INTERPRETING SOIL CONSERVATION SERVICE INFORMATION FOR PLANNING RESIDENTIAL DEVELOPMENTS IN KANSAS

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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Chapter 1

INTRODUCTION

City planning has occurred to varying degrees over a wide expanse of history, but the process has not included, until fairly recently, the use of natural resource data. Planners have become increasingly concerned with the degree of stress placed upon a limited resource base from scattered land developments and urban sprawl which, if uncontrolled, could seriously damage or destroy the quality of life expected by the American people.

Much technical data on natural resources is available. However, a number of problems exist that make it difficult to compile and incorporate into the planning process. A survey of natural resource planners and other professionals in Ontario has helped to document some of these problems, not the least of which is some lack of knowledge as to what information is available and, once it is obtained, how to use it. Most natural resource data is in a format that is useful to a specific scientific discipline but which may be difficult for a non-scientist planner to fully understand and translate into meaningful planning policy. Further difficulties may involve the question of how to process basic data from a number of scientific disciplines that have not been prepared at the same scale or at the same levels of generalization (21, 25). These issues will not be resolved until a generally accepted method of processing natural resource information is provided to aid the sciences in coordinating preparation and interpretation of the base data.

A number of natural resource planning methodologies have been developed in recent years, but many are beyond the means of smaller communities which do not have or cannot afford the expertise needed to handle the quantities or complexities of information involved. Yet these communities cannot afford to wait until a widely accepted and economically feasible comprehensive system can be devised to handle all the input of scientists, sociologists, economists, biologists and planners. The potential for loss of the intrinsic environmental qualities as well as possible damage to the economic and social welfare of communities requires that the best possible use be made of available information. Ideally, this information should form a broad natural resource data base which can be expanded into more complex systems of data collection, analysis and interpretation for planning purposes as methods and technologies become available.

USE OF SOIL SURVEY INFORMATION

One system of data collection, the soil survey of the USDA Soil Conservation Service (SCS), has proven useful to many planners. Although begun at the turn of the century with an emphasis on collecting and producing information for agricultural uses of soil, these surveys were broadened to include the study of engineering characteristics of soils by the late 1920's. World War II furthered the union of soil science and soil mechanics, as predictions of soil types to be found behind enemy lines were needed for military operations where on-site soil testing was not possible. The success of this function of soil data encouraged its greater use in locating and designing houses, roads and other structures after the war. In the early 1950's, Fairfax County, Virginia was among the first to request a soil survey for the purpose of planning. Today, as the soil survey continues across the country, some communities have extended the application of this data to form the basis of ordinances and zoning regulations (1, 9).

Indeed, use of soil survey information in planning has increased and is the focus of this study for a number of reasons:

1. It has a standardized format for its preparation so that there is a nation-wide continuity.

2. It is currently available to many areas of the country and will eventually be available to almost all.

3. It has been prepared for use by farmers, ranchers, planners, engineers, developers and home builders so the scientific information is well explained and presented to the layman. There are also public agents available to help with its use.

4. The size of the mapping unit in the soil survey is small enough to give more specific information without getting so detailed as to create a process that's too complex.

5. Soils reflect and/or affect all other physical resources.

6. Soils are of major concern in most land uses, whether for their productive qualities or as the support and construction medium for most developments.

7. The soil survey is already familiar to a number of groups such as farmers, planners and engineers.

8. The soil survey provides interpretations of suitability

for a number of land uses including agriculture, rangeland, woodland, wildlife, and community development.

All of these factors make the soil survey one of the more easily obtained and useful forms of natural resource data for planners. However, the interpretations it includes for community development may prove inadequate for certain towns or cities where insufficient amounts of soils are rated as suitable for various urban uses (Figure 1) (43).

This problem arises from the method used in preparing interpretations where each soil is evaluated as having slight, moderate, or severe limitations, based on a number of engineering properties of soils, for uses such as dwellings, small commercial buildings, sanitary facilities, and local roads and streets. Soils considered to have slight limitations for a given use are generally suitable, presenting only minor problems that are easily corrected. These soils are expected to perform well and require little in the way of maintenance. If a soil is considered to be moderately limiting for a given use, it has moderately favorable properties, but at some time during the year, it will exhibit lower performance characteristics than a soil rated slight. Soil problems under this rating may be overcome or modified to an acceptable standard through special planning, design or maintenance which could also incur greater development cost. Soils with a rating of severe for a chosen land use have one or more soil-related problem that would require such specialized design or extensive soil reclamation or maintenance as to be economically infeasible. Included under this rating would be properties such as frequent flooding, water table or bedrock near the surface, very steep slopes, low bearing strength, and high shrink-swell potential (44).

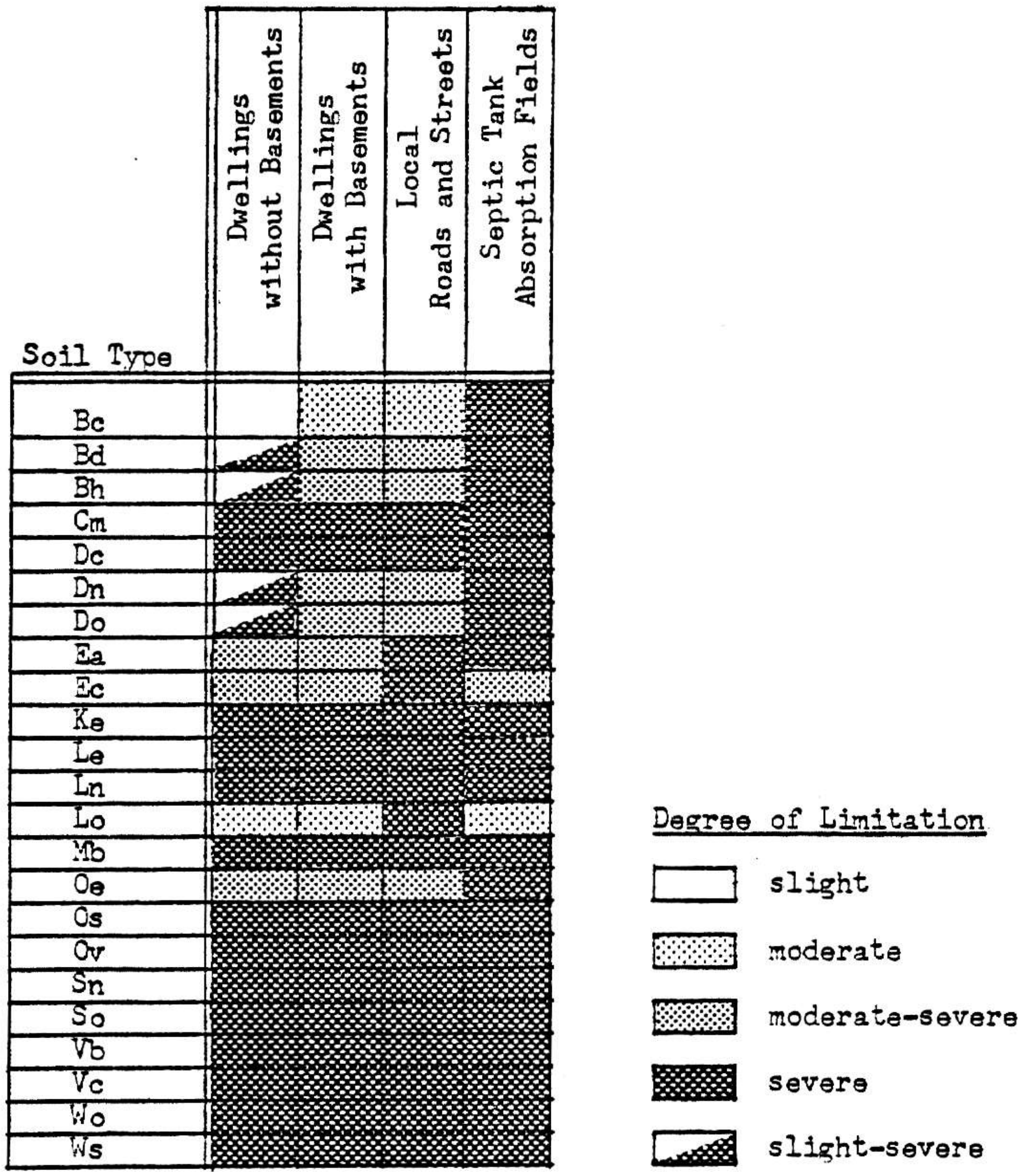

Figure 1

Limitations of Ottawa, Kansas Soils
for Residential Development

Within this rating system, no distinction is made between levels of severity of one soil characteristic over another. All are given the same weight. Yet, a soil with "severe" limitations due to hard bedrock near the surface may incur far greater costs in residential developments than one with poor bearing properties.

The inadequacy of the SCS interpretations becomes apparent when planning decisions must be made in communities where few if any soils of "slight" limitations exist or remain within reasonable proximity to a city where other planning considerations may override poor soil conditions and cause development to occur on less than favorable soils. New Orleans, Louisiana presents an extreme example of just such a city. Here, all the soils are severely limiting for residential development due to instability, flooding and high water table. Local builders have learned how to minimize some of these problems through design and construction techniques. But obviously, it is of benefit to planners to be able to determine which unfavorable soil characteristics are easier to modify or correct within the context of available construction methods and the economic means of the New Orleans area (26).

Most cities, fortunately, are not faced with soil problems of the same magnitude as New Orleans and would probably find methods used there to be cost prohibitive in their own area. Nevertheless, these communities may elect to establish higher standards even for soils with "slight" limitations, if dictated by specific local community objectives, necessitating evaluation and ranking of soils potential. A planning system that can relate the existing natural resources to local socio-economic conditions and that can easily be revised as goals, economic conditions and technologies change, will prove to be a more useful tool in preparing comprehensive community development plans.

PURPOSE AND SCOPE

A methodology has been developed by the University of Massachusetts, known as the Metropolitan Landscape Planning Model (METLAND) for quantitatively evaluating landscape resources which include landform, vegetation, soil, water, and cultural features such as housing, farms and recreational developments. This type of system seeks to maximize the positive effects of landscape resources and their natural opportunities for development, while minimizing any hazards or damage to the environment. It is designed primarily to assess landscape resources for communities as they expand further into the less developed rural fringe, and to present this information in a form which allows communities to evaluate it and make trade-offs consistent within their own socio-economic framework.

This study will utilize a portion of the METLAND methodology, the assessment of the Physical Development Suitability of a landscape, to show how Soil Conservation Service data can be used to evaluate the soil/subsurface conditions of Kansas for residential development, but will include the following alterations:

1. Cost estimates will be based on average lot and home sizes and designs typical of Kansas communities.

2. This study will evaluate soil/subsurface conditions for houses with basements, slab on grade homes, asphalt and concrete streets, and water and sanitary sewer lines. Suitability for conventional septic tank absorption fields will also be discussed.

3. Soil engineering properties significant to residential development in Kansas will be used.

4. Terminology and quantitative ranges of soil engineering properties will coincide with those used in the standard SCS Guide for Interpreting Engineering Uses of Soils so that information provided in this paper can be related to SCS soil survey report data.

5. Average feasible additional development costs related to soil/subsurface problems will be determined for Kansas.

In order to provide sufficient background information to understand terminologies and the implications of soil and related subsurface conditions on residential planning, this study will include a brief discussion of soil formation, classification and a review of major soil engineering properties that are evaluated by the Soil Conservation Service. The METLAND methodology will also be reviewed, with an emphasis on the Physical Development Suitability aspect of the Assessment Phase which uses SCS soil maps and data.

A presentation of estimates obtained from Kansas contractors on the added residential development and construction costs related to soil and subsurface problems will then be made. Interpretations of this information for Kansas communities will be applied to a case study for Ottawa, Kansas, with concluding remarks on implications for residential planning on Kansas soils.

Although this study will only address one aspect of an extensive planning system that has been designed for use with computers, its intention is to exemplify how even small communities of limited means can make use of one widely available source of landscape data in making critical planning decisions. These communities must determine their most important landscape resource concerns, whether it be hazards such as flooding, special resources such as agriculturally productive land, development suitability or ecological stability. By building upon a planning model such as that provided by the METLAND system, any city or town can work toward the optimum use of their land.

Chapter 2

SOIL FORMATION, CLASSIFICATION AND ENGINEERING PROPERTIES

The concept of what soil is has evolved over an expanse of many years, but today, it is considered to be a naturally occurring body composed of minerals, air, water and organic matter with more or less recognizable horizons or layers that lie parallel to and at the earth's surface. Some soils have formed from residual deposits of weathered bedrock material, but most are formed from sediments weathered from bedrock in one location and transported to another by means of wind, water, ice or gravity (8, 24).

As a result of weathering, soils develop horizons, with the surface layers containing greater amounts of organic matter which grade downward to layers higher in mineral content and materials leached from above. The development of these soil layers varies according to five major factors:

1. Type of parent material from which the soil is formed.

2. Climate under which it was formed (temperature, precipitation, etc.).

3. Topography or land form on which it developed (aspect, drainage characteristics, etc.).

4. Plant or animal life on or within the soil.

5. Amount of time during which the above processes have been in operation.

Soils with a similar background in these five factors will have similar characteristics. Thus, scientists have been able to classify soils and have developed a system of mapping and describing soils for a given area in a more or less standardized soil survey report.

SOIL CLASSIFICATION SYSTEMS IN THE SOIL SURVEY REPORT

The U. S. Department of Agriculture (USDA) soil classification system is used in preparing the soil survey report, but classification under two other systems used by engineers, the Unified Soil Classification System of the U. S. Army Corps of Engineers and the American Association of State Highway Officials (AASHO) system, is also provided. This information in conjunction with that of estimates of engineering properties of soils and interpretations provided in the report is extremely useful for general planning and design considerations. It should be noted, however, that on-site investigations to verify or add to the information will generally be necessary for specific site designs. The map scale does not permit inclusion of small areas of contrasting soils, and soil properties are only considered to a depth of 5 to 6 feet. Nevertheless, soil surveys provide the best available estimate of the engineering properties of a given soil at this time (44).

Understanding these three classification systems, differences in their terminologies and the limitations of their use will aid in making informed planning and design decisions.

USDA Soil Classification System

Around 1900, the U. S. Department of Agriculture adapted the Russian soil classification system for the purpose of conducting the American soil survey. Due to its agronomic orientation, this system emphasizes the surface layers of soils which provide nutrients and support for plant materials and is based on grouping soils according to their properties.

Soil survey reports are concerned with the more detailed levels of the classification system which groups soils by series and type. Soils within a particular series have developed under similar conditions and have similar profiles except for the texture of the surface layers. Differences in surface texture within a soil series are denoted through type classification based on texture of the soil particles. The three general textures are sand (0.05-2mm), silt (0.002-0.05mm), and clay (less than 0.002mm in diameter). Gravel, which is considered to be material between 2mm and 3 inches in diameter, is not included in the textural classification except as an adjective modifier to describe one of the basic textural classes (8, 33, 44).

USDA basic textural classes in order of increasing proportion of fine particles are:

S--sand	SCL--sandy clay loam
LS--loamy sand	CL--clay loam
SL--sandy loam	SICL--silty clay loam
L--loam	SC--sandy clay
SI--silt	SIC--silty clay
SIL--silt loam	C--clay

Unified Soil Classification System

Engineers are concerned with the properties of soils as they affect structural foundations and excavations and in their quality for use as fill material. They therefore define soil as all unconsolidated material, no matter how deep it is. The Unified system was developed during World War II for the Corps of Engineers to estimate the suitability of soils for roads and airfields, and has since been revised and expanded in cooperation with the U. S. Bureau of Reclamation to include suitability of soils for foundations and embankments.

Soils in this system are grouped as coarse-grained soils if they include 50% or more gravel (4.7mm-3 inches) and/or sand (0.074-4.76mm), as fine-grained soils if they include 50% or more silts and/or clays, or as highly organic soils. Silts and clays are classified according to their plasticity index and liquid limit characteristics. Highly organic soils can usually be identified on sight as to whether they contain sufficient quantities of organic matter to create engineering problems (33, 44).

Soils are classified as follows under the Unified system:

Coarse-grained Soils

GW--Well-graded gravels, gravel-sand mixtures, little or no fines.
GP--Poorly-graded gravels, gravel-sand mixtures, little or no fines.
GM--Silty gravels, gravel-sand-silt mixtures.
GC--Clayey gravels, gravel-sand-clay mixtures.
SW--Well-graded sands, gravelly sands, little or no fines.
SP--Poorly-graded sands, gravelly sands, little or no fines.
SM--Silty sands, sand-silt mixtures.
SC--Clayey sands, sand-clay mixtures.

Fine-grained Soils

ML--Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
CL--Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
OL--Organic silts and organic silty clays of low plasticity.
MH--Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
CH--Inorganic clays of high plasticity, fat clays.
OH--Organic clays of medium to high plasticity, organic silts.
Pt--Peat and other highly organic soils.

Each soil type in the USDA Soil Conservation Service soil survey publication is classified under the Unified system and includes estimates of its engineering properties to a depth of 5 or 6 feet. Although many engineering works are concerned with soil and bedrock qualities at greater depths, sufficient data can be gained from soil surveys for the preliminary designing, cost estimating and planning of further investigations for many engineering projects.

AASHO Classification System

The American Association of State Highway Officials (AASHO) system was originally designed in the late 1920's by the U. S. Bureau of Public Roads and is based upon soil properties and soil performance under highway pavements. Materials up to 3 inches in diameter are classified as granular if 75% or more by weight of the material is gravel (2-3 inches) or sand (0.74-2mm), and as silt-clay if more than 35% by weight is less than 0.74mm in diameter (33, 44).

Soils are grouped further according to basically similar load carrying capacity and service characteristics. These soils can be described as follows, in order of those generally best suited for road subgrades to poorest (33):

Granular Materials

A-1 soils are well-graded mixtures from coarse to fine with a nonplastic or feebly plastic soil binder. This group also includes coarse materials without soil binder.

A-2 soils are composed of a wide range of granular materials that cannot be classified as A-1 or A-3 because of their fines content, plasticity, or both.

A-3 soils are composed of sands deficient in soil binder and coarse material.

Silt-Clay Materials

A-4 soils, very common in occurrence, are composed predominantly of silt, with only moderate to small amounts of coarse material and only small amounts of sticky colloidal clay.

A-5 soils, limited in occurrence, are similar to A-4 soils except that they include very poorly graded soils containing such materials as mica and diatoms, which are productive of elastic properties and very low stability.

A-6 soils, very common in occurrence, are composed predominantly of clay, with moderate to negligible amounts of coarse material.

A-7 soils are composed predominantly of clay, as are the A-6 soils, but because of the presence of one-size silt particles, organic matter, mica flakes, or lime carbonate, they are elastic.

The USDA Soil Conservation Service soil survey publication gives the AASHO classifications for each soil type and estimates engineering properties to a depth of 5-6 feet. This information is sufficient for making preliminary cost estimates, designs and plans for further investigations for local roads and streets that receive minimal heavy traffic.

ENGINEERING PROPERTIES OF SOILS

A portion of each soil survey report provides information on the estimated engineering properties of the soils to be found within the survey area. This section will briefly discuss the more major properties, the problems they may present to development, and how difficult they may be to improve or correct. Understanding this information is not only important to engineers, designers and builders, but also to communities in approving site plans and in determining the best use of their land.

Depth to Bedrock and Stoniness

Soil surveys describe the type of bedrock that is found within a soil mapping unit, and provide an estimate of its depth and hardness.

