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**SLUDGE APPLICATION SITE SCREENING USING A
GEOGRAPHIC INFORMATION SYSTEM**

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SUMMARY:

A GIS technique has been developed to identify the best sites for land application of sludge. Areas are ranked by determining a Suitability Index for Land Application of Sludge (SILAS) value. The SILAS methodology, applied to 587 square miles in Centre County, PA streamlined the site selection process by eliminating non-permittable or marginal tracts from consideration.

KEYWORDS:

Sludge, GIS, land application, SILAS, Soil Pollutant Attenuation Potential.

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Abstract

Geographic Information Systems (GIS) represent a powerful tool for making decisions concerning the use of natural resources. A GIS is a computerized system that allows geographically registered information to be stored, manipulated, and analyzed for the generation of interpretive maps and associated statistics. A technique using GIS has been developed to systematically evaluate large land areas to find the best potential sites for land application of municipal sludge. Areas are ranked by determining a Suitability Index for Land Application of Sludge (SILAS) value. The SILAS value is comprised of a soil pollutant attenuation parameter and a factor indicating a site's vulnerability to ground water pollution. This information is integrated with land use and topographic data layers to identify the most promising disposal areas that also meet minimum regulatory criteria.

The SILAS methodology was applied to a 587 square mile area in Centre County, PA of which 37% (139,000 acres of forest and agricultural lands) was found to meet minimum state regulatory criteria. Only 24,100 acres (6.4%) were ranked in the top three SILAS categories, representing the best areas for sludge application. Detailed field investigation of a highly-rated area confirmed the validity of the model. This screening procedure streamlined the site selection process by eliminating non-permittable or marginal tracts from consideration. Moreover, it proved valuable in communicating to landowners and the general public that extensive efforts were made to insure that municipal sludge utilization was to be accomplished in an environmentally sound manner.

SLUDGE APPLICATION SITE SCREENING USING A GEOGRAPHIC INFORMATION SYSTEM

INTRODUCTION

The estimated annual sewage sludge production in the United States approaches 7 million dry tons (USEPA, 1983). This figure will continue to increase as higher wastewater treatment efficiencies are mandated by regulatory agencies. At the present time, most municipal sewage treatment plant sludges are disposed of by incineration, landfilling, ocean dumping, or land application methods. According to the U.S. Environmental Protection Agency, land disposal application methods are being increasingly adopted by municipalities. Approximately 40 percent of the U.S. sludge production is land treated (USEPA, 1983). The reason for this interest is the emphasis on recycling of waste materials and cost effectiveness of land application. Land-based utilization methods are the only disposal options which beneficially recycle this waste material. Increasing energy costs for incineration, conservation of valuable landfill space, and restrictions on ocean dumping will undoubtedly lead to even more interest in land disposal (Elliott, 1986).

A principal advantage of agricultural or forest land sludge utilization projects is that municipalities usually do not have to pay for access to the sites. Rural property owners often voluntarily participate in municipal sludge recycling programs in return for the benefit of the nutrients supplied by the sludge application. However, in recent years growing public concern over environmental pollution has caused some landowners to lose interest. In some cases, municipalities have purchased agricultural lands to guarantee access to a disposal site. Population pressures on rural areas coupled with negative public perceptions regarding sludge disposal will likely force more municipalities to purchase land for sludge disposal. Purchase of suitable farm acreage or forest land for the purpose of recycling sludge nutrients is a costly investment for municipalities, justifying a rigorous and thorough site selection process.

Traditionally, site selection has focused almost exclusively on land costs, nearness to waste sources, ease of acquiring land, and ease of site approval. Sites located by these criteria have historically been problematic (Fuller and Warrick, 1985). Screening for potential sites is often accomplished by "word-of-mouth" inquiries, using regulatory limits, together with manual reviews of existing topographic, soils, and land use maps. This approach is a time-consuming "hit or miss" methodology which only accidentally identifies the "optimum" site. Often the nearest location to the sewage treatment plant known to be available which meets the minimum regulatory requirements is selected. Beyond this, little or no consideration is given to minimizing environmental pollution risk.

A more rational site screening approach is needed. It is suggested that recent developments in Geographic Information Systems (GIS) technology, micro-computer hardware, and environmental pollution risk modeling may be employed to accomplish comprehensive preliminary site screening. The GIS approach involves the creation of a computerized database with spatial information registered to a geographic coordinate system. In general, a GIS (which may reside on a micro-, mini, or mainframe computer) is designed to store, process, retrieve, manipulate, and display spatially-referenced data. Various maps and tables can be generated. In situations where complex environmental relationships exist, data reflecting different aspects of the physical environment can be used more effectively in combination than separately. One of the primary functions of a GIS is the combination and evaluation of disparate data sets for the purpose of providing "new", composite information. Land use planners are increasingly turning to GIS technology to integrate huge quantities of information and synthesize relationships which enable objective, rational planning decisions.

Younos and Metz (1987) recently used the Virginia Geographic Information System (VIRGIS) database and the Map Analysis Package (MAP) to identify lands best suited for agricultural application. The methodology consisted of successive area elimination screenings based on U.S. Environmental Protection Agency guidelines. Data layers in the study included: slope, soil permeability, seasonal groundwater table depth, buffer distances to streams, and land use. The study concluded: "GIS appears to be a very useful and cost-effective tool for site selection for land application of wastes".

The objective of this work was to develop a GIS methodology for screening large areas to locate sites which not only meet regulatory criteria, but also minimize the risks of environmental pollution associated with land application of sludge. A second objective was to demonstrate GIS procedures to be employed for effective application of the screening analysis. Finally, evaluation of a 587 square mile study area located in eastern Centre County, Pennsylvania was used to assess performance of the model and its practical application.

PROCEDURES

The degree of environmental risk from waste land application is inextricably related to site characteristics. This concept is fundamental to all of the "environmental risk indexing" methods associated with waste disposal and handling, and is the basis for site criteria requirements established by regulatory agencies. It is hypothesized here that certain site factors may be generally identified, objectively ranked, and combined into a single "Suitability Index for Land Application of Sludge" (SILAS) which will enable one to judge the relative environmental desirability of one site over another.

Key factors selected for the SILAS model were grouped into four general categories: Applicable regulatory criteria, land use and topography, soil pollutant attenuation potential (SPAP), and ground water pollution potential (GWPP). For this study, only agricultural and forest lands with slopes less than 25% were deemed suitable for sludge utilization. To identify these areas, 1985 land use data was obtained from the county planning commission. Digitizing of the county maps enabled delineation of land uses into 16 categories including agricultural land, forest land, urban areas, single and multi-family residential, recreation, transportation, water, and several other categories. Principal state and township roads were also digitized. Digital elevation data for the study area from the US Geological Survey, was obtained from the Pennsylvania State University Environmental Resource Research Institute. A Digital Elevation Model (DEM) was used to generate slope information from the elevation data set using a 1% slope class interval.

