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**THE USE OF HIGH ALTITUDE REMOTE SENSING
IN DETERMINING EXISTING VEGETATION
AND MONITORING ECOLOGICAL STRESS**

by

Kennith Foster & Alex Garcia

**CASE FILE
COPY**

A report of work performed
under NASA grant No. NGL 03-002-313
in cooperation with the Pima
County Planning Department, City of Tucson

**OFFICE OF ARID LANDS STUDIES
College of Earth Sciences
University of Arizona
Tucson, Arizona**

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FOREWORD

This Bulletin is published in furtherance of the purposes of NASA grant NGL 03-002-313 entitled "Research for Application of Remote Sensing to State and Local Governments." The purpose of the grant is to assist, with the use of NASA high-altitude photography and satellite imagery, state and local agencies whose responsibility lies in planning, zoning, and environmental monitoring and/or assessment.

This report is the second in a series of publications designed to present information bearing on remote sensing research and applications in Arizona. In the present investigation, high-altitude color and multispectral black and white photography was used to survey existing vegetation and soil conditions on the Empire Ranch where large scale development will soon begin. Utilizing stereo pairs of the high-altitude color photography, four vegetation classifications were discernable as a function of topography and foliage characteristics.

In contrast to the undeveloped Ranch, the same photography was used to detect environmental changes in the Tucson metropolitan area as a result of rapid urbanization. The most prevalent change related to development is the removal of vegetation in high density areas to allow for housing starts. Erosion then occurs where vegetation has been removed.

INTRODUCTION

Increased demands to consider ecology have been or are being placed upon land planning commissions and others involved with large scale developments. The Pima County Planning Department has the demanding task of reviewing future development plans in light of the environmental balance demanded today. Data is needed regarding environmental characteristics so that urban zoning policies can be better formulated to allow development and ecological balance to progress simultaneously.

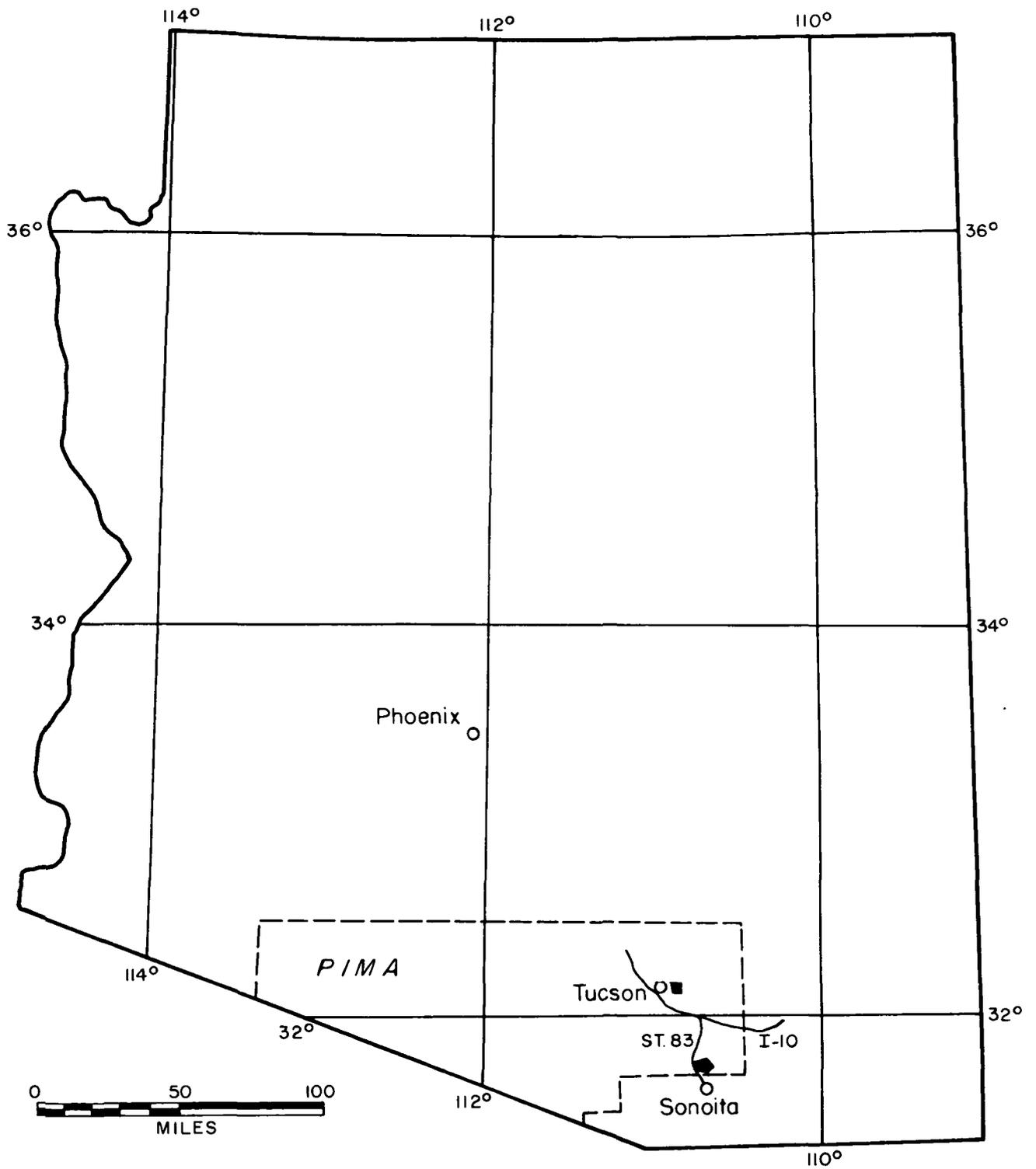
Primary areas of concern for this particular study were: (1) the Empire Ranch predevelopment site consisting of approximately 5,300 acres, and (2) portions of urban Tucson which border the East Saguaro National Monument as shown in Figure 1.

This study was conducted jointly by the Office of Arid Lands Studies, University of Arizona and the Pima County Planning Department, with funding provided through NASA contract NGL 03-002-313 entitled "Application of Remote Sensing to State and Local Governments."

Purpose of the Study

The purpose of this study was to examine the feasibility of using high altitude remote sensing as a tool for determining preurbanized conditions of existing semi-arid vegetation and soils. Remote sensing was also examined with regard to establishing an ecological stress monitoring system on National Forests and Monuments which border the Tucson urban area. Data made available from NASA ultra high altitude aerial photography was used to examine the existing vegetation and soils distribution over a 5,300 acre development site on the Empire

Figure 1. Delineation of the Study Area



Ranch. This data was compared with the vegetation patterns previously reported by the developers and the same nomenclature was used for the vegetation patterns as mapped from high altitude photography. Thus a common vocabulary is used in this report in those already submitted to the planning Department by the developers at the Empire Ranch.

DESCRIPTION OF THE VEGETATION DISTRIBUTION MAP

NASA high altitude color photography (Mission 155, 18 January '71) at a contact scale of 1:125,000 was used to determine vegetation characteristics and their associated distribution. The four vegetation classifications used are as follows:

L.H.-Lower Hills, B.-Bottomland, T.-Terrace, mapped at 1:125,000, and G.-Grassland. Figure 2 shows the vegetation distribution over the site.