The description of the soil profile also makes reference to size and percentage of stones or rocks that may be encountered.

Removal of shallow bedrock can be a major construction expense of as much as 3 to 20 times the cost of earth excavation (see Table 4, page 48). Basements may be economically infeasible if soil depths are much less than 5 or 6 feet, and shallow soils may prove inadequate for the growth of trees and shrubs. Septic tank absorption fields may fail if there is insufficient soil for absorption, filtration and purification of the effluent, and may become a source of pollution if the bedrock is porous or contains many factures that may allow the effluent to contaminate ground water important for domestic use.

Large amounts of stones or rocks in the soil may hamper or economically prohibit construction activities or may cause damage to special pipe or structural coatings. Rocky or stony surface soils could prohibit the establishment of conventional grass lawns or interfere with the growth of other plant materials.

If it is not possible to avoid development on shallow soils, overcoming these problems may include:

--removal of rock with hand tools or light equipment if it is soft; blasting or use of air hammers for hard rock (extremely costly).

--eliminating basements in very shallow soils.

--prohibiting conventional septic tank absorption fields and providing public sewer systems or alternate on-site disposal systems such as package treatment plants.

--bringing in additional fill material if cut depths are limited by bedrock and bringing in additional topsoil for landscaping.

--avoiding steeper slopes requiring greater cut and fill.

Slope

The slope of a soil refers to its per cent change from a level horizontal plane. For example, a 10% slope is 10 feet of vertical change in 100 horizontal feet. Each soil type described in the soil survey has a characteristic slope or slope range which can be used in determining soil suitability for different land uses.

A major concern of development on steeper slopes is that they have a greater potential for erosion if there is a significant reduction in the amount of vegetative cover and permeable soil surface so that the rate of run-off is increased. This situation will result in the loss of topsoil and increased sedimentation in water bodies.

Steeper slopes may also greatly increase construction costs if a large amount of earthwork is required for cuts and fills for foundations and for utility and road excavations that may require longer lengths to maintain specific grades of gentler slope. Special structural design or soil modification may be required, or development may need to be prohibited on those slopes subject to mass failure if the soil's shear resistance is insufficient to support the weight of the structure, fill, and any water above it.

On-site sewage treatment may also be infeasible on steeper slopes where the layout and building of septic tank absorption fields is difficult or where lateral seepage or down slope flow may result, especially where soils are underlain by shallow bedrock or hardpan layers. Sewage lagoons may also be impractical to build on slopes greater than 7% unless there is sufficient impermeable soil for leveling (44).

Development on excessively steep slopes should be avoided except for uses such as conservation, forestry, rangeland, recreation, or occasionally permitted low density housing. Where other types of development are unavoidable, consideration should be given to the following measures:

--maintenance of as much vegetative cover as possible and design of drainage systems to minimize the rate of run-off and erosion.

--proper compaction of subgrade and fills to improve shear strength of soils on slopes and careful design of structures and fills to reduce weight on subgrades that might result in shear failure.

--proper use of retaining structures.

--avoiding developments at the base of steep slopes that may be subject to flooding or sedimentation and damage from drainage problems.

--placement of septic tank absorption field drain trenches with the contour of the slope to slow the flow of effluent through the drains and disperse it into the absorption field, or prohibiting use on excessively steep slopes.

--adding lift stations where necessary to aid gravity flow utilities.

--designing roads to follow contours on steeper slopes.

Depth to Water Table

The water table is a level within the soil below which the soil is saturated with water. Variations in seasonal moisture conditions may raise or lower this level periodically, and is thus referred to as the seasonal water table. Generally, the soil survey does not consider water table levels below a 5 to 6 foot depth of soil, but will note its depth if within this range and during which months it will most likely occur.

Knowing the seasonal depth of the water table is important in planning construction schedules and techniques to avoid difficult and possibly hazardous conditions in activities such as excavating, grading, or movement of heavy machinery that will incur extra cost for corrective measures or costly delay in construction. Sometimes altering the depth of the water table may not be feasible if it could result in excessive settlements or damage to properties off the construction site. Remedying the situation may call for more elaborate measures and more careful design.

Moisture variability can also have a detrimental impact on soil strength, compressibility and volume change that could result in structural damage or failure if not controlled. Conventional septic tank absorption fields may not be able to function properly, there may be flooding of basements and utilities, and there may be damage to or loss of plant materials. Thus, control of the water table level or other corrective measures may also be part of the required maintenance and expense after construction.

Of concern also is that water table levels near the surface may be susceptible to pollution from developments such as sanitary landfills, agriculture, and industry if there is insufficient soil to filter out the pollutants. This may involve greater expense in water treatment if the ground water serves as the major source of the domestic supply.

Avoiding development on sites with near-surface water tables, especially if they occur over prolonged periods, is most advisable. If this is not possible, one or more of the following measures may be required to improve the situation to varying degrees:

--installing a sump with pump and subsurface drainage system to lower the water level (providing a good outlet for the pump's discharge).

--limiting excavation depth and building on reinforced concrete slab above the water table.

--waterproofing or eliminating basements.

--if structure is already in existence, adding drains around outside walls or under basements (lowering water level under basements may cause unequal settlement that could crack walls).

--excavating an isolated high water area for development as a site amenity.

--draining perched water tables (underground "pockets" of water), if of limited extent, by drilling a hole through the impervious layer.

Any of the above measures that rely on the permeability of the soil and gravity flow to move excess water to drainage systems for removal may not function on soils of high clay content. These soils may hold the water tightly through high pore tension and lack the permeability for good water movement. These same soils may also be capable of moving water from great depths to the surface through capillary action, even if the water table has been lowered. Height of the capillary rise can vary from a few inches in some sands to more than 100 feet in some clays (39). Corrective measures may become economically infeasible in many cases.

Soil Drainage

Each soil in a survey area is given a soil drainage classification which indicates how often and for what length of time it is saturated or partially saturated under natural conditions. Drainage conditions are affected by soil texture, topographic position of a soil, flooding, and the depth to the water table, bedrock or impermeable layer. Coarse-grained soils generally drain rapidly with resultant replacement of water in voids by air. Fine-grained soils with low permeability and tight water retention may, in some cases, be drained only by consolidation of the soil.

Problems related to poor drainage characteristics may include reduction of a soil's bearing strength, increased difficulty in excavation, grading and compaction during construction, damage to underground structures or vegetation from soil wetness, undesirable surface ponding, and failure of septic tank absorption fields. Excessively drained soils may contribute to ground water contamination if they transmit sewage effluent too quickly.

Corrective or modifying measures for these problems as well as their success can vary considerably with soil characteristics and may involve:

--grading around structures for positive drainage.

--creating small diversions or ditches to carry off water.

--proper installation of downspouts to collect roof run-off that may be emptied into subsurface drainage systems that will carry it to street gutters or storm sewers or into outlet spreaders that will disperse it over grassy areas.

--proper installation of sub-surface drainage systems to help control moderate soil wetness through gravity movement of ground water (one of least expensive and most reliable methods except when dealing with fine-grained soils such as silts and clays).

--pre-compressing or pre-loading the soil to drain it through consolidation where necessary to improve soil strength and reduce frost action and shrink-swell (especially useful in clayey soils that are impossible to drain by other means).

--trenching through dense, thin soil layers near the surface that cause ponding or perched water and replacing with permeable material.

--altering the topsoil or installing drainage systems to prevent damage to or loss of plant materials.

--requiring lower density developments to minimize additional run-off.

--waterproofing basements and installing dehumidifiers or eliminating basements.

Soil Bearing Capacity

A number of soil characteristics can affect the bearing capacity of a soil and determine whether there may be large settlements after construction that would result in damage to structures. Some of the major considerations include a soil's shearing strength, compressibility, and elasticity.

The shearing strength or load supporting potential of a soil is influenced by internal friction between soil particles, and cohesion, which is the result of the attraction of particles due to moisture or molecular forces. Gravels and sands generally have greater internal friction and are less affected by moisture content, while clays tend to have low internal friction, especially when high in moisture which causes greater slippage between particles.

Cohesion can be greatly altered by moisture in the soil, especially in clays. Dry clays may have little cohesion, but cohesion increases with the addition of moisture to the point where the soil becomes a liquid with a consequent decrease in cohesion. Silts and sands have little to no cohesion.

An example of a soil with good shearing strength would probably be of gravel and sand which provide good internal friction, with enough silt to fill the voids and enough clay to give good cohesion. At the other extreme, a wet clay lacking coarse grains would have poor bearing characteristics because of little friction or cohesion. Removal of some of the moisture would increase its cohesiveness.

Soil shearing strength is important to the stability of excavations and slopes, and to the support of structures and roads. Failure of the soil to bear the weight of fill material or structures can cause extensive damage, particularly where the movement is unequal.

Another major concern is that of the compressibility or potential for decrease in volume of a soil under a load. The total amount of settlement, both immediate and long term is important to design techniques. But even more important is how great the differential settlement will be. Variance in fill depths or cut and fill under a structure will cause the settlement to be uneven. Compressible soils beneath a properly constructed but heavy fill will also require that allowance for settlement be made when designing structures. Gravels and sands are generally the least compressible and very plastic clays are the most.

Elasticity, or the rebound of a soil after an applied load is removed, rarely presents problems under structures such as residences, but may be a very important factor in road design. Soils that have elastic characteristics are poor subgrade material for flexible pavements that will fluctuate with each passing vehicle and eventually break apart. Soils of the AASHO classification A-5 and A-7 are extremely elastic.

Construction and design techniques that may improve a soil's bearing characteristics include:

--carrying footings below unstable soil layers.

--proper design and depth of footings and reinforcement of foundations.

--avoiding development on peat and highly organic soils.

--implementing good drainage systems to minimize changes in stability due to moisture.

--altering the soil through densification (compaction, preloading, drainage methods or vibroflotation) or through additives which may include grouting or chemical stabilization.

Shrink-Swell Potential

The potential for a soil to shrink or swell refers to its ability to compress or decrease in volume upon drying and to expand upon wetting. This phenomenon occurs in areas of lower rainfall where there is less weathering of the montmorillonite clay minerals to less active clays and there is insufficient leaching to remove them from the upper soil layers. Generally, fine-grained clays are the most susceptible to shrinking and swelling, but some silts may also have this tendency.

The pressures associated with swelling can be great enough to cause cracking in foundations and walls that may result in structural failure and to cause damage to roads, and the cracks occurring in the soil upon its drying may easily transmit water, causing wet basements.

Due to such factors as the soil being drier beneath a structure than around it, there may also be damage from differential settlement.

If the soil moisture could be controlled, the problems related to shrinking and swelling could be prevented. But because it is not possible to eliminate all volume change and because development may necessarily occur on expansive soils, one or more of the following measures should be undertaken:

--reinforcing foundations to withstand stress.

--placing small structures on relatively stiff mats that are able to rise and fall with soil volume changes, but which will not deflect enough to cause problems.

--using flexible foundations and structures that are able to deform without damage if the soil volume change is not very irregular.

--carefully designing drainage systems to move water quickly away from roads and buildings, and preventing leaks within the system that could cause the soil to swell; placing pipes under floor slabs in concrete troughs to protect the soil from any leakage and to protect pipes from damage due to soil movement.

--altering the soil by adding cement, lime or other workable admixture to reduce or eliminate the volume change that results from wetting and drying, or by decreasing density through compaction of the soil in a wet condition (must balance this procedure with anticipated settlement).

--designing structural foundations to include spaces for soil to expand into.

--controlling water beneath foundations by laying an impermeable sheet to block water from below and at a depth so that the weight of fill and structures above will control any volume change (residential structures would probably lack sufficient weight); using good paving, grading and drainage techniques at the surface to keep significant amounts of water from penetrating.

--locating footings below the depth of volume change, leaving room at the surface for the soil to expand beneath the building without damage.

--avoiding use of AASHO classification A-7 soils for road subgrade or, if unavoidable, requiring adequate subbase and pavement depths on them.

--limiting the use of trees and shrubs near building and roads that may increase shrinkage, settling and cracking of foundations.

Potential Frost Action

In order for a soil to be susceptible to frost action, three conditions must be met:

1. The soil must be exposed to freezing temperatures.

2. There must be a water source such as a water table sufficiently close to the frost line, capillary supply, water in soil voids, or water from filtration that will serve to feed the ice layers.

3. The soil must have the ability to rapidly transmit water from the water source to the ice layers. Generally, fine sands and silts will have the optimum combination of fine pores and relatively high permeability. Clays will also be susceptible to frost action if they contain cracks and fissures for rapid water movement.

If temperatures remain below freezing for an extended period, ice layers will form in the soil and grow downward. Because water expands about 10% when frozen, these ice layers will cause the ground surface to rise or heave. This force can be great enough to move light buildings with shallow foundations, and its lack of uniformity can cause concrete pavement to crack or tilt and flexible pavements to wave or develop bumps.

The other major concern with frost action in soil is that when the ice layers melt from the surface downward, the uppermost soil will remain wet from the ice melt until the lower layers also melt and allow the moisture to drain through. This soil wetness at the surface can cause the soil to lose strength and may result in the failure of structural foundations. The weight of a truck upon a roadway supported by this liquid soil may force the moisture through expansion joints in concrete pavement or form holes in flexible pavements such as asphalt.

Measures to reduce or eliminate the effect of frost action in soils may include:

--removing susceptible material and replacing with sand or gravel base and subbase.

--placing foundation footings below the frost line.

--backfilling around foundation walls or footing pedestals with granular material.

--designing structures and pavements to withstand heave and low strength; basements may be preferable to slab foundations.

--implementing good drainage systems to minimize water accumulation in soil pores.

--lowering the water table so that the height of capillary rise is below the frost line.

--blocking upward movement of moisture from the water table by placing clean, coarse gravel, sand, or crushed rock in a layer thicker than their capillary rise; must be protected with a filter both above and below it to keep out fine soils and for proper drainage.

--blocking upward movement of moisture from the water table with impervious material such as asphalt, plastic or commercial bentonite.

--adding chemicals to the soil that cause higher density and lower permeability.

Corrosivity

Corrosivity as used in the soil survey refers to a soil's ability to chemically dissolve or weaken concrete or uncoated steel. Concretes may deteriorate more rapidly due to soil-related properties such as the amount of certain sulfates in the soil, soil acidity and soil texture. Soil conditions such as texture, drainage, acidity and the electrical conductivity of the soil may combine to cause more rapid corrosion of uncoated steel. If such soil tendencies are not recognized or remedied, replacement of damaged structures such as pipes can be costlier than pre-treating the steel or concrete or replacing it with a non-corrosive material.

Methods of overcoming this problem may include:

--using concretes with special admixtures that resist the source of corrosion, that reduce the concrete's permeability, or methods that slow the rate of deterioration.

--protecting steel with special coatings (coatings must be protected from damage by rock fragments or gravel).

--providing cathodic protection by burying sacrificial metals or anodes that are connected to the steel (design-life must be considered).

--avoiding use of connected dissimilar metals that may increase the rate of deterioration.

--substituting non-corrosive materials.

Other Data

It is important to note that other data on soil engineering properties, soil physical and chemical properties, and water features is usually available from the Soil Conservation Service (see Appendix A). Some of this information may also prove useful to community planners, but its interpretation is beyond the scope of this study.

Although this study is only involved with soil properties that relate to residential development, soil survey reports provide information for planning other uses. These include siting sanitary landfills and sewage lagoons, locating construction materials such as sand and gravel, and suitability for recreation and agricultural, wildlife, and woodland production. Because of this, SCS soil maps and data are a valuable input into planning systems such as the Metropolitan Landscape Planning Model Study.

Chapter 3

THE METLAND REVISED PHYSICAL DEVELOPMENT SUITABILITY ASSESSMENT PROCEDURE

The University of Massachusetts has developed a system known as the Metropolitan Landscape Planning Model Study (METLAND) which is an effort to assign a quantified value to environmental resources in order to give them equal consideration with social and economic values in the planning process. This method was initiated in response to the steady spread of urbanization and consequent deterioration or loss of the natural resource base in eastern Massachusetts (16).

The planning model has been divided into 3 phases as follows:

1. Assessment phase which is intended to determine the type and estimate the quantity, quality, and value of environmental problems and constraints and to map this data.

2. Plan formulation phase which analyzes information from the assessment phase in order to develop alternative uses of the land based on a variety of viewpoints, variously emphasizing landscape values, ecological values and public service resources.

3. Plan evaluation phase which analyzes alternative directions that planning could take, resulting in informed decisions that recognize probable trade-offs.

The assessment phase is composed of 4 major environmental areas: special resources, hazards, development suitability and ecological stability. These components are further divided into variables and sub-variables as shown in the conceptual diagram (Figure 2).

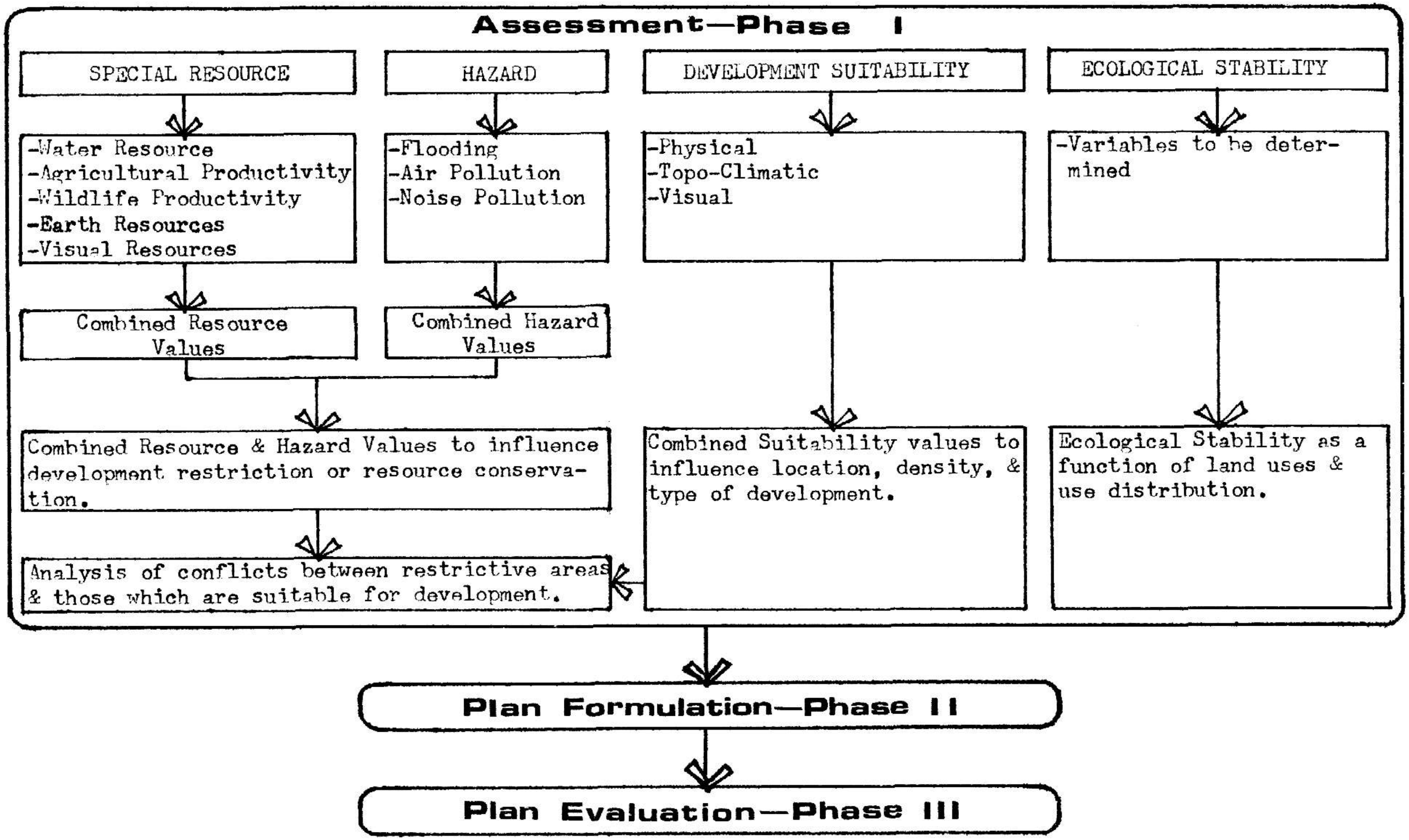

Figure 2

Conceptual Diagram of the METLAND Model Process

Only one aspect of the system, the Physical Development Suitability variable of the Assessment phase, will be considered in this study. It relies on SCS soil maps and information for its data base, with input from developers to form the interpretations for development suitability. Only residential development suitability is examined, since it is assumed that suitable commercial and industrial sites would be limited to certain locations within the same area. Typical subdivision housing of the New England-North Atlantic region consisting of single-family wood-frame houses with basements and at a density of 2 dwelling units per acre are considered.

