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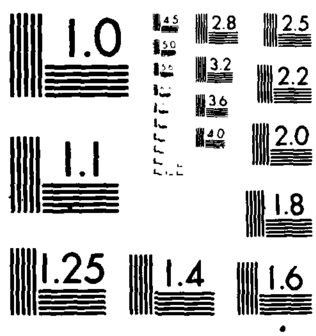

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SITE SELECTION METHODOLOGY FOR THE LAND TREATMENT OF WASTEWATER

John R. Ryan and Raymond C. Loehr

Prepared for
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A methodology is presented that covers facets of site selection from preliminary screening to field data acquisition for the preparation of a final design for a land treatment system. The basic assumption underlying the methodology is an approach to site selection in which the entire study area is investigated for potential sites while considering the whole spectrum of land treatment processes. Due to the extensive nature of such a study, several iterations are required to determine the most feasible site and land treatment alternatives. The methodology is presented in three parts. Level I defines the technical feasi-

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bility of implementing land treatment for a particular wastewater problem. The boundaries of the study area are defined and available land areas are rated for their suitability for land treatment based on topography, land use, hydrogeology and soil characteristics. A preliminary design for each suitable level I site candidate is prepared in the level II site analysis. The design is based on an evaluation of soil/waste interactions that considers responses to limiting soil conditions. A cost-effectiveness evaluation of waste treatment alternatives and site candidates is developed in level II. The most cost-effective site candidate is then selected for intensive level III field investigations. Data acquired in the level III field investigations will determine the design requirements of the land treatment system.

PREFACE

This report was prepared by John R. Ryan and Dr. Raymond C. Loehr of the Department of Agricultural Engineering, Cornell University. The information presented in this report was developed under a grant from the U.S. Army Cold Regions Research and Engineering Laboratory (Grant Agreement DACA 89-78-G-006) to Cornell University. This grant is part of the U.S. Army Corps of Engineers Civil Works Project CWIS 31634, Development of Data to Update Design Manual for Land Treatment of Wastewater.

The authors would like to express appreciation to Carolyn J. Merry of CRREL for her continual assistance throughout the project and to her and Dr. Dale A. Carlson (Department of Civil Engineering, University of Washington) for technical review of the manuscript. Special thanks also go to Mark Moser for developing the soil rating matrix which was the base from which this report grew.

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SITE SELECTION METHODOLOGY FOR THE LAND TREATMENT OF WASTEWATER

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INTRODUCTION

In 1978 Cornell University and the U.S. Army Corps of Engineers began a project to develop a methodology that would help determine regional and specific sites for the land treatment of wastewater. This report presents the methodology developed as a result of the project.

Compared to other forms of wastewater treatment, land treatment systems are very site specific. The technical and economic feasibility of land treatment will depend on transmission distances from the waste source to the site, topography, land use, soils and hydrology. The interactions between these factors must be considered in identifying suitable sites.

Large amounts of information exist that can be used for site characterization and selection, but much of this information is in a format and in disciplines that are not directly useful to design engineers. The basic problem facing design engineers is how to locate the most cost-effective and technically feasible site within a given radius surrounding a given waste source. The engineer must 1) determine the effective radius of the study area from a control collection point based on economically feasible transmission distances, 2) identify technically feasible land treatment sites located within the study area, 3) identify the most cost-effective options from the sites considered technically feasible, and 4) identify and collect the necessary field data for final design preparation.

With these objectives in mind, a methodology was developed which follows the general design principles presented in Loehr et al. (1979). The design methodology developed by Loehr et al. (1979) is a state-of-the-art approach for integrating the multitude of factors involved in the design of land treatment systems that can be used as a screening procedure for both preliminary evaluation of land treatment feasibility and final design development.

The design procedure is divided into three parts. The level I procedure is a general evaluation which includes a problem definition and an initial solution definition and limitations (Fig. 1). The necessarily

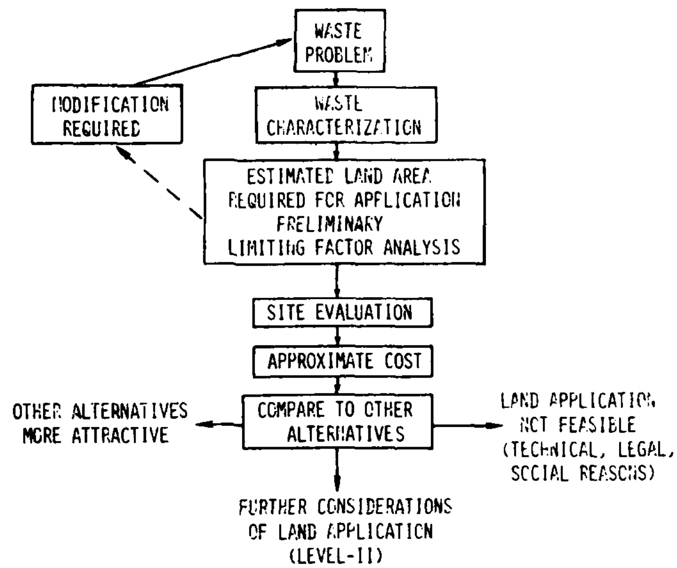

Figure 1. Simplified level I design procedure for land application of wastes (Loehr et al. 1977).

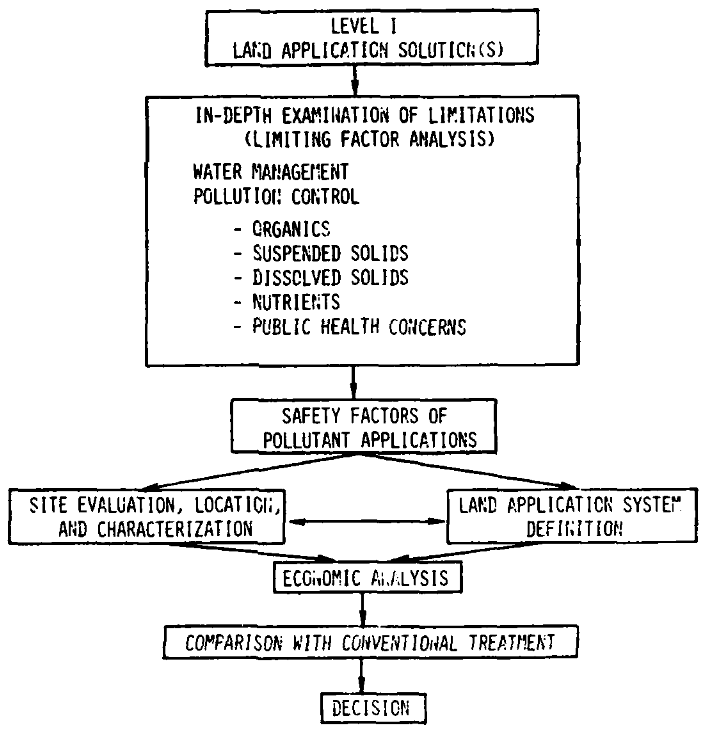

Figure 2. Generalized activities completed during level II analysis (Loehr et al. 1978).

broad scope of level I is meant to screen out site and treatment alternatives which are clearly not feasible. Level II analysis (Fig. 2) permits a more detailed analysis of potential site and treatment options and it should define a solution to the waste treatment problem from which a final design can be prepared. The level III procedure should develop a final solution design.

It is beyond the scope of this report to examine each individual step in the level I, II and III design procedures. The relationship between the steps has been clearly identified in Loehr et al. (1979). Figures 3 and 4 illustrate the various steps involved in levels I, II and III. In level I site analysis only sites or land treatment options which clearly are not economically, technically or politically feasible should be discarded. The level II site analysis involves a much more detailed evaluation of the limitations of site alternatives and the technical and economic feasibility of the site options. The level II site analysis should define general design requirements and permit an engineer to select the most cost-effective site option. These design requirements can then be modified after field investigations in level III.

LEVEL I ANALYSIS

The level I site evaluation is primarily concerned with defining technical feasibility. The study area parameters are broadly defined, general land area requirements and feasible transmission distances specified, and discharge restrictions to surface waters and groundwaters noted. Potential sites and land treatment systems are then identified, and only land areas or land treatment systems clearly not feasible should be excluded.

Several different types of published information are available for evaluating the important features in the site selection procedure. This information will vary as to the level of detail covered for each important feature in the site selection process. The following discussion presents 1) the important criteria which should be considered for each of the steps presented in Figure 3, and 2) the available sources of information for defining these criteria for a particular land treatment system.

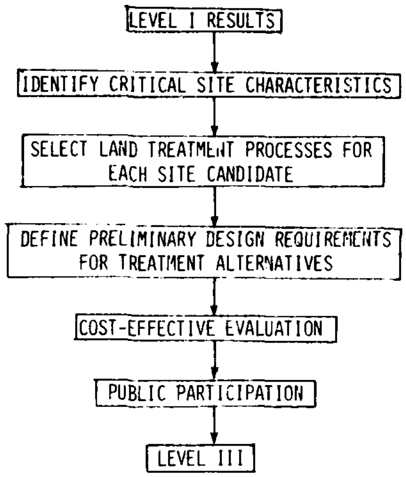

Figure 4. Level II site analysis.

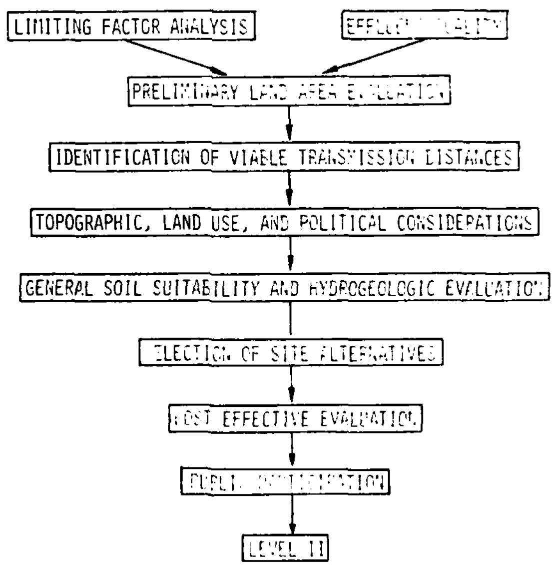

Figure 3. Level I site analysis.

PRELIMINARY LAND AREA EVALUATION

Land area requirements will often dictate the technical and economic feasibility of land treatment. The application rate of the following parameters will significantly affect the required land area and land treatment strategy in regard to (1) hydraulic capacity of the site, (2) organics, (3) nutrients, (4) potentially toxic elements and (5) salts. The parameter which requires the largest land area to avoid environmental problems becomes the limiting parameter.

The level I analysis is a general evaluation of land areas. The limiting parameter is assumed to be the hydraulic loading for rapid infiltration and overland flow systems, and the nitrogen loading is limited for slow rate systems at the level I design stage. These assumptions will be verified or changed in the level II design based on an intensive analysis of site and waste characteristics. Applications of the limiting parameter principle are discussed in detail by Loehr et al. (1979) and Overcash and Pal (1979).

Effluent discharge requirements and expected treatment efficiencies should be evaluated at this point in the design process. Reported treatment efficiencies for land treatment systems are listed in Table 1.

Table 1. Reported treatment efficiencies for land treatment (Loehr et al. 1979).

Treatment process	Design removal efficiency (%)				Effluent quality (mg/L)			
Land application systems*	BOD	SS	P	N	BOD	SS	P	N
Slow rate	98+	98+	80-99+	85+	4	5	2	6
Overland flow	92+	92+	40-80	70-90	18	18	2-7	3-9
Rapid infiltration	85-99	98+	60-95	0-50	30	5	4	15-30

* It is assumed that the wastewater to these systems receives preliminary treatment.

Most groundwater discharge permits require the effluent to meet drinking water standards (U.S. EPA et al. 1977), although certain exceptions may occur when groundwater is not used as a primary source of drinking water. Slow rate systems have the highest treatment efficiencies and the effluent can generally meet drinking water standards. Rapid infiltration systems generally result in groundwater quality that may exceed drinking water standards for nitrogen, and can require recovery of the renovated water and further treatment for discharge to a surface stream. Overland flow systems can result in a point discharge so that oxygen demand and phosphorus and nitrogen assimilation capacities of the proposed discharge point should be considered. The level I analysis should indicate which systems require additional treatment to meet groundwater or effluent discharge criteria.

IDENTIFICATION OF FEASIBLE TRANSMISSION DISTANCES

A formal procedure has not been developed for determining feasible distances of the land treatment site from a given waste source. Maximum feasible distances will depend on the cost of the type of transmission system, the conventional alternative, the waste flow, the pumping head, and the cost of the other components of the land treatment system.

The purpose of this procedure is to define the maximum limits of the study area. Once the limiting parameters are defined, hydraulic loading rates can be assumed and used to define all costs of the components of the land treatment systems except transmission costs. The components of the land application system can be estimated by using "Cost of Land Treatment Systems" (Reed et al. 1979). The cost of the land treatment system is then compared to the cost of the conventional alternative. The difference in costs represents the maximum amount of money which can be allocated to transmission.

When the maximum allowable transmission distance is defined, the least limiting assumption would be to assume a gravity pipe transmission system. An examination of topographic maps may indicate that this assumption is not valid, and a force main and pumping head should be assumed.

The cost evaluation is very general at this point in the site selection process. The costs presented in Reed et al. (1979) are national averages which use 1973 as a base date, and local construction costs, when available, can provide a better cost comparison.

LAND USE AND POLITICAL CONSIDERATIONS

Unacceptable areas based on land use and political considerations should be screened out in the level I analysis. The screening procedure involves using available land use information in conjunction with discussions with local and regional government officials.

Land use information varies widely in terms of specificity. Local and regional agencies can provide pertinent land use information. An excellent example is the New York State Land Use and Natural Resource Inventory (LUNR) which tabulates statewide land use data derived from the interpretation of aerial photographs. The LUNR Inventory divides land into 13 main categories (agricultural, recreational, residential, etc.) and 130 subcategories (vineyards, golf courses, low density residential, etc.). Transparent overlays of the LUNR information are available for use with 7.5-minute USGS topographic maps.

Few states have developed as detailed an evaluation of existing land use as New York State. However, the same type of information that is available in LUNR can be developed from aerial photographs by experienced personnel. Topographic maps can also provide information regarding land use. Residential densities, recreational areas and location of surface bodies of water can be evaluated from topographic maps.

There are no set criteria regarding land use restrictions for land treatment. Slow rate systems are commonly located on agricultural land, but can be located in recreational areas situated in dry areas. Rapid infiltration systems are often located in dry creek beds in southern California to recharge the groundwater. A detailed discussion with local officials and community leaders can pinpoint the types of land use that fit most favorably with the planning objectives of the community. This type of feedback is crucial early in the design stage. Town officials can help in locating potential sites as well as in developing a spirit of cooperation between the community and the engineers.

The major concern in defining land use restrictions is usually to avoid creating a public nuisance. In sites located near areas with high population densities, buffer zones in excess of standard recommended widths (usually 75 m) may be desirable. Water management is crucial in areas accessible to the public. Ponding of water and the associated odors must be completely avoided at all times. Lower design hydraulic loading rates may be necessary to avoid these nuisances.

Areas with low visibility, such as forest lands, may have a high priority for site location from the town planning aspect. Land application may also be compatible with other planning aims such as developing a wildlife refuge. Although there is limited information available on the subject, wetlands appear to have a high renovation capacity potential (Reed and Bastian 1980).

Political boundaries can act as constraints in the site selection process. Certain questions can arise regarding the legality of one municipality owning land within the jurisdiction of another municipality. Whenever possible, it is best to deal with a waste problem locally rather than export the wastewater to another community.

HYDROGEOLOGY AND SOIL FEATURES

The hydrogeology and soils of an area are the most important features in the site selection procedure that define the technical feasibility of land treatment. The hydrogeology of a site will determine whether groundwater contamination may be a problem and dictate potential hydraulic loadings. The soils of an area will define the feasible types of land treatment systems. The level I analysis utilizes the most general sources of soil and hydrogeologic information. The main goal of the analysis is to define the suitability of those areas which fall within feasible transmission distances and desirable land use types. Only soil properties which significantly control land treatment system design are considered.

There are very few cases where the hydrogeology or soils of an area will exclude land treatment based on technical feasibility, but certain soil and hydrogeology features will favor one type of land treatment system over another or may require certain structural modifications. The goal of the level I soil and hydrogeology evaluation, therefore, is to establish a relative ranking of potential sites and to define which types of land treatment systems are workable within the study area.