Table 1 summarizes the Pennsylvania Department of Environmental Resources (PaDER) site suitability guidelines. The SPAP ranking system used in the study follows the methodology described by Madison (WIS-DNR, 1985). The SPAP index is a relative value allowing comparative evaluation of differing soil mapping units for sludge renovative capacity. Madison's model recognizes seven physical and chemical characteristics of the soil solum (A and B horizons): texture, organic matter content, and pH of the surface (A) horizon, texture of the subsoil (B) horizon, depth of the soil solum, permeability of the subsoil horizons, and soil drainage class. Using this system, numerical values were manually assigned to each mapping unit. These units were then grouped into 4 soil associations based on relative suitability for attenuation of applied contaminants. When evaluating the SPAP, units clearly unsuitable for waste disposal were not ranked, but were assigned an "unsuitable" label (eg. rubble land, urban fill, muck, rock outcrops, etc.). Digital soil mapping unit data was obtained from the USDA-SCS.

The GWPP was ranked using a hydrogeologic setting evaluation method based on Pesticide DRASTIC (PD) (Aller et. al., 1987). Only five of seven basic PD features were selected for evaluation: the aquifer media, impact of vadose zone media, water table depth, net groundwater recharge, and aquifer hydraulic conductivity. Each factor was numerically ranked with respect to

ground water pollution potential. Soil media and topography (percent slope) were eliminated from the list of evaluation factors. The SPAP rating system (previously discussed) was used in SILAS to emphasize soil characteristics in this study. Topography was eliminated because conflicting interpretations of the significance of site slope exist. As slope increases, rainfall runoff increases and surface water pollution potential increases, however groundwater pollution potential decreases. On flat slopes the opposite is true. While surface water quality was not included in the SILAS model, its importance was not overlooked. Installation and maintenance of soil conservation practices and structures can significantly alter the runoff/infiltration characteristics of a site, thereby modifying the impact of site slope. These considerations, together with the low weight placed on slope in the original PD model, resulted in a decision to drop the slope factor in the GWPP procedure. Bedrock geology mapping used in the GWPP evaluation was digitized from existing maps contained in work by Wood (1980). Manual interpretation of the GWPP factors was performed by Shuman (1988).

The area chosen for study comprises the eastern half of Centre County, Pennsylvania, encompassing approximately 587 square miles. This area was selected to facilitate the siting of land application facilities on privately owned land for Bellefonte Borough. Study area boundaries were chosen to coincide with local political divisions. An added feature of this study area is that it allowed analysis of two physiographic regions - the Ridge and Valley Province and the Allegheny Plateau Province (see Fig. 1).

Table 2 describes the basic system components. Two GIS software packages were utilized: pcARC/INFO and Earth Resource Data Analysis System (ERDAS). The pcARC/INFO package is a vector-based GIS system incorporating a series of modules with numerous processing capabilities. This system was utilized for all digitizing and conversion to raster (grid cell) format, as well as intermediate map output generation. The ERDAS software was employed for raster (30 meter resolution) data analysis and final output generation.

SILAS analysis began with compilation of the basic data layers which included land use and road system mapping, DEM slope class mapping, SCS soil mapping unit data, and bedrock geology mapping. Each of the digital layers was referenced to the PA state plane coordinate system. ERDAS was used to recode data layer attributes for the desired SILAS elements. The original 16 land use categories were redefined into 5 categories: agricultural lands, forest lands, urban areas, water, and others. The DEM slope file was recoded into 4 slope classes: 1-15%, 16-20%, 21-25%, and >25%. Soil mapping unit data was recoded twice. Once for "regulated" suitability characteristics (e.g., unsuitable, or potentially suitable), and then separately for SPAP associations. Bedrock geology data was redefined into the 4 GWPP associations.

Stepwise composite analysis of the individual GIS data coverages was performed using ERDAS. This procedure allowed generation of intermediate study area maps and statistics, and assisted in troubleshooting output discrepancies. Figure 2 illustrates the GIS coverage "layering" analysis procedure. Model verification was performed by detailed soils and hydrogeologic field investigations conducted on the best land application area identified for use by Bellefonte Borough.

RESULTS

GIS processing revealed that 91% of the study area was occupied by suitable land uses (ie., forest and agricultural lands). Forest lands represented the largest proportion of the area at approximately 251,000 acres (67% of the study area). Agricultural lands occupied another 92,000 acres (24% of the area). Mixed urban, water, and "other" land uses represented approximately 1%, 1%, and 7% respectively. About 96,000 acres (25%) was found to be on slopes exceeding 25%. Slope classes including 0-15%, 16-20%, and 21-25%, occupied 186,000 acres, 53,000 acres, and 41,000 acres, respectively (see Fig. 3).

GIS overlay analysis, excluding land use considerations, revealed that about 59% of the study area was unsuitable according to regulatory criteria (see Fig. 4). When regulatory criteria were not considered only 25% of the area was delineated as unsuitable. The principal difference between these two coverages is explained by the greater selectivity of PaDER guidelines concerning shallow, poorly drained, and flood plain soils. Table 3 provides an example of the SPAP ranking system. Table 4 lists all Centre County soil mapping units by SPAP associations and indicates those soils which are unsuitable based on PaDER regulatory criteria. SPAP ranking of PaDER-suitable tracts showed that approximately 31,000 acres of the 152,000 acre potentially suitable area were judged as "best-suited" for waste application. Second-best areas (SPAP rank 4) amounted to 11,000 acres, followed by 23,000 acres in SPAP rank 3, and 87,000 acres in the "least" suited SPAP category (see Fig. 5).

GIS analysis of ground water pollution potential showed that the "best" suitability category (GWPP rank 5) contained 23% of the total study area. The least suitable GWPP (rank 2) occupied 16% of the area, and ranks 3 and 4 contained 35% and 25%, respectively. Table 5 shows how the GWPP ranking system was applied to the Centre County study area geology.

Figure 6 illustrates the results of SILAS mapping near Bellefonte Borough, keyed to PaDER suitable areas (shown in Figure 4). The results of the GIS-SILAS analysis for forest and agricultural lands are presented in Figs. 7 and 8. The total forested acreage occupying the top three SILAS categories (8, 9, and 10) was found to be approximately 5000, 1000, and 250 acres, respectively. The distribution of agricultural lands for these same categories was 9200, 5800, and 2800 acres, respectively.

Computer-generated SILAS maps of the study area indicated that agricultural lands appeared to offer the greatest potential for successful siting of land treatment facilities for Bellefonte Borough. Review of ag-land SILAS maps with local agricultural support agencies (SCS, County Conservation District, and Ag Extension) was greeted positively, resulting in recommendations of individual farm operations in highly-ranked SILAS areas. Communication with farmers identified as likely participants was facilitated by using the SILAS methodology, resulting in largely positive feedback. The favorable reaction to the SILAS methodology and resulting outputs was viewed as a major benefit of this detailed site selection procedure.

Detailed site investigations on one tract (encompassing 3 farms on 800 acres) verified the presence of expected soils and hydrogeologic conditions. The soils and hydrogeologic conditions found in this area appeared well suited to land application of sewage sludge. Relative to other locations in the study area, irrespective of the SILAS study, this area was judged to be a preferred location. This site was approximately 5.3 road miles from the wastewater treatment plant.

DISCUSSION

Originally, plans included use of data layer coverages containing "blue line streams" (USGS) and public water supply service area boundaries. GIS delineation of "buffer" areas to be excluded from consideration, and more detailed delineation of slope classes were also considered. As SILAS screening progressed, it became clear that inclusion of additional factors for further refinement was unnecessary. On examination of SILAS outputs, individuals familiar with county agriculture immediately focused on compatibility of waste disposal with existing local farm operation activities and schedule. It is also noted that the slope class data coverage, as it was used in the study analysis, did not significantly contribute to the final results. The DEM data ultimately was used only to exclude areas with slopes greater than 25%. The same result was duplicated (perhaps to a lesser degree of accuracy) when soil mapping units with >25% slopes were excluded in the SPAP ranking. Future applications of SILAS to other areas will likely exclude the DEM data.