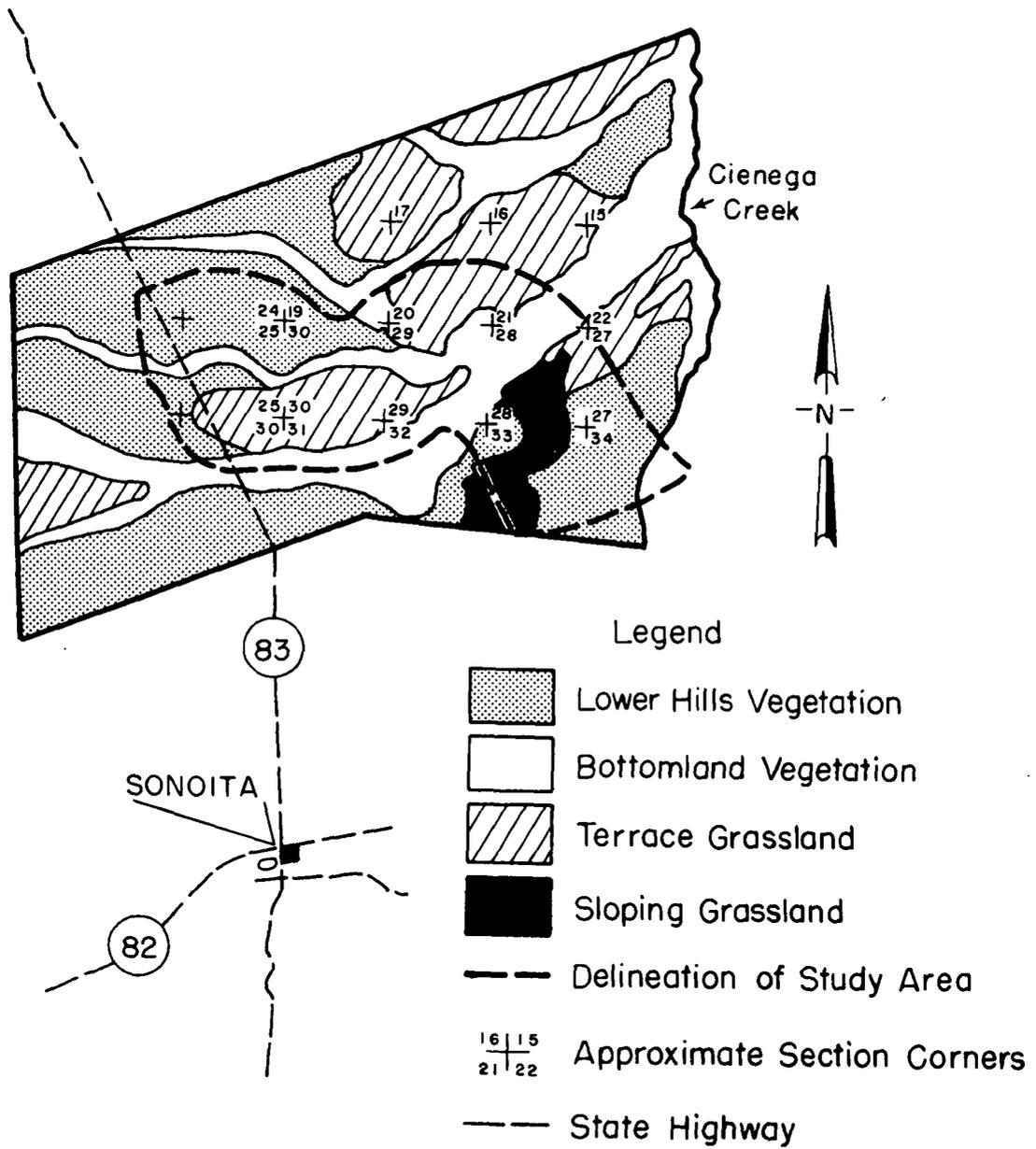
Lower Hills Vegetation

The lower hills vegetation consists of grasslands which have scattered mesquite and oak trees along with some occurrence of yucca. As can be seen from the map, the lower hills vegetation is widely distributed throughout the proposed development site. This vegetation type is dominated by black grama, curly mesquite, side oats grama, blue grama, and threeawn.

Bottomland Vegetation

The bottomland vegetation consists of primarily the same types of grass species as the lower hills vegetation. That is, blue grama, side oats grama threeawns, and sacaton are found in this vegetation type. The specific species cannot be identified from the data. Therefore, no differences between these broad vegetation types could be detected by species composition of the grasses. However, the bottomland tree vegetation could be distinguished by use of this data. The trees are primarily oak, cottonwood, and mesquite. An occasional desert willow could be seen from the ground. Oak trees can be separated from cottonwood groves on the basis of color differentiation in the aerial photographs.

Figure 2. Vegetation Map of the 5300 acre Empire
Ranch Development Site



Terrace Vegetation

The terrace vegetation consists mainly of the same grassland species described in the two previous vegetation categories. The primary differences of the terrace vegetation compared to lower hills can be seen by the occurrence of oak trees and yucca on the lower hills, whereas the terrace vegetation is predominantly grassland species. However, Mesquite trees do occur occasionally in the terrace vegetation type. They are considerably larger and occur in clumps, making them easy to detect from the photography. It is doubtful that the terrace vegetation could be distinguished in all cases from the lower hills vegetation, particularly on the basis of the occurrence of scattered trees, therefore, topographic features must be used in distinguishing the two vegetation types.

Grassland Vegetation

The grassland vegetation occurs on slightly sloping topography and consists of the same grass species as Terrace Vegetation. Topographic information is used to distinguish this type which occurs between the Lower Hills vegetation and Terrace Grasslands, and is defined by its gently sloping topography.

A number of color-differentiated areas are due to vegetation characteristics. One of the vegetation types distinguishable on the high altitude data is tobosa grass. Patches of tobosa occur as dark areas on the photography and are associated with the terrace grassland vegetation, however, more extensive field checking must be completed before larger scale interpretations are made than those presented in this report.

Potential Impact of Land Use on Empire Ranch Vegetation

The differential use of the grassland by domestic livestock can be readily distinguished in the area using remote sensing data.

Different seasons of grazing along with grazing intensity by domestic livestock are well delineated. Systems of grazing management can be analyzed by use of high altitude photography taken at different times.

As water tables are lowered in the area (should they be lowered), the bottomland vegetation will be most affected. The tree life of the bottomlands in the development site would change dramatically should the watertable decline. The mesquite woodland of the area would be affected but not as rapidly as the cottonwood woodland and the oak woodland would also be less susceptible to injury or death than cottonwood. High altitude repetitive remote sensing data can be used to monitor the ecological changes of the vegetation caused by changes in water table depth. Very few changes in the grassland species composition could be detected unless associated with grazing pressures.

