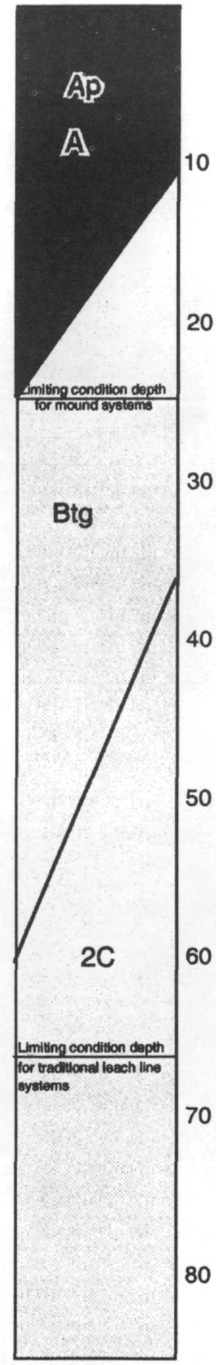

FIGURE 6. Soil unsuitable for waste application – Kokomo Series.