Identification of specific farms on computer-generated SILAS maps proved to be somewhat troublesome for agricultural agency personnel, even though principal roads had been plotted. To facilitate farm location recognition, the highest ranked SILAS areas of principal interest were manually plotted on 7 1/2 minute USGS quadrangle Mylar overlays. This approach proved very successful, as most conservation agency personnel were familiar with these maps. An added advantage to the use of the USGS quad sheets was the volume of information displayed on these maps, enabling location and interpretation of various local features which would not ordinarily be considered for inclusion in the SILAS data coverages. Eliminating the land use data layer should be considered in future applications. Production of computer-generated SILAS maps for manual overlay on USGS quads could save hundreds of hours in digitizing. In this type of application, the USGS mapping would serve as a rough basis for land use delineation, and the composite overlay map could be readily interpreted by those familiar with USGS sheets.

SUMMARY AND CONCLUSIONS

GIS application of the SILAS model is a powerful, cost-effective tool for focusing land treatment siting investigations. Through use of SILAS mapping, detailed site investigation inquiries were immediately directed to the best agricultural locations meeting regulatory constraints which comprised only 4.7% of the study area. The methodology relies on commonly available "regional" information and is based on uncomplicated sub-models which are straightforward in application. SILAS was well received by local agricultural agencies, landowners, and regulatory personnel, and helped communicate that extensive efforts were made to insure that municipal sludge utilization was to be accomplished in an environmentally sound manner.

If extensive digital database development is not necessary, it is estimated that SILAS evaluation of similar areas can be accomplished in approximately 160 man hours. In situations where digital land use and tax maps are readily available for GIS processing, SILAS rankings for specific tax map parcels may be generated with very little additional effort.

Since SILAS is a preliminary screening tool preceding detailed field investigations, the seriousness of possible minor errors in original databases and accumulated error generated through GIS processing are minimized. Perhaps the most significant error possible is the early elimination of good treatment sites from detailed evaluation.

The greatest limitation to immediate use of SILAS is the current lack of digital database information for many areas. This is particularly troublesome for the complex soils data layer. It is estimated that 40 man hours are required to digitize and process 36,000 acres (approximately equivalent to one 7 1/2 min. USGS quadrangle) of SCS soil mapping data for seamless composite coverage. However, it is suggested here that the comprehensive level of site screening offered by SILAS, and the strong positive public reaction to the methodology, may justify the added expense of database development. In addition, the potential uses of such databases for other land use planning decisions are almost limitless.

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*Available from Geo Decisions, Inc. 118 Boalsburg Road, P.O. Box 579, Lemont, PA 16851. 814-234-8625.

FIGURE 1

CENTRE COUNTY Physiography

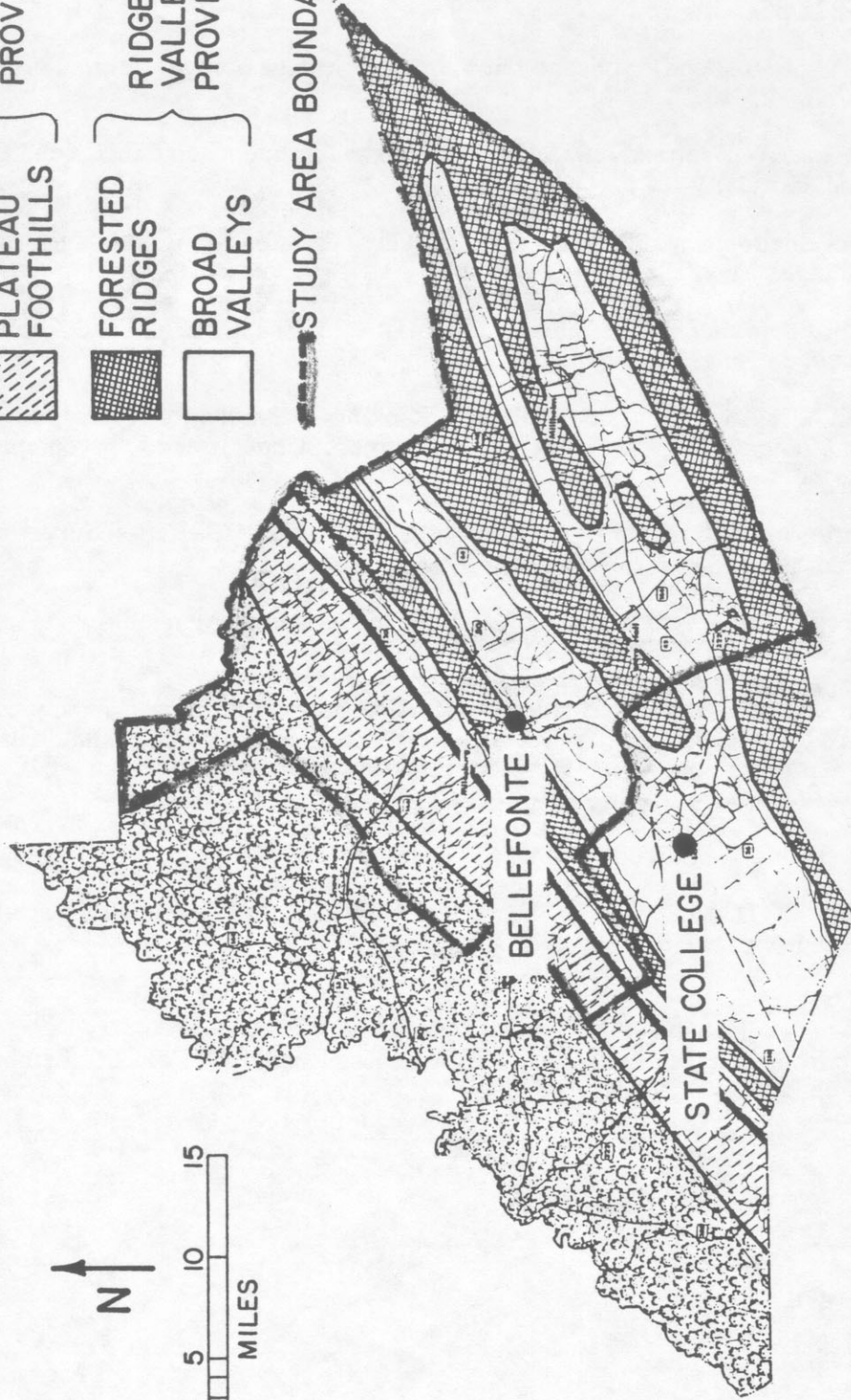
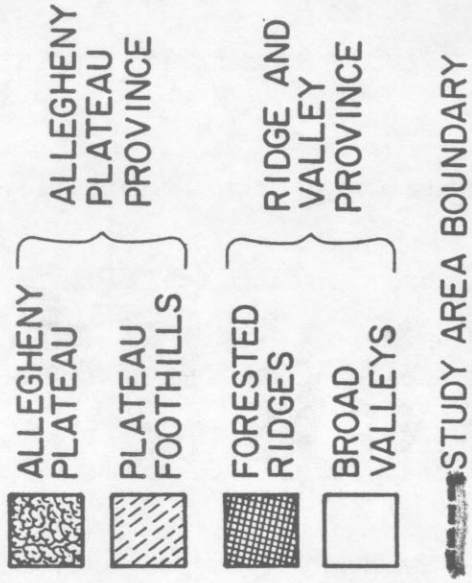
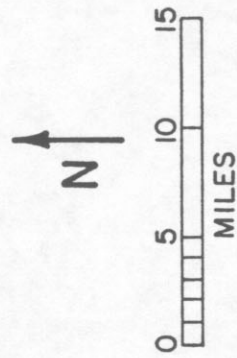