Soil Survey

High altitude photography was also used to delineate soil associations to the maximum degree possible. This effort can be termed a partial success as vegetation cover masked efforts to delineate soil types solely by tonal variations. A field survey in conjunction with the photography was conducted however, to provide general information concerning soil characteristics and interpretations within each of the four vegetation classifications.

The soils within each of the four vegetation units are delineated as associations comprised of geographic areas with each unit being a distinctive combination of soils in a characteristic and repeating pattern. The different vegetation units may have similar kinds of soil but the physical features, such as slope, differ.

Soils of the Lower Hills

The soils of the lower hills vegetation unit is the Bernardino-Hathaway Association (The name assigned to each soil series is that currently in use by the Soil Conservation Service). Bernardino soils are characterized as being well drained soils with gravelly fine textured subsoils and gravelly lime moderately coarse textured substrata. The substratum, or C horizon is defined as that part of the soil below where the processes of soil formation are not active; the parent materials. A typical profile consists of about nine inches of reddish brown gravelly clay loam surface six inches of a gravelly clay subsoil, and a limy gravelly sand loam substratum with more than 15% CaCO_3 at a depth of approximately fifteen inches. About fifty-five percent of the lower hills vegetation unit grown on this type soil.

The Hathaway Series consists of deep, dark colored, well-drained, moderately to steeply sloping, very gravelly soils occurring on dissected old alluvial fans. The soils are strongly calcareous. Approximately twenty-five percent of the vegetation unit is underlain by this type soil.

Due to the broad nature of the survey and allowing some degree of error, twenty percent of this unit was classified as "other" soils.

Soils of the Terrace and Grassland

There were no detectable soil association differences between these two vegetation units underlain by the White House-Bernardino-Sonoita Soil Association.

The White House Series consists of deep well-drained soils with clay subsoils formed in old alluvium from igneous rocks. A typical profile has a brown gravelly sandy loam or gravelly loam

surface layer three to six inches thick. The subsoil grades to dark reddish brown or dark red clay at about nine inches. Twenty-six inches below the substrata is mildly calcareous gravelly clay loam or gravelly sandy clay loam. Approximately eighty percent of the two vegetation units are underlain by this soil series.

The Sonoita series consists of deep well drained nearly level to moderately sloping soils with gravelly sandy loam subsoils. A typical profile consists of three to twelve inches of brown to yellowish red gravelly sandy loam. The subsoil and substratum are reddish brown to yellowish red sandy loam or gravelly heavy sandy loam. These soils comprise approximately five percent of the vegetation unit.

The Bernardino series as previously described, occupies approximately ten percent of the unit, with ten percent allotted to "other" soils.

Soils of the Bottomland

The bottomland vegetation is underlain by the Comoro-Grabe-Pima Association. The Comoro Series consists of deep well drained soils with moderate coarse textured subsoils and substrata. A typical profile consists of a grayish brown sandy loam surface and subsoil and gravelly-sandy loam substratum. The Comoro Series account for about fifty percent of the unit.

The Grabe Series consists of deep, well drained soils with dark colored medium or moderately coarse textured surface layers and medium textured subsoils and substrata. A typical profile consists of grayish brown loam surface and subsoils that may contain this strata of silt loam, very fine sandy loam and clay loam to 40 inches or more, or they may overlay fine sandy loam substrata below about 30 inches. Approximately thirty percent of the unit consists of this series.

The Pima Series consists of deep well drained soils with dark colored loam or light clay loam surface and subsurface layers. The Pima series covers approximately ten percent of the unit with five percent devoted to "other".

Soil Interpretations

The preceding descriptions of each soil associations is important for a basic understanding of the soil characteristics. Equally or more important however, are the capabilities, limitations and engineering interpretations of the soil for future development on the land.

Tables A,B, and C provide criteria and basic data for better planning based upon the knowledge of a soils capability and limitations for a given developmental purpose. A referral to the Appendix and Glossary at the end of the report provides additional information regarding Tables A,B, and C.

Future Monitoring

The nature and small scale data upon which this report was based provide basic environmental information for relatively large areas often without regard to fine details a planner would desire, however the study area will provide unique setting for monitoring the changes large scale urbanization will create on a semi-arid environment.

At this time no development has been initiated at the site, however access roads will be installed in the near future linking U.S. Highway 83 to locations within the study area. Future development will be monitored using ERTS-1 satellite imagery. This work provides information regarding vegetation and soils characteristics which will help explain any future regional variation.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING INTERPRETATIONS FOR RESIDENTIAL, INDUSTRIAL, AND RECREATIONAL USES^{1/}

FOR THE INITIAL DEVELOPMENT SITE, EMPIRE RANCH, PIMA COUNTY, ARIZONA

TABLE A

Map Symbol and Major Soil Components ^{2/}	Estimated Properties of the Soils					Suitability as a Source of:			Other Features:			
	Permeability In./hr.	Available Water Capacity In./Inch	Shrink-swell Potential	Reaction	Corrosivity (uncoated steel)	Road Fill	Sand and/or gravel	Topsoil	Hydrological Soil Group	Flooding Hazard	Erosion Hazard	Suitability as a Habitat for Wildlife
LH. Bernardino gravelly loam, 0 to 15% slopes. (55% of unit)	Slow in subsoil .06 to .20 Moderate in substratum	High .14 to .18 in surface and subsoil. Low in substratum .07 to .09	Moderate. High in thin subsoil. Low in substratum.	pH 7.9 - 8.4	High	Good for whole soil. Poor upper 15 to 20 inches. CH over SM material.	Poor. Excessive fines	Poor. Excessive gravel - clayey material	C	Slight	Slight to moderate	Rangeland - Fair, Principal Species: Scaled and Gambel's quail, mourning and white-winged dove, and pronghorn antelope. A few mule deer and javelina are found along brushy draws.
Hathaway gravelly loam, 5 to 30% slopes. (25% of unit)	Moderate .60 to 2.0	Low .06 to .09	Low	pH 7.9 - 8.4	Moderate	Good. GM material. Slope 5 to 30%.	Poor for sand. Fair for gravel. 10 to 25% fines.	Poor. Very gravelly materials	B	Slight	Slight	
T. and G. White House gravelly loam, 0 to 8% slopes. (80% of units)	Slow in subsoil .06 to .20. May be moderately slow in substratum .20 to .60	High .14 to .16	High	pH 6.1 - 8.4	High	Poor. CH material High shrink-swell	Poor. Excessive fines	Poor. Clayey material, gravelly in surface.	C	Slight	Slight	
Bernardino gravelly loam, 0 to 8% slopes. (10% of units)	Same as above in L H. unit.											
B. Comoro sandy loam, 0 to 3% slopes (50% of unit)	Moderately rapid. 2.0 to 6.0	Low to moderate. Sandy loam - .10 to .13	Low	pH 6.6 - 8.4	Low	Good. SM material	Poor. Excessive fines. May be suitable below 60 inches in local areas.	Good where non-gravelly. Entire profile	B	Slight to moderate. Subject to seasonal overflow in local areas. Short duration. Severe in stream bottoms within the area.	Generally slight. Possible stream bank cutting. Possible gullying if piping starts.	Rangeland - Fair, Principal species; Gambel's quail, songbirds, dove, javelina, mule deer, and cottontails.