Hydrogeology features

Very little work has been done on hydrogeologic features which affect land treatment. Most work has been directed towards defining field investigations of hydrogeology which would determine groundwater velocities, mounding potential and flow directions under recharge basins (Bouwer 1978).

Nonethelesss four hydrogeologic conditions have been found to be generally unfavorable for land treatment and include (Warner 1976):

1. Sites with relatively impermeable bedrock such as shale, dense limestone or crystalline igneous rock 0.6 m or less from the surface and steep slopes creating seepage and overland flow of the effluent.

2. Sites located in karst topography, where clayey residual soils overlie limestone or dolomite with fracture and solution porosity and permeability. In such locations, infiltration into the soil itself is very slow, but effluent will rapidly enter the bedrock where soil is absent, creating sinkholes and paths for direct flow of the applied wastewater into the groundwater system. Parizek (1973) reported several sinkholes developing at two separate land treatment sites employing slow rate irrigation located in karst topography. In one case, although the depth of soil was 12 to 18 m above the limestone, two large sinkholes developed.

3. Sites with little topographic relief where the groundwater table is at or very near the surface. Old lake beds or floodplain areas are examples of these situations.

4. Areas with fractured bedrock and a shallow soil depth such as often occur in granitic areas. Effluent applied to these areas may pass into aquifers with little renovation taking place.

Soil features

The soil criteria selected for the level I site evaluation should (1) significantly control land treatment system design, (2) be independent of climatic influence, (3) be easily identified from available sources of information, and (4) not duplicate other selected properties. Table 2 lists important site properties that control land treatment design and Table 3 quantifies descriptions of soil permeability. The soil criteria presented in Table 2 adequately meet the constraints necessary for a level

Table 2. Comparison of site characteristics for land treatment processes (U.S. EPA et al. 1977)

Characteristics	Principal processes			Other Processes	
	Slow rate	Rapid infiltration	Overland flow	Wetlands	Subsurface
Slope	Less than 20% on cultivated land; less than 40% on noncultivated land	Not critical; excessive slopes require much earthwork	Finished slopes 2 to 8%	Usually less than 5%	Not critical
Soil permeability	Moderately low to moderately rapid	Rapid (sands, loamy sands)	Slow (clays, silts, and soils with impermeable barriers)	Slow to moderate	Slow to rapid
Depth to ground-	0.6 to 1 m (minimum)	3 meters (lesser depths are acceptable where underdrainage is provided)	Not critical	Not critical	Not critical
Climatic	Storage often needed for cold weather and precipitation	None (possibly modify operation in cold weather)	Storage often needed for cold weather	Storage may be needed for cold weather	None

TABLE 3. Permeability classes (Loehr et al. 1979)

Permeability class	Permeability (cm/hr)
Very slow	<0.15
Slow	0.15-0.5
Moderately slow	0.5-1.5
Moderate	1.5-5.0
Moderately rapid	5.0-15.0
Rapid	>15.0

Table 4. Acceptable or desirable ranges of significant soil properties for land treatment processes (adapted from Table 7.5, Moser 1979).

Land treatment process		Acceptable ranges of property		
		Minimum	Desirable	Maximum
Slow Rate	Depth (m)	0.6	≥ 1.[illegible]	none
	Slope (%)	0	≤15	35
	Permeability (cm/hr)	0.50	1.5-5	50
Overland Flow	Depth (m)	0.3	> 0.9	none
	Slope (%)	0	2-8	15
	Permeability (cm/hr)	none	< 0.5	1.5
Rapid Infiltration	Depth (m)	1.5	≥ 3	none
	Slope (%)	none	≤ 5	15
	Permeability (cm/hr)	1.5	> 5	50

I soil suitability evaluation.

Moser (1979) developed a numerical rating matrix for the soil properties presented in Table 2 that can be used in a level I analysis. The matrix approach recognizes the dynamic relationship between the soil properties that affect soil suitability for land treatment. Table 4 identifies the acceptable ranges of each soil property for land treatment, Table 5 describes Moser's considerations for assigning the rating values, and Table 6 presents the rating values assigned to the individual soil properties at the series level. Table 7 defines Moser's suitability rating descriptions.

Moser's rating values for each soil property were developed by an iterative trial and error approach. The rating matrix was tested first with hypothetical situations. In-depth discussion with experts and testing using soil maps of operating land treatment systems allowed further adjustments to rating values and validation of the matrix. Moser's rating matrix is intended to be used in conjuction with information available in modern (post-1956) soil surveys. Although the breaks between suitability classes are somewhat arbitrary, this information, in conjunction with land use, hydrogeology and transmission considerations, can serve as a final screening for level I site suitability. A detailed description of how to use the matrix is presented in Moser (1979).

Sources of information for defining soil and hydrogeology suitability

A variety of information is available for characterizing the hydrogeology and soils of an area. The three main sources of information are USGS surveys, soil surveys and airphotos. Each source varies according to the level of detail, the type of information and the quantitative nature of the information available.

The USGS has available several types of reports on a regional basis including well logs of water levels and quality, and drilling logs detailing surface and subsurface geology, depth to water and saturated thickness. The geographic areas covered by these reports are very extensive, and considerable variance from the tabulated data may be found locally. The application of these reports to the level I analysis is limited, al-

Table 5. Considerations made in assigning rating values when determining potentially acceptable sites for land treatment (Moser 1979).

Soil characterictic	Land treatment process: Slow rate	Overland flow	Rapid infiltration
Soil depth (m)			
0.1 - 0.6	Inadequate for treatment unless extremely low applciation rate, excludes use of process	Usable, only minimal earthwork possible, special design	Inadequate for treatment excludes use of process
0.6 - 1.5	Usable, with low application rate, low rating	Adequate for treatment, potential problems with earthwork, moderately high rating	Inadequate for treatment, excludes use of process
1.5 - 3	Desira[illegible], high rating	More than desirable to allow earthwork highest rating	Usable with special design, low application rate, low rating
1.5 - 3[a]	--	--	Special case, high rating, so as not to exclude soils where total depth not reported
>3	Greater than desirable depth,e xtra capacity for treatment, highest rating	No benefit from extra depth, no increased rating	Minimum desirable depth, highest rating
Limiting permeability (cm/hr)			
>0.15	Very low application rate, special design that depends on depth of limiting soil peameability, very low rating	Desirable, possible erosion problems during construction, high rating	Excludes use of process
0.15 - 0.5	Usable at low application rate, large land area requirement, low rating	Desirable, highest rating	Excludes use of process
0.5 - 1.5	Low application rate, moderate rating	Desirable, may require soil compaction, high rating	Very low application rate, special design very low rating
1.5 - 5	Desirable, highest rating	Special design and construction to reduce infiltration, low rating	Usable at less than desirable application rate, moderate rating
5 - 50	Implied reduced, pollutant retention moderate rating	Excludes use of process	Desirable, highest rating
> 50 (>20)	Low pollutant retention excludes use of process	Excludes use of process	Very low pollutant retention, special design, low rating
Predominant Slope, (%)			
0-3	Desirable, high rating	Earthwork required to increase slope slightly high rating	Desirable, high rating

Table 5. (Continued).

Soil characteristic	Land treatment process: Slow rate	Overland flow	Rapid infiltration
3-8	Pumping design consideration, high rating	Most desirable range, high rating	Earthwork need to form basins, moderate rating
8-15	Runoff, wastewater distribution, potential problems; moderately low rating; woodland moderate rating	Potential earthwork to reduce slope, low rating	Much earthwork needed to form basins, subsurface flow considerations, very low rating
15-30	Wastewater distribution, farming practices limited, very low rating; woodland-low rate application, moderate rating	Steep slope excludes process use	Steep slope excludes process use
30-45	Steep slope excludes agricultural process use; woodland-wastewater distribution, timber harvest problems, low rating	Steep slope excludes process use	Steep slope excludes process use
> 45	Steep slope excludes agricultural process use; woodland-wastewater distribution, timber harvest problems, very low rating	Steep slope excludes process use	Steep slope excludes process use

[a] To be used where soil depths below 1.5 m not investigated.

though they can serve to define groundwater quality for an area, acceptable waste concentrations in water reaching the groundwater, and local geologic conditions. In addition, intensive information may be available for local areas detailing the lithology, porosity, horizontal and vertical permeability, transmissibility and water quality of an area. These reports can prove quite valuable at all levels of the design procedure. Local USGS offices should be contacted to determine the availability of this information.

The level I soil and hydrogeology evaluation can be assessed from information available in modern (post-1956) soil surveys at either the soil association or soil series level. The soil series analysis provides a more accurate data base, but soil association analysis can be adequate when large land areas must be evaluated.

The soil association analysis involves rating the major individual soil series units which compose the soil association. Care must be taken to ensure that the soil series unit naming the association makes up the

Table 6. Rating values for soil series[a] (adapted from Table 7.8, Moser 1979).

	Land treatment process		
Soil characteristic	Slow rate	Overland flow	Rapid infiltration
Soil depth, (m)[b]			
<0.1	E[c]	E	E
0.1-0.6	E	0	E
0.6-1.5	3	5	E
1.5-3	8	7	4 (7)[d]
>3	9	7	8
Limiting permeability (cm/hr)			
<0.15	0	8	E
0.15-0.5	2	10	E
0.5-1.5	5	7	0
1.5-5	8	2	6
5-50	6	E	9
>50			
Predominant slope, (%)[f]			
0-3	7	7	8
3-8	7 (8)[g]	8	5
8-15	4 (6)[g]	2	1
15-30	0 (5)[g]	E	E
30-45	E (2)[g]	E	E
>45	E (0)[g]	E	E
Overall suitability rating[h]			
Suitable	20-25	20-25	20-25
Moderately suitable	14-19	15-19	15-19
Unsuitable	<14	<15	<15
Excludes use of process	E	E	E

a Ratings are usable for establishing preliminary suitability only; they will not replace field testing in the design of a land treatment system

b Depth to bedrock

c E = automatic exclusion of use of process

d Rating value for rapid infiltration when soil profile investigation and report stops at 1.5-m depth

e Most slowly permeable horizon in profile
f Must be assessed from soil survey table "Proportionate Extent of Soils."
g Slope rating values for woodland irrigation
h Sum of rating values of three soil characteristics

Table 7. Definition of suitability rating descriptions (adapted from Table 7.10, Moser 1979).

Suitability descriptor	Definition
Suitable	All soil properties are within the ranges of the concepts of the ideal land treatment process. No major site design constraints identifiable.
Moderately suitable	Will require specific design considerations to allow for non-ideal site conditions.
Unsuitable	Major, costly design and construction probably will be needed to alter site to allow use.
Limits process use	Unalterable soil property precluding use of soil for the process rated

major part of the association. Often a soil association may be named after two or three soil series units, but the soil series units may compose only 30% of the soils in the association. Estimates of the percent occurrence of the soil series contained within a soil association will be described in the soil survey.

When rating soil suitability at the series level, the predominant slope of the series must be identified from the soil survey. Depth to bedrock, depth to water table and most limiting permeability of soil series are also reported. The parent material or geology of the series is reported in the description of the series.

Modern soil surveys are not available for many areas of the country. In these cases, engineers must rely on airphotos to provide the necessary information on hydrogeology and soil features. Although quantitative information is difficult to define from airphotos, trained individuals can distinguish many soil and hydrogeologic features that affect site selection. Table 8 lists some of the major landforms which can be identified from airphotos and the important soil and hydrogeology features which will affect the suitability and choice of land treatment systems on these landforms.

Several other landforms such as those listed in Table 9 can be identified from airphotos (Way 1960). However, environmental concerns or heterogeneous conditions either render these landforms unsuitable for land treatment or require an in-depth analysis before any generalizations can be made regarding their suitability for land treatment.

SELECTION OF SITE ALTERNATIVES

Upon completion of the soil and hydrogeologic evaluation, several areas suitable for the different land treatment processes should be identified. It is assumed at this point that only areas with acceptable land use characteristics within economic transmission distances and containing sufficient land areas have been evaluated. The hydrogeologic and soil evaluation is the last cut in the level I site selection procedure. Only areas that are clearly not technically feasible should be screened out at this point. The location of the suitable areas, the type of land treatment systems best suited to these areas and the acreage available for the land treatment systems should then be defined. The level I design procedure can then be completed with a general economic comparison of the feasible land treatment system(s) to a conventional alternative. A discussion

Table 8. Suitability of selected landforms for land treatment.

A. Eskers

1. Topographic characteristics

a. long low narrow steep-sided ridge

b. <1 km to 160 km in length

c. 3 to 30 m in height and 60 m in width at the top

2. Soil characteristics

a. comprised of irregularly stratified sands and gravels

b. high permeability

c. deep soils

3. Subsurface geology

a. often found in moraine or till areas

4. Suitability for land treatment

a. highly suitable for rapid infiltration systems

b. limited for slow rate due to limited area of level slopes and high permeability of soils

c. overland flow is excluded due to high permeability

B. Kames

1. Topographic characteristics

a. long, low steep-sided hill, 15-25 m in height and diameter less than 125 m

b. steep sided slopes

2. Soil characteristics

a. composed of poorly sorted stratified sands and gravels
b. high permeability
c. deep soils

3. Subsurface geology

a. often found in moraine or till areas

4. Suitability for land treatment

a. limited for slow rate and rapid infiltration due to limited area of level slopes

b. unsuitable for overland flow

C. Outwash plains

1. Topographic characteristics

a. near-level broad tracts gently sloping from the apex or origin

2. Soil characteristics

a. composed of well-sorted coarse materials

b. the apex is composed of large gravels whereas the extreme fringe of the pan is predominantly a sand plain

Table 8. (Continued).

c. well-drained but a high water table may be found a few feet from the surface, particularly at the fringe of the pan

3. Suitability for land treatment

a. suitable for spray irrigation

b. moderately suitable for rapid infiltration depending on depth to groundwater

c. unsuitable for overland flow

D. Terraces

1. Topographic characteristics

a. flat areas with stair-stepped development commonly between river and upland

b. areal extent varies

2. Soil characteristics

a. glacial terraces - deep granular deposits of high permeability
b. marine terraces - deep, fine sands and silts of high to moderate permeability
c. lake terraces - deep clays of low permeabilities

3. Suitability for land treatment

a. glacial terraces - suitable for rapid infiltration and slow rate, unsuitable for overland flow

b. marine terraces - suitable to moderately suitable for rapid infiltration and slow rate depending on permeability, unsuitable for overland flow

c. lake terraces - suitable for overland flow with minor earthwork, moderately suitable to unsuitable for slow rate depending on permeability, unsuitable for rapid infiltration

E. Lake Beds

1. Topographic characteristics

a. broad, exceptionally flat surface

2. Soil characteristics

a. fine-textured deep soils of low permeability

b. high water tables

3. Suitability for land treatment

a. suitable for overland flow with some minor grading

b. moderately suitable for slow rate if low application rates and drainage are used
c. unsuitable for rapid infiltration

F. Till Plains

1. Topographic characteristics

a. young till plains - broad, gently rolling
b. old till plains, - broad, level areas

Table 8. (Continued).

2. Soil characteristics
   a. young till plains - silty to clay textured soils with a shallow depth to groundwater and bedrock

   b. old till plains - silty soils with a clay subhorizon and a moderately deep water table and bedrock

3. Subsurface geology

   a. dense compact unsorted till sometimes occurring over shale or limestone

4. Suitability for land treatment

   a. moderately suitable to suitable for overland flow and slow rate depending on permeability and depth of soil

   b. unsuitable for rapid infiltration

G. Alluvial fans

1. Topography

   a. smooth moderate slopes - transitional area between highlands and lowlands

2. Soil characteristics

   a. graded from coarse gravels to silts from apex of fan to bottomlands

   b. generally deep soils with good permeability

   c. high groundwater may occur at bottom of fan
   d. subject to erosion and additional filling

3. Suitability for land treatment

   a. suitable to moderately suitable for rapid infiltration and slow rate depending on depth to ground water and stability of distributory channels which create the filled valleys
   b. unsuitable for overland flow

H. Playas

1. Topographic characteristics
   a. broad, exceptionally flat surfaces.

2. Soil Characteristics

   a. fine-textured, deep soils of low permeability

3. Suitability for land treatment

   a. moderately suitable to unsuitable for slow rate and overland flow depending on permeability and soil salinity

I. Loess

1. Topographic characteristics

   a. undulating topography with smoothly rounded convex hills

2. Soil characteristics

   a. predominantly silts with moderate permeabilities

   b. highly subject to erosion

   c. shallow to deep soils depending on degree of erosion and topography

Table 8. (continued).