The procedure of assessing the physical development suitability for residential use is relatively simple. Data and soil maps are obtained from the SCS, with the identification of study area soils and determination of the major soil characteristics or physical subvariables to be examined. The METLAND study uses depth to bedrock, depth to water table, drainage, slope, topsoil and bearing capacity as its physical subvariables (Figure 3).

Estimates of expected additional development costs per housing unit are then assigned to each subvariable. These estimates are based on the recent experience of housing developers in Massachusetts (Table 1).

The added development costs are totaled for each soil type (Table 2). Soils are then placed into A, B, C, or D classes for physical development suitability based on their total added cost (Table 3). A, B, C, and D classes are defined by what these costs mean in terms of square footage per house.

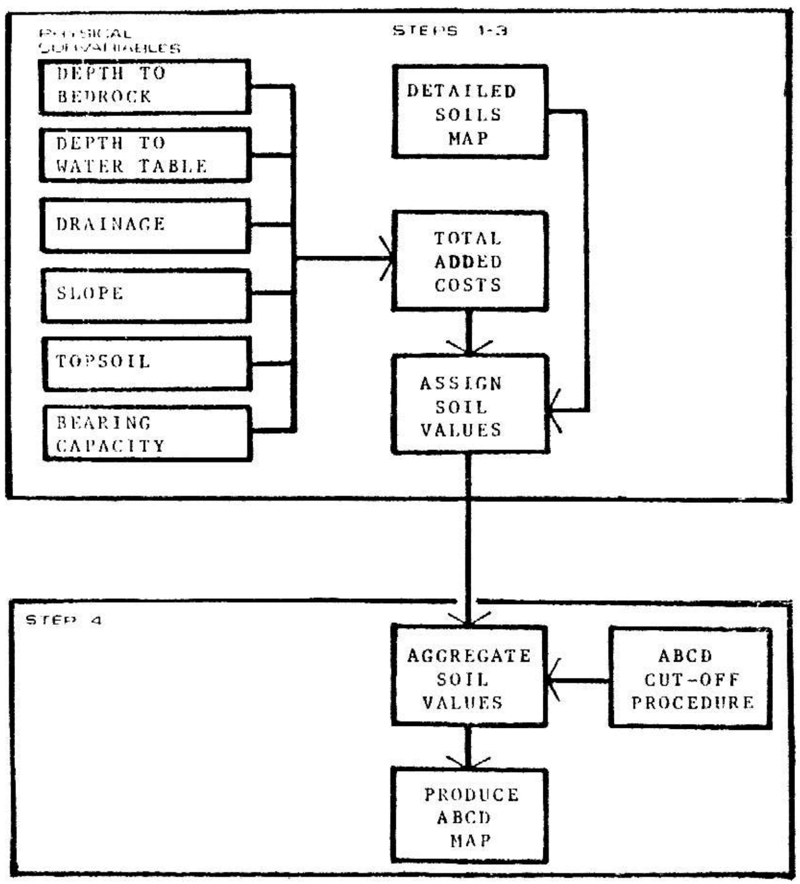

Figure 3

METLAND Revised Physical Development Suitability Assessment Procedure

Table 1

METLAND Estimated Added Development Costs for Physical Subvariable Dimensions

Subvariable and Dimensions	Estimated Added Development Costs
Depth to Bedrock:	
0 - 2'	$20,000
2 - 5'	5,000
5' +	200*
Depth to Water Table:**	
0 - 3'	$ 5,000
3 - 5'	1,400
5' +	0
Drainage: **	
Poorly to Very Poorly Drained	$ 5,000
Mod.-Well Drained with Hardpan	1,400
Otherwise	0
Slope:	
15% +	$******
8 - 15%	1,300
0 - 8%	0
Topsoil:	
Poor (0 - 4")	$ 1,500
Fair (4 - 6")	600
Good (6" +)	0
Bearing Capacity:	
Plastic & Non-Plastic Silts & Clays; Peat; Muck	$ 1,500
Otherwise	0

*Depths of bedrock well below five feet would incur no additional costs to development. However, since very deep bedrock cannot be ascertained from soil typings, a minimum cost of $200, which is applicable for less deep bedrock conditions, is assumed.

**It should be noted that high water table and poor drainage conditions often occur simultaneously, and that the same correction techniques and costs are usually involved. As will be seen, the METLAND assessment technique recognizes this fact. However, the two subvariables are shown separately here because they can in certain instances occur independently of each other.

Table 2

Illustration of How METLAND Individual and Total Added Development Costs are Recorded for Soil Types

Map Soil Symbol	SOIL NAME	Depth to Water Table	Depth to Bedrock	Slope	Drainage	Bearing Capacity	Topsoil	TOTAL ADDED DEVELOPMENT COSTS*
		PHYSICAL SUBVARIABLE — EXPECTED ADDED DEVELOPMENT COSTS						
	DEERFIELD							
138-A-1	Deerfield loamy sand 0-3% slope	$1400	$200	$0	$1400	$0	$1500	$3100
138-B-2	Deerfield loamy sand 3-8% slope	1400	200	0	1400	0	1500	3100
	ENFIELD							
79-A-1	Enfield v. fine sandy loam 0-3% slope	0	200	0	0	0	0	200
	ESSEX							
23-B-1	Essex v. stony fine sandy loam 3.8% slope	0	200	0	1400	0	600	2200
23-C-1	Essex v. stony fine sandy loam 8-15% slope	0	200	1300	1400	0	600	3500
23-D-1	Essex v. stony fine sandy loam 15-25% slope	0	200	*****	1400	0	1500	*****
24-B-1	Essex extr. stony fine sandy loam 3-8% slope	0	200	0	1400	0	1500	3100
24-C-1	Essex extr. stony fine sandy loam 8-15% slope	0	200	1300	1400	0	1500	4400

*Note that in determining total added development costs, where both depth to water table and drainage problems occurred simultaneously, only the cost of solving one of the constraints was used. This is because solving for one problem will also correct the other.

***** - Generally prohibitive added development costs.

Table 3

METLAND A-B-C-D Classes for Physical Development Suitability

Total Added Costs	Aggregation Class
\$ 0 - \$ 2000	A
\$ 2001 - \$ 4000	B
\$ 4001 - \$ 9000	C
\$ 9001 +	Undevelopable (or Class D)

Class A soils, which are well suited to physical development, can incur up to $2000 in additional costs, or the equivalent of 100 square feet (a typical small bedroom) based on 1975 cost estimates. This means that in order to achieve the same profit margin, a house built on a soil with $2000 additional development costs would have to eliminate an area the size of a small bedroom. Class B would include soils with $2000 to $4000 additional costs, comparable to 200 square feet (2 small bedrooms, a 2-car garage, or a livingroom), and class C soils with $4000 to $9000 in additional costs, equal to 450 square feet (a large livingroom) would mark the limit for feasible development. Class D soils are assumed to be undevelopable for the typical subdivision housing described.

The information from this assessment can be put into a computer to produce a map of the study area which delineates the boundaries of A, B, C, and D areas. Computers can also be programmed to process data from this stage of the planning model in relation to the other environmental resources to acquire alternatives to development that reflect a variety of community viewpoints.

Chapter 4

INTERPRETING ENGINEERING PROPERTIES OF KANSAS SOILS FOR PLANNING RESIDENTIAL DEVELOPMENTS

The landscape of the state of Kansas is a plain of low relief that has developed on sedimentary shales, limestones, and sandstones, and on wind, water, and glacial deposits of gravel, sand, silt, and clay. Its two major physiographic provinces are the Central Lowlands in the eastern half of the state and the great Plains in the western half.

In general, soils in the eastern segment of the state have formed on shale, limestone, and sandstone, and support tall grass vegetation in the uplands and hardwoods in the valleys. The major exception is in the northeast corner of the state where soils have developed on glacial till and the deep loess deposits which blanket it. The flatter terrain of the western half of the state where rainfall amounts are lower is a short grass landscape with soils based on old alluvium and wind-blown silts and sands. South central and southwest Kansas, in conjunction with the Arkansas River, have areas of sandy soils and sand dunes (36).

Soil and subsurface conditions in Kansas present a number of engineering concerns for residential developments. Much of the state has clayey soils that are more difficult to excavate and compact, which cause drainage and shrink-swell problems, and which are too impermeable for septic tank absorption fields. Silts may be subject to frost action where temperature and water conditions make this possible, and deep alluvial and loess deposits may cause bearing problems for some developments. Some sandy soils may require more earthwork and stabilization in deeper excavations and may not provide adequate filtering in sewage absorption fields.

Many areas of Kansas have seasonal high water tables that, even though often of only a month's duration, can cause wet basements, failure of inadequately designed streets, foundations and septic tank systems, and increased shrink-swell problems or frost heave. A number of soils are also shallow to bedrock, but most of this rock is rippable. In addition to increasing excavation costs, some of these areas have problems of stoniness and may also be unsuitable for sewage absorption.

Although most of the state is relatively flat or of gently sloping hills, the red hills in the south as well as parts of the flint hills and the dissected till plains have more extensive areas of steeper slopes. Most Kansas communities should be able to plan residential developments to avoid locally steep sites.

Costs related to these and other engineering characteristics of Kansas soils will be presented in the following sections by using the Physical Development Suitability assessment procedure of the METLAND planning model. It is, however, important to first review some of the assumptions and generalizations that were made in this study.

REVIEW OF ASSUMPTIONS AND METHODS USED FOR COST ESTIMATIONS

Housing designs and sizes as well as lot sizes and landform are quite variable, so it is necessary to assume average and uniform conditions in order to make calculations and apply unit costs. For the purposes of this study, houses are assumed to be 1500 square-foot, one to two-story wood-frame structures placed at an average of 4 per acre on 1-8% slopes and 2 per acre on 8-15% slopes. Density of housing units varies with slopes because of greater difficulties and costs involved in maintaining suitable grades for streets and houses on greater inclines and potential bearing, drainage, and erosion problems.

In estimating earthwork quantities, an average uniform slope of 4% is used for any soil falling in the 1-8% group, and 12.5% is used for those falling in the range of 8-15%. Earthwork calculations are only made for minimal grading to achieve proper drainage and to maintain street gradients so as not to exceed an average of 5%. Slopes greater than 8% are considered unsuitable for slab on grade homes, and those greater than 15% are considered infeasible for typical housing developments, although major design modifications and adjustment of housing density could make some type of development possible. The only design modification considered in this study is an allowance for walk-out basements on steeper sites (with an average excavation depth of 3 feet), and not on those sites that are more level (with an average basement excavation of 5 feet), so that quantities of earth to be excavated are minimized. It should be noted once again that because subsurface conditions below a depth of 5 or 6 feet are not included in SCS information, significant costs beyond the estimates presented in this study could be incurred.

Earthwork and pavement calculations for the 30-foot wide street are based on 75 feet of frontage (shared by two lots) on 1-8% slopes and 150 feet of frontage (shared by two lots) on 8-15% slopes.

Lengths of water and sewer lines for each lot are assumed to be 40 feet for main and 35 feet for service on sites with 1-8% slopes, and 75 feet for main with 35 feet of service on 8-15% sites. Material and installation costs for other utilities are not considered in this study.

Unit cost estimates for earthwork and construction were obtained from area contractors (Appendix B) and averaged (Table 4, page 48). These unit costs were then used, along with estimated earthwork and material quantities, to determine total development cost per lot under various soil and subsurface conditions.

Although a number of assumptions and generalizations were necessary to determine costs for different operations, and these figures could not be applied to any specific project, they do reflect the fact that certain soil and subsurface conditions will usually increase costs during development and construction. They also indicate a comparison of the difficulty in handling the various problem conditions encountered. The stated costs are not so important in themselves, as these are constantly changing. But the per cent increase that various soil conditions may incur can serve to give a better perspective on selecting good residential sites and as an important input in making well-informed planning decisions.

ESTIMATED COSTS RELATED TO EARTHWORK

Earthwork costs can be greatly affected by soil, rock, water, and slope conditions. Some costs are predictably high, as in the case of removing large quantities of bedrock during operations. But, sometimes, numerous smaller added costs, or those such as subsurface water conditions that are harder to predict, may add significantly to the cost of developing a site.

This section will review the costs encountered by area excavators when dealing with various soil characteristics. By determining the impact that one or a combination of soil properties has on excavation costs, it becomes possible to evaluate and compare the suitability of available community land for residential development.

Stripping and Stockpiling Topsoil

Topsoil, the layer of surface soil high in organic matter, mantles much of the earth's surface. It varies in depth from an inch or two to two feet or more, depending on factors that affect its formation, such as the amount of precipitation and type of vegetation under which it developed. On residential development sites, this layer needs to be stripped from construction areas and retained for the finish grade, as the organic matter it contains can cause its compressibility to be less predictable, and therefore, less desirable in many fills and embankments.

When existing topsoil on a site is thin, additional topsoil will have to be purchased and hauled in. This added expense ranges from \$4.50/CY to \$6.70/CY in Kansas (see Appendix B). If, for example, only 2 inches of additional topsoil were needed on a site, it could cost from \$300 to \$600. Descriptions of topsoil conditions may be obtained from Soil Conservation Service maps and profile descriptions.

Excavation and Backfill for Streets and Slab on Grade Foundations

The cost of moving earth in bulk wide area excavations, used to establish subgrades by depositing soils in thin layers over large areas, relates, in part, to the type of equipment that is used. Factors contributing to the choice of equipment include the accessibility to the work site, the quantity of earthwork to be done, and the type of soil and subsurface conditions that are encountered. Bulldozers or scrapers, each with a different capacity and speed for moving earth, are usually used for this type of work (10). Contractors' cost estimates will, therefore, vary with the scale of work and the type of equipment that they have available for a job (see Appendix B).

As shown in Table 4, page 48, contractors reflect the greater difficulty in excavating heavy clays, hardpan soils, rock, and soils below the water table in their cost estimates. Increased costs may be due to slower operation of equipment, as when in heavy plastic clays, or to additional procedures and equipment that may be required, as in ripping hardpan and soft rock layers, blasting or drilling hard rock, or dewatering the soil so that work may proceed. Costs added to the average base unit cost of $1.80/CY in light or medium soils ranged from 25% in heavy clays to more than 2000% when hard rock has to be removed by means other than blasting.

The slope of a site also has an impact on the quantity of soil or rock to be moved and, consequently, on cost. The slope range described for each soil type in a soil survey report can be used to calculate an estimate of the volume of earthwork that may be required. The cost of excavation for streets on 1-8% slopes may increase by an average of more than 300% for those on slopes of 8-15%. This is due to larger amounts of cut and fill and the longer length of road excavation required to maintain no more than an average 5% grade. Slopes beyond 15% not only increase excavation costs, but additional considerations of slope and soil stability, run-off, and soil erosion necessitate special design, construction, and densities not as commonly found in conventional housing developments.

Excavation and Backfill for Basement Foundations

Excavation methods for the establishment of basement subgrades differ from those used for bulk wide area excavation in that work to a considerable depth is usually involved, and the larger volume of earth must frequently be hauled away from the site. Equipment generally operates from within the excavation itself, working against the bank of the pit to remove soil. This requires the use of a power shovel, which is most efficient for large pits, or a front-end loader for smaller jobs (10). When the pit is wet, when the soil is loose and unstable, or when there is poor access to the site, excavation may have to proceed from the surface above rather than within the pit. This situation can greatly increase costs if special equipment such as a dragline must be brought in to perform the operation, but is not included in this study since it involves specific site considerations.

Basement excavation unit costs are higher overall than for streets or slab on grade homes (see Appendix B), because it is usually a slower operation. The base unit cost of digging in good conditions averages \$2.65/CY in Kansas (Table 4, page 48). Heavy clays can add at least 15% to the cost while hard rock removal could add more than 1600%. Slopes of 8-15% can actually decrease excavation quantities and costs by almost one-half that on lesser slopes if walk-out basements are designed to take advantage of the topography. However, on steeper sites it is possible to run into more rock ledges if soils are shallow, and water tables that are near the surface may be harder to work with.

Excavation and Backfill for Trenches

Trenching is a linear excavation of a designated minimum width in which the earth is usually deposited to the side for later backfilling. Work is performed from outside and above the trench by using a trencher machine, which is very efficient for depths less than 5 feet where grading is not required, or a backhoe, which is used for either shallow or deeper trenches and in cases where a specified gradient must be maintained (10).

Major difficulties can occur in wet conditions where some soils lose their shear strength or with sandy soils lacking the cementing qualities of clay particles. Wider trenches with the sides tapered back to a stable slope or bracing may become necessary in these situations.

Cost estimates (Table 4, page 48) reflect that heavy clay soils only increase the base unit cost of $2.50/LF for shallow trenches by 5% and add 10% to the base cost of $5.25/LF for trenches 10 to 12 feet deep. At the other extreme, hard rock can increase costs up to 1000%. Placing trenches on development sites with slopes averaging from 8-15% can increase excavation costs by almost one-half, since increased utility lengths will result from lower density housing.

Compaction

When soil is disturbed, it increases in volume so that compaction is necessary to eliminate excessive air space and prevent excessive settling when it is placed as fill or backfill. This operation includes careful control of the soil moisture content, with an optimum of 8% for sands, 15% for silts, and 20% for clays, and placing and compacting the fill in layers of 6-12 inches. Fill material that must support the load of streets or buildings must be compacted to 95% of its maximum density, while lawn areas should be done to 85-90% of maximum density.

Variation in cost estimates for compacting sandy, silty, or clayey soils is shown in Table 4, page 48. In general, sandy soils are the easiest to compact, with silty soils being slightly more difficult. Some clayey soils may require different equipment and/or placement of fill in thinner layers that necessitates more passes by the equipment, thus, increasing costs. The greater ease of compacting larger areas where more efficient machines can be used is reflected in an average cost of $.60/CY if soils are easily compacted. Backfill in narrower areas around basements and in trenches costs more to compact, from $2.00-$2.85/CY, under good conditions, since hand operated equipment slows down the process.

ESTIMATED COSTS RELATED TO DESIGN AND CONSTRUCTION

Soil and subsurface conditions can affect the design and cost of constructing home foundations, streets, utility lines, and septic tank absorption fields. Major concerns include soil bearing properties, potential for shrinking or swelling, potential frost action and drainage or water table conditions. As described in chapter 2, there are a number of ways to deal with each of these situations. But they are not all feasible techniques for residential developments or for every community.