^{1/} See Appendix for explanation of terms and column headings.
See Tables B and C for soil limitation ratings based on soil properties in this table.

^{2/} Subject to change when detailed soil surveys are made.

TABLE A.

Map Symbol and Major Soil Components ^{2/}	Estimated Properties of the Soils					Suitability as a Source of:			Other Features:			
	Permeability In./hr.	Available Water Capacity In./Inch	Shrink-swell Potential	Reaction	Corrosivity (uncoated steel)	Road Fill	Sand and/or gravel	Topsoil	Hydrological Soil Group	Flooding Hazard	Erosion Hazard	Suitability as a Habitat for Wildlife
B. (Continued) Grabe loam, 0 to 3% slopes. (30% of unit)	Moderate. .63 to 2.0	High .16 to .18 Moderate .11 to .13 if surface is sandy loam.	Low	pH 7.9 to 8.4	Low to moderate	Fair ML material	Poor. Excessive fines. May overlie sand or gravel.	Good. Entire profile.	B	Slight to moderate. Subject to seasonal overflow in local areas. Short duration. Severe in stream bottoms within the area.	Generally slight. Possible stream bank cutting. Possible gullying if piping starts.	
Pima loam, 0 to 2% slopes. (10% of unit)	Moderately slow. .20 to .60	High. .16 to .21	Moderate	pH 7.4 - 8.4 Local areas may be saline (North center and on Cienega Creek.)	Moderate to high	Fair. ML or CL material.	Poor. High content of fines.	Fair - Entire profile clay loam	B			

SOIL LIMITATION RATINGS ^{1/} AND SOIL FEATURES AFFECTING ENGINEERING INTERPRETATIONS FOR RESIDENTIAL AND LIGHT INDUSTRIAL USES

TABLE B

FOR THE INITIAL DEVELOPMENT SITE, EMPIRE RANCH, PIMA COUNTY, ARIZONA ^{2/}

Map Symbol and Major Soil Components	Soil Limitations and Soil Features Affecting Residential and Light Industrial Uses:							
	Septic tank Absorption Fields	Shallow Excavations	Dwellings without basements (Foundation Support)	Sanitary Land Fill	Local Roads and Streets	Water Areas (Ponds, Sewage, Lagoons, etc.)	Embankments, Dikes and Levees	Irrigation - Cropland Golf Fairways, Lawns and Similar Uses
LH. Bernardino gravelly loam, 0 to 15% slopes. (55% of unit)	Moderate. Moderate permeability in substratum. Slope.	Moderate. 20 to 35% gravel in profile. Clayey subsoils.	Moderate. Moderate shrink-swell potential in subsoil. Slopes up to 15%.	Moderate. Clayey subsoils. 20 to 35% gravel - moderate for cover.	Moderate. SC materials (CH in thin subsoil); moderate shrink-swell potential.	Moderate on slopes < 7%. Severe on slopes > 7%. Moderate permeability in substratum.	Moderate. Medium to low shear strength. Poor to fair compaction characteristics. Low compacted permeability.	Moderate to severe. Gravelly surface. Shallow to high lime. Slope > 8% excessive for irrigated cropland. Moderate water holding capacity.
Hathaway gravelly loam, 5 to 30% slopes. (25% of unit)	Slight on < 8% slopes; moderate on 8 to 15% slopes; severe on slopes > 15%	Severe. Poor sidewall stability. Very gravelly profile. Slope > 15% is excessive.	Slight on < 8% slopes. Moderate on 8 to 15% slopes. Severe on slopes > 15%	Moderate. Very gravelly profiles. Poor cover material due to high gravel content	Slight on < 8%, moderate on 8 to 15%, severe on > 15 percent slopes. GM materials	Severe. Very gravelly profiles. Moderate permeability. Slope > 7% is excessive	Moderate. High to medium shear strength; medium to low compacted permeability; medium to low susceptibility to piping. Fair compaction characteristics.	Severe. Very gravelly and limy profiles. Low water holding capacity. Slope > 15% is excessive.
T. and G. White House gravelly loam, 0 to 8% slopes. (80% of units)	Severe. Moderately slow permeability in substratum.	Severe. Clayey profile.	Severe. High shrink-swell potential in subsoil.	Severe. Clayey materials. Poor workability.	Severe. CH material. High shrink-swell potential.	Slight on slope < 2%. Moderate on slopes < 7%.	Moderate. Poor to fair compaction characteristics; low shear strength; high compressibility.	Moderate. Gravelly surface. Slow permeability. High water holding capacity.
Bernardino gravelly loam, 0 to 8% slopes. (10% of units)	Same as above in L H. unit (except that slope is generally < 8 percent).							
B. Comoro sandy loam, 0 to 3% slopes. (50% of unit)	Slight. Moderately rapid permeability. Severe where subject to flooding.	Slight. Moderate if gravelly. Severe if subject to flooding.	Slight. Severe where subject to flooding.	Slight. Severe where subject to flooding.	Slight. SM materials. Severe if subject to flooding more than once in 5 years	Severe. Moderately rapid permeability.	Slight to moderate. Medium to high susceptibility to piping. Medium to low compacted permeability. Medium shear strength.	Slight to moderate. Moderate water holding capacity. Gravelly sandy loam has low water holding capacity. Some areas subject to flooding.
Grabe loam, 0 to 3% slopes. (30% of unit)	Slight to moderate. Moderate permeability. Severe if subject to flooding.	Slight. Severe if subject to flooding.	Moderate. ML materials. Severe if subject to flooding.	Slight. Severe if subject to flooding.	Moderate. ML materials. Severe if flooded > 1 in 5 years.	Moderate. Moderate permeability. Severe for sewage lagoons if subject to flooding.	Moderate. Medium to low shear strength. Medium compressibility. High susceptibility to piping.	Slight. Severe if flooded > 1 in 10 years.

^{1/} Suitable only for broad planning purposes. On-site investigation must be made to obtain reliable information for a specific site or use.

^{2/} See appendix for explanation of terms and criteria for table headings. See Table A for soil properties upon which these interpretations are based.