3. Suitability for land treatment

   a. suitable to moderately suitable for slow rate depending on depth of soil mantle

   b. moderately suitable to unsuitable for overland flow depending on permeability of soil

   c. unsuitable for rapid infiltration

Table 9. Additional landforms which can be identified from airphotos concerning suitability for land treatment.

Type of land form	Reason for Exclusion	Comments
Moraine	Highly heterogeneous material	Detailed soil analysis of airphotos required
Floodplain	Frequent flooding Environmental concerns	Exclude
Drumlins	Limited areas and steep slopes	Exclude
Filled Valleys	Heterogeneous material dependent on parent material and climate	Detailed soil analysis of airphotos required
Delta	Frequent flooding Environmental concerns	Exclude
Beach ridges	Limited area, heterogeneous conditions, high ground water	Exclude
Coastal plains	Highly heterogeneous material	Detailed soil analysis of airphotos required
Tidal flats	Frequent flooding Environmental concerns	Exclude
Sand dunes	Wind erosion Unstable landform	Exclude

of the technical and economic feasibility of land treatment will indicate whether a level II analysis is appropriate.

PUBLIC PARTICIPATION

The success of a land application project is often determined by public acceptance of the project. The public should be involved in the early stages of wastewater treatment planning. Public hearings are a useful medium for education as well as for obtaining information and public support. Public participation is particularly useful in screening potential site options. Information developed from public hearings should be incorporated at each level of the site selection procedure to screen site alternatives successfully.

LEVEL II SITE ANALYSIS

A schematic of the level II site analysis procedure was presented in Figure 4. The level II procedure is a cost-effectiveness evaluation of the level I site candidates and treatment systems. The level II site evaluation must (1) identify critical site characteristics of each of the level I site candidates, (2) select the land treatment process or processes to be investigated for each level I site candidate, (3) define the preliminary design requirements for each land treatment process and site candidate, (4) develop a cost-effectiveness evaluation for each alternative, (5) encourage public participation throughout the planning stages and (6) select a site or sites for intensive level III field investigations. The level II procedure utilizes available published information although field checks may be desirable if the available information is dated.

EVALUATION OF IMPORTANT SITE CHARACTERISTICS

A detailed map of each level I site candidate is prepared at the beginning of the level II investigation. The map should show the boundaries of the site and the location of the various soil types that occur at the site. The most detailed level of available soil information should be used to delineate the soil types at the site.

Land use information collected in the level I analysis should be verified. Field checks of this information may be desirable since land use patterns can change rapidly and may affect the amount of land area considered available for land application. The type and extent of vegetation found at each site should be identified from soil surveys or aerial photography in order to determine the degree of site clearing required. Soil type, characteristics, and areal extent should be evaluated from soil surveys at the soil phase level whenever possible. Table 10 summarizes the major site characteristics which should be identified at the beginning of the level II site evaluation.

The site characteristics presented in Table 10 should be identified for each soil phase at the beginning of the level II procedure. They will be referred to throughout the level II design process to (1) identify the suitable land treatment processes for each site candidate, and (2) define the design requirements for each selected process and site.

The level I procedure identified slope, depth to bedrock, and limiting permeability as the major soil properties which significantly affect the

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Table 10. Major site characteristics identified in the level II site evaluation.

General characteristics
Land use
Existing vegetation
Soil characteristics
Soil type
Areal extent
Slope
Depth to bedrock
Depth to groundwater
Depth of individual soil horizons
Permeability of individual soil horizons
Flooding frequency
Erosion class

feasibility of implementing land treatment at a given location. These properties should be evaluated at the soil phase level in the level II evaluation. In addition, the level II site characterization should include the depth and permeability of each horizon of the soil phases identified at the selected sites, as well as depth to groundwater, flooding frequency and erosion class for each soil phase. Soil phases will have approximately the same horizons, permeabilities, depth to bedrock, flooding frequency and depth to groundwater as the soil series in which they are included. Slope values will differ for different soil phases of the same soil series. Depth to groundwater defines the aerated zone within the soil and hence the zone of wastewater renovation for rapid infiltration and slow rate systems. Overland flow systems are generally not affected by depth to groundwater due to the design requirements of the system.

In cases with inadequate depths to groundwater (less than 1.5 m for slow rate and less than 3 m for rapid infiltration systems), drainage is necessary and the cost of drainage should be considered in the level II analysis. The effective drainage depth also should be considered. The effective drainage depth is defined as the depth to a slowly permeable (less than 0.5 cm/hr) horizon or a horizon where the permeability is 10 times less than the permeability of the horizon overlying it (de Ridder 1974).

Perched water tables may occur above these horizons and drain tile placed below these horizons will not effectively drain the soil (Schwab et al. 1966). If slowly permeable horizons are located within 0.6 m of the soil surface, the soil should be excluded as a potential slow rate site as there will be an inadequately aerated zone for waste treatment.

The frequency of flood events is an important consideration in site selection. Flooding can erode or deposit soil at a site and create saturated soil conditions during which wastewater cannot be applied. Pollutants and flooding can become soluble under long-term flooding conditions and leave the site with transported sediments. Flooding frequency is described in the soil survey at the series level as (1) none or slight, (2) occasional and (3) frequent. An occasional flooding frequency denotes a soil which has a 10 to 50% change of flooding once every two years. Frequent flooding denotes a soil which has a greater than 50% chance of flooding once every two years. In addition to flooding frequency, soils may be described as seasonally ponded (or seasonally wet). This description generally denotes soils that occur in low-lying areas of the landscape, have poor surface drainage, and become saturated when major runoff events occur.

Frequently flooded soils should generally be excluded in the level II site analysis. Soils which are occasionally flooded may potentially be used, but field investigation is required. Structural controls such as flood routing or embankments may temporarily alleviate problems related to flooding. Avoiding waste application during flooding events also may be a potentially cost-effective method of site use, but treatment costs may increase due to larger storage requirements and land areas. Seasonally ponded soils may require drainage, diversion of off-site runoff or decreased application rates. These considerations will affect total treatment costs.

Table 11 presents considerations regarding soils with limiting ranges of depth to groundwater or flooding frequency. These considerations are useful in defining the cost-effectiveness of utilizing a site with these limiting conditions.

LAND TREATMENT PROCESS SELECTION

Identifying the technical suitability of a site candidate for a particular land treatment process or processes involves (1) identifying unsuitable land areas at each site based on land use and flooding frequency,

Table 11. Considerations regarding soils with limiting alterable properties.

Depth to groundwater (m)	Slow rate	Rapid infiltration	Overland flow
< 1.5	Inadequate zone of treatment, requires drainage	Inadequate zone of treatment, may not be possible to drain, requires field investigations	Potentially usable with adequate rest period
1.5-3	Adequate zone of treatment, excessive application rates may require drainage	Inadequate zone of treatment, recovery wells necessary	Desirable
> 3	Desirable	Desirable	Desirable
Flooding frequency (SCS classification)	**Slow Rate**	**Rapid Infiltration**	**Overland Flow**
None-slight	Desirable	Desirable	Desirable
Occasional	Excludes application during flooding event, additional storage and land area may be required	Same as slow rate	Same as slow rate
Frequent	Excludes use of process	Excludes use of process	Excludes use of process
Ponded or seasonally saturated	Excludes application during wet times of year, drainage and diversions may make site usable during these periods	Same as slow rate	Same as slow rate

(2) rating the individual soil types for their suitability for land treatment, and (3) evaluating if sufficient land areas of suitable soils exist for a particular land treatment process.

Soil suitability for land treatment is evaluated for each of the soil types not excluded from further analysis. A variety of systems have been proposed for rating soil suitability for land treatment based on available published information of soil characteristics (Moser 1979). Soil characteristics will generally not limit the usefulness of a site, but they influence the method of treatment. Often a site may be suitable or moderately suitable for two processes so that a cost-effective evaluation of both processes should be prepared.

The values for rating soil series in the level I analysis (Table 6) can also be used to rate soil phases in level II using the actual slope of the soil phase rather than that of the soil series. The erosion status of the soil phase should also be considered in assigning a value as it can affect the selection of a site. Table 12 presents the definition of

Table 12. Concerns for soil erosion resulting in decreased rating values (from Table 7.11, Moser 1979).

Soil erosion Class (number)	Concern in establishing Slow rate	Overland flow	Rapid infiltration
Slight (none)	none	none	none
Moderate (2)	Reduced depth for treatment in shallow soil	Reduced depth for slope formation in shallow soil	none
Severe (3)	Reduced depth, increased difficulty with cropping	Reduced depth, increased earthwork	Increased earthwork
Very Severe (4)	Earthwork needed to make site usable	Earthwork needed to make site usable	Earthwork needed to make site usable

various erosion classes identified in soil surveys.

Table 13 is a matrix for rating soil phase properties for land treatment (Moser 1979). Rating values for limiting permeability and slope are the same as those developed for rating soil series. The limiting permeability for overland flow is considered to be the permeability of the surface horizon. Soils with surface horizons having permeabilities exceeding 1.5 cm/hr are excluded from use as overland flow sites.

The effective drainage depth should be used rather than the depth to bedrock for determining a rating value for soil depth when rating soil phases for slow or rapid infiltration suitability. The effective drainage depth will identify the potential unsaturated zone for wastewater treatment. Soils with an effective drainage depth of less than 0.6 m for slow rate and 1.5 m for rapid infiltration exclude the use of these processes.

The total available land area of suitable soil phases for the various processes at the individual site candidates should be compared to the land area requirements for each of the land treatment processes. Land area requirements for each of the land treatment processes are based on a limiting

Table 13. Rating values for soil phases[a] (from Table 7.12, Moser 1979).

Soil characteristic	Land treatment process: Slow rate				Overland flow				Rapid infiltration			
Erosion Class[b]	1	2	3	4	1	2	3	4	1	2	3	
Soil Depth, m[c][d]												
0.1-0.6	E	E	E	E	0	0	E	E	E	E	E	E
0.6-1.5	3	2	1	0	5	5	4	2	E	E	E	E
1.5-3	8	7	7	3	7	7	6	6	5	5	5	4
1.5-3	-	-	-	-	-	-	-	-	7[e]	7[e]	7[e]	7[e]
>3	9	8	8	4	7	7	6	6	8	8	8	7
Limiting Permeability, cm/hr[f]												
<0.15	0				8				E			
0.15-0.5	2				10				E			
0.5-1.5	8				7				0			
1.5-5	5				2				6			
5-50	6				E				9			
>50	E				E				0			
Slope, %[g]												
0-3	8				7				8			
3-8	7(8)[h]				8				5			
8-15	4(6)[h]				2				1			
15-30	0(5)[h]				E				E			
30-45	E(2)[h]				E				E			
>45	E(0)[h]				E				E			
Overall Suitability[i]												
Suitable	20-25				20-25				20-25			
Moderately Suitable	14-19				15-19				15-19			
Unsuitable	<14				<15				<15			
Excludes use of Process	E				E				E			

a. Ratings are usable for establishing preliminary suitability only; they will not replace field testing in the design of a land treatment system
b. Erosion class of soil phase mapping unit
c. E = automatic overall exclusion of use of process
d. Depth to bedrock
e. Rating value for rapid infiltration when soil profile investigation and report stops at five foot depth
f. Most slowly permeable horizon in profile
g. Slope class of soil phase mapping unit
h. Slope rating values for woodland irrigation
i. Sum of rating values of soil characteristics

parameter principle. A brief discussion on evaluating land area requirements is presented to illustrate the general principles and demonstrate how site factors can affect land area requirements. The subject is covered in considerably more detail in several references (Loehr et al. 1979, Overcash and Pal 1979, U.S. EPA et al. 1977).

In determining the required area for a land treatment system, instantaneous and weekly application rates must be evaluated to identify the hydraulic loadings, daily application rates must be considered to identify organic loadings, and yearly and long-term application rates should be evaluated to identify the nutrient, salt and toxic element loadings. The most limiting of these rates will determine the required land area.

The hydraulic loading is generally the limiting parameter for overland flow and rapid infiltration systems. Slow rate systems are generally limited by either the hydraulic loading or the nutrient loading. Hydraulic loadings are based on soil characteristics and climatic considerations, whereas nutrient loadings are based on crop nutrient requirements. Land area requirements based on nutrient loading limitations are primarily a function of crop growth requirements. A portion of the nutrients can be assimilated in the soil system by biological and chemical processes but nutrient removal efficiencies by these processes are difficult to quantify. Nutrient loadings are commonly expressed as kilograms/hectare year (km/ha yr). Land area requirements are computed by dividing the total mass of nutrients available in the wastewater each year by the plant soil assimilative capacity on a hectare year basis.

The hydraulic loading for slow rate and rapid infiltration systems is determined by a mass balance which is expressed as

$$W + R = P + ET \qquad (1)$$

where W = wastewater additions
R = precipitation
P = soil hydraulic capacity
ET = evapotranspiration.

Slow rate and rapid infiltration systems are designed so that hydraulic inputs and outputs are equal. The soil hydraulic capacity is defined by the Darcy equation as

$$Q = K\,A\,dH/dL \qquad (2)$$

where Q = soil hydraulic capacity
K = soil saturated hydraulic conductivity (horizontal or vertical)
A = cross-sectional area normal to the direction of flow
dH/dL = hydraulic gradient.

In situations where an impermeable layer, bedrock, or groundwater is fairly deep (greater than 1.5 m), vertical flow predominates and the saturated hydraulic conductivity (K value) of the soil is equal to the permeability of the most limiting horizon. The hydraulic gradient (dH/dL) is assumed to be 1 in these cases.

If the depth to an impermeable layer, bedrock or groundwater is shallow (less than 1.5 m), horizontal flow predominates. The saturated hydraulic conductivity of the soil is assumed to be equal to the permeability of the saturated horizon with the highest permeability value. The hydraulic gradient is assumed to be equal to the slope of the limiting layer and can be approximated by the slope of the surface horizon.

Drainage systems will increase the hydraulic gradient of shallow soils and maintain an aerated zone for wastewater treatment. These systems may substantially increase the hydraulic assimilation capacity of a soil and potentially decrease land area requirements. The cost-effectiveness of drainage will depend on the drainage spacing which is a function of soil type. Table 14 lists typical drainage spacings for various soil textures.

The hydraulic capacity of overland flow sites is based on slope values. Suggested loading rates are:

Slope < 6%	25 cm/wk loading
Slope 6-9%	10 cm/wk loading
Slope > 9%	7 cm/wk loading

Overland flow sites are commonly graded to a uniform terrace slope and

Table 14. Subsurface drainage spacings and depths for various soil types (Schwab et al. 1966).

Soil	Hydraulic conductivity class	Spacing (m)	Depth (m)
Clay	Very slow	9-15	0.9 - 1.1
Clay loam	Slow	12-21	0.9 - 1.1
Average loam	Moderately slow	18-30	1.1 - 1.2
Fine sandy loam	Moderate	30-36	1.2 - 1.4
Sandy loam	Moderately rapid	30-61	1.2 - 1.5
Peat and muck	Rapid	30-91	1.2 - 1.5
Irrigated soils	Variable	46-183	1.5 - 2.4

length. Loading rates can potentially be maximized by earthwork. The feasibility and cost of substantially altering existing slopes is a function of the soil slope and depth to bedrock. Minimal earthwork will be possible where the depth to bedrock is less than 0.6 m. Earthwork cost estimates can be approximated from topographic surveys, but actual cut and fill requirements must be determined from a detailed field topographic survey.

Hydraulic loadings are commonly expressed as centimeters/hectare week (cm/ha wk). Land area requirements based on hydraulic limitations are determined by developing a monthly water budget, as precipitation and evapotranspiration amounts will vary on a monthly basis. A method for developing a monthly water budget which takes into account the number of operating days is presented in Powell (1976). The number of potential operating days can greatly affect land area requirements based on hydraulic loading limitations.