Interviews with area contractors showed some variation in methods that might be used to overcome soil problems. In some cases, no extra measures are taken, while in others, more than one technique might prove useful. Obviously, the method chosen would determine the added costs. Design and construction techniques commonly used by those contractors interviewed will be discussed in the following sections.

Slab on Grade Foundations and Basements

Because soils most often provide the supporting media for home foundations, understanding their engineering characteristics and possible limitations is essential to planning good layouts and designs. When a soil problem is encountered, there are basically two ways that it can be approached. The soil itself may be modified to eliminate or minimize the problem, and/or the design of the structure may be altered to compensate for any negative impact.

Techniques most commonly used by those Kansas contractors (11, 19, 47) that were interviewed for this study included:

1. Poor bearing
   - A. Careful compaction at optimum moisture content
   - B. Pier foundations
   - C. More reinforcement in footings
   - D. Good surface and subsurface drainage
2. High shrink-swell
   - A. 4-8" sand or gravel base
   - B. Heavier reinforcement in slabs
   - C. More reinforcement in footings
   - D. Good surface and subsurface drainage
3. High potential frost action
   - A. Footings carried below frost depth

B. 2"-thick styrofoam perimeter insulation

C. Good surface and subsurface drainage

D. Plastic sheeting under slabs

E. Additional reinforcement in basement walls

4. Poor drainage or high water table

A. Underdrain system of at least 12 inches of gravel with 2-4" drain pipe to sump or gravity drain

B. Positive surface drainage around structures

C. Proper design and installation of gutters and downspouts (costs not included in this study)

Some of these procedures may be standard practice in many communities, as in the case of placing footings below the frost line and providing subsurface drainage systems. But variable soil conditions often will require more extensive measures and evaluation by qualified engineers.

A comparison of construction and development costs for foundations that may result from poor soil conditions is shown in Table 4. Although per cent increases appear to be small, it is important to note that the unit costs on which they are based are sometimes quite substantial, resulting in significant additional dollar amounts. In addition, the fact that the contractors do not in all cases make construction modifications causes the average per cent presented in Table 4 to indicate the relative influence that a poor soil condition may have on cost when compared to other soil problems rather than how much it will actually cost to correct it. For estimates that more nearly reflect actual costs, refer to Appendix B.

Streets

Both asphalt and concrete street paving for residential use have been evaluated in this study. Each may have advantages and disadvantages for specific design situations. For example, flexible asphalt paving is generally easier to construct and repair and snow melts more quickly on it (18, 23, 41) while the rigid nature of concrete may provide load-distribution characteristics that make it a desirable choice on soils where bearing characteristics are less than optimum (33, 40). Clarification of which type of paving is preferable is not a focus of this study. Only the impact that poor soil and subsurface conditions have on design and construction techniques and costs is presented here. Some of the commonly used techniques of area contractors (2, 11, 17, 37, 47) include:

1. Poor bearing
    - A. Soil modification, such as lime treatment
    - B. Increased depth of base and/or subbase
    - C. Careful compaction at optimum moisture content
2. High shrink-swell
    - A. Soil modification, such as lime treatment
    - B. Replacement of expansive soil with non-expansive fill
3. High potential frost action
    - A. Good surface and subsurface drainage
    - B. Gravel subbase
4. Poor drainage or high water table
    - A. Proper design and implementation of surface drainage
    - B. Subsurface drainage

The summary of cost estimates in Table 4 shows that asphalt paving may be less expensive under good soil conditions, but becomes more comparable to concrete when modifications must be made under

Table 4

Summary of Average Estimated Costs of Residential Construction Related to Soil/Subsurface Conditions in Kansas*

Soil or Subsurface Conditions Affecting Costs	Streets		Foundations: Slab on Grade: Footing	Foundations: Slab on Grade: Slab	Foundations: Basements		Utilities: 5' Trench (18" wide)		Utilities: 10' Trench (30" wide)	
Excavation and Backfill										
Light or medium soil	$1.80/CY		$2.52/LF	$1.80/CY	$2.65/CY		$2.52/LF		$5.25/LF	
Heavy clay	+26%		+4%	+26%	+16%		+4%		+10%	
Hardpan	+68%		+26%	+68%	+45%		+26%		+31%	
Soft rock	+217%		+48%	+217%	+54%		+48%		+95%	
Hard rock (blasting)	+872%		+275%	+872%	+466%		+275%		+511%	
Hard rock (no blasting)	+2076%		+1091%	+2076%	+1661%		+1091%		+1057%	
Water Table (in sand)	+350%		+340%	+350%	+350%		+340%		+418%	
Water Table (in other soil)	+15%		+128%	+15%	+15%		+128%		+157%	
Slope (excavation quantity)										
1-8%	1.15 CY/LF		.11 CY/LF	278 CY	308 CY		75 LF		75 LF	
8-15%	+320%		0	infeasible	-40%		+45%		+45%	
0-1%, 15%+	infeasible		infeasible	infeasible	infeasible		infeasible		infeasible	
Compaction					General Site	Walls & Slab				
Sandy soil	$.62/CY		$2.00/CY	$.62/CY	$.62/CY	$2.00/CY	$2.83/CY		$2.83/CY	
Silty soil	+16%		0	+16%	+16%	0	+35%		+35%	
Clayey soil	+21%		+100%	+21%	+21%	+100%	+71%		+71%	
Design of Pavement, Foundations, and Utilities	Asphalt Pavement	Concrete Pavement	Concrete Footing	Concrete Slab	Concrete Wall/Ft.*ing	Concrete Slab	Water Line: Main	Water Line: Service	Sewer Line: Main	Sewer Line: Service
Good Conditions	$8.23/SY	$14.83/SY	$10.39/LF	$1.80/SF	$22.75/LF	$1.20/SF	$7.25/LF	$3.00/LF	$13.10/LF	$10.25/LF
Poor bearing	+38%	+16%	+11%	0	+9%	0	----	----	----	----
High shrink-swell	+42%	+22%	+5%	+8%	0	+18%	----	----	----	----
High potential frost action	+39%	+6%	+3%	+1%	+2%	0	----	----	----	----
Poor drainage or high water table	+30%	+19%	0	+20%	0	+20%	----	----	----	----
Slope (pavement & pipe length)										
1-8%	----	----	----	----	----	----	----	----	----	----
8-15%	+100%	+100%	----	----	----	----	+90%	0	+90%	0
0-1%, 15%+	----	----	----	----	----	----	----	----	----	----

*The costs, percentages, and quantities shown in this table represent average estimates, not exact amounts. Actual amounts would fall within a reasonable range of higher or lower figures.

poorer conditions. With the continuing increase in the cost of asphalt, this margin will no doubt diminish in the near future.

Slope of residential sites may have a significant impact on construction costs, even under otherwise good soil conditions. In order to maintain no more than an average 5% maximum slope, sites of 8-15% may necessitate doubling the length of the road. Added on top of increased excavation costs, street construction expenditures may form a substantial portion of total development costs. Careful site selection is, therefore, essential.

Utilities

Major costs of utility installation related to soil and subsurface conditions are encountered during excavation for trenches, particularly if rock, water, or steep slopes are involved. Steeper slopes of 8-15% can also increase the cost of materials and installation by 50-60%, since housing density will be lower than on 1-8% slopes and require longer lines. But in the selection of materials and design of pipelines, consideration also needs to be given to the corrosovity of soil and possible damage or breakage that may occur to improperly installed lines in high shrink-swell soils or those subject to frost action.

The Soil Conservation Service provides information on the potential a given soil has to corrode uncoated steel or concrete (44). Most pipes in a residential development are of ductile iron, clay, or various plastics which are not affected. Concrete pipes are not commonly used, except in sizes beyond 24 inches in diameter. If they must be installed in highly corrosive soils, acidic soils high in sulfate, consideration must be given to protecting the concrete from rapid deterioration by using special cements or methods such as air entrainment of the concrete.

Steel pipes have been used in parts of some older Kansas water systems, but ductile iron and plastic are most commonly used now (34). Gas pipes are generally of steel, but companies such as Kansas Power and Light and the Gas Service Company use coated steel to reduce the rate of corrosion (27, 29). Pipe joints must also be wrapped for protection, and coated pipes must be placed in a protective bed of sand (at least 6 inches above and below the pipe) if located on bedrock or stony soils to protect the coating. They routinely provide cathodic protection with each installation, regardless of the soil type, to retard the rate of corrosion of pipe lines.

Corrosion of uncoated steel pipes results from a physical-biochemical process where iron is converted into its ions, and it is high in soils with low resistance to flow of electrical current. Cathodic protection in the form of sacrificial anodes of zinc or magnesium which are attached to pipes, reverses the flow of electrons toward the pipe, slowing down their deterioration, and deteriorating the anode instead. In highly corrosive soils, additional anodes may be required.

Costs of anode installation vary, depending on size and length of pipes and corrosivity of the soil. One 17-pound anode will serve as protection for 1,000 feet of 4-inch pipe for 10 years in a highly corrosive soil, costing around $100 for materials and installation. The major cost, however, relates to the yearly maintenance that is required (29). Anodes must be checked to see if they are still functioning at the desired level or whether they need to be replaced or supplemented with other anodes as they deteriorate. More use is now being made of plastic pipes such as polyethylene, which eliminates problems with soil-caused corrosion.

Other concerns of utility installation are related to soils subject to movement in conditions of moisture variation. Extreme differential movement, shrinking and swelling of the soil, or frost heaving may cause lines to break if design and installation is inadequate (7). Pipes should be placed below frost depth, which can range from 42 inches in northern Kansas to 30 inches in the south part of the state. In soils subject to extreme shrink-swell, pipes may have to be placed in sand, gravel or crushed rock (6 inches below and 12 inches above) at an added cost of $100-$200 per 1000 feet of pipe to minimize movement and damage. All water and sanitary sewer pipes must have water tight joints to prevent leakage and consequent moisture changes in the soil which could add to bearing, settlement, shrink-swell, or frost heave problems. The engineer responsible for design of utilities should be sure that they are adequate for the limitations of the subsurface conditions.

Septic Tank Absorption Fields

The suitability of soils for septic tank absorption fields is frequently of concern in developing rural or suburban areas that are not provided with a sanitary sewer system. Although disposal of sewage effluent through a sanitary sewer system and treatment is the preferred method, it is not always possible in cases where development is scattered or far from existing facilities, or when funds are not immediately available for installation.

A septic tank absorption field system is a quite desirable means of disposing of effluent, if soil conditions are suitable, because it utilizes the natural purifying ability of soils and soil organisms, and it can often be installed in isolated areas at a reasonable cost. The simplest designs consist of a water-tight septic tank that receives the sewage from a building sewer and which allows the solids to settle out before the clarified liquid proceeds through a system of subsurface distribution pipes laid in trenches of coarse aggregate. As the liquid is dispersed into the soil, it is further purified and returns to the natural water cycle.

In determining the suitability of a given soil for a seepage field, certain conditions are of primary importance. These include frequency of flooding, depth to water table, depth to bedrock or impermeable layer, slope, and permeability of the soil. Minimum standards for a soil that would present only slight limitations for septic tank absorption fields are as shown in Table 5. The bottom of the seepage field must be at least 4 feet above any bedrock, impermeable layer or seasonal water table to minimize failure or potential pollution problems. Failure of the system may also result if the area is subject to flooding or has slow permeability that prevents movement and filtration of the effluent within the soil. Steeper slopes may cause the effluent to move down slope where it may surface before being purified (32, 44, 45).

Soils with moderate limitations, as shown in Table 5, may be adapted through design techniques to function adequately, but at a greater expense than suitable soils. Rare or minor flooding, high water table, or shallow bedrock may necessitate a specially designed

Table 5

Soil Limitations for Waste Disposal in Septic Tank Absorption Fields

Item Affecting Use	Soil Limitation Rating		
	Slight	Moderate	Severe
Flooding	none	rare	occaisional or frequent
Depth to Water Table	72"+	48-72"	0-48"
Depth to Bedrock or Other Impermeable Layer[1]	72"+	48-72"	0-48"
Permeability Class[2]	rapid[3], moderately rapid, upper end of moderate	lower end of moderate (1.0-0.6"/hr.)	moderately slow and slow
Slope	0-8%	8-15%	15%+

[1]Ratings for these depths are based on the assumption that seepage field tiles are at a depth of 2 feet.

[2]Limitation ratings should be applied to permeability of soil layers at or below the tile line depth.

[3]Pollution may be a hazard if there is a near by water source.

system that is composed of granular fill that raises the seepage bed sufficiently to avoid failure of the system. Steeper slopes may need careful layout of the pipes along the contours of the slope at a specified grade. Slowly permeable soils may require that systems be placed in a better fill material, avoiding very coarse textures such as gravel and sand that are relatively poor filters, or that dispersion fields be located over a larger area. It should be noted that larger lot size to accommodate septic systems in moderately or severely limiting soils may make future installation of a sanitary sewer system economically infeasible (6, 32).

In Kansas, septic tank absorption fields for average size homes may run from $1500 under good conditions to $2500 or more if problems are encountered. This compares to a sanitary sewer system installation cost in the range of $1200-$1900 with good conditions and an average size lot (2, 7, 22).

Those soils that are rated as having severe limitations, in most cases, are probably not feasible for conventional septic tank absorption fields. Any time moderate or severe soil problems are encountered, a careful site study must be conducted and the layout design prepared by a competent soil engineer who gives consideration to environmental and health safety.

If neither sanitary sewers or septic tanks are feasible, alternative methods may include package treatment plants and treatment ponds (42). Choice of method will depend on many factors such as cost, availability of proper technology, scale of development, and social and environmental issues which go beyond the scope of this study.

INTERPRETATION OF COST ESTIMATE DATA FOR PLANNING

In order to present the cost estimates obtained from Kansas contractors and the soil data provided by the SCS in a form that is more useful to planners, it is necessary to assign dollar amounts to the range of variable conditions under each soil property evaluated that summarize major development costs affected by that property. By using Tables 6 and 7, planners can quickly extract the information on costs that apply to soils in their area of concern.

Table 6 outlines the total costs that each soil property may incur during excavation for streets, foundations, and utilities. A comparison of the soil engineering properties indicates that shallow, hard rock has the greatest impact on costs, since it can add anywhere from $1700 to almost $18,000 per lot, depending on its depth, whether blasting is allowed, slope of the site, and whether the home is to have a basement. Soil wetness, due to poor drainage or a high water table in very permeable soils, can add $1200 to $4300. It should be noted that, although hard rock and wet soil conditions may incur the greatest single additional costs, even areas such as soil workability and compaction characteristics, where only $100-$400 may be added to development costs, could combine with other "smaller" problems to make significant dollar amounts.

The steeper slope of a site does not add appreciably to the cost of excavation for homes with basements, if soil conditions are favorable, because the design modification of a walk-out basement helps to reduce earthwork quantities, while the amount for utilities and streets is increased. However, costs related to steep slopes have a greater impact when very shallow, hard rock is encountered, since utility excavation costs can become the dominant factor, causing site development to increase by $1000 to $1200.

In Table 7, costs have been separated into two general categories, one reflecting added costs per lot for design and construction of asphalt street pavement, home foundations, and utilities, and one reflecting the difference in costs if streets are of concrete. There is a relatively small difference between the two when comparing added cost due to bearing, shrink-swell, or drainage problems, but high potential for frost action may require $300-$600 per lot more for constructing asphalt streets than for concrete.

Table 6

Estimated Added Earthwork Costs Resulting from Soil/Subsurface Conditions

SOIL/SUBSURFACE FACTOR	ADDED COST/LOT		
	Slab on Grade	Basement	
	1-8%[a]	1-8%[a]	8-15%[a]
Base Cost, Good Conditions[b]	$ 1,600	$ 1,600	$ 1,800
Workability of Soil (Unified Classification)			
Heavy plastic soils (CH, OH)	$ 200	$ 200	$ 300
Highly organic soils (Pt)	NS[c]	NS[c]	NS[c]
Light to medium soils (all except CH, OH, Pt)	0	0	0
Depth to Hardpan			
0-20"	$ 400	$ 500	$ 500
20-60"	100	200	200
60"+	0[d]	0[d]	0[d]
Depth to Soft Rock (shales, sandstones)			
0-20"	$ 1,000	$ 800	$ 1,200
20-60"	300	400	500
60"+	0[d]	0[d]	0[d]
Depth to Hard Rock (blasting allowed)			
0-20"	$ 4,800	$ 5,500	$ 6,500
20-60"	1,700	2,700	2,600
60"+	0[d]	0[d]	0[d]
Depth to Hard Rock (blasting not allowed)			
0-20"	$12,400	$16,700	$17,900
20-60"	4,000	7,500	6,500
60"+	0[d]	0[d]	0[d]
Depth to Seasonal Water Table (GW, GP, SW, SP soils)[e]			
0-30"	$ 3,000	$ 4,000	$ 4,300
30-60"	1,200	1,700	1,800
60"+	0[d]	0[d]	0[d]
Depth to Seasonal Water Table (all except GW, GP, SW, SP)[e]			
0-30"	$ 900	$ 800	$ 1,100
30-60"	400	400	600
60"+	0[d]	0[d]	0[d]
Drainage Class[e]			
Poorly to Very Poorly Drained	$ 3,000	$ 4,000	$ 4,300
Otherwise	0	0	0
Depth of Topsoil			
Poor (0-4")	$ 600	$ 600	$ 1,300
Fair (4-6")	200	200	300
Good (6"+)	0	0	0
Compaction Characteristics (Unified Classification)			
OL, MH, CH, OH	$ 200	$ 400	$ 400
GM, GC, SM, SC, ML, CL	100	100	200
Pt	NS[c]	NS[c]	NS[c]
GW, GP, SW, SP	0	0	0

[a]Slopes less than 1% or greater than 15% are generally infeasible for typical residential developments. Slopes greater than 8% are infeasible for slab on grade foundations.

[b]Base cost assumptions for 1-8% slopes: 4 houses/acre, 1500 SF wood-frame structures up to 2 stories, average of 75' street frontage (30' wide), 75' of 5' deep utilities trench, and 75' of 10' deep sanitary sewer trench per lot; 8-15% slopes: 2 houses/acre, 1500 SF wood-frame structures up to 2 stories, average of 150' of street, 110' of 5' deep trench, and 110' of 10' deep trench per lot.

[c]Not suitable.

[d]Conditions below a 5' depth are unknown and may incur additional costs.

[e]Where poor drainage is related to a high water table, only one of the two costs should be included in the total, as correction methods are usually the same.

Table 7

Estimated Added Costs for the Design and Construction of Pavement, Foundations, and Utilities Resulting from Soil/Subsurface Conditions

SOIL/SUBSURFACE FACTOR	ADDED COST PER LOT (w/Asphalt Streets)			ADDED COST PER LOT (w/Concrete Streets)		
	Slab on Grade	Basement		Slab on Grade	Basement	
	1-8%[a]	1-8%[a]	8-15%[a]	1-8%[a]	1-8%[a]	8-15%[a]
Base Cost, Good Conditions[b]	$6,700	$7,800	$9,500	$7,500	$8,600	$11,100
Soil Bearing Capacity (Unified or AASHO Classification)						
ML, CL, OL, MH, CH, OH or A-4, A-5, A-6, A-7	$ 600	$ 700	$1,100	$ 500	$ 600	$ 900
Pt	NS[c]	NS[c]	NS[c]	NS[c]	NS[c]	NS[c]
Otherwise	0	0	0	0	0	0
Potential Shrink-Swell						
High	$ 700	$ 800	$1,200	$ 700	$ 700	$ 1,100
Low or Moderate	0	0	0	0	0	0
Potential Frost Action						
High	$ 500	$ 500	$ 900	$ 200	$ 200	$ 300
Low or Moderate	0	0	0	0	0	0
Drainage Conditions						
Poorly to Very Poorly Drained or Seasonal Water Table Depth at 0-60"	$ 800	$ 700	$1,000	$ 900	$ 700	$ 1,100
Otherwise	0	0	0	0	0	0

[a]Slopes less than 1% or greater than 15% are generally infeasible for typical residential developments. Slopes greater than 8% are infeasible for slab on grade foundations.