TABLE B

Map Symbol and Major Soil Components	Soil Limitations and Soil Features Affecting Residential and Light Industrial Uses:							
	Septic tank Absorption Fields	Shallow Excavations	Dwellings without basements (Foundation Support)	Sanitary Land Fill	Local Roads and Streets	Water Areas (Ponds, Sewage, Lagoons, etc.)	Embankments, Dikes and Levees	Irrigation - Cropland Golf Fairways, Lawns and Similar Uses
<p>B. (Continued)</p> <p>Pima loam, 0 to 2% slopes. (10% of unit)</p>	<p>Severe. Moderately slow permeability. Possible flooding</p>	<p>Moderate. Clay loam texture. Severe where subject to flooding.</p>	<p>Moderate. Moderate shrink-swell. ML or CL materials. Severe if subject to flooding.</p>	<p>Slight to moderate. Moderately fine-textured subsoils. Severe if subject to flooding.</p>	<p>Moderate. ML or CL materials. Severe if subject to flooding more than once in 5 years.</p>	<p>Slight to moderate. Substratum may have moderate permeability. Severe for sewage lagoons if subject to flooding.</p>	<p>Moderate. Poor to medium stability; high to medium susceptibility to piping. Medium to low shear strength.</p>	<p>None to slight unless subject to flooding. Moderately slow permeability.</p>

SOIL LIMITATION RATINGS AND SOIL FEATURES AFFECTING RECREATIONAL USES

FOR THE INITIAL DEVELOPMENT SITE, EMPIRE RANCH, PIMA COUNTY, ARIZONA ^{1/}

TABLE C

Map Symbol and Major Soil Components	Camp Areas	Playgrounds	Paths & Trails	Picnic Areas
LH. Bernardino gravelly loam, 0 to 15% slopes. (55% of unit)	Moderate. Gravelly loam surface. Slow permeability in subsoil.	Severe. Gravelly surface. Slope > 6% is excessive.	Moderate. Gravelly loam surface.	Moderate. Gravelly loam surface.
Hathaway gravelly loam, 5 to 30% slopes. (25% of unit)	Moderate on slopes < 15%. Gravelly surface. Severe on slopes > 15%	Severe. Gravelly surface. Slope > 6% is excessive.	Moderate on slopes < 25%. Severe on slopes > 25%.	Moderate on slopes < 15%. Severe on slopes > 15%. Gravelly surface.
T. and G. White House gravelly loam, 0 to 8% slopes. (80% of units)	Moderate. Gravelly loam surface. Slow permeability.	Severe. Gravelly surface. Slow permeability.	Moderate. Gravelly surface.	Moderate. Gravelly surface.
Bernardino gravelly loam, 0 to 8% slopes. (10% of units)	Same as above	in L H. unit.		
B. Comoro sandy loam, 0 to 3% slopes. (50% of unit)	Slight. Severe if subject to flooding during period of use.	Slight. Severe if subject to flooding during period of use.	Slight.	Slight. Severe if subject to flooding during period of use.
Grabe loam, 0 to 3% slopes. (30% of unit)	Slight. Severe if subject to flooding during period of use.	Slight. Severe if subject to flooding during period of use.	Slight	Slight. Severe if subject to flooding during period of use.

^{1/} See footnotes 1 and 2, Table B.

TABLE C

Map Symbol and Major Soil Components	Camp Areas	Playgrounds	Paths & Trails	Picnic Areas
<p>B. (Continued)</p> <p>Pima loam, 0 to 2% slopes. (10% of unit)</p>	<p>Moderate. Moderately slow permeability. Severe if sub- ject to flood- ing during period of use.</p>	<p>Moderate. Moderately slow perme- ability. Severe if subject to flooding dur- ing period of use.</p>	<p>Slight.</p>	<p>Slight. Severe if subject to flood- ing during period of use.</p>

One area along Greaterville Wash has been established as a site to monitor channel erosion cutting into the terraces adjacent to the Wash. An area of approximately three to five acres is involved. Unless efforts are made to stabilize the erosion, any vegetation alteration will cause excess runoff which may aggravate the problem.

ECOLOGICAL IMPACT SURVEY OF TUCSON URBAN BOUNDARIES

The Empire Ranch area, as previously discussed, represents the initiation of urban development and the potential problems associated with it. The Pima County Planning Department is also confronted with existing urbanization and its potential environmental implications in the Tucson area. The present area of interest extends from Harrison Road between Speedway Boulevard and Escalante Road east to the Saguaro National Monument. The Department is currently operating under the "Rincon Area Residential Zoning Plan" which calls for a variable housing density of 34 houses per acre (CR-3) up to one-half mile east of Harrison Road then a step-wise reduction to 1 house per acre (CR-1) and finally 1 home per 4 acre (SR) along the Monument boundary. The plan's objective is to provide a "buffer zone" between high-density housing and the monument boundary. This zone will thus minimize possible ecological effects upon the Monument itself. Recently, however, developers have attempted to obtain a zoning change, thus allowing high density zoning closer to the Monument boundary.

It was decided for this part of the study to use remote sensing techniques as a means of monitoring development within the buffer zone itself. The area between Harrison Road and Houghton Road and Speedway and Broadway was chosen for study. This area is the division between CR-3 and CR-1 zoning and simulates the cause effect relationships expected between what is now SR zoning and the Monument boundary should the SR zoning be allowed to become high density. The area enclosed by the four roads is one square mile and the CR-3 CR-1 zoning division is a north-south line one half mile between Harrison and Houghton Roads.

A study of Mission 101, 10 August '69 high altitude photography revealed no development activity within the section. Prior to January 1971 development in the southwest corner of the section had begun in the CR-3 zoning area.

Typical high density zoned area was the immediate clearing of all vegetation and installation of roads easily discernable on later high altitude flights. For example 18-day repetitive U-2 photography shows the clearings as bright areas surrounded by the undisturbed darker tones of natural vegetation and undisturbed soil. An area of CR-1 zoning just south of the study area, but within the buffer zone, revealed the basic difference in CR-3 and CR-1 zoning. CR-1 zoning allows for more acreage surrounding each home and alleviates the necessity of having to clear all vegetation for the development.

Once high density zoning occurs in an area, the human factor then enters into the ecological impact. Off-road vehicles have become popular for desert pleasure riding. Results of such activity have been the physical destruction of vegetation and the initiation of erosion on the sloping lower hills. The known erosion problem areas in Tucson caused by off-road vehicles was studied using Mission 155 photography. The areas were discernable as being a lighter tone in contrast to the darker undisturbed areas. However, the erosion is in an advanced state before detection occurs.

The area from Harrison Road east contains an abundance of natural vegetation with a large diversity occurring throughout this area. There are small areas containing Saguaro forest, while others have an abundance of mesquite and Palo Verde trees. Cholla cactus becomes important on the hillsides and hilltops, along with creosote bush and many other species.

Although not discernable from high altitude photographs, the wildlife that currently inhabits the buffer zone should be considered. That is, if development is allowed which would eliminate the vegetation. The wildlife must seek refuge in either Saguaro National Monument or in the Colorado National Forest. This would in turn place much more demand on the environment and the management in these two areas. However, open areas that are left untouched by housing development projects would protect the wildlife. Furthermore, it would appear that developers and citizens at large should share the responsibility of maintaining the natural vegetation environment.

An intensive ecological inventory needs to be conducted on this area to determine the exact environmental impact that extensive development would have on the vegetation of Saguaro National Monument and the Coronado National Forest. That is, if the inventory revealed that the wildlife populations were rather sparse, then there may be little or no impact on the vegetation resources of Saguaro National Monument. However if the wildlife populations are of significant magnitude to affect the Monument or the Forest, then careful consideration should be given to the habitat requirements for wildlife currently found along the urban boundaries.

There is an abundance of vegetation found in a large portion of this area, therefore, development which would interfere with vegetative cover would also contribute to increased erosion hazards and decreased water infiltration into the soil. There is an abundance of trees found in this area, and denuding of the area or removal of these trees on a large scale will introduce environmental complications.