FIGURE 2
SILAS ANALYSIS FLOW DIAGRAM

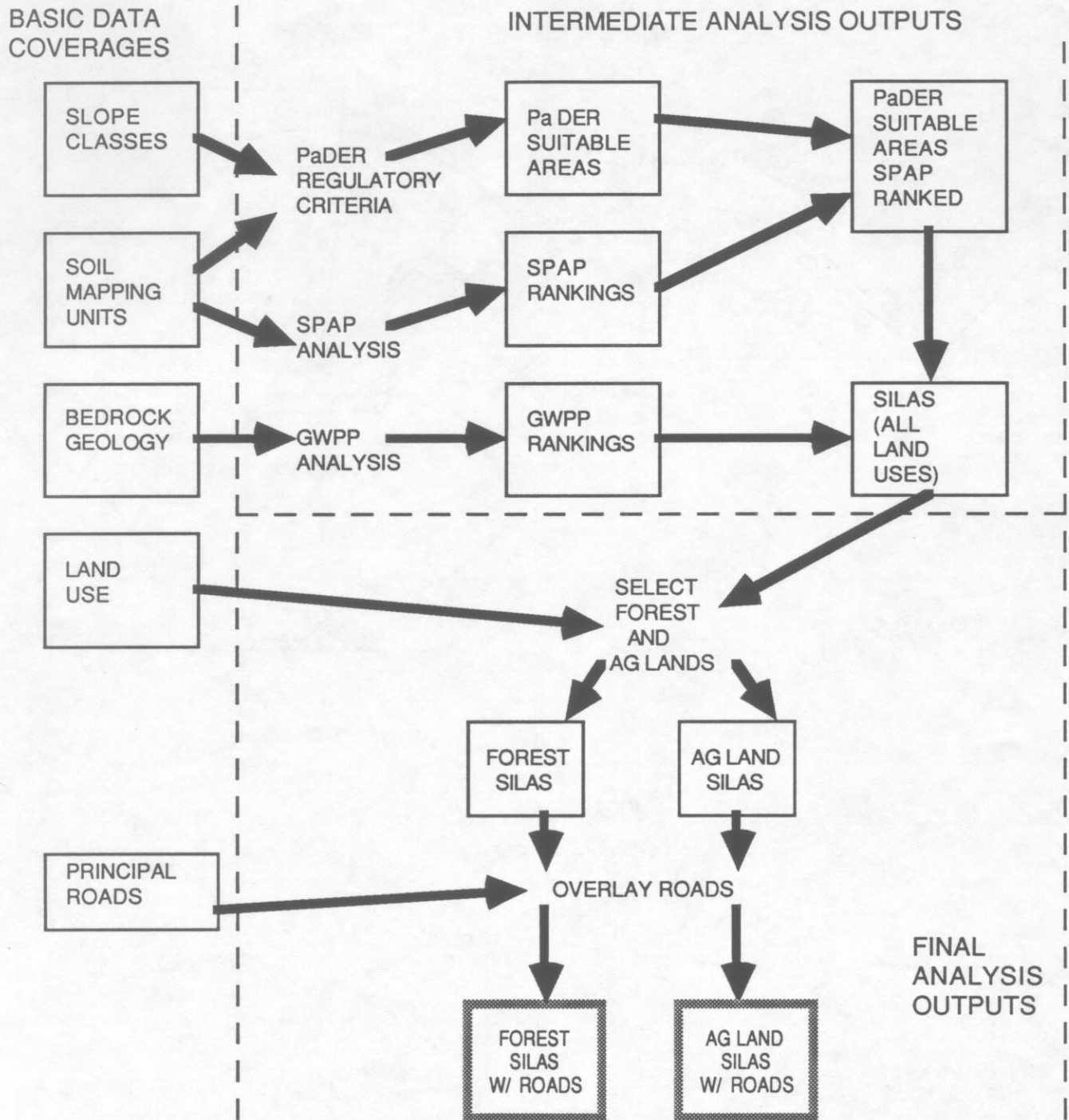


FIGURE 3
SILAS STUDY AREA
LAND USE AND TOPOGRAPHY

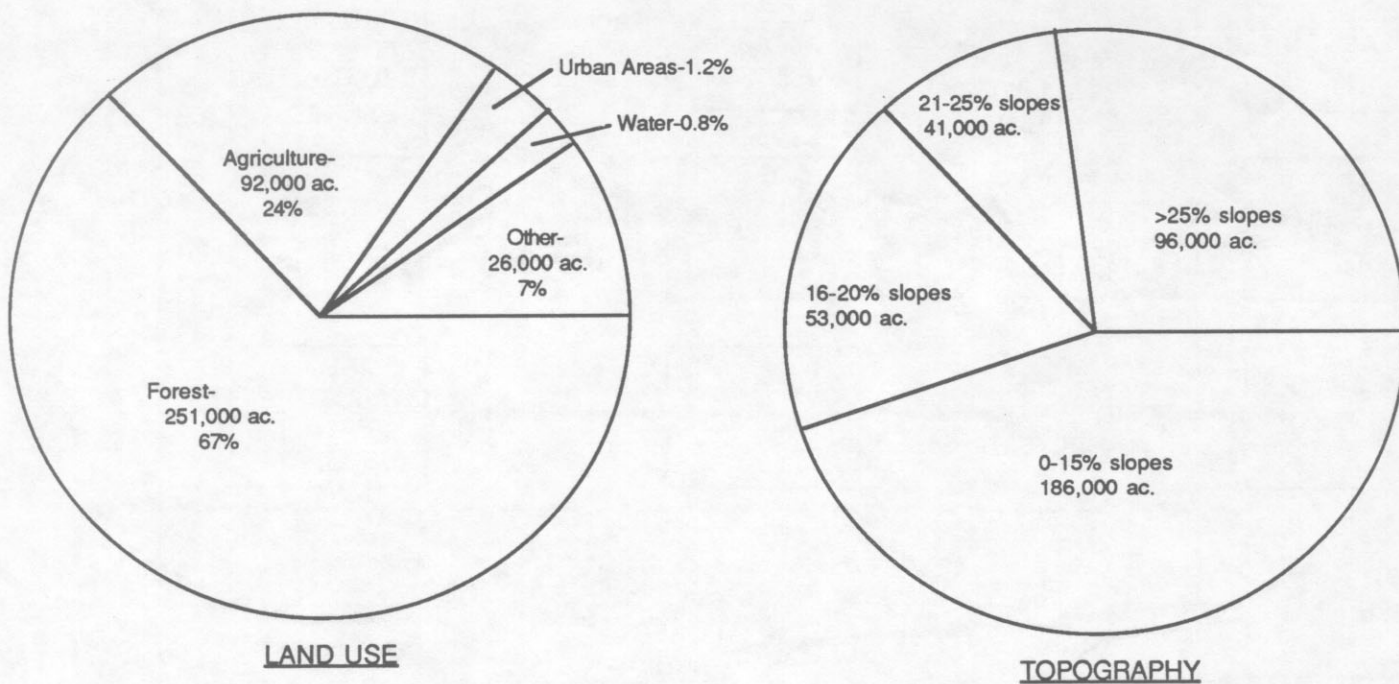