The operating period for a land application system is a function of climate, soil flooding potential, type of crop grown at the site and the type of land treatment process. In general, rapid infiltration systems have the greatest flexibility in cold climates as they can operate when the ambient temperature is below freezing. Wastewater applications for overland flow and slow rate systems are limited or excluded during periods of precipitation or below-freezing temperatures. A computer program for determining storage requirements and application periods for land treatment systems has been developed by the National Weather Service (Loehr et al. 1979). The program takes into account only climatic influences. The choice of crop for a slow rate system can potentially affect the length of the application season. Annual crops generally have a shorter growing season than perennials, but may produce a higher crop revenue that could offset the increased operation and maintenance costs. Crops will vary in terms of their nutrient uptake and salt and toxic element tolerance, which can also affect land area requirements if these waste characteristics are limiting parameters. Crop selection is also affected by soil characteristics. Soil phases with slopes greater than 15% will not be suitable for annual row crops due to runoff and erosion considerations. Crop selection should be an iterative procedure which takes into account economic factors, site and waste characteristics, and management considerations. The subject of crop selection is discussed in detail in Loehr et al. (1979), Overcash and Pal (1979) and U.S. EPA et al. (1977).

Selection of the appropriate processes for each of the site candidates is an iterative procedure. The limiting parameter analysis will determine the technical feasibility of implementing one or more processes at a particular site and will define (1) land area requirements, (2) optimum application rates and scheduling, and (3) potential design alternatives for each process and site alternatives which may prove cost-effective. Potential design alternatives would include (1) choice of crop for slow rate systems, (2) earthwork requirements for overland flow systems, and (3) drainage or recovery systems for slow rate and rapid infiltration systems. The cost of each of the design and process alternatives is then compared for each of the site candidates to determine the most cost-effective options.

COST-EFFECTIVENESS EVALUATION

Sources of Cost Information

The level II cost-effectiveness evaluation is prepared from a preliminary design of each process and site alternative. Two principal sources of cost information for level II cost evaluation are the computer model CAPDET (Computer-Assisted Procedure for the Design and Evaluation of Wastewater Treatment Systems) and Reed et al. (1979). Local construction costs should be used whenever possible to refine the cost information presented in these two sources.

Reed et al. (1979) present a series of cost curves, derived from construction cost data of over 20 land treatment projects, for the principal components of the three land treatment processes. Basic design assumptions are included for each cost curve, and cost adjustment factors are given for modifications of the basic design assumptions. In general, the cost curves are expected to be within about 15% of the actual costs.

CAPDET was developed to complement a Corps of Engineers design manual on wastewater treatment (U.S. Department of the Army 1978). The program contains cost data for both conventional and land application wastewater treatment alternatives. CAPDET contains costs for over 65 unit processes and can be used as a screening tool to quickly compare a wide range of alternative treatment designs.

Cost information available in Reed et al. (1979) and the CAPDET program include the following types of data for the major components of a land treatment system: (1) preapplication treatment, (2) transmission, (3) storage, (4) pumping, (5) field preparation, (6) distribution, (7) recovery of renovated wastewater, (8) roads and fences, (9) administrative and laboratory facilities, and (10) monitoring systems. The level II cost evaluation should also include the cost of (1) land purchase or leasing, (2) crop management, (3) yardwork, (4) relocation of residents, (5) purchase of water rights, and (6) service and interest factors. These additional costs are not easily represented by cost curves but Reed et al. (1979) identify sources of information for these costs.

Figures 5-7 present flow charts that demonstrate the relationship between the major land treatment components for which cost curves are available. Procedures for using these flow charts are presented in Reed et al. (1979).

Preapplication Treatment

Preapplication treatment requirements will depend on (1) site location, (2) the ultimate fate of the wastewater (discharge point), and (3) the intended use of the wastewater (i.e. irrigation of food crops, use in golf courses, etc.). Table 15 presents current EPA guidance for determining the level of preapplication treatment necessary for specific cases.

Storage Systems

Storage systems can achieve significant wastewater renovation and should be considered as part of the preapplication treatment system. The top 0.9 m of a storage lagoon can act as a facultative pond, and expected effluent qualities from storage lagoons can be predicted from standard design equations for facultative ponds. Aeration may be desirable prior to wastewater storage to control potential odors. General design guidance for integrating storage and preapplication treatment system design is presented in Reed et al. (1979).

Transmission Systems

Transmission systems may consist of gravity pipe or open channel systems, force main systems or a combination of gravity and force main systems. The choice of system is largely dependent on the topography of the area.

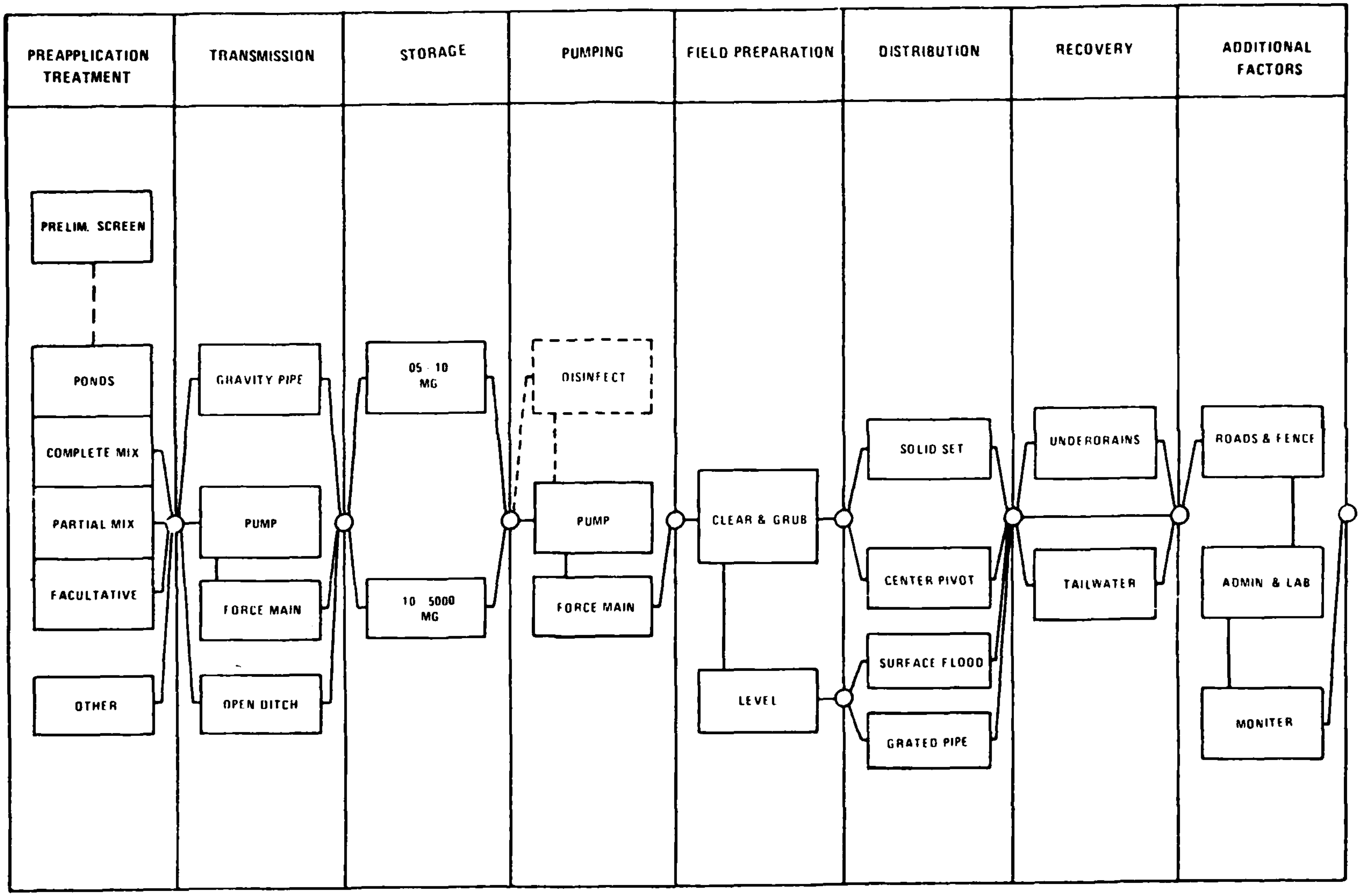

Figure 5. Slow rate systems - relationship of cost curves (Reed et al. 1979).

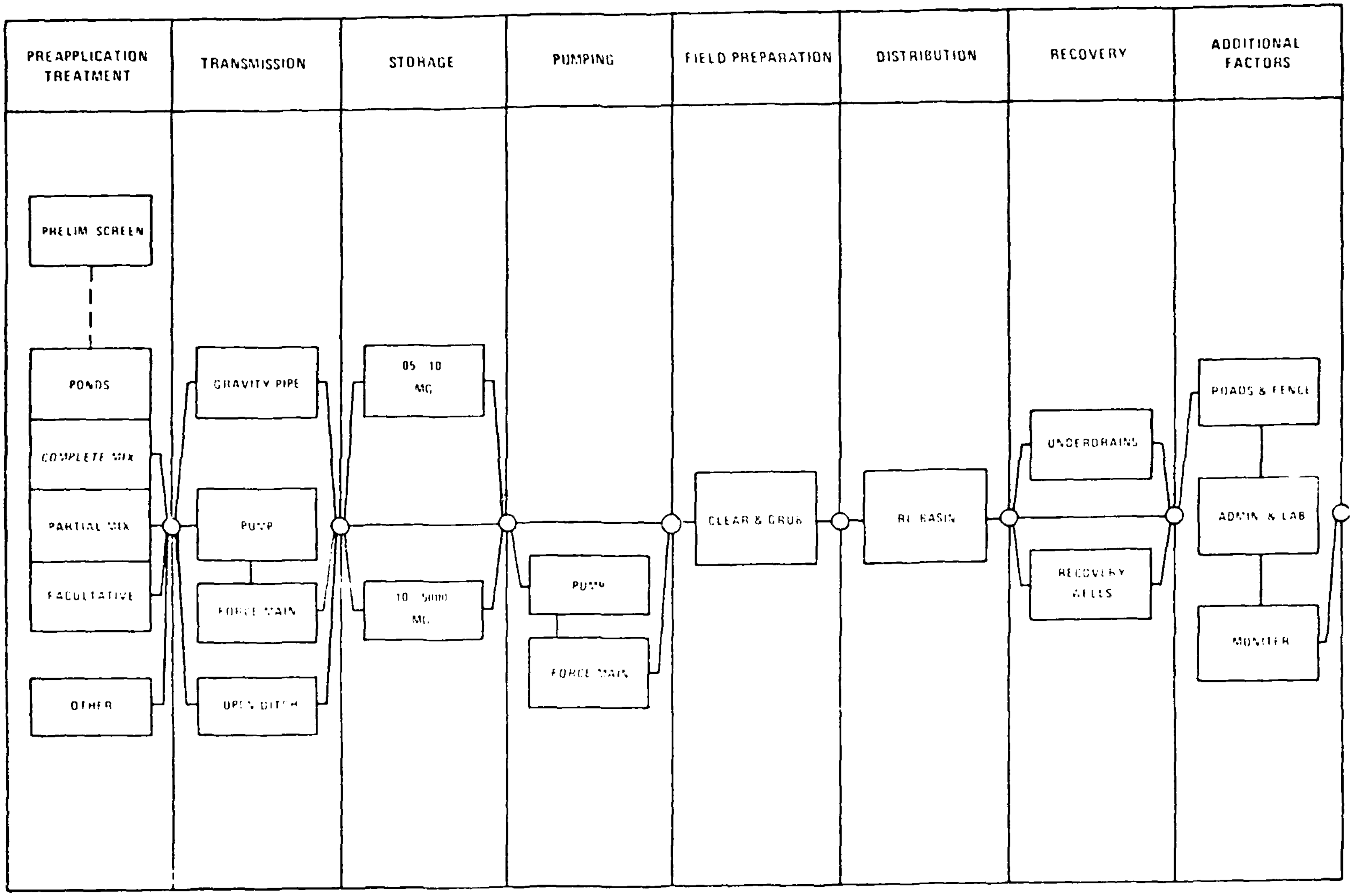

Figure 6. Rapid infiltration systems - relationship of cost curves (Reed et al. 1979).

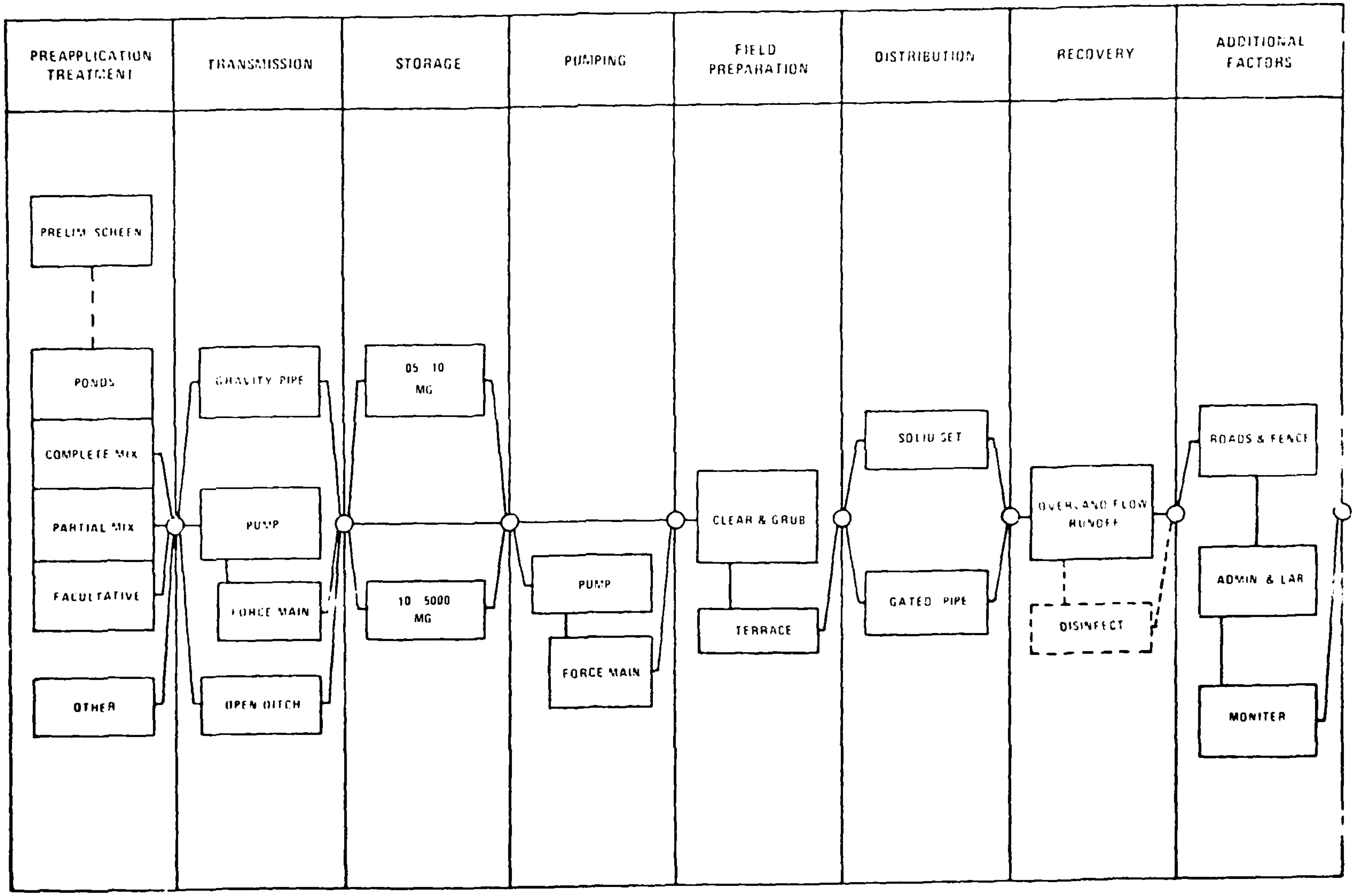

Figure 7. Overland flow systems - relationship of cost curves (Reed et al. 1979).

Table 15. Guidance for assessing level of preapplication treatment (Adapted from Table 4, Reed et al. 1979).

I. Slow rate systems (reference sources include, "Water Quality Criteria," 1972, EPA-R3-73-003, "Water Quality Criteria," EPA 1976, and various state guidelines).

A. Primary treatment - acceptable for isolated locations with restricted public access and when limited to crops not for direct human consumption.

B. Biological treatment by lagoons or inplant processes plus control of fecal coliform count to less than 1,000 MPN/100 ml acceptable for controlled agricultural irrigation except for human food crops to be eaten raw.

C. Biological treatment by lagoons or inplant processes with additional BOD or SS control as needed for aesthetics plus disinfection to log mean of 200/100 ml (EPA fecal coliform criteria for bathing waters) - acceptable for application in public access areas such as parks and golf courses.