Acknowledgements

The authors would like to express their appreciation to Dr. Charles D. Bonham, Associate Professor of Range Management, Colorado State University for his evaluation of the photography in this preparation of the vegetation map and related vegetation analysis.

APPENDIX

APPENDIX

EXPLANATION OF ENGINEERING INTERPRETATION TABLE HEADINGS

The first column of tables A and B lists the map symbol that appears on the General Soil Map and the major components of each mapping unit that is described in the text. The approximate proportion is also given. Definitions of the following headings in Table A are given in the glossary and will not be repeated here: Permeability, available water-holding capacity shrink-swell (potential), alkalinity (reaction) and salinity and hydrologic soil group. Explanations of the remaining headings for Table A are discussed below followed by those in Table B:

Corrosivity--On-the-surface structural materials, such as steel and concrete corrode when buried in or placed on soils. A given material will corrode in some soils more rapidly than in others. Corrosivity ratings are given on two different structural materials as follows:

- (a) Uncoated Steel Pipe--Steel will corrode in some soils more rapidly than in others. Soil corrosivity differs with the characteristics of the soil. Corrosion of uncoated steel pipe is a physical-biochemical process converting iron into its ions. Soil moisture is needed to form solutions with soluble salts before the process can operate. This constitutes a corrosion cell. Any factors influencing the soil solution or oxidation-reduction reactions taking place in the soil will influence the operation of the corrosion cell. Soil properties such as total acidity, electrical resistivity, or resistance to flow of current, soil drainage, and soil texture are considered. The metal pipe is usually located in the subsoil or substratum of the soil.
- (b) Concrete materials placed in some soils deteriorate to varying degrees. In this area only soils with high amounts of sulfates present in the soil appear to cause deterioration and only the soils having this characteristic are noted in the table.

Soil Suitability as a Source of Roadfill--The purpose of this interpretation is to provide ratings of soils as sources of road fill. This purpose requires predictions of how well the soil will perform after it has been moved from its original location and placed in a road embankment; and, it also requires evaluation of soil characteristics, such as slope, that affect the ease or difficulty of getting the soil out.

Roadfill is soil material used for making embankments for roads. As low embankments, or the upper part of high embankments, serve as the subgrade (foundation) for the road, The material good for road fill also needs to be good for subgrade.

If the thickness of suitable material is less than about three feet, due to shallow depth of bedrock or to other unsuited or poorly suited material, the entire soil is rated poor regardless of the quality of the material less than three feet thick.

Soil Suitability as a Source of Sand and Gravel--The principal purpose of this interpretation is to provide guidance about where to look for sand and gravel. Ratings are based on the probability that soils contain sizable quantities of sand or gravel, excluding soft materials such as shale or siltstone. To qualify as either a good or fair probable source, the layer should be at least about three feet thick. All of this, however, need not be in the top five or six feet--the soil that we classify and map.

Soil Suitability as a Source of Topsoil--The purpose of this interpretation is to provide information for use by engineers, landscapers, nurserymen, planners, and others who make decisions about selection, stockpiling and use of topsoil. Whether to save and stockpile surface soil at a construction site, for example, ought to depend on how good it is for topsoil and the relative availability of other topsoil in the immediate vicinity.

Good topsoil has physical, chemical, and biological characteristics favorable for the establishment and growth of adapted plants. It is friable and easy to handle and spread. While a high content of plant nutrients in good balance is desirable, it is less important than responsiveness to fertilization, or to soil amendments, if pH adjustments are necessary.

A soil that qualifies as a good source not only has material with these favorable characteristics, but also has characteristics such that, with material stripped off for topsoil, the remaining soil is reclaimable. Some damage to a borrow area is to be expected, but if the damage is great enough so that revegetation and erosion control become major problems, the soil should be rated as a poor source of topsoil regardless of the quality of the surface materials.

Flooding Hazard--Flooding hazard is defined in the glossary. Frequency and duration are noted in the tables.

Erosion Hazard--As defined in the glossary. Soil properties that influence water erosion are: (1) Those that affect infiltration rate, movement of water through the soil, and water storage capacity; (2) those that affect dispersion, detachability, abrasion, and mobility of soil particles by rainfall and runoff. Some of the most important properties are soil texture and organic matter content of the exposed layer, size and stability of structural aggregates, permeability of the subsoil, depth to impermeable layers, amount of rock fragments, and slope. Ratings are slight, moderate, and severe.

Wind erosion is not a major problem in most parts of Arizona except in a few areas of bare cultivated or denuded rangeland. It is mentioned only in soil associations where it might occur if unsheltered smooth, barren areas are likely to occur.

Suitability as a Habitat for Wildlife--There are few direct relationships between the kinds of soil and wildlife species. Habitat Suitability ratings deal with relationships, kinds of soils and kinds of plants and water developments that make up wildlife habitat. Each soil is rated for its suitability for the improvement, maintenance or creation of specific wildlife elements. The 8 elements considered are: (1)-grain and seed crops; (2)-domestic grasses and legumes; (3)-wild herbaceous plants; (4)-hardwood trees; (5)-coniferous plants; (6)-shrubs; (7)-wetland plants; and (8)-shallow water areas.

Four kinds of wildlife habitat types are rated. These are: 1 -Openland (irrigated and dryland); 2 -Woodland; 3 -Wetland; and, 4 -Rangeland. Only the principal kind or kinds of habitat type occurring in a soil association are listed.

1. - Openland wildlife consists of birds and mammals common to irrigated cropland, pastures, lawns and the immediate surrounding area extending from a few hundred feet to several miles. Principal wildlife species are white-winged and mourning dove, Gambel's quail, non-game birds and cottontails. Javelina and mule deer also may water and feed on the outer fringes of irrigated areas. Exotic species, such as white-winged pheasant and chukar have been introduced in some areas.

2. - Woodland wildlife--birds and mammals of wooded areas containing either hardwood or coniferous trees and shrubs, or a mixture of both. In Arizona these are the oak-juniper-pinyon pine woodlands and chaparral types usually at about 4000 to 6500 feet elevation and 16 to 25 inch rainfall; and, pine-fir-spruce woodland above about 6500 feet and more than 20 inch rainfall. Woodland composition varies considerably from the northern to southern part of the state. Only very small amounts of woodland and chaparral occur in the southwestern part of Arizona and only where elevations exceed about 4000 feet. Wildlife species in the oak-juniper woodland are desert mule deer and white-tailed deer, javelina, black bear, turkey, band-tailed pigeon, Gambel's and Mearns's quail, and doves. Big horn sheep inhabit some areas of the arid, sparsely wooded southwestern mountains. In the high forested areas of the state, such as the White Mountains, game species are elk, white-tailed deer, turkey, blue grouse, Abert squirrel, black bear, and mountain lion.

3. - Wetland wildlife--birds and mammals of swampy, marshy, or open water areas. Species include ducks, geese, non-game water birds, muskrat and beaver. The principal water areas in Arizona are the Central Arizona irrigation reservoirs, the Colorado River lakes, the Colorado River itself and marshy areas along it, and irrigation canals and a few farm ponds. These areas occupy only a small part of the state and are not rated in some of the general soil map reports.