FIGURE 5
SPAP RANKING OF PaDER
SUITABLE AREAS

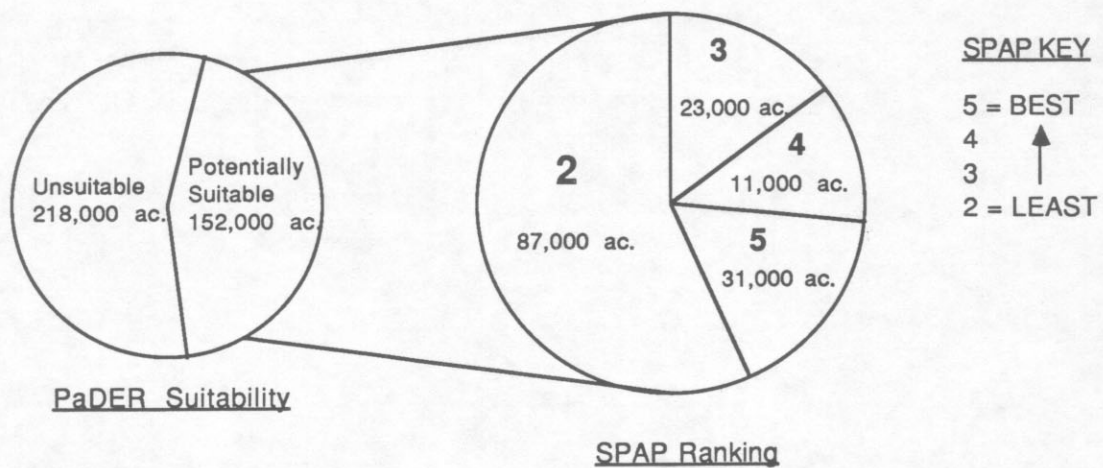
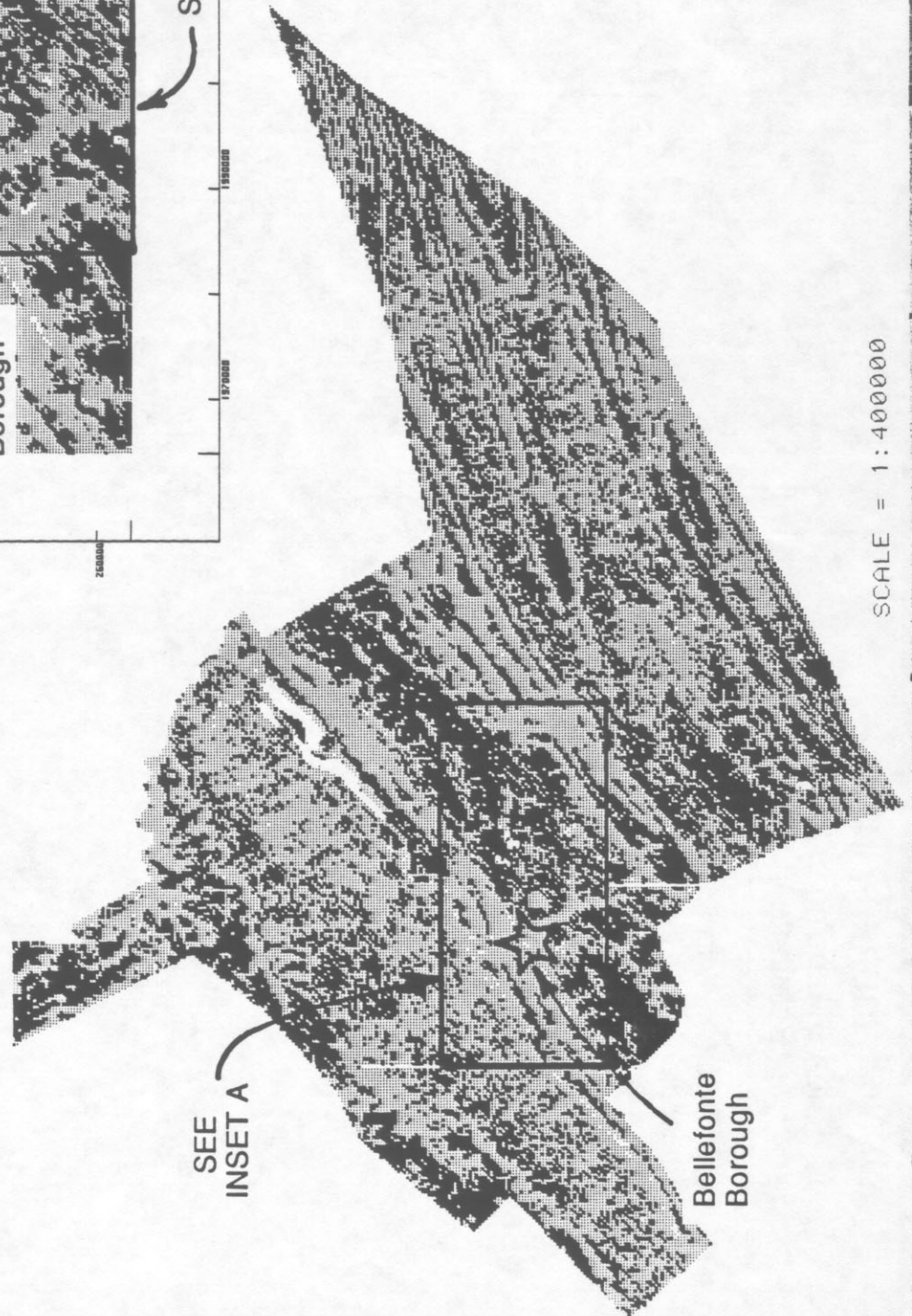
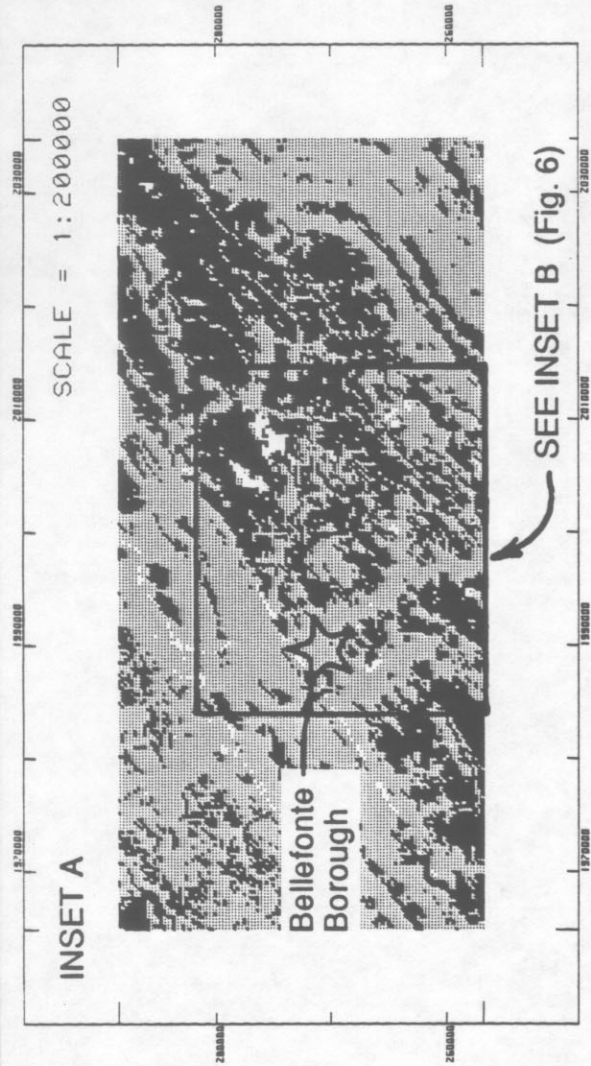