II. Rapid infiltration Systems

A. Primary treatment - acceptable for isolated locations with restricted public access.

B. Biological treatment by lagoons or inplant processes - acceptable for urban locations with controlled public access.

III. Overland flow Systems

A. Screening or comminution - acceptable for isolated sites with no public access.

B. Screening or comminution plus aeration to control odors during storage or application - acceptable for urban locations with no public access.

* From EPA Construction Grants Program Requirements Memorandum PRM 79-3, issued Nov. 15, 1978.

The capital cost of transmission systems may exceed 50% of the total capital costs for certain site options. Operation and maintenance (O & M) costs associated with pumping requirements can also be significant. The choice of site location and the associated transmission system are particularly important in light of continually increasing energy costs.

Field Preparation

Field preparation costs include initial site clearing requirements and the necessary earthwork for specific overland flow and slow rate distribution systems. Initial site clearing costs depend on the existing vegetation, which can be determined from airphotos or land use maps. Land leveling is necessary for slow rate surface irrigation systems and overland flow systems. General cut and fill requirements can be estimated from topographic maps.

Distribution Systems

The choice of distribution system will depend mostly on the process selected. Distribution systems for rapid infiltration processes are limited to flooding basins. Wastewater may be applied to overland flow systems by gated pipes or spray irrigation systems located near the top of the flow terraces. A variety of surface and spray irrigation systems are available for wastewater application to slow rate systems.

The selection of appropriate distribution systems for slow rate processes is site specific and involves management and economic considerations. Surface distribution systems are generally not feasible on slopes greater than 6% and may experience erosion problems on slopes greater than 2% (Israelson and Hansen 1962). The total cost of surface systems per unit land area is generally lower than that for sprinkler irrigation systems; however, surface systems (1) result in uneven water distribution, creating potential salt buildup problems, (2) require some form of tailwater collection and return, and (3) require a higher degree of management than sprinkler systems to achieve comparable efficiencies of water distribution (Kovda et al. 1973).

Israelson and Hansen (1962) and Kovda et al. (1973) give information on the selection and design of conventional irrigation systems. Loehr et al. (1979) and U.S. EPA et al. (1977) discuss the selection and design of overland flow and rapid infiltration wastewater distribution systems.

Recovery Systems

The need for and design of a recovery system will depend on (1) the land treatment process, (2) the distribution system selected, and (3) site conditions. Recovery systems are a necessary component of overland flow processes and slow rate processes with surface irrigation systems. Slow rate and rapid infiltration processes may require recovery of the renovated water if they are hydraulically limited due to inadequate soil depth or cannot meet groundwater discharge requirements. Slow rate systems will require recovery of storm water runoff.

Recovery of subsurface water from slow rate and rapid infiltration processes may be accomplished by either subsurface drains or recovery wells. Recovery wells are generally used if the water table is greater than 3 m below the ground surface due to technical limitations on installing deep subsurface drains. The spacing of subsurface drains or the number of recovery wells required is highly dependent on soil characteristics. Design guidance for surface and subsurface recovery systems is presented in de Ridder (1974).

Additional Costs

Land costs are part of the additional cost category and can be a significant portion of total treatment costs. Local land purchase costs should be obtained for each site alternative from realtors or local planning boards.

It should be noted that a salvage value should be included for land purchase costs which are eligible for federal funds. The present worth of land purchase is considerably lower than the present price under these conditions. Examples of cost calculations for determining the actual cost of land purchase and the other components of land treatment systems are included in Walsh and Beaton (1973).

PUBLIC PARTICIPATION

The public should be actively involved in the level II site selection procedure. Public support is also important in the implementation and operation of a land treatment system. Public meetings should be held to present the level II site evaluation results. The economic and environmental impacts on the community of the various alternatives should be discussed, and public concerns such as odors and health effects should be identified and addressed. Public participation may indicate support for certain site alternatives which stress recreational or environmental benefits, but are more expensive than other alternatives. This input is valuable in identifying the level III site candidates for intensive field investigations and final design.

LEVEL III SITE EVALUATION

Level III site evaluation involves a detailed analysis of the physical, chemical and hydraulic properties of the site selected in the level II site selection procedure. Level III site evaluation procedures are reviewed in various sections of U.S. EPA et al. (1977). This section (1) synthesizes the material presented in U.S. EPA et al. (1977), (2) places the level III site evaluation within the context of the site selection procedure, and (3) develops a chronology for field investigations.

SOIL PHYSICAL PROPERTIES

Soil features necessary for evaluation will vary, depending on constituents present in the wastewater and on the choice of land treatment system. Table 16 summarizes soil parameters commonly measured in field investigations. Generally, the selection of physical and hydraulic properties to be measured will not be affected by the characteristics of the wastewater, while selection of important soil chemical and biological properties is strongly affected by the nature of the wastewater. Table 17 lists soil chemical analyses that should be performed when concentrations of certain waste characteristics are exceeded. The soil parameters will determine the assimilation capacity of the soil for the various waste constituents.

Soil physical properties should be measured at the beginning of the level III field investigation. Data collected from soil profile descriptions will be used to prepare a detailed soil map of the site that will aid in determining the location of sampling points as well as preparing a management scheme for the land treatment system. A detailed topographic map of the site should be developed from a survey of selected grid points so that land grading requirements, drainage and the layout of the distribution system can be evaluated. Data from the topographic survey can also be used later in the level III investigations to determine the hydraulic gradient of the site.

Table 16. Soil parameters commonly measured in field tests.

Physical	Chemical and biological	Hydraulic
Soil description	*CEC	Infiltration rates
Topography	*Exchangeable cations	Aquifer pump tests
	pH	Drainable porosity
	*Electrical conductivity	Hydraulic conductivity
	% Organic matter	
	Nutrients	
	*Boron	
	*P adsorption	
	Base saturation	

*Need for analysis should be based on an evaluation of waste characteristics.

Table 17. Relationship between waste constituents and soil properties that should be measured.

Waste characteristic	Soil chemical analysis	Reference
P/N ratio > 1/4	P Adsorption Test	Enfield and Bledsoe (1975)
EC > 0.75 mm hr/cm	Electrical conductivity	Richards (1954)
SAR > 6	CEC and exchangeable cations	Richards (1954)
Boron > 0.5 mg/L	Boron adsorption test, and Extractable Boron	Black (1965)
Cd > 0.01	CEC and total Cd	Walsh and Beaton (1973)
Cu > 0.02	CEC and total Cu	Walsh and Beaton (1973)
Ni > 0.02	CEC and total Ni	Walsh and Beaton (1973)
Pb > 5.0	CEC and total Pb	Walsh and Beaton (1973)
Zn > 2.0	CEC and total Zn	Walsh and Beaton (1973)

A grid system should be used for determining topographic elevations and preparing soil descriptions. A grid spacing of 25 to 50 m is desirable. Soil cores should be extracted and described at various locations along the topographic grid at locations where soil surveys indicate boundaries between soil types or where changes in slope occur. The spacing between cores need not be as intensive as the elevation intervals. Spacings of 200 to 430 m are generally recommended.

Soil cores should be extracted at depths of 2 to 3 m in 10-cm increments. Disturbed cores can be extracted using either hand-driven or portable hydraulic drilling rigs with barrel auger attachments of 5 to 10 cm in diameter. In areas with humid climates and a seasonal high groundwater table, it may be desirable to install wells after the cores have been extracted. The wells can consist of perforated PVC pipe, 5 cm in diameter and wrapped with cheesecloth to prevent entrance of soil into the well. The disturbed earth around the wells should be backfilled, sealed with bentonite clay at the surface and capped with a removable stopper. The wells are useful in developing hydraulic conductivity data later in the field investigations, preparing a hydrologic map of the site and evaluating the response of the groundwater table to varying climatic conditions.

Profile descriptions of each soil boring should be prepared which include (1) depth of profile, (2) boundary of profile (i.e. abrupt, wavy, etc., (3) texture when moist, (4) structure, (5) degree of mottling, (6) presence of carbonates, (7) Munsell color value, (8) depth to groundwater, (9) type of vegetation, and (10) percentage and type of coarse fragments (greater than 7.5 cm). The descriptions should be prepared by a soil scientist (personnel of the local Soil Conservation Service may be able to assist in the procedure). The descriptions can then be correlated to descriptions of known soil series which occur in the area.

Once the first set of field data is collected, detailed soil and topographic maps can be developed. The type of hydraulic tests and the location of sampling points for chemical and hydraulic parameters can be determined from this information. The information developed from the chemical and hydraulic soil tests is used to verify and refine level II design parameters for application rates and limiting constituents.

SOIL CHEMICAL PROPERTIES

Certain soil chemical parameters should be routinely measured, whereas the need for evaluating other parameters will be determined on the basis of the concentration of various constituents present in the wastewaster. Table 17 presents the soil chemical properties which should be measured when waste constituents exceed certain concentrations. Results of these tests can be used to verify or modify the level II analysis. The parameters listed in Tables 16 and 17 should not be considered comprehensive, but indicate the types of considerations commonly used in the design of land treatment systems.

Percentage organic matter and pH measurements should be routinely conducted in all site investigations to provide background data for subsequent monitoring. If pH corrections are required, base saturation should be analyzed to determine the lime requirement of a soil. Available nutrients should be determined for overland flow and slow rate systems to determine if additional fertilization may be required to promote good crop growth.

If the phosphorus/nitrogen ratio of the waste is greater than 1:4, or if a rapid infiltration system will be used, a phosphorus adsorption test should be conducted (see Enfield and Bledsoe 1975). Normally the test is conducted over a five-day period. Tofflemire and Chen (1977) concluded that total phosphate retention in a soil system will be at least two to five times the estimate based on the five-day adsorption test.

The electrical conductivity (EC) of a soil saturation extract should be determined if the EC of the wastewater exceeds 0.75 mmhos/cm and a slow rate or overland flow system is planned. The EC value of the soil can be used to determine the leaching requirement necessary to prevent salt damage to crops. Procedures for calculating the leaching requirements and lab methods for determining EC are presented in Richards (1954).

The exchangeable sodium percentage (ESP) of a soil should be determined if the sodium adsorption ratio (SAR) of the wastewater exceeds six. ESP is defined as the ratio of exchangeable sodium in the soil to the total cation exchange capacity (CEC) of the soil. The SAR of a solution is a measure of the degree to which sodium will be absorbed by a soil from the solution under equilibrium conditions. Methods for determining ESP and SAR are presented in available texts (Richards 1954, Black 1965).

Potential problems related to excess sodium can generally be corrected by adjusting the ratio of sodium to other exchangeable bases either in the wastewater or soil. A determination of the ESP of a soil in the level III investigation will provide background data for subsequent monitoring. Corrective measures can then be implemented prior to problem development. Critical concentrations of metals listed in Table 17 are those developed as irrigation water standards (Overcash and Pal 1979). Although these elements may not be the land limiting constituent in a land treatment system, their fate should be determined as well as the lifetime assimilation capacity of the site for these metals. CEC is commonly measured to determine lifetime loading rates of heavy metals. In addition, total metals should be analyzed to provide background information for subsequent monitoring.

Boron toxicity has been observed in some plant species at soil solution concentrations exceeding 0.5 mg/L. Boron toxicity problems could occur either from excess boron applied in wastewater or from high concentrations occurring naturally in the soil. Excess soil boron is found in scattered areas in arid and semi-arid climates and is often associated with the use of irrigation waters with a high boron content. Adsorption processes for boron in the soil are similar to phosphorus adsorption processes. Nonadsorbed boron is easily available for leaching and plant uptake processes. To determine the plant-soil assimilation capacity for boron, a boron adsorption test similar to that for phosphorus (Enfield and Bledsoe

1975) should be conducted, and soil units located at the site should be analyzed for extractable boron. Methods for determining extractable boron are presented in Black (1965).

Samples for the determination of soil chemical properties should be collected from each soil type mapped at the site. Each soil type should be subdivided into sampling units of 2 to 10 ha, either in a uniform grid or based on differences in vegetation or land management. The major soil horizons should be analyzed for the chemical parameters listed in Table 16. A composite sample of each horizon, composed of 5 to 10 subsamples, should be prepared in the field for each sampling unit. Composite samples should represent an equal volume of each subsample and be of an appropriate size for lab processing. Generally, a composite volume of 1 L is adequate.

SOIL HYDRAULIC PROPERTIES

An intensive analysis of the hydraulic assimilation capacity of the site should be performed during the level III site evaluation.

Soil hydraulic properties were estimated from published information in the level II process. The hydraulic properties measured during the level III field tests are highly dependent on the type of land treatment system which will be implemented at the site. Table 18 presents hydraulic properties of soils normally measured for the various land treatment systems.

In deep homogeneous soils, the predominant flow of water is in the vertical direction and the long-term infiltration capacity of a soil should equal the saturated vertical hydraulic conductivity of the soil. However, in situations where a shallow depth to groundwater or an impermeable layer exists, the predominant flow path will be in the horizontal direction and

Table 18. Soil hydraulic properties measured for land treatment processes.

Processes		
Slow rate	Rapid infiltration	Overland flow
Infiltration rate	Infiltration rate	Infiltration rate
Saturated hydraulic conductivity	Saturated hydraulic conductivity	
Drainable porosity	Aquifer tests	
Subsurface geology	Subsurface geology	

the hydraulic gradient should be determined (Ryan et al. 1980).

Vertical saturated hydraulic conductivities in the soil region above the groundwater table can be measured by the air entry parameter (Bouwer 1966), double tube, or gradient intake methods (Bouwer 1964). Vertical saturated hydraulic conductivities can be measured in the laboratory by the constant head method. Laboratory measurements are hard to reproduce in the field due to the difficulty of extracting an undisturbed soil curve.

Horizontal saturated hydraulic conductivities are difficult to measure, but can be approximated with the use of the auger hole method (Van Bavel and Kirkham 1948), which requires the presence of a shallow groundwater table. If a groundwater table is not present or a hardpan formation occurs above the natural groundwater table, equipment and techniques developed by Bouwer (1964) can be used to determine horizontal saturated hydraulic conductivities.

The infiltration rate of surface soils will determine the maximum instantaneous application rate for a given soil. Flooding basin studies should be used if a rapid infiltration system is planned. Sprinkler infiltrometers are used primarily for determining limiting infiltration rates for systems using sprinklers. They may give more accurate results than ring infiltrometer tests, but are more difficult to conduct due to machinery and manpower requirements. A review of each of these tests is available (U.S. EPA et al. 1977).

In certain situations it may be necessary to exceed the hydraulic assimilation capacity of slow rate or rapid infiltration systems. Applications of excess wastewater will result in the formation of a groundwater mound which can decrease the effective aerated zone of a soil. Complex analytical equations have been developed to determine the growth and decay of groundwater mounds (Marino 1974). Projected increases in groundwater heights can be developed by dividing the estimated excess water by the drainable porosity of the saturated zone. Techniques for determining drainable porosity are presented in Black (1965).

Rapid infiltration systems may require aquifer pumping tests in situations where the groundwater table is very deep and an auger hole test cannot be implemented. These tests measure the response of water levels in various wells when one well is recharged or discharged at a constant rate. Results are related mathematically to the saturated hydraulic conductivity of the saturated layer (U.S. EPA et al. 1977).

Deep borings should be conducted to determine the subsurface geology of a site if not characterized in the initial soil borings. A characterization of the geology will (1) identify major groundwater flow patterns, (2) determine the geologic rock type, (3) quantify depth to bedrock and (4) evaluate the potential for short-circuiting due to faulting or sink holes.

Considerable variability can exist in measured soil hydraulic properties within a given soil type (U.S. EPA et al. 1977), and no specific guidelines are available regarding the number of tests required for determining a particular soil property. A statistical analysis such as the Student t-test can determine the number of samples required within a given confidence limit of the mean, but may prove impractical due to time and budget constraints. A minimum of three conductivity and infiltration tests is suggested for each of the 2- to 10-ha sampling units used to collect soil samples for chemical analysis. If data from a given sampling unit vary by an order of magnitude, it may be desirable to run additional tests. One deep boring at each sampling unit should adequately describe the subsurface geology of the site. Some of the borings can be used to install monitoring wells for future use.

Little information exists regarding the relationship between measured hydraulic capacity and actual operating capacity. At present, it appears that loadings in the range of 5 to 25% of the measured infiltration rate will produce satisfactory results (U.S. EPA 1977). However, a careful hydrologic budget must be developed in order to avoid groundwater mounding problems.

CHRONOLOGY OF FIELD TESTING PROCEDURES

Level III field investigations should be performed in a chronology of four steps (Table 19).