[b]Base cost assumptions for 1-8% slopes: 1500 SF wood-frame structures up to 2 stories, average of 75' street frontage (30' wide) shared by 2 lots, 40' of water and sewer mains and 35' of sewer and water service lines per lot; 8-15% slopes: 1500 SF wood-frame structures up to 2 stories, average of 150' street frontage (30' wide) shared by 2 lots, 75' of water and sewer mains and 35' of sewer and water service lines per lot.

[c]Not suitable.

By examining Table 7, it can be seen that added construction costs vary relatively little between residential developments with slab on grade foundations and those with basements, or between the various soil engineering properties, with the exception of steepness of slope. Under optimum soil conditions, 8-15% slopes can increase costs by $1700 to $2500, since streets and utility lengths may be doubled. A multiple impact occurs on paving costs when design modifications must be made for poor bearing, shrink-swell, frost or drainage problems where these costs are also doubled because of steep slopes.

The information in Tables 6 and 7 can be used in conjunction with Soil Conservation Service data for a given area to anticipate potential added residential development and construction costs that relate to soil conditions. The following case study for Ottawa, Kansas will demonstrate the use of this information in determining total added costs for specific soils, and how it is mapped for use by planners.

CASE STUDY: OTTAWA, KANSAS

The city of Ottawa is located in Franklin County in Kansas, about 51 miles southeast of Topeka and 54 miles southwest of Kansas City, on the Marais des Cygnes River. It is bisected from north to south by U.S. 59 highway and is also served by Interstate 35 which links it to the Kansas City Metropolitan area and Emporia, Kansas.

As part of an important agricultural and rangeland region, this community, with a population of 10,953, is located in the gently rolling hills of Kansas known as the Osage Cuestas (36). This landform has developed upon sedimentary shale, sandstone, limestone and silt-stone strata of late Pennsylvanian age which dips very slightly to the

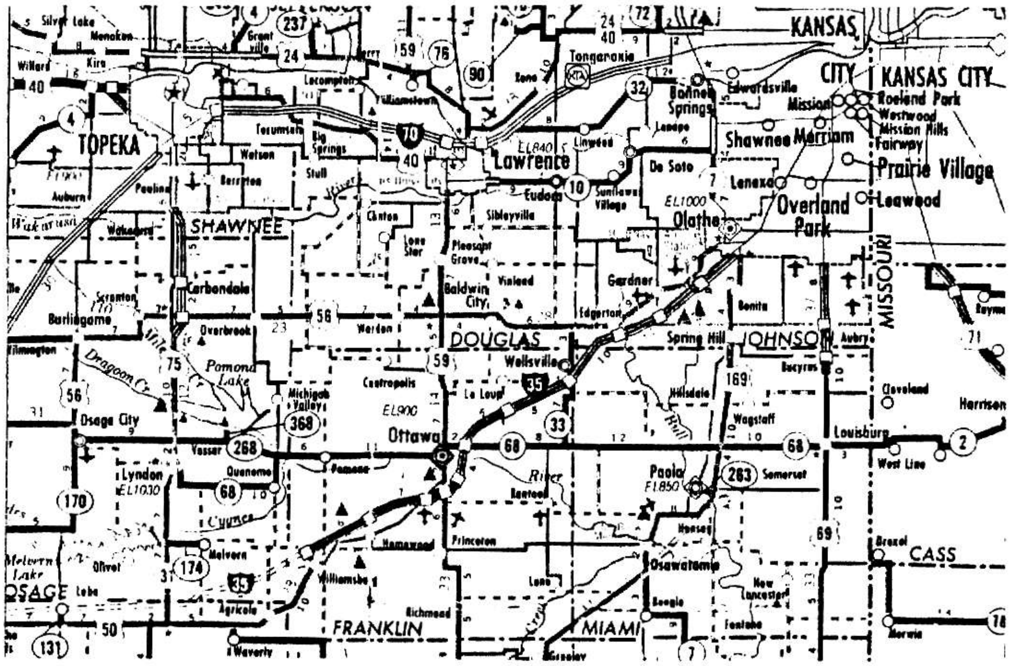

Figure 4

Location Map for Ottawa, Kansas

west and northwest away from the Ozark Dome area of Missouri. The more resistant limestone layers form northeast to southwest trending escarpments where exposed at the surface, with flatter or gently rolling plains between these ridges forming in the more easily weathered rock. Maximum relief of the study area is approximately 150 feet, ranging from the low flood plain of the Marais des Cygnes to the Sand Hills northwest and southeast of the city (see Figure 5).

The soils of the Ottawa area are of three general associations related to their topographic position and parent material. The deepest are the alluvial silt loam soils of the flood plain which are used primarily for agriculture, with some use as pasture and woodland.

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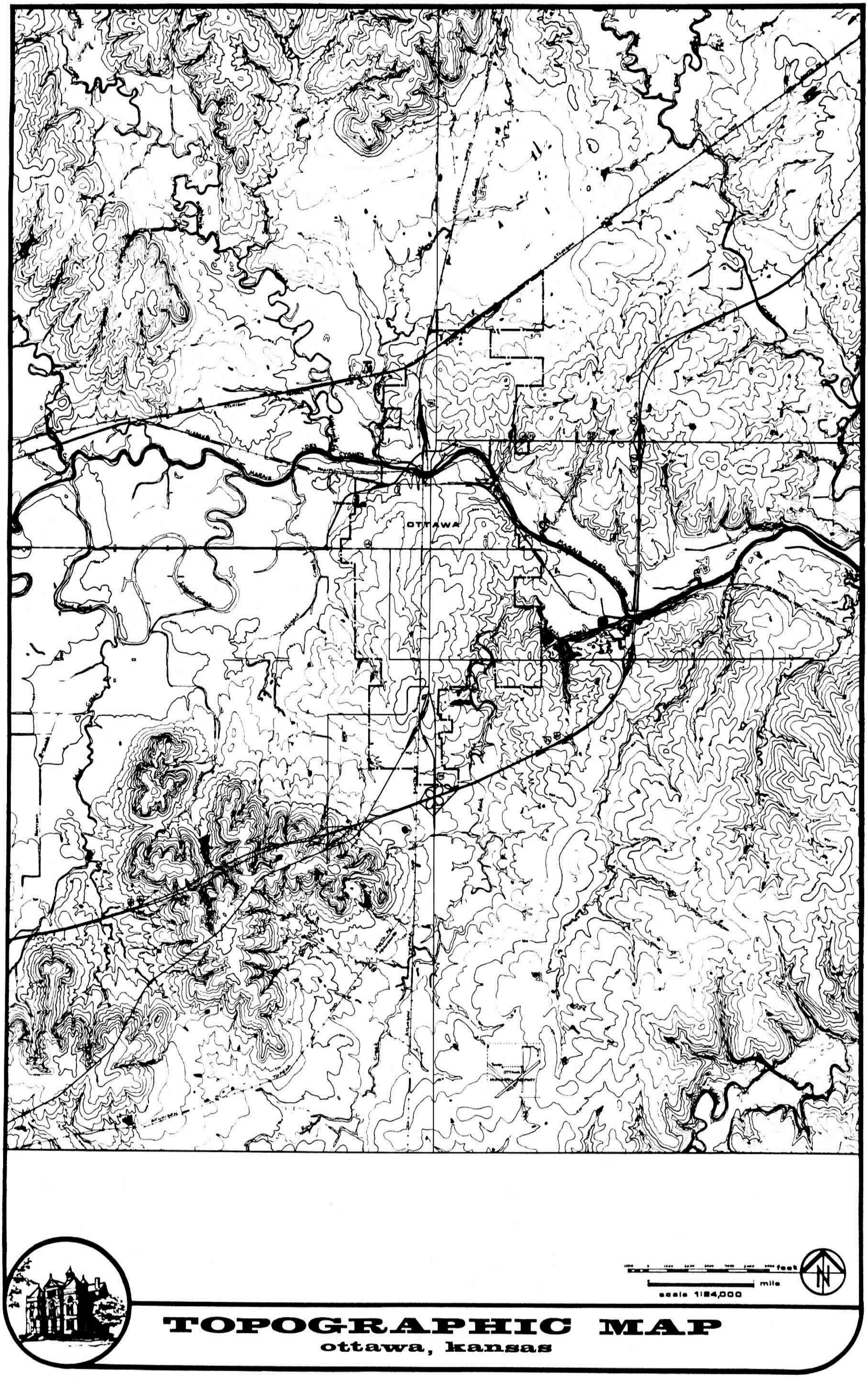
OTTAWA
feet
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TOPOGRAPHIC MAP
ottawa, kansas

Figure 5

Problems associated with these soils for community development include flooding, poor bearing characteristics, shrinking and swelling, and wetness.

Most of the city of Ottawa is located on old alluvial terraces high in silt and clay. These soils present some difficulties related to high shrinking and swelling, poor bearing qualities, and seasonally perched water tables. Outside the city, these soils are used for cropland and rangeland.

The remainder of upland soils are generally residual soils formed from limestone and shale or from sandstone and shale. They are predominately used for cropland and rangeland. Residential development would be affected primarily by the potential occurrence of shallow bed rock, steeper slopes, and shrink-swell and bearing problems.

More specific soil information can be obtained by referring to the map of Ottawa which locates the soil types within the 3-mile planning area (Figure 6). Descriptions of the engineering properties of these soils are included in Appendix A (15, 31, 43).

Interpretation of Soil and Cost Data

In Table 8, for residential developments with slab on grade homes and asphalt streets, and Table 9, for those with basements, the soil types for the Ottawa planning area have been listed and assigned corresponding dollar amounts (taken from Tables 6 and 7) for each engineering problem that they possess. These individual costs are totaled and presented in the last column for comparison of development and construction costs involved for each soil. Attention should be given to the fact that where both seasonal high water table and poor

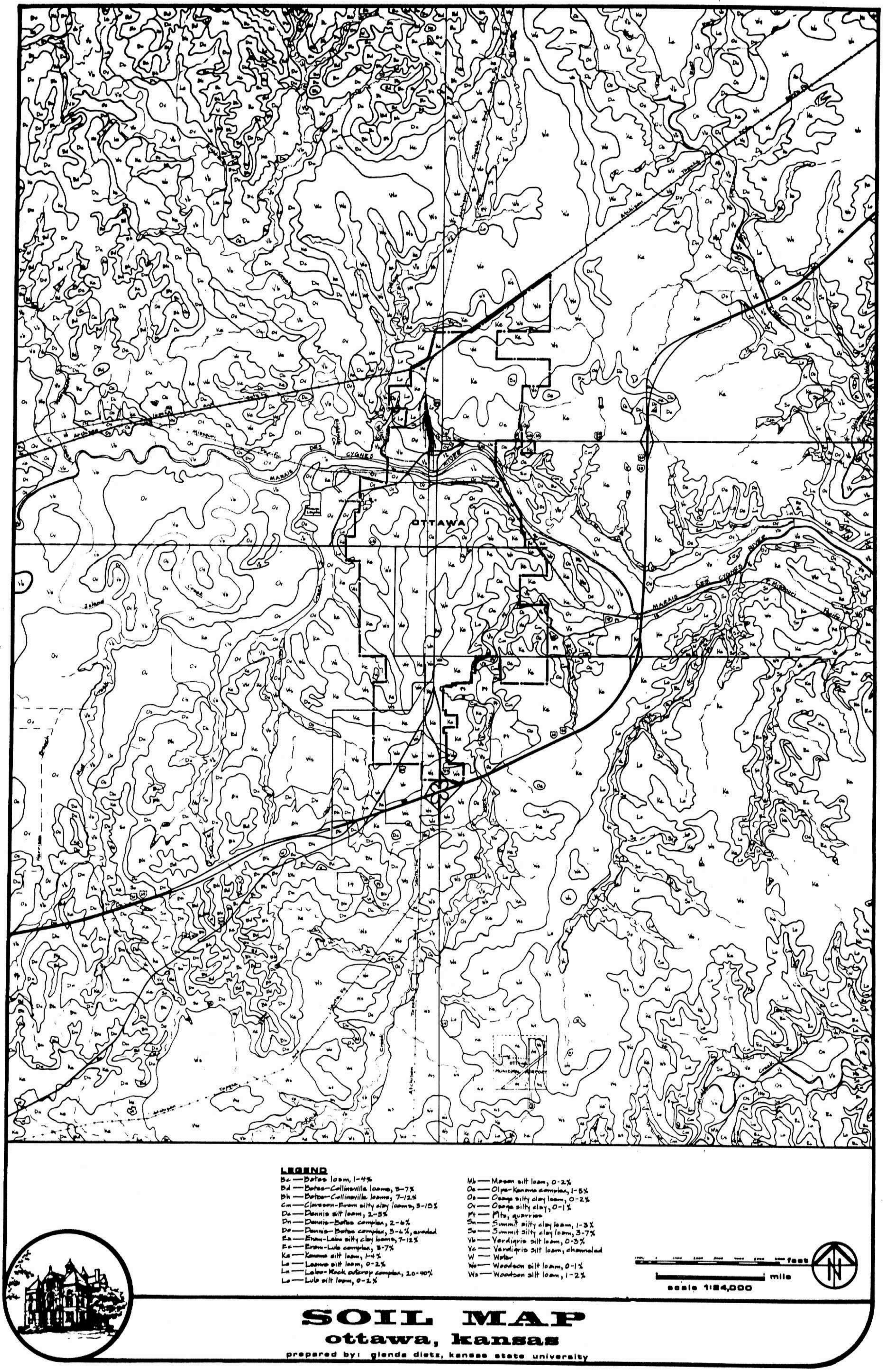
OTTAWA
MARAIS DES CYGNES RIVER
LEGEND
Bc — Bates loam, 1-4%
Bd — Bates-Collinsville loams, 3-7%
Bh — Bates-Collinsville loams, 7-12%
Cm — Clareson-Eram silty clay loams, 3-15%
Dc — Dennis silt loam, 2-5%
Dn — Dennis-Bates complex, 2-6%
Do — Dennis-Bates complex, 3-6%, eroded
Ea — Eram-Lebo silty clay loams, 7-12%
Ec — Eram-Lula complex, 3-7%
Ka — Kenoma silt loam, 1-4%
La — Leanna silt loam, 0-2%
Ln — Lebo-Rock outcrop complex, 20-40%
Lo — Lula silt loam, 0-2%
Mb — Mason silt loam, 0-2%
Oa — Olpe-Kenoma complex, 1-8%
Os — Osage silty clay loam, 0-2%
Ov — Osage silty clay, 0-1%
Pt — Pits, quarries
Sn — Summit silty clay loam, 1-3%
So — Summit silty clay loam, 3-7%
Vb — Verdigris silt loam, 0-3%
Vc — Verdigris silt loam, channeled
W — Water
Wo — Woodson silt loam, 0-1%
Ws — Woodson silt loam, 1-2%
feet
mile
scale 1:24,000
N
SOIL MAP
ottawa, kansas
prepared by: glenda dietz, kansas state university

Figure 6

Table 8

Estimated Added Costs Related to Soil/Subsurface Conditions for Residential Developments with Slab on Grade Homes and Asphalt Streets in Ottawa, Kansas

MAP SYMBOL	SOIL NAME	SOIL/SURSURFACE FACTORS													
		COSTS RELATED TO EARTHWORK								COSTS RELATED TO DESIGN					
		Soil Workability	Slope[b]	Depth to Hardpan[c]	Depth to Rock[c,d]	Depth to Seasonal Water Table[c]	Drainage Class	Depth of Topsoil	Compaction Characteristics	Soil Bearing Capacity	Potential Shrink-Swell	Potential Frost Action	Drainage Conditions	Slope[b]	TOTAL ADDED DEVELOPMENT COSTS[e]
Bo	Bates loam, 1-4%	$ 0	$ 0	$0	$ 300	$ 0	$ 0	$ 0	$100	$600	$ 0	$ 0	$ 0	$ 0	$1000
Bd	Bates-Collinsville loams,[a] 3-7%	0	0	0	6300	0	0	0	100	600	0	0	0	0	7000
Bh	Bates-Collinsville loams,[a] 7-12%	0	0-NS	0	6300	0	0	0	100	600	0	0	0	0-NS	7000-NS[b]
Cm	Clareson-Eram silty clay loams,[a] 3-15%	200	0-NS	0	$2200	600	0	0	200	600	400	200	400	0-NS	4800-NS[b]
Dc	Dennis silt loam, 2-5%	100	0	0	0	600	0	0	100	600	700	500	800	0	3400
Dn	Dennis-Bates complex,[a] 2-6%	0	0	0	200	300	0	0	100	600	400	300	400	0	2300
Do	Dennis-Bates complex,[a] 3-6%, eroded	0	0	0	200	300	0	0	100	600	400	300	400	0	2300
Ea	Eram-Lebo silty clay loams,[a] 7-12%	100	0-NS	0	300	300	0	0	200	600	400	300	400	0-NS	2600-NS[b]
Eo	Eram-Lula complex,[a] 3-7%	100	0	0	2100	300	0	0	100	600	400	300	400	0	4300
Ke	Kenoma silt loam, 1-4%	200	0	0	0	0	0	0	200	600	700	0	0	0	1700
Le	Leanna silt loam, 0-2%	200	0-NS	0	0	900	3000	0	200	600	700	0	800+	0-NS	5500-NS[b]
Ln	Lebo-Rock outcrop complex,[a] 20-40%	0	NS	0	600	0	0	200	100	0	0	0	0	NS	NS[b]
Lo	Lula silt loam, 0-2%	0	0-NS	0	4000	0	0	0	100	600	0	0	0	0-NS	4700-NS[b]
Mb	Mason silt loam, 0-2%	0	0-NS	0	0	0	0	0	100	600	0	0	0	0-NS	700-NS[b]
Oe	Olpe-Kenoma complex,[a] 1-5%	100	0	0	0	0	0	0	200	300	300	0	0	0	900
Os	Osage silty clay loam, 0-2%	200	0-NS	0	0	900	3000	0	200	600	700	0	800	0-NS	6400-NS[b]
Ov	Osage silty clay, 0-1%	200	0-NS	0	0	900	3000	0	200	600	700	0	800	0-NS	3500-NS[b]
Pt	Pits, quarries	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
Sn	Summit silty clay loam, 1-3%	200	0	0	0	600	0	0	200	600	700	500	800	0	3600
So	Summit silty clay loam, 3-7%	200	0	0	0	600	0	0	200	600	700	500	800	0	3600
Vb	Verdigris silt loam, 0-3%	0	0-NS	0	0	0	0	0	100	600	0	0	0	0-NS	700-NS[b]
Vc	Verdigris silt loam, channeled	0	NS	0	0	0	0	0	100	600	0	0	0	NS	NS
Wo	Woodson silt loam, 0-1%	200	0-NS	0	0	900	0	0	200	600	700	0	800	0-NS	3400-NS[b]
Ws	Woodson silt loam, 1-2%	200	0	0	0	900	0	0	200	600	700	0	800	0	3400

[a]Costs are averaged for the two soils found within this soil type. Development costs may vary, depending on the predominant characteristics found at a specific site.