FIGURE 4**PaDER Site Suitability**

NOTE: Black Areas meet minimum criteria for land application of sludge based on PA Dept. of Environmental Resources criteria



SCALE = 1:400000



SCALE = 1:200000

FIGURE 6, INSET B
SILAS Mapping of Immediate
Bellefonte Vicinity

NOTE: Shading intensity indicates SILAS Value; Darkest shaded areas are best locations.



BELLEFONTE
Borough



Bellefonte Sludge
Permitting Area

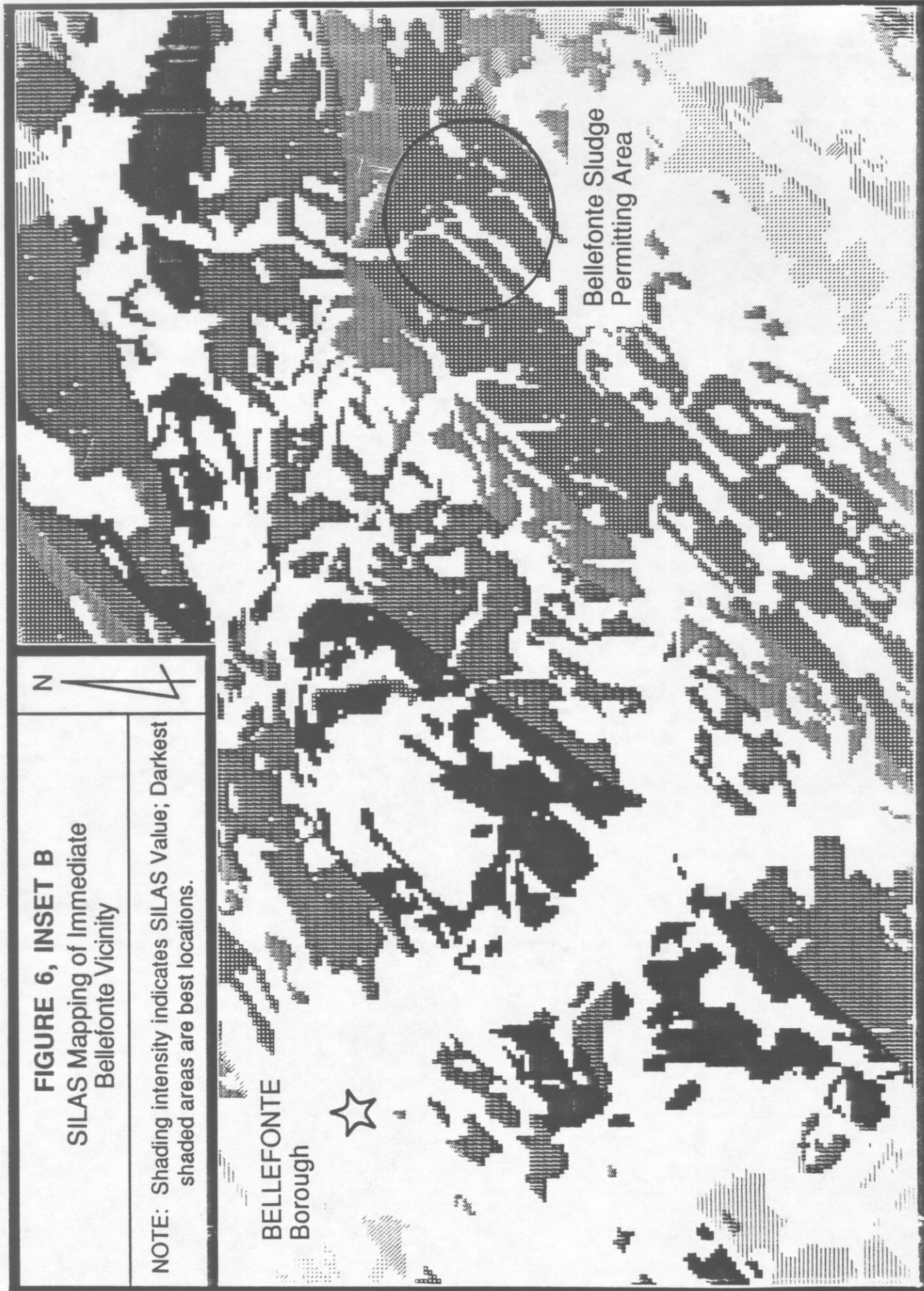
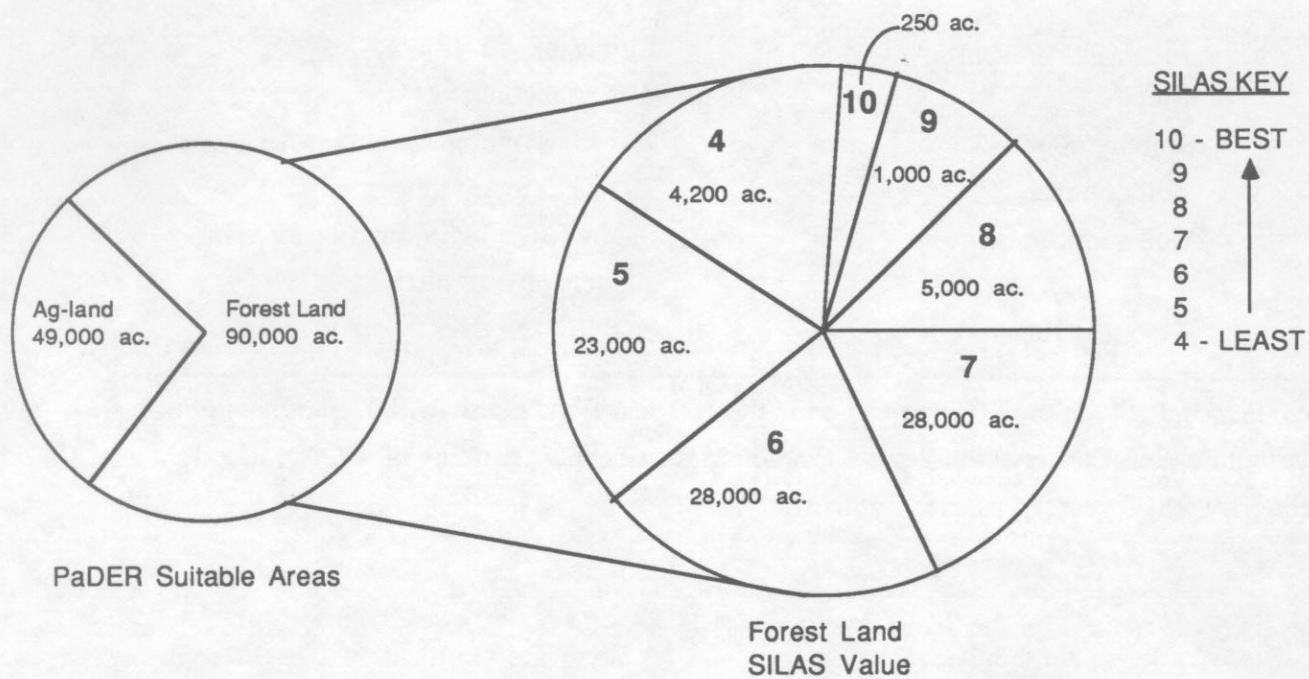
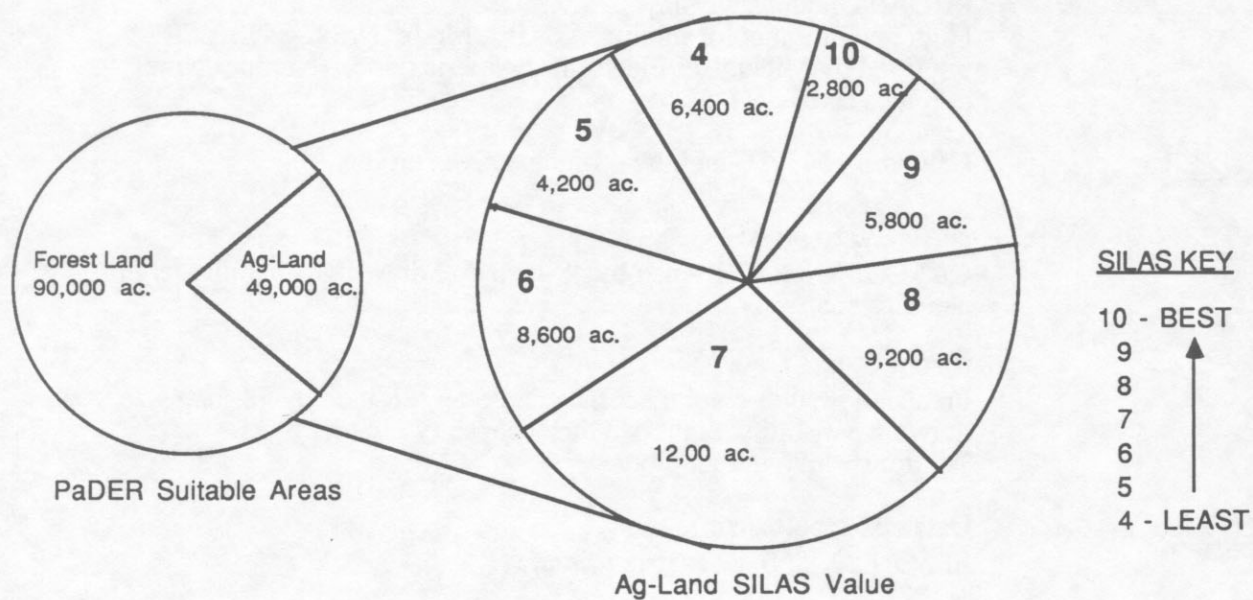