Step 1 involves developing a base map from available published information. The base map can be drawn from overlays of topographic maps and aerial photographs or from soil survey information. The prepared map is used to define the location of soil examination sites on a grid system as well as random sampling points used to check expected soil boundaries.

Preliminary field investigations take place during step 2. Grid points are surveyed and marked, and the elevation of each point is determined. Soil cores are extracted at selected grid points and soil

Table 19. Chronology of field acquisition.

	Step 1
1.	Prepare soil maps from air photos, soil survey and topographic map overlays.
2.	Determine approximate soil boundaries and grid spacing, and location of monitoring points.
	Step 2
1.	Lay out grid and determine elevation of individual grid points.
2.	Conduct soil borings and describe soils at designated grid points. Note vegetation and farming practices in grid area.
3.	Install temporary groundwater monitoring wells.
	Step 3
1.	Develop topographic maps of soil surface elevations, impermeable horizon elevations, groundwater elevations and depth to bedrock.
2.	Analyze soil descriptions and correlate to known soil series.
3.	Develop soil map and indicate location of sampling units for each soil type.
4.	Determine which chemical and hydraulic parameters should be measured.
	Step 4
1.	Collect samples for chemical analysis.
2.	Conduct hydraulic tests at selected grid points.
3.	Conduct deep borings to determine subsurface geology.

boundary locations. Profile descriptions are prepared for each soil core and differences in vegetation and land management schemes are noted. If seasonally high groundwater tables are observed, temporary monitoring wells are installed at selected boring locations.

Data collected in the field investigations are analyzed in step 3. Soil profile descriptions are correlated to known soil series descriptions, and base maps are altered to show any soil inclusions not previously reported. Topographic maps showing groundwater or impermeable horizon contours are developed from the soil descriptions. Soil descriptions are used to determine the major soil water flow paths or indicate where additional hydraulic data are required to determine the flow paths. Waste parameters specified in the level II design process are analyzed to determine which soil chemical properties should be evaluated. Each soil type delineated in the base map is subdivided into sampling units either on a uniform grid basis or on differences in vegetation or management. The location of sampling points for the determination of soil hydraulic properties and subsurface geology is then specified for each sampling unit.

Step 4 provides the basic field information for the level III design. Results of the hydraulic and chemical soil tests will determine the required land area for the land limiting constituent. A cost-effectiveness analysis can compare the cost of alternatives for reducing the land-limiting constituent to the cost of installing the system without any modifications to the site or the waste stream. A detailed review of this procedure is presented by Overcash and Pal (1979). Design and final construction can commence once the necessary step 4 information has been acquired. In situations where innovative technologies are planned, it may be desirable to implement a pilot project prior to final construction in order to verify design parameters.

SUMMARY

The level I site analysis defines general land area requirements based on a preliminary limiting factor analysis. An evaluation of transmission distances will help identify the effective radius from a central wastewater collection point in which site investigations will take place. One possible approach would be to identify general land treatment costs and compare them to conventional treatment costs utilizing transmission distances as a variable.

Once an effective radius from the wastewater source has been identified, suitable sites can be screened on the basis of topography, land use and political considerations. Land areas considered suitable after this evaluation can be further screened on the basis of general soil suitability. The soil suitability evaluation can be the final cut in the level I selection of site alternatives.

The level II site evaluation is a detailed cost-effectiveness evaluation of the level I site candidates. This evaluation involves a preliminary design and cost analysis of the process alternatives which are technically feasible at each site candidate. The various design configurations available for a specific land treatment process and site alternatives are selected according to site characteristics and management considerations. Expected water quality, capital cost, and operation and maintenance costs of each design configuration, process and site candidate should be compared to select the most cost-effective, technically feasible option.

In addition, the level II site analysis involves an evaluation of the individual soil phases of each of the level I site alternatives. The level II site analysis should consider the problems associated with limiting soil phase properties. Potential responses to these problems should be identified and incorporated into a preliminary design of each of the site alternatives. A evaluation of each design alternative should then identify the feasibility of land treatment and t: : most cost-effective site option. Level III field investigations are then conducted at the chosen site.

Use of available published soil information does not preclude the necessity of field investigations for final design requirements. Published soil information at the soil association, series and phase level can provide the information necessary for a rational site selection procedure. A site selection approach based on soil survey information can be used when large land areas must be reviewed. Field investigations are more appropriate in systems requiring less than 4 ha.

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APPENDIX A. EXAMPLE OF LEVEL I AND LEVEL II SITE SELECTION PROCEDURES

INTRODUCTION

An example of the level I and level II procedures is presented in this section to illustrate the use of the site selection methodology. A hypothetical waste treatment problem is applied to an existing area in southern New Jersey. Only one conventional waste treatment system will be considered for comparison purposes.

PROBLEM DEFINITION

A regional wastewater treatment system has been proposed to service several communities and two military reservations located in the townships of New Hanover and North Hanover, Burlington County, New Jersey. The central collection point for the wastewater will be located at Cookstown. Design flows are 13,200 m^3/day, and effluent quality must meet the standards presented in Table A1. Waste characteristics and climatic considerations are presented in Table A2. Extended aeration with denitrification and ferric chloride ($FeCl_3$) addition was selected as the conventional alternative for cost comparison purposes based on effluent discharge requirements and waste characteristics. The CAPDET program was used to determine costs for the conventional alternative. The cost relationships developed for EPA (Reed et al. 1979) were used to determine the costs for the land treatment alternative.

PRELIMINARY LAND AREA EVALUATION

The preliminary land area evaluation is based on an analysis of design effluent qualities and a limiting factor analysis. General assumptions must be made at this point regarding hydraulic and nutrient loading limitations, which depend on the choice of site and vegetative cover. The level I analysis assumes that hydraulic limitations determine the land area required for overland flow and rapid infiltration processes. Land area requirements for the slow rate process are based on hydraulic or nutrient loading limitations. Hydraulic loadings will be assumed to be 60 cm/ha wk for rapid infiltration, 10 cm/ha wk for overland flow, and 5 cm/ha wk for slow infiltration. Nutrient loadings for slow infiltration will be based on 200 kg/ha yr of nitrogen. These assumptions will be refined in the level II analysis.

Table A3 indicates the land area required for the various processes and the expected effluent quality. Rapid infiltration and overland flow require considerably less land area than slow rate land treatment. However, slow rate treatment is the only process capable of meeting discharge requirements. A combination of overland flow followed by rapid infiltration may be capable of meeting discharge requirements and the use of the two processes should be considered.

IDENTIFICATION OF VIABLE TRANSMISSION DISTANCES

A comparison of typical slow rate costs to advanced wastewater treatment costs indicates that transmission distances greater than 16 km could prove cost-effective. An additional consideration is to locate sites within the political boundaries of the North Hanover township or the military reservations if possible. Figure A1 presents a map of the study area.

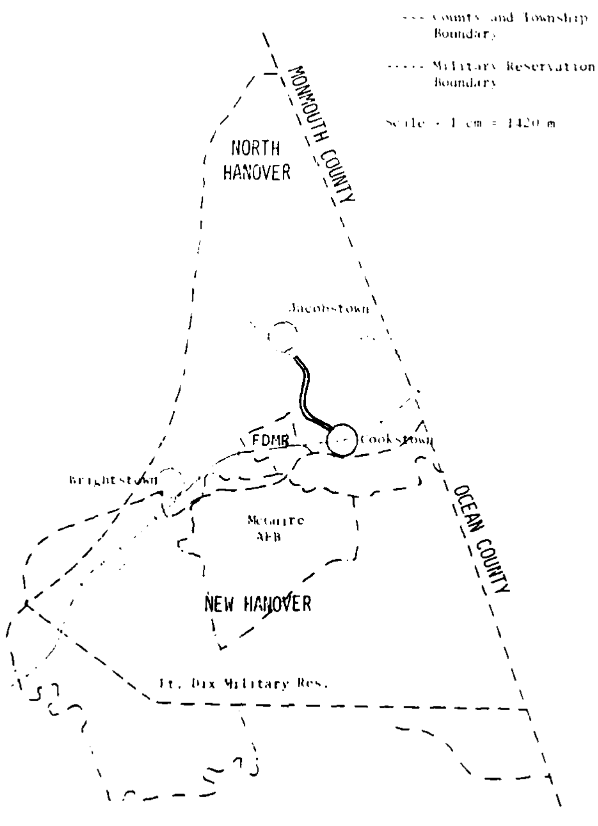

Figure A1. Study area.

TOPOGRAPHIC, LAND USE AND POLITICAL CONSIDERATIONS

A preliminary screening of the proposed study area is based on topographic and land use considerations. Political considerations define the boundaries of the study area. The topography of the area is generally flat with slopes less than 5%. Complex slopes sometimes exceeding 30% occur in scattered areas around stream tributaries. Agriculture is the primary form of land use in the study area with the exception of the military reservations. Large areas of wetlands occupy portions of the study area. Unique features of this area are the cranberry bogs situated in the wetlands.

Figure A2 indicates the areas that were excluded according to topographic and land use considerations. Areas with complex slopes, high residential densities or wetlands were excluded from further analysis.

HYDROGEOLOGY AND SOIL FEATURES

The geology of the area is composed of unconsolidated marine deposits typical of coastal plain landforms. The water-bearing stratum often occurs near the ground surface and is part of a large aquifer serving as a water

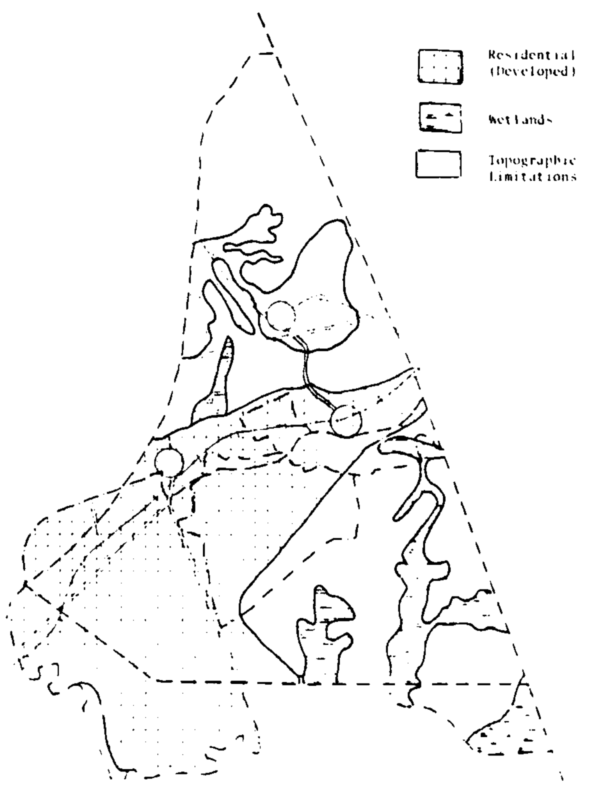

Figure A2. Level I land use screening.

supply for many communities in the state. Soils formed in the marine deposits tend to have moderate to rapid permeabilities in the surface horizons. Less permeable clayey subhorizons may be found in some soils in the study area.

Six soil associations occur in the study area (Fig. A3). The characteristics of the major soil series in each association are listed in Table A4 with the corresponding numerical rating value for their suitability for land treatment. Depth to bedrock in all cases is reported as greater than 1.5 m in the county soil survey.

Rating values for soil series were derived from Table 6. As the reported ranges for various soil properties did not match the ranges used in Table 6, rating values were adjusted subjectively. The Freehold soil series, for instance, has a range of limiting permeabilities of 0.5 to 15 cm/hr. The permeability rating values for this series for overland flow suitability could range from 7 to a value that would exclude the process from consideration. The surface horizon texture for the Freehold series is a fine sandy loam. The coarse texture of this horizon would suggest

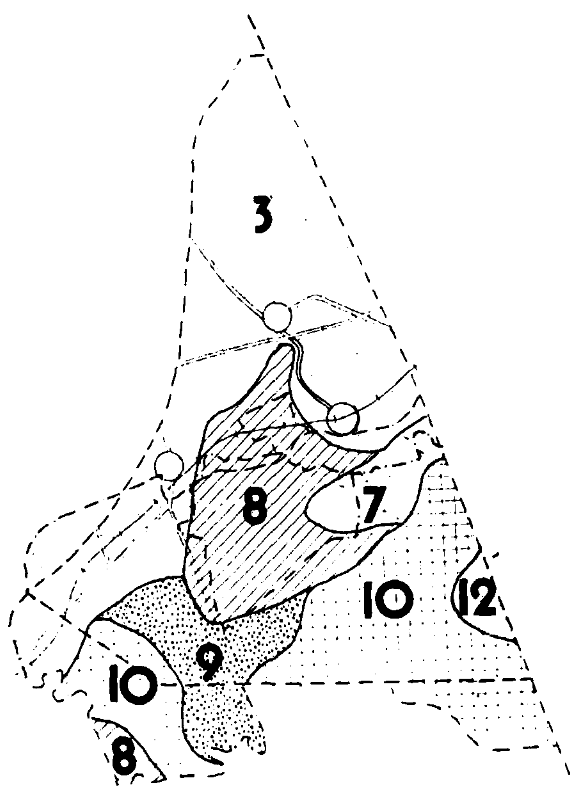

Figure A3. Soil associations.

moderate to rapid permeabilities. Hence, a rating value of 0 is assigned for the permeability rating for overland flow suitability.

All the major series of each soil association are suitable for slow infiltration, but not for overland flow. The major soil series in each soil association is suitable for rapid infiltration. The use of a combined overland flow and rapid infiltration system is excluded due to the lack of suitable soils for implementing overland flow. The potential exists to recover the effluent from a rapid infiltration system and attain additional wastewater renovation by using aquaculture or conventional wastewater treatment systems. This alternative will not be discussed in the example, due to the limitations of this report. Therefore, the soil suitability analysis indicates that the slow rate infiltration process is the only technically feasible land treatment alternative.

LEVEL I SITE SELECTION

The level I site candidates were selected from considerations regarding 1) land area requirements for the slow rate infiltration process, and 2) land areas not excluded in the topographic and land use evaluation. Four site alternatives exist with suitable soil characteristics and sufficient land area for slow rate land treatment (Fig. A4). Two sites are located within the boundaries of the military reservations and two sites are outside the military reservations.

Preliminary cost estimates indicate that slow rate land treatment is a cost-effective waste treatment alternative when compared to the conventional alternative. Estimated costs for slow rate are $0.40/m^3$ of wastewater. As slow rate land treatment appears technically and economically feasible, a detailed level II investigation of the level I site alternatives is conducted.

LEVEL II SITE CHARACTERISTICS

The level II site characterization should provide detailed information on the land use, vegetative cover and soil characteristics of the individual soil types at each site. The county soil survey was used to define the pertinent soil properties of the soil phases at each site. Vegetative cover and land use for the soil phases was determined from available aerial photographs. Updated aerial photographs or site visits would be necessary in an actual site evaluation procedure. A summary of

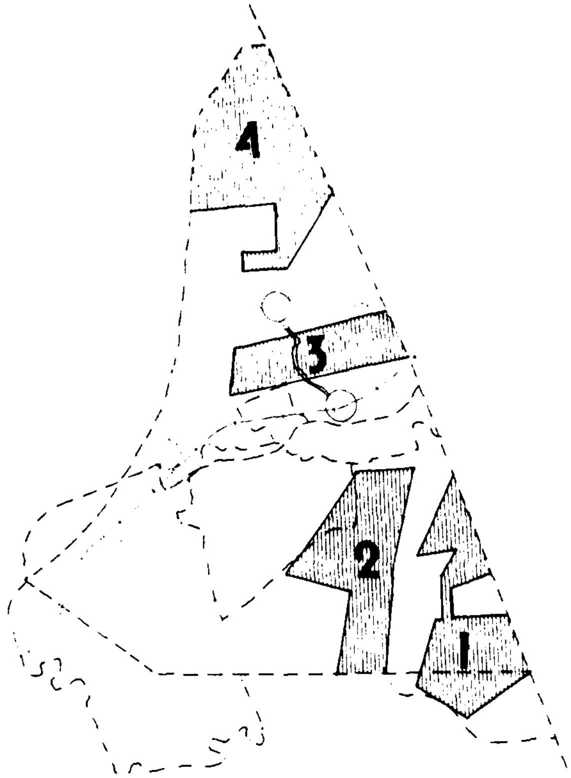

Figure A4. Level I site candidates.

the level II site characterization for each of the site alternatives is presented in Tables A5 - A8.