[b]Slopes less than 1% or greater than 8% are generally not suitable (NS) for residential developments with slab on grade homes.

[c]Greater earthwork costs may be incurred if this condition is present at depths greater than 5 feet, for which information is unavailable.

[d]These costs assume that blasting for removal of rock is not allowed. If blasting is permitted, costs may decrease significantly in hard rock excavations.

[e]If both poor drainage and high seasonal water table conditions are present, only the higher of the two costs is included in the total, since the same corrective measures would usually apply to both. Soils with either of these problems are generally undesireable for home sites.

Table 9

Estimated Added Costs Related to Soil/Subsurface Conditions for Residential Developments with Basement Homes and Asphalt Streets in Ottawa, Kansas

MAP SYMBOL	SOIL NAME	SOIL/SUBSURFACE FACTORS: COSTS RELATED TO EARTHWORK								COSTS RELATED TO DESIGN					
		Soil Workability	Slope[b]	Depth to Hardpan[c]	Depth to Rock[c,d]	Depth to Seasonal Water Table[c]	Drainage Class	Depth of Topsoil	Compaction Characteristics	Soil Bearing Capacity	Potential Shrink-Swell	Potential Frost Action	Drainage Conditions	Slope[b]	TOTAL ADDED DEVELOPMENT COSTS[e]
Bc	Bates loam, 1-4%	$ 0	$ 0	$0	$ 400	$ 0	$ 0	$ 0	$100	$700	$ 0	$ 0	$ 0	$ 0	$ 1200
Bd	Bates-Collinsville loams,[a] 3-7%	0	0	0	8500	0	0	0	100	700	0	0	0	0	9300
Bh	Bates-Collinsville loams,[a] 7-12%	0	100	0	8900	0	0	0	200	900	0	0	0	900	11000
Cm	Clareson-Eram silty clay loams,[a] 3-15%	100	100	0	3700	400	0	0	300	900	500	300	400	900	7600
Dc	Dennis silt loam, 2-5%	100	0	0	0	600	0	0	200	700	800	500	700	0	3600
Dn	Dennis-Bates complex,[a] 2-6%	0	0	0	200	300	0	0	100	700	400	300	400	0	2400
Do	Dennis-Bates complex,[a] 3-6%, eroded	0	0	0	200	300	0	0	100	700	400	300	400	0	2400
Ea	Eram-Lebo silty clay loams,[a] 7-12%	100	100	0	500	400	0	0	200	900	500	300	500	900	4400
Ec	Eram-Lula complex,[a] 3-7%	100	0	0	4000	300	0	0	100	700	400	300	400	0	6300
Ke	Kenoma silt loam, 1-4%	200	0	0	0	0	0	0	400	700	800	0	0	0	2100
Le	Leanna silt loam, 0-2%	100	0-NS	0	0	800	4000	0	300	700	800	0	700	0-NS	6600-NS[b]
Ln	Lebo-Rock outcrop complex,[a] 20-40%	0	NS	0	900	0	0	800	200	600	0	0	0	NS	NS[b]
Lo	Lula silt loam, 0-2%	0	0-NS	0	7500	0	0	0	100	700	0	0	0	0-NS	8300-NS[b]
Mb	Mason silt loam, 0-2%	0	0-NS	0	0	0	0	0	100	700	0	0	0	0-NS	800-NS[b]
Oe	Olpe-Kenoma complex,[a] 1-5%	100	0	0	0	0	0	0	200	300	400	0	0	0	1000
Os	Osage silty clay loam, 0-2%	200	0-NS	0	0	800	4000	0	400	700	800	0	700	0-NS	6800-NS[b]
Ov	Osage silty clay, 0-1%	200	0-NS	0	0	800	4000	0	400	700	800	0	700	0-NS	6800-NS[b]
Pt	Pits, quarries	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
Sn	Summit silty clay loam, 1-3%	200	0	0	0	600	0	0	400	700	800	300	700	0	3700
So	Summit silty clay loam, 3-7%	200	0	0	0	600	0	0	400	700	800	300	700	0	3700
Vb	Verdigris silt loam, 0-3%	0	0-NS	0	0	0	0	0	100	700	0	0	0	0-NS	800-NS[b]
Vc	Verdigris silt loam, channeled	0	NS	0	0	0	0	0	100	700	0	0	0	NS	NS[b]
Wo	Woodson silt loam, 0-1%	200	0-NS	0	0	800	0	0	400	700	800	0	700	0-NS	3600-NS[b]
Ws	Woodson silt loam, 1-2%	200	0	0	0	800	0	0	400	700	800	0	700	0	3600

[a]Costs are averaged for the two soils found within this soil type. Development costs may vary, depending on the predominant characteristics found at a specific site.

[b]Slopes less than 1% or greater than 15% are generally not suitable (NS) for residential developments with basements.

[c]Greater earthwork costs may be incurred if this condition is present at depths greater than 5 feet, for which information is unavailable.

[d]These costs assume that blasting for removal of rock is not allowed. If blasting is permitted, costs may decrease significantly in hard rock excavations.

[e]If both poor drainage and high seasonal water table conditions are present, only the higher of the two costs is included in the total, since the same corrective measures would usually apply to both. Soils with either of these problems are generally undesireable for

drainage conditions are present, only the higher of the two costs is included in the total, since the same corrective measures would usually apply to both.

The soil types were then placed in groups according to whether their total added development costs gave them high, moderate, or low potential for residential development. This was achieved, as in the METLAND method, by determining what these added costs mean in terms of housing square footage.

Soils with high suitability ranged from \$0 to \$4000 in additional costs. With an average of \$40 per square foot estimated building cost (30, 48, 50), the \$4000 limit would compare to 100 square feet or a small bedroom. Thus, in order to maintain the same profit margin without increasing the cost, the equivalent of one small bedroom would need to be eliminated.

Moderately suitable soils fall within the range of \$4000 to \$8000. Development on these soils would necessitate the elimination of 200 square feet of housing, or area comparable to two small bedrooms or a two-car garage, to avoid cost increase or loss in profits. Although soils of this group have a number of costly problems, they do not necessarily have to be avoided. More extensive evaluation and careful design modification could alter these costs in a way that makes them less extreme.

Soils that cause additional costs to run from \$8000 to \$18,000 are considered to have low suitability. The \$18,000 cut-off represents 450 square feet of housing space or an amount equal to a large living and dining room. Beyond this cost, it is unlikely that a site would have any potential for extensive residential development.

Areas that are considered undevelopable, such as those with soil or subsurface problems that exceed $18,000 in additional costs, rock quarries, stream channels, and excessive slopes, are categorized as "not suitable." Because slope ranges may vary broadly for each soil type, those areas where some slopes exceed 8% for slab on grade developments and 15% for those with basements, or where the terrain is partially flat with some slopes less than 1%, are grouped to indicate this variable condition. Further evaluation would be necessary to determine the extent of unsuitable slopes within these areas.

Maps have been prepared for the Ottawa area that organize soil types according to the costs they incur. Figure 7 shows the range of suitability for developments with slab on grade homes and Figure 8 shows the suitability for constructing homes with basements. The cost information placed on maps can be used in conjunction with other data that can be mapped to aid in making planning decisions.

Implications for Planning

A review of Tables 8 and 9 shows that there are a number of soil and subsurface problems in the Ottawa area that stand out. Those that are individually most critical, as far as development and construction costs are concerned, include slope, shallow bedrock, and wet conditions from poor drainage and/or a seasonal high water table.

Steep slopes are generally not the major concern for broad scale planning in Ottawa. Only the Lebo-Rock outcrop complex soil type is unsuitable for typical residential development due to slopes of 20-40%. Three other soil classifications contain slopes that may be unsuitable for slab on grade homes and that could be costly for basements in certain locations where shallow bedrock is encountered.

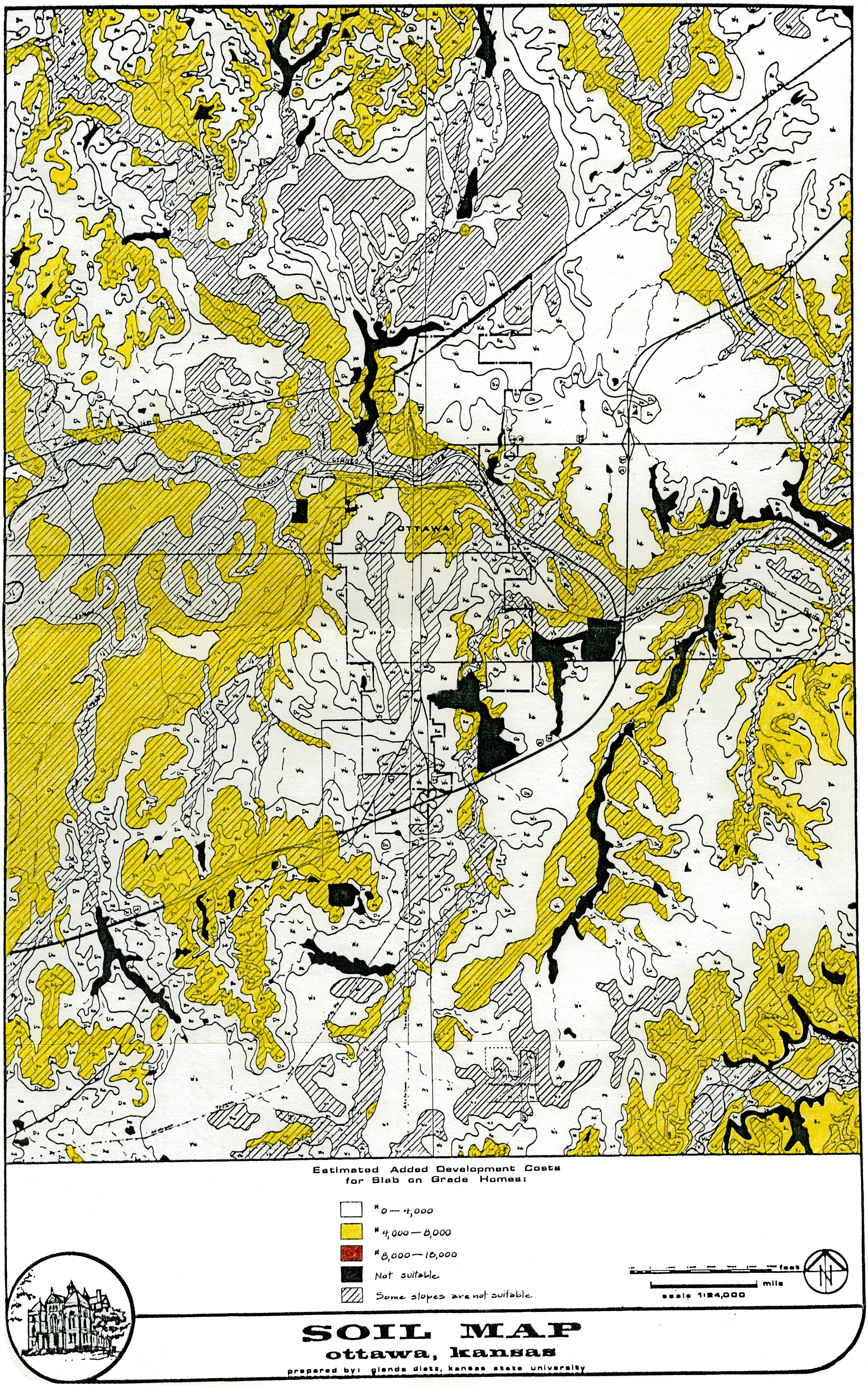
OTTAWA
Estimated Added Development Costs
for Slab on Grade Homes:
$0 — 4,000
$4,000 — 8,000
$8,000 — 18,000
Not suitable
Some slopes are not suitable
feet
mile
scale 1:24,000
N
SOIL MAP
ottawa, kansas
prepared by: glenda dietz, kansas state university

Figure 7

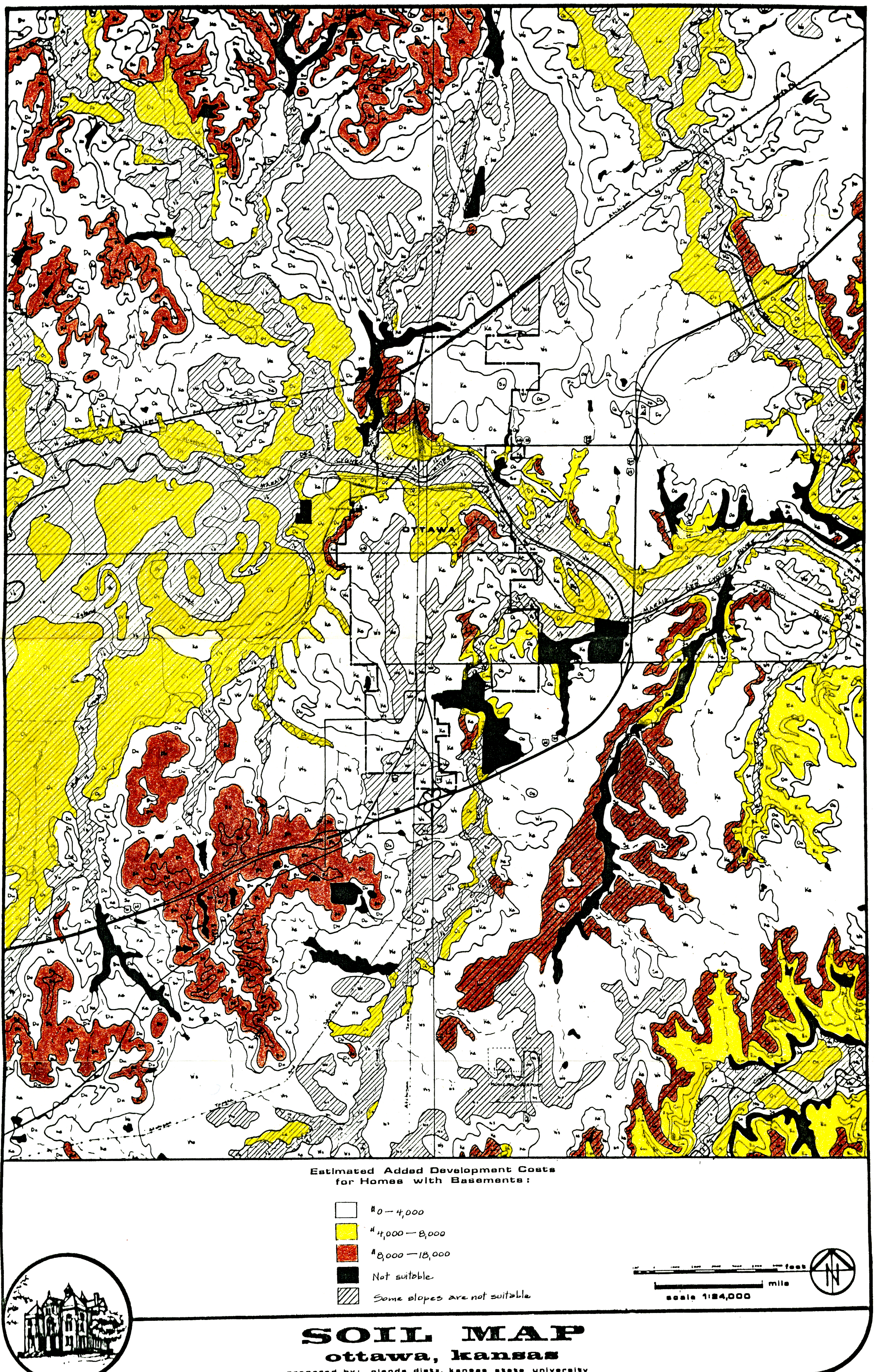
OTTAWA
Estimated Added Development Costs
for Homes with Basements:
$0 — 4,000
$4,000 — 8,000
$8,000 — 18,000
Not suitable
Some slopes are not suitable
feet
mile
scale 1:24,000
N
SOIL MAP
ottawa, kansas
prepared by: glenda dietz, kansas state university

Figure 8

Of greater concern are the numerous areas of almost flat terrain, due mainly to the extensive flood plain of the Marais des Cygnes River and some level, old river terraces. Because many of these soils are subject to flooding where not protected by the levee, and some are associated with a seasonal high water table and poor drainage conditions, careful investigation of any proposed residential development on such sites must be made.

The flood plain map for Ottawa will indicate areas to be prohibited to housing developments, while information from this study can be used to locate soils that will cause wetness problems. These locations may be better served by maintaining them as open spaces or by only allowing lower density housing in order to minimize run-off amounts. Key natural drainage ways, such as "Skunk Run," which traverses the city, must be protected from overdevelopment and maintained to minimize further expenditures on storm drainage systems and repairs to damaged streets. Homes with basements should be avoided, and codes and regulations should require adequate design of gutters, downspouts, and subsurface drainage systems, as well as proper grading of land surfaces to carry water away from structures. Many of these poorly drained or seasonally wet soils will require larger capital improvement expenditures by the city for storm drainage systems, costs beyond those presented in this paper.

Some of the soils within the Ottawa planning area have bedrock near the surface. The costs for removal of hard rock shown in Tables 8 and 9, are those that would be involved if blasting is not permitted. If selected sites could be blasted as a means of breaking up hard rock, these costs could be significantly reduced and might improve the feasibility of these sites for residential development. It should also be noted that in a number of cases, two soil series have been grouped together, so that within the soil type there may be a combination of both softer sandstone or shale and hard limestone. The costs in the tables reflect an average of the rock conditions that are found, as well as an average of the influence of slope steepness. Therefore, certain areas within the specific soil type may be considerably more feasible than others. Careful evaluation of proposed development sites should be made.

Steep slopes should be avoided where bedrock is near the surface, since longer utility lines and streets will require larger quantities of rock to be removed and higher costs. Although shallow bedrock has considerable impact on the cost of excavating for utilities, in some cases, the cost for site development may be reduced by as much as one-third to one-half by eliminating basements. Obviously, extensive development in shallow soil areas is generally undesirable for a number of reasons beyond those considered here, but careful planning and design modifications can be used where necessary to minimize some of the drawbacks.

Because almost all of Ottawa's soils have undesirable bearing and shrink-swell characteristics, these problems can generally not be avoided. Consequently, it is important for planners to stress the importance of implementing codes and regulations establishing minimum standards for street and building construction. By approving only residential development plans that provide both adequate surface and subsurface drainage and reinforcement in foundations and pavements, damage and deterioration that can lead to extensive maintenance costs can be reduced.

A comprehensive city plan was prepared for Ottawa in 1975 (3). In it, projected residential growth areas will occur to the northeast, southwest, and southeast of the city and, with minor exceptions, are compatible with the conclusions drawn in this study. The area to the southwest is expected to be the fastest growing and should present few major soil problems other than with small sections of Woodson silt loam where a seasonal high water table and 0-1% slopes could present drainage and wetness problems, especially for homes with basements. No major soil problems occur in the northeast growth area, but land along Rock Creek to the south and southeast of the city will require greater care in locating home sites. Here, the Clareson-Eram silty clay loams could increase development costs with shallow bedrock and a seasonally high water table, and some slopes will be too steep for slab on grade homes. The small area of Lula silt loam on Rock Creek near the quarry also has shallow bedrock and may be too flat in some locations for good drainage.