FIGURE 7

**FOREST LAND SILAS VALUE FOR
PaDER SUITABLE AREAS**

**FIGURE 8**

**AG-LAND SILAS VALUE FOR
PaDER SUITABLE AREAS**



REGULATORY CRITERIA USED TO DETERMINE
SITE SUITABILITY (PADER, 1988)

<u>Site Characteristics</u>	<u>Limitations</u>
Slope	25% maximum
Depth to Bedrock	20 inches minimum
Soil drainage	20 inches to mottling minimum
Soil surface texture	Sandy loam, loam, sandy clay loam, silty clay loam, silt
Flooding Hazard (1)	NONE

(1) Land disposal criteria prohibit application in the 100 year flood plain. U.S. Department of Agriculture, Soil Conservation Service flood hazard susceptibility rating of NONE (flood frequency > 100 years) was used in this study.

TABLE 2

MICROCOMPUTER SYSTEM CONFIGURATION

<u>COMPUTER</u>	COMPAC 386/20 with 1 MB RAM memory, 5.25-inch high-density diskette drive, 61 MB hard disk drive, and 80387 Math co-processor.
<u>DATA STORAGE</u>	Two - 5.25-inch Bernoulli II cartridge drives (1 internal, 1 external) with 21 MB storage capacity per cartridge.
<u>GRAPHIC VIDEO DISPLAYS</u>	Zenith ZCM-1490 14-inch flat screen color monitor with 640 x 350 resolution in EGA-mode (Zenith Z-449 video card). ERDAS Graphics Display: High resolution color monitor, 32-Bit, Model No. C-3419 LPR, imported by Mitsubishi Electronics America, Inc. (Number Nine graphics card).
<u>DIGITIZER</u>	Calcomp 1043, 36-inch by 48-inch active surface.
<u>PLOTTERS</u>	pcARC/Info plots: CALCOMP 9100, 36-inch by 48-inch size drawing capability, eight pen turret capacity. ERDAS plots: Precision Images color electrostatic plotter, 36-inch by 48-inch size drawing capability, eight pen turret capacity. Ink jet plots - Tektronix 4696 ink jet plotter.
<u>PRINTER</u>	Database reports, etc: EPSON LX-800 dot matrix printer.

CODED VALUES AND RANKING FOR SOIL POLLUTANT ATTENUATION POTENTIAL - EXAMPLE
CENTRE COUNTY, PENNSYLVANIA

1/25/89	Slope Class Mapping Symbol	Soil Map Unit Name	Texture of A Horizon	Texture of B Horizon	Organic Matter Content (A Horizon)	pH (A Horizon)	Solum Depth (A + B)	Permeability (B Horizon)	Soil Drainage Class	Attenuation Potential (1) Value Rank
			1	1	5	4	1	8	10	30 2
MVD	8%-25%	Murrl very stony silt loam	9	7	3	6	10	8	10	53 5
NO	0%-5%	Nolin silt loam, local alluvium	8	9	5	4	1	8	10	45 4
OHB	3%-8%	Opequon-Hagerstown complex	8	9	5	4	1	8	10	45 4
OHC	8%-15%		8	9	5	4	1	8	10	45 4
OHD	15%-25%		8	9	5	4	1	8	10	45 4
ORF	Steep		Unsuited							1
OXB	0%-8%	Opequon-Rock outcrop complex	Unsuited							1
OXD	8%-25%		Unsuited							1
PH		Philo loam	9	7	3	4	8	8	4	43 4
PK		Philo and Atkins very stony soils	9	7	3	4	8	8	1	40 3
PO		Pope soils	7	7	3	4	8	6	10	45 4
PU		Purdy silt loam	9	9	5	4	10	9	1	47 4
RAB	2%-10%	Rayne silt loam	9	1	5	4	1	8	10	38 3
RU		Rubble land	Unsuited							1
SM		Strip mines, acid	Unsuited							1
TY		Tyler silt loam	9	7	5	4	10	9	1	45 4
UMB	3%-8%	Ungers channery loam	1	1	5	4	1	8	10	30 2
UMC	8%-15%		1	1	5	4	1	8	10	30 2
UMD	15%-25%		1	1	5	4	1	8	10	30 2
UNB	8%-25%	Ungers very stony loam	1	1	5	4	1	8	10	30 2
UND	8%-25%		1	1	5	4	1	8	10	30 2
URB	Gently sloping	Urban Land-Hagerstown complex	Unsuited							1
VAC	5%-20%	Vanderlip loamy sand	1	1	3	4	3	4	10	26 2
WEC	5%-15%	Weikert silty loam	1	1	3	4	1	6	10	26 2
WED	15%-25%		1	1	3	4	1	6	10	26 2
WHA	0%-3%	Wharton silt loam	9	7	5	4	8	9	4	46 4
WHB	3%-8%		9	7	5	4	8	9	4	46 4
WHC	8%-15%		9	7	5	4	8	9	4	46 4
WYA	0%-5%	Wyoming gravelly sandy loam	1	1	3	4	1	4	1	15 2