LEVEL II PROCESS DESIGN

The level I site characterization indicated overland flow is not technically feasible due to the moderate to rapid permeabilities of the major soil series of the soil associations located in the study site. An examination of the soil phase properties presented in Tables A5 - A8 verifies the level I conclusion. Suitable soil conditions exist for rapid infiltration, but the process cannot meet discharge requirements. Rapid infiltration, however, may prove to be a cost-effective form of pretreatment by reducing land area requirements for slow rate systems in which the limiting parameter is the nutrient loading. Process investigations for the level II site selection procedure will therefore consider a slow rate system and a combined rapid infiltration/slow rate system.

Land area requirements for slow rate were determined from hydraulic or nitrogen loading limitations. Hydraulic loadings were computed based on the permeability of the most limiting horizon of each soil type. Nitrogen loadings were computed based on crop uptake for several different preapplication and crop alternatives.

Table A9 presents the hydraulic assimilative capacity and drainage requirements of each of the soil phases located at each site. Due to the shallow hydraulic gradient (less than 3%) and climatic considerations, drainage was considered necessary for any soil phase with a groundwater table less than 1.5 m from the surface. Net inputs and outputs of water due to precipitation and evapotranspiration are approximately equal in Burlington County between May and October. Hence, in situations with a shallow groundwater table, additional inputs of water due to wastewater irrigation would result in groundwater mounding and potential surface ponding and runoff.

Weekly hydraulic loadings were computed based on 25% of the daily permeability for the most limiting horizon. Soil phases with shallow groundwater tables which could not be drained due to a high rate of groundwater recharge were excluded from the site selection process. Table A9 indicates that some of the soils exhibit a considerable range of permeabilities, but in general all the soils have a high hydraulic assimilation capacity and should not be hydraulically limited for slow infiltration.

Land area requirements were determined based on crop nitrogen requirements and preapplication systems. Crop selection was based on existing land use patterns. Sites 1 and 2 are predominantly forested due to the droughty nature of the soil and are not well suited to agricultural crops. The forested areas would be selectively cleared and planted with forage grasses to enhance nitrogen removal since mature tree stands have limited nitrogen requirements. The areas would be cleared to enable conventional harvesting equipment to enter and harvest the forage grasses two or three times a year. The sites would be operated on a year-round basis as the soils do not freeze in this area and can maintain their infiltration capabilities on a year-round basis. Hydraulic loads during the winter months would only be half the hydraulic loads during the summer months to account for the decrease in biological activity due to low temperatures.

Sites 3 and 4 are predominantly agricultural areas and are considered suitable for agricultural field crops. Corn and forage grasses, common field crops of the area, were selected for an economic analysis. Since the growing season for corn is shorter than for forage grasses, a shorter application period was selected for the corn alternative.

Two preapplication alternatives were considered for sites 1 and 2: (1) an aerated lagoon with a three-day detention time to minimize odors followed by storage, and (2) an aerated lagoon with a three-day detention time followed by rapid infiltration, recovery, and storage. The rapid infiltration alternative could reduce the nitrogen load by half, thereby reducing land area requirements for slow infiltration.

The rapid infiltration preapplication alternative was not considered for sites 3 and 4 as there are not any suitable soils for implementing rapid infiltration. Soils at these sites were limited by either high water tables or potentially low infiltration rates (0.5 cm/hr). Only site 1 has soils suitable for rapid infiltration (Lakehurst sands and Lakewood sands). The proximity of site 1 to site 2 makes rapid infiltration a potential preapplication alternative for site 2.

Table A10 summarizes field and total land area requirements, application periods and storage requirements for the various preapplication and crop alternatives. The associated hydraulic load per hectare per week was determined on the basis of the field area requirements and the application period. The hydraulic loads are well within the weekly hydraulic assimilation capacity of all the soil phases of each site alternative (Table A9). Nitrogen is therefore the limiting parameter for all the site alternatives.

An examination of the available land areas of suitable soils at each site indicates that site 3 does not have sufficient land area for either alternative C or D. However, site 4 does have sufficient land area for the field area requirements of alternatives C and D. Enough land area of unsuitable soils exists around site 4 to meet the buffer and storage area requirements.

Implementation of alternative A at sites 1 or 2 would require sufficient land areas available for both rapid infiltration and slow rate land treatment. Table A10 lists only land area requirements for slow infiltration. Land area requirements for rapid infiltration are a function of the soil hydraulic assimilation capacity and the loading rates which optimize nitrogen removal. Experience with previous systems indicates that approximately 50% nitrogen removal can be achieved at loading rates between 30 to 60 cm/ha wk. If an application rate of 30 cm/ha wk was selected, approximately 35 ha of field area and 50 ha of total land area would be required for rapid infiltration.

Sufficient land area exists at site 1 to implement alternative A but not alternative B. Sufficient land area exists at site 2 to implement alternative A, but the rapid infiltration site would have to be located at site 1 due to the shallow groundwater table which exists on all the soils at site 2. Due to the proximity of the two sites, alternative B could be implemented by combining the two sites. Table A11 summarizes the land area and drainage requirements for each of the site and crop alternatives.

COST-EFFECT... ESS EVALUATION

The cost-effectiveness evaluation of the site and crop alternatives involves an evaluation of the cost of the individual system components. Several alternatives may exist for an individual component such as distribution, and the most cost-effective option should be selected. Costs for the site and crop alternatives were evaluated using Reed et al. (1979). Costs were updated to sewage treatment costs for December 1978 using cost indices presented in this reference.

The land area and drainage requirements for each treatment option are presented in Table A11, and storage requirements are presented in Table A10. Table A12 describes transmission and site clearing requirements for each treatment alternative. Figure A5 illustrates the flow schematic for the six treatment schemes.

The system components and costs for each of the treatment schemes are presented in Table A13.

Table A14 summarizes the cost of the various treatment alternatives. Alternative 4D is the most cost-effective option. Alternatives 1A and 4C are within 7% of the total cost for alternative 4D. A potential 15% error is assumed in preliminary cost estimates. Therefore, alternatives 1A and 4C are also considered cost-effective.

Alternative 1A offers the advantage of low visibility, does not remove any land from active agricultural production, and provides greater system flexibility and reliability because of the rapid infiltration pretreatment. Options 1A and 4C have lower operation and maintenance cost than 4D. These considerations will affect the ultimate choice of a level III site alternative. Public participation at this point in the level II site selection procedure would provide valuable input into selecting a final site candidate.

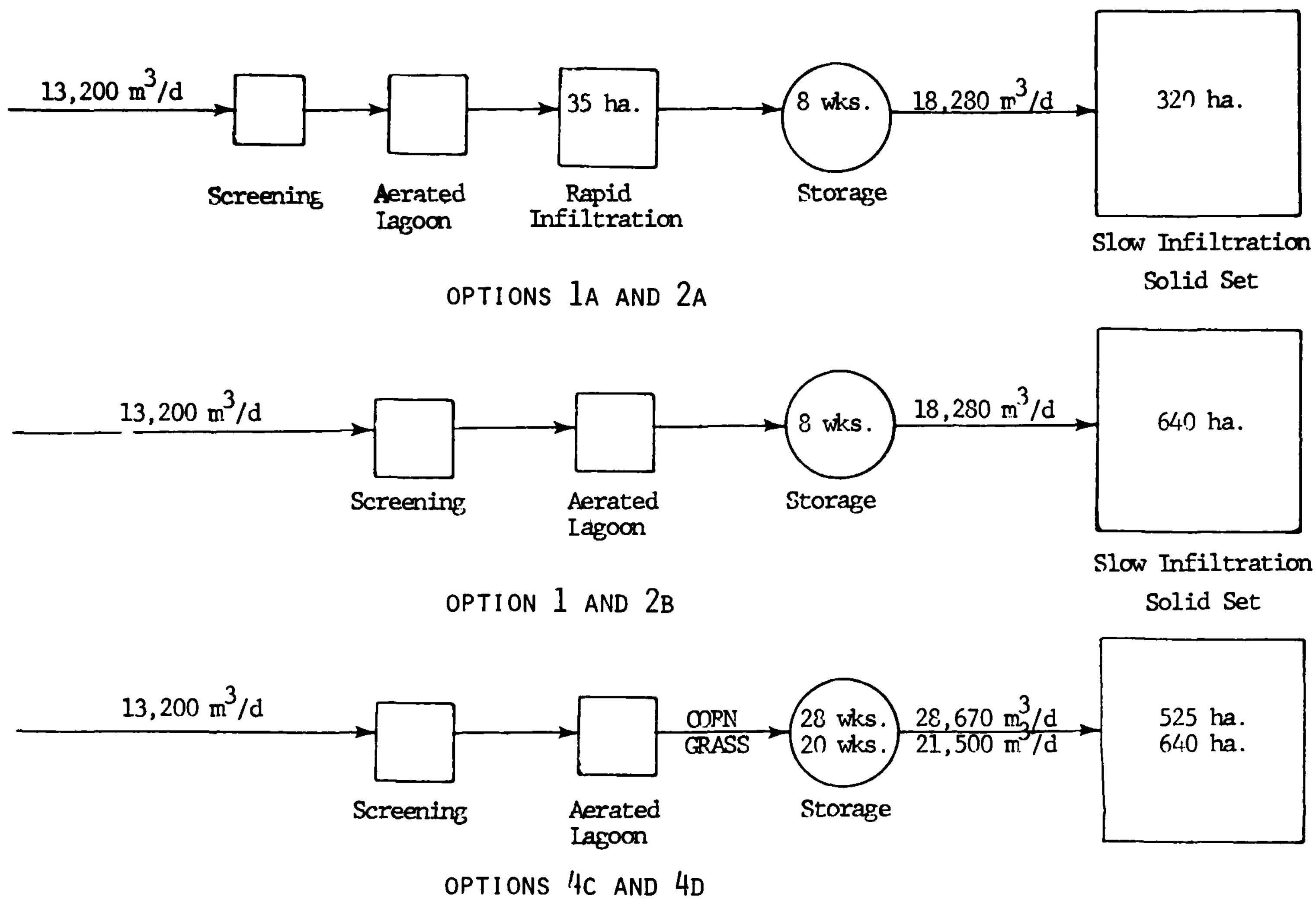

Figure A5. Flow schematic for treatment alternatives.

Table A1. Effluent quality limitations.

Discharge to surface bodies of water:

Parameter	Concentration (mg/L)
BOD	20
SS	20
Total P	1
TKN	2
Total N	5

Discharge to groundwater:

Parameter	Concentration (mg/L)
NO3-N	10
Other Parameters	Drinking water standards

Table A2. Waste and climatic characteristics.

RAW WASTE CHARACTERISTICS

Parameter	Concentration (mg/L)
BOD_5	185
SS	170
T.S.	630
TKN	12
NH_3	18
Total P	8

CLIMATE CHARACTERISTICS

Month	Average Daily Max. Temperature (°C)	Average Daily Min. Temperature (°C)	Average Monthly Precipitation (cm)	Average Monthly Evapotranspiration (cm)
January	6	-4	8.5	0
February	6	-4	7.5	3.1
March	11	0	9.5	4.7
April	18	4	8.7	6.5
May	24	10	8.7	7.1
June	28	15	9.0	9.5
July	30	18	11.5	12.5
August	29	17	12.5	11.7
September	26	13	9.8	8.1
October	20	7	7.8	7.5
November	14	2	8.7	5.1
December	7	-3	7.8	2.5

Table A3. Level I evaluation of land area requirements and expected effluent qualities.

Land Area Requirements Based on Hydraulic Loading Limitations

Process	Hydraulic loading (cm/wk)	Non-operating time (wk)	Field area requirement (ha)
Rapid infiltration	60	2	16
Overland flow	10	20	150
Slow rate	5	20	300

Land Area Requirements Based on Nitrogen Loading Limitations

Process	Nitrogen loading (kg/ha-yr)	Field area requirement (ha)
Slow rate	200	722

Expected Quality of Treated Water From Land Treatment Processes*
(mg/L)

Constituent	Slow rate[a]		Rapid Infiltration[b]		Overland flow[c]	
	Average	Maximum	Average	Maximum	Average	Maximum
BOD	<2	<5	2	<5	10	<15
Suspended solids as N	<2	<5	2	<5	10	<20
Ammonia nitrogen as N	<0.5	<2	0.5	<2	0.8	< 2
Total nitrogen as N	3	<8	10	<20	3	< 5
Total phosphorus as P	<0.1	<0.3	1	<5	4	< 6

a. Percolation of primary or secondary effluent through 1.5 m of soil.
b. Percolation of primary or secondary effluent through 4.5 m of soil.
c. Runoff of comminuted municipal wastewater over about 45 m of slope.
* U.S. EPA et al. (1977).

Table A4. Chracteristics of the major soil series of each soil association.

Soil Association	Soil Series	% of Association Comprised By The Series	Limiting Permeability (cm/hr)	Slope %	Rating Value S.R.	O.F.	R.I.
3	Freehold	25	0.5-15	0-5	21	16	18
	Holmdel	20	0.5-15	0-5	21	16	18
	Adelphia	15	0.5-5.0	0-5	21	16	16
7	Pocomoke	40	1.5-5.0	0-2	24	16	21
	Pasquotank	35	1.5-5.0	0-2	24	16	21
	Fallsington	10	1.5-5.0	0-2	24	16	21
8	Nixonton	40	0.5-5.0	0-2	22	16	19
	Westphalia	20	0.5-5.0	0-5	21	16	17
9	Downer	60	1.5-5.0	0-5	23	16	21
	Sassafras	20	0.5-5.0	0-5	21	17	19
	Woodstown	10	0.5-15	0-5	22	15	20
10	Lakehurst	40	5-15+	0-5	21	E	23
	Lakewood	30	5-15+	0-10	21	E	23
	Evesboro	20	1.5-15	0-5	22	E	21
12	Atsion	50	5-15+	0-2	21	E	23
	Muck	15	*	0-2	a	a	a
	Alluvial Land	10	15+	0-2	20	E	23

* highly variable
a-no rating possible due to variable soil conditions

Table A5. Level II site characterization for site 1.

Soil Phase	Map Symbol	Areal Extent (ha)	Predominant Vegetative Cover	Erosion Hazard	Flooding Frequency	Depth to Seasonal Groundwater (m)	Slope	Horizon Depth (cm)	Horizon* Texture	Horizon Permeability (cm/hr)
Atsion Sand	At	250	Forest	Slight	Frequent	0.3	0-2	0-150	S or LS	5-15+
Lakehurst Sand	La[A]	160	Forest	Slight	Slight	0.3-1.0	0-3	0-150	S or F.S.	15+
Lakewood Sand Loamy Substratum	Lv[B]	150	Shrubs & Trees	Slight	Slight	>1.5	0-5	0-100 100-150	S or F.S. SL	15+ 5-15
Lakewood Sand	Lt[B]	220	Forest	Slight	Slight	>1.5	0-5	0-150	S or F.S.	15+

* F-Fine
S-Sand
L-Loam
C-Clay

A soil texture denoted by 2 or more letters describes the combination of characteristics identified by the letters. FSL would indicate a soil horizon with a fine sandy loam texture.

Table A6. Level II site characterization for site 2.

Soil Phase	Map Symbol	Areal Extent (ha)	Predominant Vegetative Cover	Erosion Hazard	Flooding Frequency	Depth to Seasonal Groundwater (m)	Slope (%)	Horizon Depth (cm)	Horizon* Texture	Horizon Permability (cm/hr)
Lakehurst Sand (thick surface)	Ll[A]	230	Forest	Slight	Slight	0.5-1.5	0-3	0-150	S or F.S.	15+
Lakehurst Fine Sand	Ln[A]	160	Forest	Slight	Slight	0.5-1.5	0-3	0-150	F.S. or S	15+
Atsion Fine Sand	Av	275	Forest	Slight	Frequent	0.3	0-2	0-60 60-150	F.S. S	5-15 15+

* F-Fine
S-Sand
L-Loam
C-Clay

A soil texture denoted as FSL would be a fine sandy loam. Two soil textures jointed together denotes thin alternating layers of the two textures.

Table A7. Level II site characterization for site 3.