The plan recognizes the poor quality of Ottawa's soils for use in septic tank absorption fields and has proposed new sanitary sewer lines for all three projected growth areas. Provision for easements along natural drainage ways and streams has also been made to aid in ameliorating some of the drainage problems the city has, and new development areas of the city are being provided with subsurface systems.

Use of the information provided in this study, by itself, is not sufficient to make residential planning decisions that will be in the best interest of a city like Ottawa. But it should also be apparent that not using information that is available on soil and subsurface conditions can result in some costly and damaging mistakes.

While Ottawa may not presently have the capability of implementing a system as extensive as the METLAND planning model in its entirety, it may benefit from using it as a guide in processing landscape resource data that is of greatest importance to the community. For example, two features that might be of particular concern to Ottawa are the flood hazard of the Marais des Cyngnes River and the agricultural productivity of the area as a special resource. The 100-year flood plain map is available for Ottawa and the soil map used in this study can easily be converted to a map showing the capability of the same soils for agricultural production. Both of these maps are useful planning tools now, and could later be supplemented with the additional information required by the METLAND system, if such a system was chosen for evaluating landscape resources for community planning.

Greater benefit can be achieved by producing a composite map of all landscape resources, such as the physical development suitability described in this study, agricultural productivity, flood hazard, or any other key resource, so that priorities may be set up in line with established community goals. If preservation of prime agricultural land is a major community or regional objective, those areas where residential development is likely to encroach on it will be shown so that policies can be devised to regulate this occurrence. If some of this same land should also present a flood hazard, this, in combination with its value as a special agricultural resource, can serve to reinforce any decisions to prevent residential development. On the other hand, when current land use maps are overlayed on agricultural productivity maps, some prime farming sites may be determined to be less suitable for preservation because of land uses that alter their productivity.

It is important for towns and cities like Ottawa to inventory their landscape resources and to use this information in preparing policies that will guide their future growth and development. The evaluation of soil and subsurface conditions for residential use, as presented in this case study, is only one input into the planning process but very basic to making decisions that will benefit the community as a whole.

Chapter 5

SUMMARY AND CONCLUSION

The use of natural resource data in urban planning has gained wider acceptance in the last two decades, but has yet to develop its full potential. Translating base information that has generally been designed for a specific scientific community into a workable system for city planners, has been difficult to say the least. The Soil Conservation Service, recognizing the value of making its information available to those involved with determining the use of the land, whether for agricultural production or urban development, has sought to include interpretive material along with its basic data.

As pointed out in this study, there are some limitations to the usefulness of the SCS interpretations. Thus, planners have followed this important initiative by attempting to devise a method that more precisely interprets soil data within the range of their own specific needs. The Metropolitan Landscape Planning Model Study (METLAND), designed by the University of Massachusetts at Amherst, is one such attempt that is concerned with establishing measurable values for landscape resources in order to facilitate their evaluation and comparison to other planning concerns. All aspects of landscape resources are explored, including special or unique qualities, potential hazards, development suitability, and ecological stability.

This study selected the assessment of the physical development suitability phase of the METLAND model for further study and adaptation for Kansas communities, because it is a relatively simple procedure that requires only soil maps and data, and input from local contractors for implementation. By interviewing area builders and excavators and receiving cost estimates related to soil and subsurface problems, it is possible to determine potential added residential development costs for each specific soil within a given region and to rank these soils according to the additional costs they may incur.

In Kansas, the greatest individual cost factors will generally be related to excavation of shallow limestone bedrock. Soil wetness can also be extremely critical where shallow water table depths or poor drainage are present, because both excavation and construction costs can be affected, and the cost of maintenance is likely to be an on-going problem. However, every community has its own unique problems that may or may not prove to be cost prohibitive for residential development.

A case study for Ottawa, Kansas showed that, as with many Kansas soils, added costs will generally be incurred for less than optimum bearing characteristics and for a tendency of the soils to shrink when dry and swell when wet. These characteristics increase development costs, but do not in themselves always help to distinguish which soils are better suited as residential sites. Thus soils that have shallow depths to bedrock and that are frequently wet begin to stand out as having the key differentiating factors, especially since these also involve significant additional costs.

It should be remembered that because any planning method must necessarily occur at a broad scale, many generalizations must be made and that it is important to not completely rule out areas based only on this generalized data. Follow-up information should be gathered from on-site inspections to confirm or disprove broad findings, and alternative designs and construction methods that may change feasibility should be explored before decisions are finalized.

Analysis of landscape resources other than the soil and subsurface conditions presented in this paper should also be made. The Soil Conservation Service soil survey reports provide a wide range of useful data because of the intimate tie between soils and other natural resources. The METLAND methodology makes use of this fact by including SCS soil maps and data in the analysis of the special resources of agricultural and wildlife productivity as well as in assessing physical and topoclimatic development suitability. Only soil maps and information on the potential of the land to sustain agriculture or wildlife production and a land use map to delineate existing uses that detract from production potential are required.

Other landscape resources are not so simply analyzed through METLAND technique, because it has been designed for use at the mezo-regional scale where it should be possible to amass the expertise, base landscape resource and economic information and computer services required for implementation. If states would adopt this or a similar methodology to be set up on a regional basis, even small communities could then benefit from such a system in which they are able to extract basic resource information and insert their own local values and community goals.

Whether or not an elaborate planning methodology is available for immediate use, it should be apparent that every effort must be made to begin a process of gathering landscape resource information in a way that allows greater flexibility in its interpretation. In this way, communities of all sizes and characteristics can benefit by using this data to clarify their own values and goals and to reinforce planning policies that will help them to achieve the kind of growth that will not destroy those values held in highest regard.

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APPENDIX A

SCS SOIL DATA FOR OTTAWA, KANSAS (15)

Engineering Index Properties

[The symbol < means less than; > means more than. Absence of an entry indicates that data were not estimated]

Soil name and map symbol	Depth	USDA texture	Classification: Unified	Classification: AASHTO	Fragments > 3 inches	Percentage passing sieve number-- 4	10	40	200	Liquid limit	Plasticity index
	In				Pct					Pct	
Bc: Bates	0-19	Loam	ML, CL, CL-ML	A-4, A-6	0	90-100	85-100	80-100	55-90	20-40	3-15
	19-34	Loam, clay loam, sandy clay loam.	ML, CL, SC, SM	A-4, A-6, A-7	0	85-100	85-100	80-100	45-85	25-45	3-20
	34	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Bd*, Sh*: Bates	0-19	Loam	ML, CL, CL-ML	A-4, A-6	0	90-100	85-100	80-100	55-90	20-40	3-15
	19-34	Loam, clay loam, sandy clay loam.	ML, CL, SC, SM	A-4, A-6, A-7	0	85-100	85-100	80-100	45-85	25-45	3-20
	34	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Collinsville	0-11	Loam	SM, SC, ML, CL	A-4	0-3	60-100	60-100	60-95	36-75	<30	NP-10
	11-17	Fine sandy loam, loam,	SM, SC, ML, CL	A-4	3-40	80-100	60-100	60-95	36-75	<30	NP-10
	17	channery loams Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Cm*: Clareson	0-7	Silty clay loam	CL	A-4, A-6	0-25	90-100	90-100	85-95	85-95	30-40	8-18
	7-15	Silty clay loam, flaggy silty clay loam.	CL	A-6, A-7	0-65	90-100	90-100	85-95	85-95	35-45	11-20
	15-26	Flaggy silty clay, flaggy silty clay loam.	CL, CH	A-7	50-85	85-100	85-100	80-95	80-95	41-60	18-35
	26	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Eram	0-7	Silty clay loam	CL	A-6, A-7	0	85-100	85-100	85-100	75-95	33-48	12-25
	7-38	Clay, silty clay, silty clay loam.	CL, CH	A-7, A-6	0	95-100	95-100	90-100	95-96	37-65	15-35
	38	Weathered bedrock	---	---	---	---	---	---	---	---	---
De: Dennis	0-10	Silt loam	ML, CL, CL-ML	A-4, A-6	0	100	100	96-100	65-97	20-37	1-15
	10-15	Silty clay loam, clay loam.	CL	A-6, A-7	0	98-100	98-100	94-100	75-98	33-48	13-25
	15-60	Clay, silty clay, silty clay loam.	CL, CH	A-7, A-6	0	98-100	98-100	94-100	75-98	37-65	15-35
Dn*: Dennis	0-10	Silt loam	ML, CL, CL-ML	A-4, A-6	0	100	100	96-100	65-97	20-37	1-15
	10-15	Silty clay loam, clay loam.	CL	A-6, A-7	0	98-100	98-100	94-100	75-98	33-48	13-25
	15-60	Clay, silty clay, silty clay loam.	CL, CH	A-7, A-6	0	98-100	98-100	94-100	75-98	37-65	15-35
Bates	0-19	Loam	ML, CL, CL-ML	A-4, A-6	0	90-100	85-100	80-100	55-90	20-40	3-15
	19-34	Loam, clay loam, sandy clay loam.	ML, CL, SC, SM	A-4, A-6, A-7	0	85-100	85-100	80-100	45-85	25-45	3-20
	34	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Do*: Dennis	0-10	Silt loam	ML, CL, CL-ML	A-4, A-6	0	100	100	96-100	65-97	20-37	1-15
	10-15	Silty clay loam, clay loam.	CL	A-6, A-7	0	98-100	98-100	94-100	75-98	33-48	13-25
	15-60	Clay, silty clay, silty clay loam.	CL, CH	A-7, A-6	0	98-100	98-100	94-100	75-98	37-65	15-35
Bates	0-6	Clay loam	CL	A-6, A-7	0	90-100	85-100	80-100	60-85	35-45	15-20
	6-30	Loam, clay loam, sandy clay loam.	ML, CL, SC, SM	A-4, A-6, A-7	0	85-100	85-100	80-100	45-85	25-45	3-20
	30	Unweathered bedrock.	---	---	---	---	---	---	---	---	---

ENGINEERING INDEX PROPERTIES--Continued

Soil name and map symbol	Depth	USDA texture	Classification: Unified	Classification: AASHTO	Fragments > 3 inches	Percentage passing sieve number--: 4	10	40	200	Liquid limit	Plasticity index
	In				Pct					Pct	
Ea*:											
Eram	0-7	Silty clay loam	CL	A-6, A-7	0	85-100	85-100	85-100	75-95	33-48	12-25
	7-38	Clay, silty clay, clay loam.	CL, CH	A-7, A-6	0	95-100	95-100	90-100	85-98	37-65	15-35
	38	Weathered bedrock	---	---	---	---	---	---	---	---	---
Lebo	0-14	Silty clay loam	CL	A-6, A-7, A-7-6	0-5	95-100	90-100	90-100	80-95	35-50	15-25
	14-28	Channery silty clay loam, shaly silty clay loam, silty clay loam.	CL	A-6, A-7-6	0-5	75-95	55-95	55-85	50-80	35-50	15-25
	28	Weathered bedrock	---	---	---	---	---	---	---	---	---
Ec*:											
Eram	0-7	Silty clay loam	CL	A-6, A-7	0	85-100	85-100	85-100	75-95	33-48	12-25
	7-38	Clay, silty clay, clay loam.	CL, CH	A-7, A-6	0	95-100	95-100	90-100	85-98	37-65	15-35
	38	Weathered bedrock	---	---	---	---	---	---	---	---	---
Lula	0-7	Silt loam	CL, ML, CL-ML	A-4, A-6	0	100	100	96-100	65-97	21-37	1-15
	7-12	Silty clay loam, clay loam, silt loam.	CL	A-6, A-4, A-7	0	100	100	96-100	65-98	30-43	9-20
	12-44	Silty clay loam, clay loam.	CL	A-6, A-7	0	95-100	95-100	95-100	75-98	33-50	12-26
	44	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Ka Kenoma	0-11	Silt loam	CL, CL-ML, ML	A-4, A-6	0	85-100	85-100	85-100	85-100	25-40	3-18
	11-34	Silty clay, clay	CH	A-7	0	85-100	85-100	85-100	85-100	50-75	30-48
	34-60	Silty clay, silty clay loam.	CL, CH	A-7	0	85-100	85-100	75-100	75-95	45-65	25-44
Le Leanna	0-17	Silt loam	CL, CL-ML	A-4, A-6	0	100	100	95-100	85-100	25-40	5-20
	17-32	Silty clay, silty clay loam, clay.	CH, CL	A-7	0	100	100	95-100	90-100	45-65	25-40
	32-60	Silty clay loam, silty clay.	CL, CH	A-6, A-7	0	100	100	95-100	90-100	35-55	20-35
Ln*:											
Lebo	0-7	Stony silty clay loam.	CL	A-6, A-7-6	25-50	75-95	55-75	55-70	50-65	35-50	15-25
	7-12	silty clay loam, shaly silty clay loam, silt.	CL	A-6, A-7-6	0-5	75-95	55-95	55-85	50-80	35-50	15-25
	12-28	shaly silty clay loam, very shaly silt loam.	SC	A-2-6, A-2-7	0-5	50-75	10-50	5-40	5-35	35-50	15-25
	28	Weathered bedrock	---	---	---	---	---	---	---	---	---
Rock outcrop.											
Lo Lula	0-7	Silt loam	CL, ML, CL-ML	A-4, A-6	0	100	100	96-100	65-97	21-37	1-15
	7-12	Silty clay loam, clay loam, silt loam.	CL	A-6, A-4, A-7	0	100	100	96-100	65-98	30-43	9-20
	12-44	Silty clay loam, clay loam.	CL	A-6, A-7	0	95-100	95-100	95-100	75-98	33-50	12-26
	44	Unweathered bedrock.	---	---	---	---	---	---	---	---	---
Wb Mason	0-7	Silt loam	ML, CL, CL-ML	A-4, A-6	0	100	100	96-100	65-98	20-35	1-13
	7-60	Silty clay loam, clay loam, silt loam.	CL	A-6, A-4, A-7	0	98-100	98-100	96-100	65-98	30-43	9-20
Oe*:											
Olpe	0-16	Silty clay loam	CL	A-6, A-4	0	80-100	75-100	65-95	60-90	25-40	7-15
	16-44 60	Very gravelly clay loam, very gravelly clay.	GC, SC, GP-GC, SP-SC	A-2, A-6, A-7	0	30-65	10-50	10-50	10-45	30-50	11-22
Kenoma	0-11	Silt loam	CL, CL-ML, ML	A-4, A-6	0	85-100	85-100	85-100	85-100	25-40	3-18
	11-34	Silty clay, clay	CH	A-7	0	85-100	85-100	85-100	85-100	50-75	30-48
	34-60	Silty clay, silty clay loam.	CL, CH	A-7	0	85-100	85-100	75-100	75-95	45-65	25-44
Os Osage	0-14	Silty clay loam	CL	A-6, A-7	0	100	100	100	95-100	40-50	16-25
	14-60	Silty clay, clay, silty clay loam.	CH	A-7	0	100	100	100	95-100	50-80	30-55
Ow Osage	0-17	Silty clay	CH	A-7	0	100	100	100	95-100	50-75	30-55
	17-60	Silty clay, clay, silty clay loam.	CH	A-7	0	100	100	100	95-100	50-80	30-55
Pt*. Pits											
Sn, So Summit	0-6	Silty clay loam	CL, CH, ML, MH	A-6, A-7	0	100	100	96-100	80-99	35-60	11-30
	6-14	Silty clay, silty clay loam, clay.	CL, CH, MH	A-7, A-6	0	100	100	96-100	80-99	37-65	15-35
	14-57	Clay, silty clay	CH, MH, CL	A-7	0	98-100	98-100	96-100	80-98	41-70	18-40
	57-60	Clay, silty clay, silty clay loam.	CH, MH, CL	A-7	0	98-100	98-100	96-100	80-98	41-70	18-40
Vb, Vc Verdigris	0-16	Silt loam	CL, CL-ML, ML	A-4, A-6	0	100	100	95-100	65-100	22-30	2-13
	16-60	Silt loam, silty clay loam.	CL	A-4, A-6, A-7	0	100	100	95-100	80-100	30-45	8-23
Wd, We Woodson	0-7	Silt loam	CL, CL-ML	A-4, A-6	0	100	100	90-100	85-100	25-40	5-20
	7-60 (12)	Silty clay, clay, silty clay loam.	CH, CL	A-7-6	0	100	95-100	95-100	90-100	45-65	20-40
	12-30	Silty clay, clay	CH	A-7-6	0	100	95-100	95-100	90-100	50-65	30-45

Physical and Chemical Properties of Soils

[The symbol < means less than; > means more than. Entries under "Erosion factors--T" apply to the entire profile. Entries under "Wind erodibility group" and "Organic matter" apply only to the surface layer. Absence of an entry indicates that data were not available or were not estimated]