4. - Rangeland wildlife--birds and mammals of natural rangelands. The Rangeland habitat covers a large part of Arizona. It includes the sparse desert shrub rangeland of the Southwestern desert basins and non-wooded mountains, and also the semi-desert rolling grasslands of both Southern and Northern Arizona. Rainfall in the desert areas ranges from about 4 to 10 inches and the semi-desert from about 10 to 18 inches. Precipitation patterns are quite different in Northern and Southern Arizona. Elevations range from about 200 up to 6000 feet. The principal Rangeland wildlife game species in Southern Arizona are desert mule deer, javelina, Gambel's and scaled quail, white-winged and mourning dove and cottontail. Antelope are found in the open grasslands and a few bighorn sheep inhabit desert mountains. In the Northern Arizona rangelands, antelope, deer, cottontail, and dove are the main species.

Wildlife suitability ratings are: Good, fair, poor, and very poor.

Good - Habitats are easily improved, maintained or created with few or no soil limitations in habitat management.

Fair - Habitats can be improved, maintained, or created but moderate soil limitations require a moderate intensity of habitat management for satisfactory results.

Poor - Habitats can be improved, maintained, or created on these soils, but the soil limitations are severe. Habitat management may require difficult, expensive, and intensive effort. Results are marginal.

Very poor - Under prevailing soil conditions, it is impractical to attempt to improve, maintain, or create habitats. Unsatisfactory results are probable.

TABLE B -- SOIL LIMITATION CLASSES AND SOIL FEATURES AFFECTING:

Septic Tank Absorption Fields--The septic tank filter field is a part of the septic tank absorption system for on-site sewage disposal. It is a subsurface tile system laid in such a way that effluent from the septic tank is distributed with reasonable uniformity into the natural soil. Criteria and standards used for rating soils are made on the basis of limitations of the soils to absorb effluent.

Three degrees of limitations are used: slight, moderate, and severe. These are based on factors such as soil depth, slope, permeability, percolation rate, water table, and overflow or flooding hazards. Within the soil profile, that portion below depths of 30 inches is most critical. State law requires on-site percolation tests meeting certain criteria before approval to construct is given. Percolation rate below 30 inches is highly variable and is not given in these tables.

Assumptions

Minimum depth earth cover over lines - 12 inches
Minimum diameter of lines - 4 inches
Minimum filter material over lines - 2 inches
Minimum filter material under lines - 12 inches

Limitations for sewage lagoons are given under the heading of water areas.

Shallow Excavations--Shallow excavations are those that require excavating or trenching to a depth of five or six feet or less. Such uses include underground utility lines (pipelines, sewers, cables), cemeteries, sanitary landfills, basements, and open ditches, although some supplemental criteria are needed to establish limitation ratings for pipelines and cemeteries and other uses. Most of the anticipated uses involve backfilling, but some, such as basements and open ditches, do not. Desirable soil qualities and characteristics are good workability, moderate resistance to slumping, gentle slopes, absence of rock outcrops and big stones, and flooding.

Dwellings Without Basements--Ratings are for undisturbed soils that are evaluated for single-family dwellings and other structures with similar foundation requirements. Excluded are buildings of more than three stories and other buildings with foundation loads in excess of those equal to three-story dwellings. The emphasis for rating soils for dwellings is on foundations; but soil slope, and susceptibility to flooding and other hydrologic conditions, such as seasonal wetness, that have effects beyond those related exclusively to foundations, are considered too. The properties affecting the foundation support are those that affect bearing capacity and settlement under load and those that affect excavation and construction cost. The properties affecting bearing strength and settlement of the natural soil are density, wetness, flooding, plasticity, texture, and shrink-swell behavior. Texture and plasticity (Atterberg limits) are inferred from the Unified soil group. Properties influencing the ease and amount of excavation are wetness, slope, depth to bedrock, stoniness, and rockiness. Also considered are soil properties, particularly depth to bedrock, that influence installation of utility lines, such as those between the dwellings and the trunk lines.

Sanitary Landfill--Soil limitations for sanitary landfills consider the trench type, area type, and cover material.

- (a) Trench Type Landfill--The trench type sanitary landfill is a dug trench in which refuse is buried. The refuse is covered with at least a six-inch layer of compacted soil material daily, or more frequently if necessary. Soil material excavated in digging the trench is used for this purpose. A final cover of soil material at least two feet thick is placed on the landfill when the trench is full.

Because routine soil investigations are normally confined to depths of about five or six feet and many landfill operations use trenches as deep as 15 or more feet, there is need for a geological investigation of the area to determine the potential for pollution of ground water as well as to obtain the design of the sanitary landfill. Such investigations include the kind of stratification, rock formations, and the like that can conduct leachate to water sources such as aquifers, wells, and water courses. The presence of hard, nonrippable bedrock, creviced bedrock, sandy or gravelly strata within or immediately underlying the proposed trench bottom is undesirable from the standpoint of excavation and from the standpoint of the potential for pollution of underground water.

The size and character of landfills are such that it would not be practical to remove the refuse if a pollution problem should develop. Consequently, a thorough evaluation of site hydrology is essential to landfill design.

- (b) Area Type Landfill--In the area method of landfill operations, refuse is placed in successive layers on the surface of the soil. Daily and final cover material must be imported because no trenches are dug unless it is for the purpose of obtaining cover material. A final cover of soil material at least two feet thick is placed over the fill when it is completed.

The soil under the proposed site for an area landfill should be investigated to determine the potential for leachates produced by percolating water from the landfill to penetrate and pollute ground water supplies. The size and character of landfills are such that it would not be practical to remove the refuse if a pollution problem should develop. Consequently, a thorough evaluation of site hydrology is essential to landfill design.

- (c) Cover Material for Area-Type Landfill--As cover material for area-type landfills must be obtained from sources away from the landfill sites themselves, the soils in an area may need to be rated for suitability for cover. Soil characteristics relevant to both daily and final cover materials are nearly enough alike for one rating to suffice for both uses.

In the trench type landfill it is assumed that the material excavated can be used for cover material.

Suitability for cover is based on soil properties which reflect workability; the ease of digging, moving, and spreading the soil material over the refuse daily during both wet and dry periods; soil slope, wetness and thickness of material.

A soil rated as a good source not only has favorable properties but the remaining material or borrow area must be reclaimable. Some damage to the borrow area is to be expected, but if revegetation and erosion control are major problems, the soil should be rated as a poor source of daily cover.

Local Roads and Streets--The following factors are considered in evaluating soils for the construction and maintenance of local roads and streets. These are improved roads and streets having some kind of all-weather surfacing, commonly asphalt or concrete, and are expected to carry automobile traffic all year. They consist of: (1) underlying local soil material (either cut or fill) called the subgrade; (2) the base material of gravel, crushed rock, or lime--or soil cement--stabilized soil called the subbase; and (3) the actual road surface or pavement, either flexible or rigid. They also are graded to shed water and have ordinary provisions for drainage. With the probable exception of the hardened surface layer, the roads and streets are built mainly from the soil at hand, and cuts and fills are limited, usually less than six feet. Excluded from consideration in this guide are highways designed for fast-moving heavy trucks.