Soil Phase	Map Symbol	Areal Extent (ha)	Predominant Vegetative Cover	Erosion Hazard	Flooding Frequency	Depth to Seasonal Groundwater (m)	Slope (%)	Horizon Depth (cm)	Horizon* Texture	Horizon Permeability (cm/hr)
Pemberton Sand	Pb[A]	110	Vegetable Crops	Moderate	Slight	0.3-1.0	0-5	0-60 60-85 85-150	S or LS FSL S & SL	5-15 1.5-5 5-15
Pemberton Sand Thick Surface	Pc[A]	40	Woodland	Moderate	Slight	0.3-1.0	0-5	0-85 85-110 110-150	S FSL S and SL	
Holmdel Fine Sandy Loam	Hd[A]	35	Grain Crops	Slight	Slight	0-3-1.0	0-2	0-25 25-85 85-150	FSL SL or SCL SL and LS	0.5-15 0.5-1.5 1.5-15
Freehold Fine Sandy Loam (0-2%)	Ff[A]	35	Vegetable Crops	Slight	Slight	>1.5	0-2	0-37 37-87 87-150	FSL SL or SCL LS and FSL	0.5-15+ 0.5-15+ 1.5-15
Freehold Fine Sandy Loam (2-5%)	Ff[B]	35	Vegetable Crops	Moderate	Slight	>1.5	2-5	Same as above	Same as above	Same as above
Shrewsbury Fine Sandy Loam	Sn	110	Shrubs & Trees	Slight	Seasonally ponded	0.3	0-2	0-35 35-80 80-150	FSL or L FSCL LS and SL	1.5-5.0 1.5-5.0 5.0-15

* F-Fine, S-Sand, L-Loam, C-Clay. A soil texture denoted as FSL would be a fine sandy loam. Two soil textures joined together denotes thin alternating layers of the two textures.

Table A8. Level II site characterization for site 4.

Soil Phase	Map Symbol	Areal Extent (ha)	Predominant Vegetative Cover	Erosion Hazard	Flooding Frequency	Depth to Seasonal Groundwater (m)	Slope (%)	Horizon Depth (cm)	Horizon* Texture	Horizon Permeability (cm/hr)
Collington Fine Sandy Loam (0-2%)	Cn^A	150	Vegetable Crops	Slight	Slight	>1.5	0-2	0-35 35-95 95-150	FSL L or FSCL LS and SL	1.5-15 0.5-15 1.5-15
Collington Fine Sandy Loam (2-5%)	Cn^B	350	Field Crops	Moderate	Slight	>1.5	2-5	same as above	same as above	same as above
Collington Loam (0-2%)	Co^A	75	Field Crops	Slight	Slight	>1.5	0-2	0-35 35-95 95-150	FSL L or FSCL LS and SL	1.5-15 0.5-15 1.5-15
Collington Loam (2-5%)	Co^B	100	Field Crops	Moderate	Slight	>1.5	2-5	same as above	same as above	same as above

* F-Fine, S-Sand, L-Loam, C-Clay. A soil texture denoted as FSL would be a fine sandy loam. Two soil textures joined together denotes thin alternating layers of the two textures.

Table A9. Weekly hydraulic assimilation capacity of soil phases.

Site	Soil Phase	Limiting Permeability (cm/hr)	Depth to Groundwater (m)	Drainage Requirement	Weekly Hydraulic Assimilation Capacity (cm/ha wk)
1	Atsion Sand	5-15	0.3	Cannot be Drained	Excluded
1	Lakehurst Sand	15+	0.3-1.0	Yes	90+
1	Lakewood Sand Loamy Substratum	5-15	>1.5	No	30-90
1	Lakewood Sand	15+	>1.5	No	90+
2	Atsion Fine Sand	5-15	0.3	Cannot be Drained	Excluded
2	Lakehurst Sand (thick surface)	15+	0.5-1.5	Yes	90+
2	Lakehurst Fine Sand	15+	0.5-1.5	Yes	90+
3	Pemberton Sand	1.5-5	0.3-1.0	Yes	9-30
3	Pemberton Sand (thick surface)	5-15	0.3-1.0	Yes	30-90
3	Holmdel Fine Sandy Loam	0.5-1.5	0.3-1.0	Yes	3-9
3	Freehold Fine Sandy Loam	0.5-15	>1.5	No	3-90
3	Shrewsbury Fine Sandy Loam	1.5-5.0	0.3	Yes	9-30
4	Collington Fine Sandy Loam	0.5-15	>1.5	No	3-90
4	Collington Loam	0.5-15	>1.5	No	3-90

Table A10. Land area requirements for slow infiltration based on nitrogen limitations.

Alternative	Preapplication	Vegetation	Application Period (wks)	Storage Requirement (wks)	Storage Requirement (ha)	Nitrogen Loading (kg/ha yr)	Field Area (ha)	Field Area & Buffer	Hydraulic Loading (cm/ha wk)
A	Aerated Lagoon + Rapid Infiltration + Storage	Forest + Forage Grasses	50	8	25	225	320	400	4 cm/ha-24 wks 2 cm/ha-26 wks
B	Aerated Lagoon + Storage	Forest + Forage Grasses	50	8	25	225	640	700	2 cm/ha-24 wks 1 cm/ha-26 wks
C	Aerated Lagoon + Storage	Corn	24	28	90	275	525	600	3.8
D	Aerated Lagoon + Storage	Forage Grasses	32	20	65	225	640	700	2.4

Table A11. Land area and drainage requirements for each alternative.

Site	Alternative	Field Area (ha)	Total Land Area (ha)	Field Area Which Must Be Drained (ha)
1	A	355	475	None (35 ha of R.I)
2 + R.I on Site 1	A	355	475	320 + 35 ha of R.I
1 + 2	B	640	725	270
4	C	525	690	None
4	D	640	765	None

Table A12. Site characteristics of treatment alternatives.

OPTION 1A
Transmission from waste source to preapplication/storage site requires 2000 meters of 50 centimeter diameter gravity pipe and 3520 meters of 150 centimeter diameter pipe with a static head of 7 meters.
Rapid infiltration site and storage area is covered with brush and trees. Slow rate site is predominantly forested.
OPTION 2A
Transmission to preapplication/storage site is the same as 1A. Transmission to S.R site from the preapplication/storage site requires 2400 meters of 40 cm diameter force main with a 7 meter static head.
Slow rate site is predominantly forested.
OPTION 1 & 2B
Transmission to preapplication/storage site requires 2560 m of 50 cm diameter gravity pipe. Transmission from storage to slow rate site requires 800 meters of 50 cm diameter force main with a static head of 7 meters.
OPTION 4C and 4D
Transmission to preapplication/storage site requires 4640 meters of 50 cm diameter force main with a static head of 35 meters.
Slow rate site is in field crops (no site clearing required)

Table A13. Cost analysis of treatment options.

Calculation Date - Dec. 1978

Sewage Treatment Plant Update Index - $\frac{314.1}{177.5}$ - 1.77

Sewer Construction Cost Update Index - $\frac{334.5}{194.2}$ - 1.72

Operating and Maintenance Cost Update Index - 1.74

<u>OPTION 1A</u>

Rapid Infiltration Followed by Forest Irrigation

Component	Capital	O&M
1. Gravity Transmission - raw sewage 2000 m., 50 cm., peak factor of 2	277,040	1,148
2. Pumping, raw sewage TDH - 15 m., peak factor of 2	407,100	22,223
3. Force Main, raw sewage 3520 m., 50 cm., peak factor of 2	539,440	1,212
4. Preliminary Screening	115,050	18,966
5. Partial Mix Aeration Pond 3-day detention, asphalt liner	220,010	37,715
6. Rapid Infiltration		
A-Pumping from lagoon to R.I basins TDH 15 m., operating head 3 m, pump facilities built into side of dike	226,560	12,971
B-Force mains from lagoon to R.I basins or bypass to storage 500 m, 40 cm	56,760	142
C-Field Preparation 35 ha, brush and trees	68,800	
D-Distribution	344,000	25,927
E-Recovery Wells	28,320	16,078
F-Force mains to storage ponds	22,700	57
7. Storage 8 wks, 739,200 m^3, asphalt lining	1,324,400	99
8. Pumping for S.I. Distribution TDH 30 m, peak factor 1.5 Structure built into dike of storage pond	288,800	33,190
9. Field Preparation 3/4 of field area cleared and grubbed	1,548,000	
10. Distribution Solid set system, irregular shaped field	3,465,800	88,128
11. Administrative and Lab Facilities	141,600	22,533
12. Monitoring wells 15 wells, 10 m deep	18,060	2,556
13. Roads and Fencing	326,800	10,022
14. Land Total Area - 475 ha, leased at $20/ha Total cost = $\frac{\text{Annual Cost}}{\text{Capital Recovery Factor (CRF)}}$ CRF - 8%, 20 yrs = .1019	93,230	

Table A13. (continued).

OPTION 2A

Rapid Infiltration Followed by Forest Irrigation

1. Gravity Transmission - raw sewage 2000 m, 50 cm, peak factor of 2	227,040	1,148
2. Pumping - raw sewage TDH - 15 m, peak factor of 2	407,100	22,228
3. Force Main - raw sewage 3520 m, 50 cm, peak factor of 2	539,440	1,212
4. Preliminary screening	115,050	18,966
5. Partial mix aeration pond 3-day detention, asphalt liner	220,910	37,715
6. Rapid Infiltration		
A- Pumping from lagoon to R.I basins	226,560	12,971
B- Force mains from lagoon to R.I basins or bypass to storage	56,760	142
C- Field preparation 35 ha, brush and trees	68,300	
D- Distribution	344,000	28,927
E- Recovery wells	28,320	16,078
F- Force mains to storage ponds 200 m, 40 cm	22,700	57
7. Storage 8 weeks, 739,200 m^3, asphalt lining	1,324,400	99
8. Pumping for S.I. Distribution TDH 30 m, peak factor 1.5 Structure built into dike of storage pond	288,800	33,190
9. Force main to application area 2400 m, 40 cm	272,430	689
10. Field preparation 3/4 of field area cleared and grubbed	1,548,000	
11. Distribution Solid set system, irregular shaped field	5,465,300	88,128
12. Recovery, underdrains 120 m spacings, 320 ha	378,400	20,886
13. Administrative and Lab Facilities	141,600	22,535
14. Monitoring wells 15 wells, 10 m deep	18,060	2,558
15. Roads and fencing	326,300	16,022
16. Land Total area - 475 ha, leased at $20/ha Total cost = Annual Cost / Capital Recovery Factor (CRF) CRF - 8%, 20 yrs - 0.1019	93,230	

$$\text{Total cost} = \frac{\text{Annual Cost}}{\text{Capital Recovery Factor (CRF)}}$$

Table A13. (continued).

Component	Capital	O&M
OPTION 1 and 2B — Forest Irrigation		
1. Gravity transmission to preapplication, storage - 2560 m, 50 cm, peak factor of 2	290,610	1,470
2. Preliminary screening	115,050	18,966
3. Aeration pond, 3-day detention	220,010	37,715
4. Pump to storage 15 m head, 5 m operating capacity	226,560	12,971
5. Force main 200 m, 40 cm	22,700	57
6. Storage - 8 wks	1,324,400	5,456
7. Pumping for S.I Distribution 30 m design head, peak factor 1.5	288,800	53,190
8. Field preparation - 3/4 total area	3,268,000	
9. Distribution - solid set system, irregular shaped fields	7,012,200	155,904
10. Recovery - underdrains 270 ha	344,000	12,919
11. Laboratory Facilities	141,600	22,553
12. Roads and Fencing	533,200	18,096
13. Monitoring	18,060	2,558
14. Land Total area 725 ha, leased at $20/ha CRF = 0.1019	142,300	
OPTION 4C — Slow Infiltration - Corn		
1. Pumping - raw sewage TDH 30 m, peak factor of 2	477,900	44,152
2. Force main - raw sewage 4640 m, 50 cm	711,090	485
3. Preliminary Screening	115,050	18,966
4. Aeration pond 3-day detention, ashpalt liner	220,010	37,715
5. Pumping to storage area TDH-15 m, 5 m operating capacity	226,560	12,971
6. Force main to storage 200 m, 40 cm	22,700	57
7. Storage $2.4 \times 10^6\ m^3$, asphalt liner	4,248,400	13,300
8. Pumping for S.I. Distribution TDH-30 m., peak factor 2 operating period - 24 wks Built into dike of storage pond	382,320	22,654
9. Field preparation grass only, 525 ha.	11,180	

Table A13. (continued).

OPTION 4C (continued)

Component		Capital	O&M
10. Distribution			
Option 1 - Ridge and Furrow			
A- Field grading, 200 m^3/ha		243,600	
B- Gated pipe - 150 m furrow spacing, irregular field		827,750	515,488
	Total	1,071,350	515,488
	Present Worth	5,058,760	
Option 2			
C- Solid set, irregular field		5,031,000	133,719
	Present Worth	6,543,260	
Option 3			
D- Center pivot, irregular field		1,583,400	149,857
Force main, 100 m, 30 cm		14,760	54
	Present Worth	3,069,120	
(Option 3 is most cost-effective. Select center pivot)			
11. Laboratory facilities		141,600	22,553
12. Roads and fencing		473,000	15,216
13. Monitoring		18,060	2,538
14. Land	Present Worth	534,590	
Total area 690 ha, $2,000/ha			
Present worth = present worth factor (*PWF*)[*salvage value*]			
Salvage value = 1.806 (present price) 3%, 20 yrs			
PWF 8%, 20 yrs = .2145			

OPTION 4D

Slow Infiltration - Forage Grasses

Component	Capital	O&M
1. Pumping - raw sewage TDH 50 m, peak factor of 2	477,900	44,152
2. Force main - raw sewage 4640 m, 50 cm	711,099	485
3. Preliminary screening	115,050	18,966
4. Aeration pond	220,010	37,715
5. Pumping to storage area TDH-13 m, 5 m operating capacity	226,560	12,970
6. Force main to storage 200 m, 40 cm	22,700	57
7. Storage 1.85 x $10^6 m^3$, asphalt liner	3,010,000	10,657
8. Pumping for S.I. Distribution TDH-30m, peak factor 2, operating period - 24 wks built into dike of storage pond	382,320	22,654
9. Force main to S.I. Distribution 100 m, 30 cm	14,760	54

Table A13. (continued).

	OPTION 4D (continued)		
	Component	Capital	O&M
10.	Field preparation grass only, 640 ha	12,900	
11.	Distribution, center pivot, irregular field	2,012,400	175,390
12.	Administrative and lab facilities	141,600	22,535
13.	Roads and fencing	533,200	18,100
14.	Monitoring	18,060	2,560
15.	Land - 765 ha, $2,000/ha Present Worth	592,700	

Table A14. Summary of treatment alternative costs (Dec. 1978).

System Components	ALT. 1A Capital	ALT. 1A O&M	ALT. 2A Capital	ALT. 2A O&M	ALT. 1&2B Capital	ALT. 1&2B O&M	ALT. 4C Capital	ALT. 4C O&M	ALT. 4D Capital	ALT. 4D O&M
Transmission	845,940	2,560	1,118,390	2,040	313,310	1,530	748,550	580	748,550	580
Pumping	922,460	68,390	922,460	68,390	515,360	46,160	1,086,780	87,330	1,086,780	87,330
Preapplication TMT	775,380	101,690	755,380	101,690	335,060	56,680	335,060	56,680	335,060	56,680
Storage	1,324,400	5,450	1,324,400	5,450	1,324,400	5,460	4,248,000	13,300	3,010,000	10,660
Field Preparation	1,548,000		1,548,000		3,268,000		11,180		12,900	
Distribution	3,465,000	82,130	3,465,000	82,130	7,012,200	155,900	1,583,406	149,860	2,012,400	175,390
Recovery			378,400	20,880	344,000	12,920				
Lab Facilities	141,600	22,530	141,600	22,530	141,600	22,530	141,600	22,530	141,600	22,530
Roads and Fences	326,800	10,020	326,800	10,020	533,200	18,100	473,000	15,220	533,200	18,100
Monitoring	18,060	2,560	18,060	2,560	18,060	2,560	18,060	2,560	18,060	2,560
Crop Revenue								-52,500		-32,000
Subtotal	9,367,640		10,018,490		13,805,190		8,645,630		7,898,550	
Service & Interest	2,810,290		3,005,550		4,141,560		2,593,690		2,369,560	
Subtotal	12,177,750	295,330	13,024,040	315,690	17,946,750	321,840	11,239,320	292,560	10,268,110	341,830
Land	93,230		93,230		142,300		534,590		592,700	
Total Costs	12,270,980	295,330	13,117,270	315,690	18,089,050	321,840	11,773,910		10,860,810	
Total Present Worth	15,169,210		16,215,310		21,243,520		14,674,400		14,215,370	

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