Soil name and map symbol	Depth	Clay <2mm	Moist bulk density	Permeability	Available water capacity	Soil reaction	Salinity	Shrink-swell potential	Erosion factors K	Erosion factors T	Wind erodibility group	Organic matter
	In	Pct	G/cc	In/hr	In/in	pH	Mmhos/cm					Pct
Bc-------------- Bates	0-19	15-27	1.40-1.50	0.6-2.0	0.20-0.24	5.1-6.5	<2	Low--------	0.28	4	5	1-4
	19-34	18-35	1.50-1.60	0.6-2.0	0.15-0.19	5.1-6.5	<2	Low--------	0.28			
	34	---	---	---	---	---	---	-----------	----			
Bd*, Bh*:												
Bates-----------	0-19	15-27	1.40-1.50	0.6-2.0	0.20-0.24	5.1-6.5	<2	Low--------	0.28	4	5	1-4
	19-34	18-35	1.50-1.60	0.6-2.0	0.15-0.19	5.1-6.5	<2	Low--------	0.28			
	34	---	---	---	---	---	---	-----------	----			
Collinsville----	0-11	5-20	1.30-1.65	2.0-6.0	0.12-0.16	5.1-6.5	<2	Low--------	0.32	2	---	1-2
	11-17	5-20	1.30-1.65	2.0-6.0	0.09-0.13	5.1-6.5	<2	Low--------	0.20			
	17	---	---	---	---	---	---	-----------	----			
Ca*:												
Claremore--------	0-7	15-30	1.25-1.35	0.6-2.0	0.16-0.22	5.6-7.3	<2	Moderate	0.32	2	7	---
	7-15	27-40	1.20-1.40	0.2-2.0	0.09-0.21	5.6-7.3	<2	Moderate	0.24			
	15-26	35-50	1.35-1.45	0.06-0.6	0.04-0.07	5.6-7.3	<2	Moderate	0.24			
	26	---	---	---	---	---	---	-----------	----			
Eram------------	0-7	27-32	1.30-1.60	0.2-0.6	0.15-0.19	5.6-6.5	<2	Moderate	0.37	3	7	1-3
	7-38	35-55	1.45-1.75	0.06-0.2	0.14-0.18	5.1-7.3	<2	High-------	0.37			
	38	---	---	---	---	---	---	-----------	----			
Dc-------------- Dennis	0-10	10-27	1.30-1.55	0.6-2.0	0.15-0.20	5.1-6.0	<2	Low--------	0.43	5	---	1-3
	10-15	27-35	1.45-1.70	0.2-0.6	0.15-0.20	4.5-6.0	<2	Moderate	0.37			
	15-60	35-55	1.35-1.65	0.06-0.2	0.15-0.20	5.1-8.4	<2	High-------	0.37			
Dn*:												
Dennis----------	0-10	10-27	1.30-1.55	0.6-2.0	0.15-0.20	5.1-6.0	<2	Low--------	0.43	5	---	1-3
	10-15	27-35	1.45-1.70	0.2-0.6	0.15-0.20	4.5-6.0	<2	Moderate	0.37			
	15-60	35-55	1.35-1.65	0.06-0.2	0.15-0.20	5.1-8.4	<2	High-------	0.37			
Bates-----------	0-19	15-27	1.40-1.50	0.6-2.0	0.20-0.24	5.1-6.5	<2	Low--------	0.28	4	5	1-4
	19-34	18-35	1.50-1.60	0.6-2.0	0.15-0.19	5.1-6.5	<2	Low--------	0.28			
	34	---	---	---	---	---	---	-----------	----			
Do*:												
Dennis----------	0-10	10-27	1.30-1.55	0.6-2.0	0.15-0.20	5.1-6.0	<2	Low--------	0.43	5	---	1-3
	10-15	27-35	1.45-1.70	0.2-0.6	0.15-0.20	4.5-6.0	<2	Moderate	0.37			
	15-60	35-55	1.35-1.65	0.06-0.2	0.15-0.20	5.1-8.4	<2	High-------	0.37			
Bates-----------	0-6	27-35	1.40-1.50	0.6-2.0	0.17-0.19	5.1-6.5	<2	Low	0.28	4	6	1-2
	6-30	18-35	1.50-1.60	0.6-2.0	0.15-0.19	5.1-6.5	<2	Low--------	0.28			
	30	---	---	---	---	---	---	-----------	----			
Ea*:												
Eram------------	0-7	27-32	1.30-1.60	0.2-0.6	0.15-0.19	5.6-6.5	<2	Moderate	0.37	3	7	1-3
	7-38	35-55	1.45-1.75	0.06-0.2	0.14-0.18	5.1-7.3	<2	High-------	0.37			
	38	---	---	---	---	---	---	-----------	----			
Lebo------------	0-14	22-35	1.35-1.45	0.6-2.0	0.21-0.23	5.6-7.8	<2	Moderate	0.32	4	7	---
	14-28	22-35	1.40-1.50	0.6-2.0	0.15-0.18	5.6-7.8	<2	Moderate	0.24			
	28	---	---	---	---	---	---	-----------	----			
Ec*:												
Eram------------	0-7	27-32	1.30-1.60	0.2-0.6	0.15-0.19	5.6-6.5	<2	Moderate	0.37	3	7	1-3
	7-38	35-55	1.45-1.75	0.06-0.2	0.14-0.18	5.1-7.3	<2	High-------	0.37			
	38	---	---	---	---	---	---	-----------	----			
Lula------------	0-7	18-27	1.30-1.50	0.6-2.0	0.16-0.20	5.6-6.5	<2	Low--------	0.37	3	---	1-3
	7-12	24-35	1.40-1.70	0.6-2.0	0.16-0.20	5.6-6.5	<2	Moderate	0.37			
	12-44	27-35	1.45-1.70	0.6-2.0	0.16-0.20	5.1-7.3	<2	Moderate	0.32			
	44	---	---	---	---	---	---	-----------	----			
Ke-------------- Kenoma	0-11	18-29	1.35-1.45	0.2-0.6	0.22-0.24	5.1-6.5	<2	Low--------	0.43	4	6	2-4
	11-34	40-60	1.40-1.50	<0.06	0.10-0.15	5.1-7.8	<2	High-------	0.32			
	34-60	30-50	1.35-1.45	0.06-0.2	0.18-0.20	6.1-8.4	<4	High-------	0.32			
La-------------- Leanna	0-17	15-30	1.25-1.35	0.2-0.6	0.22-0.24	5.1-6.5	<2	Low--------	0.37	5	6	1-4
	17-32	35-50	1.35-1.50	<0.06	0.11-0.18	5.1-6.5	<2	High-------	0.37			
	32-60	27-45	1.35-1.45	0.06-0.2	0.11-0.20	5.6-7.3	<2	High-------	0.37			
Lo*:												
Lebo------------	0-7	22-35	1.35-1.45	0.6-2.0	0.07-0.18	5.6-7.8	<2	Moderate	0.24	4	8	---
	7-12	22-35	1.40-1.50	0.6-2.0	0.15-0.18	5.6-7.8	<2	Moderate	0.24			
	12-28	22-35	1.45-1.65	0.6-2.0	0.07-0.10	5.6-7.8	<2	Moderate	0.24			
	28	---	---	---	---	---	---	-----------	----			
Rock outcrop.												
Lu-------------- Lula	0-7	18-27	1.30-1.50	0.6-2.0	0.16-0.20	5.6-6.5	<2	Low--------	0.37	3	---	1-3
	7-12	24-35	1.40-1.70	0.6-2.0	0.16-0.20	5.6-6.5	<2	Moderate	0.37			
	12-44	27-35	1.45-1.70	0.6-2.0	0.16-0.20	5.1-7.3	<2	Moderate	0.32			
	44	---	---	---	---	---	---	-----------	----			
Mb-------------- Mason	0-7	20-30	1.30-1.60	0.6-2.0	0.16-0.20	5.1-7.3	<2	Low--------	0.37	5	---	1-3
	7-60	20-35	1.40-1.70	0.2-0.6	0.16-0.20	4.5-7.8	<2	Moderate	0.37			
Oe*:												
Olpe------------	0-16	15-30	1.25-1.35	0.6-2.0	0.20-0.23	5.1-6.5	<2	Low--------	0.43	3	6	---
	16-60	27-45	1.30-1.40	0.2-0.6	0.04-0.10	5.1-6.5	<2	Low--------	0.24			
Kenoma----------	0-11	18-29	1.35-1.45	0.2-0.6	0.22-0.24	5.1-6.5	<2	Low--------	0.43	4	6	2-4
	11-34	40-60	1.40-1.50	<0.06	0.10-0.15	5.1-7.8	<2	High-------	0.32			
	34-60	30-50	1.35-1.45	0.06-0.2	0.18-0.20	6.1-8.4	<4	High-------	0.32			

Soil name and map symbol	Depth	Clay <2mm	Moist bulk density	Permeability	Available water capacity	Soil reaction	Salinity	Shrink-swell potential	Erosion factors K	Erosion factors T	Wind erodibility group	Organic matter
	In	Pct	G/cc	In/hr	In/in	pH	Mmhos/cm					Pct
Os----------------- Osage	0-14	35-40	1.45-1.65	<0.06	0.21-0.23	5.1-7.3	<2	High--------	0.28	5	4	1-4
	14-60	35-60	1.50-1.70	<0.06	0.08-0.12	5.6-7.8	<2	Very high	0.28			
Ov----------------- Osage	0-17	40-50	1.40-1.60	<0.06	0.12-0.14	5.1-7.3	<2	Very high	0.28	5	4	1-4
	17-60	35-60	1.50-1.70	<0.06	0.08-0.12	5.6-7.8	<2	Very high	0.28			
Pt*. Pits												
Sn, So------------- Summit	0-6	27-45	1.25-1.50	0.2-0.6	0.16-0.20	5.6-7.3	<2	Moderate	0.37	4	---	1-3
	6-14	32-45	1.35-1.65	0.2-0.6	0.10-0.18	5.6-7.3	<2	High--------	0.37			
	14-57	40-60	1.35-1.60	0.06-0.2	0.10-0.18	5.6-8.4	<2	High--------	0.32			
	57-60	35-55	1.40-1.65	0.06-0.2	0.10-0.18	6.6-8.4	<2	High--------	0.32			
Vb, Vc------------- Verdigris	0-16	15-27	1.30-1.40	0.6-2.0	0.20-0.24	5.6-7.3	<2	Low---------	0.32	5	6	2-4
	16-60	18-35	1.40-1.65	0.6-2.0	0.17-0.22	5.6-7.3	<2	Moderate	0.32			
Wo, Ws------------- Woodson	0-12	18-30	1.25-1.45	0.2-0.6	0.22-0.24	5.6-6.5	<2	Low---------	0.43	4	6	1-4
	30-60	30-50	1.35-1.45	0.06-0.2	0.10-0.15	5.6-7.8	<2	High--------	0.32			
	12-30	40-60	1.30-1.45	<0.06	0.12-0.15	5.6-7.3	<2	High--------	0.32			

Soil and Water Features

[The definitions of "flooding" and "water table" in the Glossary explain terms such as "rare," "brief," "apparent," and "perched." The symbol < means less than; > means more than. Absence of an entry indicates that the feature is not a concern]

Soil name and map symbol	Hydrologic group	Flooding: Frequency	Flooding: Duration	Flooding: Months	High water table: Depth	High water table: Kind	High water table: Months	Bedrock: Depth	Bedrock: Hardness	Risk of corrosion: Uncoated steel	Risk of corrosion: Concrete
					Ft			In			
Bc----------------- Bates	B	None----------	---	---	>6.0	---	---	20-40	Soft	Low--------	Moderate.
Bd*, Bh*: Bates-------------	B	None----------	---	---	>6.0	---	---	20-40	Soft	Low--------	Moderate.
Collinsville------	C	None----------	---	---	>6.0	---	---	4-20	Hard	Low--------	Moderate.
Ca*: Claremore----------	C	None----------	---	---	>6.0	---	---	20-40	Hard	High------	Moderate.
Eram--------------	C	None----------	---	---	2.0-3.0	Perched	Dec-Apr	20-40	Soft	High------	Moderate.
Dc----------------- Dennis	C	None----------	---	---	2.0-3.0	Perched	Dec-Apr	>60	---	High------	Moderate.
Dd*, Dg*: Dennis------------	C	None----------	---	---	2.0-3.0	Perched	Dec-Apr	>60	---	High------	Moderate.
Bates-------------	B	None----------	---	---	>6.0	---	---	20-40	Soft	Low--------	Moderate.
Ea*: Eram--------------	C	None----------	---	---	2.0-3.0	Perched	Dec-Apr	20-40	Soft	High------	Moderate.
Lebo--------------	B	None----------	---	---	>6.0	---	---	20-40	Soft	Moderate	Low.
Ec*: Eram--------------	C	None----------	---	---	2.0-3.0	Perched	Dec-Apr	20-40	Soft	High------	Moderate.
Lula--------------	B	None----------	---	---	>6.0	---	---	40-60	Hard	Moderate	Moderate.
Ke----------------- Kenoma	D	None----------	---	---	>6.0	---	---	>60	---	High------	Moderate.
Le----------------- Leanna	D	Occasional	Very brief	Jan-Dec	0.5-2.0	Perched	Dec-Jun	>60	---	High------	Moderate.
Ln*: Lebo--------------	B	None----------	---	---	>6.0	---	---	20-40	Soft	Moderate	Low.
Rock outcrop.											
Lo----------------- Lula	B	None----------	---	---	>6.0	---	---	40-60	Hard	Moderate	Moderate.
Mb----------------- Mason	B	Rare----------	---	---	>6.0	---	---	>60	---	Moderate	Moderate.
Oe*: Olpe--------------	C	None----------	---	---	>6.0	---	---	>60	---	High------	Moderate.
Kenoma------------	D	None----------	---	---	>6.0	---	---	>60	---	High------	Moderate.
Os, Ov------------- Osage	D	Occasional	Brief to long.	Nov-May	0-1.0	Perched	Nov-May	>60	---	High------	Moderate.
Pt*. Pits											
Sn, So------------- Summit	C	None----------	---	---	2.0-3.0	Perched	Dec-Apr	>60	---	High------	Low.
Vb----------------- Verdigris	B	Occasional	Very brief	Dec-Jun	>6.0	---	---	>60	---	Low--------	Low.
Vc----------------- Verdigris	B	Frequent-----	Very brief	Dec-Jun	>6.0	---	---	>60	---	Low--------	Low.
Wo, Ws------------- Woodson	D	None----------	---	---	0.5-2.0	Perched	Dec-Apr	>60	---	High------	Moderate.

APPENDIX B

ESTIMATED COSTS OF RESIDENTIAL CONSTRUCTION RELATED TO SOIL/SUBSURFACE CONDITIONS IN KANSAS

Estimated Costs of Establishing Subgrades

Soil or Subsurface Conditions Affecting Costs	Streets and Slab on Grade			Basements			5-6' Trench			10-12' Trench		
	Bayer Construction Co., Inc.	Quality Excavating, Inc.	Walters Construction Co., Inc.	Bayer Construction Co., Inc.	Quality Excavating, Inc.	Ross and Michel Construction Co.	Bayer Construction Co., Inc.	ERB Contractors, Inc.	Quality Excavating, Inc.	Bayer Construction Co., Inc.	ERB Contractors, Inc.	Quality Excavating, Inc.
Excavation and Backfill												
Light or medium soil	$ 1.40/CY	$ 1.25/CY	$ 2.75/CY	$ 1.20/CY	$ 4.75/CY	$ 2.00/CY	$ 1.00/LF	$ 2.75/LF	$ 3.80/LF	$ 4.00/LF	$ 5.25/LF	$ 6.50/LF
Heavy clay	1.75	1.60	3.45	1.50	4.75	3.00	1.10	3.00	3.80	5.00	5.80	6.50
Hardpan	2.00	2.50	4.60	1.75	4.75	5.00	1.50	---	4.55	6.00	---	7.80
Soft rock	2.75	5.60	---	2.50	4.75	5.00	2.50	4.10	4.55	15.00	7.90	7.80
Hard rock (blasting)	5.00	20.00	27.50	10.00	20.00	15.00	5.00	11.65	11.70	25.00	35.65	35.65
Hard rock (no blasting)	15.00	42.50	42.50	45.00	60.00	35.00	50.00	23.35	16.70	60.00	71.30	50.95
Water table (in sand)	6.20	---	---	5.40	---	---	7.00	9.50	---	15.00	32.90	---
Water table (in other soil)	1.60	---	---	1.40	---	---	4.00	4.55	---	15.00	8.75	---
Compaction												
Sandy soil	$ .75/CY	---	$ .50	---	---	$ 2.00/CY	$ 2.00/CY	$ 2.00/CY	$ 4.50/CY	$ 2.00/CY	$ 2.00/CY	$ 4.50/CY
Silty soil	.95	---	.50	---	---	2.00	4.00	3.00	4.50	4.00	3.00	4.50
Clayey soil	1.00	---	.50	---	---	4.00	6.00	4.00	4.50	6.00	4.00	4.50

Estimated Costs of Soil as Construction Material (Delivered to Site)

Contractor	Topsoil	Soil Borrow	Sand	Crushed Rock
Bayer Construction Co., Inc.	$5.00/CY	$4.00/CY	$2.40/CY	$5.00/ton
Quality Excavating, Inc.	6.70	3.75	2.43/CY	8.00
Walters Construction Co., Inc.	4.50	---	---	---

Estimated Costs of Foundations

Soil/Subsurface Conditions Affecting Costs	Slab on Grade Foundations						Basement Foundations			
	Joe Conroy Contractor, Inc.		Graybeal Construction, Inc.		Walters-Morgan, Inc.		Joe Conroy Contractor, Inc.		Graybeal Construction, Inc.	
	Footing	Slab	Footing	Slab	Footing	Slab	Footing	Slab	Footing	Slab
Good conditions	$13.00/LF	$1.15/SF	$15.00/LF	$1.25/SF	$10.72/LF	$3.00/SF	$23.50/LF	$1.15/SF	$22.00/LF	$1.25/SF
Poor bearing	15.35	1.15	15.00	1.25	12.50	3.00	27.75	1.15	22.00	1.25
High shrink-swell	13.00	1.58	15.00	1.25	12.50	3.00	23.50	1.60	22.00	1.25
High potential frost action	14.00	1.15	15.00	1.25	10.72	3.05	24.50	1.15	22.00	1.25
Poor drainage or high water table	13.00	1.37	15.00	1.50	---	---	23.50	1.35	22.00	1.50

Estimated Costs of Street Paving and Subrade Modification

Soil/Subsurface Conditions Affecting Costs	Asphalt Paving			Concrete Paving		
	Bayer Construction Co., Inc.	Shilling Asphalt, Inc.	Van Doren Hazard Stallings	Bayer Construction Co., Inc.	Joe Conroy Contractor, Inc.	Walters Construction Co., Inc.
Good conditions	$12.00/SY	$ 7.10/SY	$ 5.60/SY	$12.00/SY	$23.00/SY	$ 9.50/SY
Poor bearing	15.00	10.60	8.40	15.00	23.00	13.50
High shrink-swell	15.00	---	10.00	15.00	25.75	13.50
High potential frost action	14.50	---	10.00	14.50	23.00	9.60
Poor drainage or high water table	14.50	---	8.40	14.50	27.20	---

Estimated Costs of Utilities

Contractor	Water Lines		Sewer Lines		Septic Tanks
	main	service	main	service	
Bayer Construction Co., Inc.	$8.00/LF	$3.50/LF	$15.00/LF	$ 5.00/LF	$1700.00 to $2500.00
BRB Contractors, Inc.	5.80	4.25	10.50	---	---
Quality Excavating, Inc.	8.00	1.25	15.50	11.00	1500.00 to 1725.00

INTERPRETING SOIL CONSERVATION SERVICE INFORMATION FOR PLANNING RESIDENTIAL DEVELOPMENTS IN KANSAS

by

GLENDA MARIE DIETZ

B.S., University of Missouri, 1972

AN ABSTRACT OF A MASTER'S THESIS

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MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1981

ABSTRACT

In recent years, the importance of inventorying a community's natural resources and determining how they can best be utilized has become increasingly apparent. Many cities and towns no longer have the option of locating their developments on the most favorable sites and are faced with critical decisions about future growth. Others have discovered, too late, that their most valuable or unique natural resources have been irreparably altered or destroyed. With this recognition also comes the realization that even with the wealth of existing scientific data on natural resources, planners may not be aware of its full potential or may have difficulty in understanding and adapting it into a functional planning format.

This study makes use of one generally available source of information, the soil survey prepared by the Soil Conservation Service (SCS), since it already has some recognition among city planners and smaller rural communities, and because of its contribution of well documented data that is important to a number of land uses including agriculture, wildlife, recreation and community development. Although interpretations of soil suitability for these uses are also included, insufficient consideration is given to the various local socio-economic conditions that may make a soil type severely limiting for a given use in one community and feasible in another.

In an attempt to improve the usefulness of SCS data for planners, the University of Massachusetts at Amherst has included in its Metropolitan Landscape Planning Model (METLAND) a means of assessing

the physical development suitability of a soil by assigning a dollar amount to its major limiting engineering characteristics for residential development. This provides an economic basis for comparison to other soils and other landscape resources. The method is designed for use at the mezo-regional scale and is relatively simple, requiring only SCS maps and information and cost estimates of contractors within the planning area.

The METLAND assessment of the physical development suitability of soils for residential use has been adapted in this study for application in Kansas. A number of common soil and subsurface problems were selected for evaluation including those with greatest impact on excavation costs and on the design and construction of foundations, street pavement and utilities. Estimated costs of working with or compensating for these various soil conditions were obtained by interviewing area contractors. Tables summarizing this information and providing the estimated total added cost per residential lot for each soil or subsurface problem are included and can be used by Kansas communities to predict the magnitude of development costs that may be encountered on each soil unit within their planning area. This procedure was applied to a case study of Ottawa, Kansas for which maps were prepared that illustrate the relative suitability of Ottawa area soils for residential development.

This study demonstrates that major soil and subsurface conditions can have a significant impact on residential development costs. By using a planning technique such as that afforded by the METLAND planning model, communities are better able to recognize the potential and limitations of their landscape and to reflect this recognition in the planning policies designed to guide their growth.