(1) Soil Associations based on Soil Pollutant Attenuation Rank
Potential: Attenuation Potential Value

Soil Mapping - USDA-SCS (1981)
SPAP Ranking - WIS-DNR (1985)

51+ (Best suitability)
41-50
31-40
0-30 (Least suitable)
Unsuited

5
4
3
2
1

TABLE 4
SPAP RANKING OF CENTRE COUNTY SOIL MAPPING UNITS

BEST SUITABILITY 5	4	3	LEAST SUITABILITY 2	UNSUITABLE 1
Allegheny silt loam	Albrights silt loam	Albrights very stony silt loam	Andover channery loam	*Carlisle muck
*Chagrin soils	*Atkins silt loam	Armagh silt loam	Andover very stony loam	*Hazelton-Dekalb association (very steep)
Hagerstown silt loam	*Basher loam	Brinkerton silt loam	Berks shaly silt loam	*Laidig extremely stony loam (steep)
Hagerstown silty clay loam	*Cavode silt loam	Ernest channery silt loam	Berks very stony silt loam	*Leck Hill and Calvin soils (steep)
Hubersburg silt loam	Clarksburg silt loam	Ernest very stony silt loam	Berks & Weikert soils	*Morrison very stony sandy loam (steep)
Millheim silt loam	*Dunning silty clay loam	Laidig channery loam	Brinkerton very stony silt loam	*Opequon-Hagerstown complex (steep)
*Nolin silt loam, local alluvium	Edom silt loam	Laidig extremely stony loam	Buchanan loam/channery loam	*Opequon-Rock outcrop complex
	*Lindside soils	*Leetonia sand, variant	Buchanan extremely stony loam	*Rubble land
	Meckesville silt loam	Meckesville very stony silt loam	Clymer sandy loam	*Strip mines, acid
	*Melvin silt loam	*Philo and Atkins very stony soils	Clymer very stony sandy loam	*Urban Land-Hagerstown complex
	Monongahela silt loam	Rayne silt loam	Gilpin channery silt loam	
	*Opequon-Hagerstown complex		Hazelton channery sandy loam	
	*Philo loam		Hazelton extremely stony sandy loam	
	*Pope soils		Leck Kill channery silt loam	
	Purdy silt loam		Leck Kill very stony silt loam	
	Tyler silt loam		*Letonia extremely stony loamy sand	
	Wharton silt loam		Markes silt loam	
			Morrison sandy loam	
			Morrison very stony sandy loam	
			Murrill channery silt loam	
			Murrill very stony silt loam	
			Ungers channery very stony loam	
			*Vanderlip loamy sand	
			*Weikert shaly silt loam	
			*Wyoming gravelly sandy loam	

*Unsuitable based on PaDER Regulatory Criteria, or clearly incompatible land use for waste application treatment.

TABLE 5

CODED VALUES AND RANKING FOR HYDROGEOLOGIC SETTINGS BASED ON GROUND WATER POLLUTION POTENTIAL

CENTRE COUNTY, PENNSYLVANIA

1/25/89	Lithology Name	Aquifer Media		Vadose Media		Water Table Depth		Net Recharge		Hydraulic Conductivity		G.W. Pollution Potential (1)	
		Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Value	Rank
	Conemaugh Group	5	15	4	16	6	30	3	12	1	2	75	4
	Allegheny Group	6	18	5	20	6	30	3	12	1	2	82	4
	Pottsville Group	7	21	6	24	6	30	6	24	1	2	101	2
	Mauch Chunk Fm.	3	9	3	12	7	35	3	12	1	2	70	5
	Burgoon Sandstone	6	18	4	16	2	10	6	24	1	2	70	5
	Rockwell/Huntley Mt. Fms.	6	18	4	16	7	35	3	12	1	2	83	4
	Catskill Fm.	6	18	4	16	7	35	3	12	1	2	83	4
	Lock Haven Fm.	5	15	4	16	6	30	3	12	1	2	75	4
	Brallier/Harrell Fms.	2	6	2	8	7	35	3	12	1	2	63	5
	Mahantago/Marcellus Fms. (Hamilton Group)	6	18	5	20	7	35	3	12	1	2	87	3
	Onondaga/Old Port Fms.	8	24	7	28	5	25	3	12	1	2	91	3
	Key/Tono./W.C./Blo./Miff. Fms.	8	24	6	24	6	30	3	12	1	2	92	3
	Rose Hill Fm.	5	15	4	16	6	30	3	12	1	2	75	4
	Tuscarora Fm.	5	15	4	16	4	20	1	4	1	2	57	5
	Juniata Fm.	6	18	5	20	7	35	3	12	1	2	87	3
	Bald Eagle Fm.	6	18	5	20	6	30	1	4	1	2	74	5
	Reedsville Fm.	6	18	5	20	7	35	3	12	1	2	87	3
	Coburn/Salona/Nealmont Fms.	9	27	8	32	4	20	6	24	1	2	105	2
	Benner/Snyder/Hatter/Loydsburg Fms.	10	30	8	32	4	20	6	24	1	2	108	2
	Bellefonte Fm.	7	21	5	20	3	15	6	24	1	2	82	4
	Axemann Fm.	9	27	8	32	4	20	6	24	1	2	105	2
	Nittany Fm.	8	24	6	24	3	15	6	24	2	4	91	3
	Stonehenge Fm.	5	15	4	16	3	15	6	24	1	2	72	5
	Gatesburg Fm.	8	24	5	20	2	10	9	36	2	4	94	3
	Warrior Fm.	5	15	4	16	2	10	8	32	1	2	75	4
	DSkm & Srh undifferentiated	8	24	6	24	6	30	3	12	1	2	92	3
	Ocn & Obl undifferentiated	10	30	8	32	4	20	6	24	1	2	108	2
	Obf & Oa undifferentiated	9	27	8	32	4	20	6	24	1	2	105	2
	On & Os undifferentiated	8	24	6	24	3	15	6	24	2	4	91	3

Information Sources:

(1) Hydrogeologic Settings based on Groundwater Pollution Potential: G.W. Pollution Potential Ranking Rank

0-74 (Best suitability)

75-84

85-94

95+ (Lease suitable)

Factor Ratings - Shuman (1988)

GWPP Ranking - after Aller et. al. (1987)