Properties that affect design and construction of roads and streets are: (1) those that affect the load supporting capacity and stability of the subgrade, and (2) those that affect the workability and amount of cut and fill. The AASHO and Unified Classification, and the shrink-swell potential give an indication of the traffic supporting capacity. Wetness and flooding affect stability. Slope, depth of hardrock, stoniness, rockiness, and wetness affect the ease of excavation and the amount of cut and fill to reach an even grade.

GLOSSARY

Water Areas, (including sewage lagoons, ponds, and other small water impoundment areas)-- A sewage lagoon is a shallow lake used to hold sewage for the time required for bacterial decomposition. Soil requirements for basin floors of lagoons are: (1) slow rate of seepage, (2) even surface of low gradient and low relief, and (3) little or no organic matter. Slope and relief must be low enough so that smoothing required to obtain the specified uniformity in depths of the liquid body is practical. Surface runoff and floodwater must be kept from entering the lagoon. Soils that flood have severe limitations as sites for lagoons. Soil limitations for other water impoundments are similar, except that shape and depth of the floor of the impounded area is not a requirement.

Embankments, Dikes and Levees--The factors considered for embankments are those features and qualities of disturbed soils that affect their suitability for constructing earth fills. Both the subsoil and substratum are evaluated where they have significant thickness for use as borrow.

These ratings apply to low height structures designed to impound or divert water. Factors to be considered are stability after compaction, compaction characteristics, compressibility, permeability when compacted and resistance to piping.

Irrigation--Cropland, Golf Fairways, Lawns and Similar Uses--The soil is classified in relation to the qualities and factors affecting suitability for irrigation. Factors are water-holding capacity, depth of root zone, permeability, salt and alkali, presence of gravel and cobble, and slope. Most of these same factors also affect watering of golf fairways, lawns, and other landscaping uses in residential areas and are so listed in the column heading.

TABLE C - SOIL LIMITATION CLASSES AFFECTING RECREATIONAL USES:

Camp Areas--Primarily those used intensively for tents and small camp trailers and the accompanying activities of outdoor living. It is assumed that little site preparation will be done other than shaping and leveling for tent and parking areas. Suitability for growing and maintaining vegetation is not considered here but it is an item to consider in the final evaluation of a site. The major soil characteristics to consider are drainage, flooding, slope, percent of surface covered by rock fragments and surface texture.

Playgrounds--Areas used intensively for playgrounds for baseball, football, badminton, and other similar organized games. The most desirable soils have nearly level surfaces, good drainage, and are free of rock outcrops and fragments. Suitability for growing and maintaining vegetation is not considered here but should be considered in the final evaluation of a site.

Paths and Trails--Are areas used for local and cross-country footpaths and trails and for bridle paths. It is assumed that these areas will be used as they occur in nature and that little or no soil will be moved. The features that affect trafficability, dust, design and maintenance of trafficways are given special emphasis.

Picnic Areas--Are areas for intensive use as park-type picknicking. It is assumed that most vehicular traffic will be confined to access roads. The most desirable soils are free from flooding, well drained, nearly level and free of rock fragments.

GLOSSARY

- A horizon**--A mineral soil horizon at or near the surface, usually containing an accumulation of organic matter and which may have lost clay, iron, or aluminum by eluviation (leaching).
- Alkali soil**--1. A soil with a high degree of alkalinity (pH of 8.5 or higher) or with a high exchangeable sodium content (15 percent or more of the exchange capacity) or both.
2. A soil that contains sufficient alkali (sodium) to interfere with the growth of most crop plants.
- Alluvial fan**--A sloping, fan-shaped mass of sediment deposited by a stream where it emerges from an upland onto a plain.
- Alluvial soils**--Soils formed in recently deposited alluvium and exhibiting essentially no horizon development or modification from the parent alluvium.
- Arid**--Lacking sufficient precipitation for crop production without irrigation and generally supporting only sparse stands of desert-type shrubs and few perennial grasses. The upper limit is about 10 inches as used in this report. (Contrast with semi-arid)
- Association**--See Soil associations.
- Available water-holding capacity**--The capacity to store water available for use by plants, usually expressed in linear depths of water per unit depth of soil. In this survey four classes are used, and are defined as follows:

	Inches per Inch	Inches per foot
High - - - - -	More than .13	>1.5
Moderate- - - - -	.09-.13	1.0-1.5
Low - - - - -	.04-.09	.5-.10
Very low- - - - -	Less than .04	< .5

- B horizon**--A subsurface horizon, often used, synonymously with subsoil, that has accumulated clay, iron, aluminum by leaching from overlying horizons.
- Calcareous soil**--Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold, dilute hydrochloric acid.
- Caliche**--A layer, usually parallel to the surface, more or less cemented by secondary carbonates of calcium or magnesium precipitated from the soil solution. It may occur as thin accumulations of soft to hard nodular material, or as thick beds at shallow depths of strongly cemented gravels with an indurated, nearly continuous, laminar capping. This layer is sometimes exposed at the surface by erosion.
- Clay**--A mineral soil separate consisting of particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt. Clayey--having properties similar to those of clay.
- Cobble**--Rock fragments, generally rounded, between 3 and 10 inches in diameter.
- Depth, effective soil**--The depth of soil material that plant roots can penetrate readily to obtain water and plant nutrients. Limiting layers may consist of bedrock, silica and/or calcium cemented hardpans or dense clay pans. Under natural conditions the effective rooting depth is determined by the depth of moisture penetration. Four depth classes were used in this survey as follows:
Deep--More than 40 inches deep.
Moderately deep--20 to 40 inches.
Shallow--10 to 20 inches.
Very shallow--Less than 10 inches deep.
- Drainage, natural**--As a condition of the soil, refers to the frequency and duration of periods when the soil is free of saturation or partial saturation. Drainage may be altered either naturally by channel deepening or blocking, or artificially by the application of irrigation water or the construction of artificial drains. Three drainage classes are recognized in this survey as follows:
Well drained--Water is removed from the soil readily but not rapidly. Normally these are medium textured soils but finer or coarser textured soils may fall in this class.
Moderately well drained--Water is removed from the soil slowly, so that the profile is wet for a small but significant part of the time. These soils commonly have a slowly permeable layer within or immediately underneath the solum.
Somewhat poorly drained--Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time.
- Erosion**--The wearing away of the land surface by wind, running water, and other geological agents.
- Erosion hazard**--The susceptibility of a soil to accelerated erosion resulting from disturbance or destruction of the vegetation. Causes may be mechanical such as construction sites, overgrazing or other misuse, or fire.
- Flooding hazard**--The susceptibility of a soil, generally due to its position of occurrence, to overflow or inundation, usually damaging, from streams or other flood channels.

Floodplain--Nearly level land situated on either side of a channel which is subject to overflow flooding.

Gravelly--Containing significant amounts of gravel. Rock fragments, generally rounded or sub-rounded, 2mm to 3 inches in diameter. In amounts, gravelly infers about 20 to 50 percent by volume of the soil mass. Very gravelly infers 50 to 90 percent by volume of the soil mass.

Hardpan--A hardened or cemented soil layer. The soil material may be sandy or clayey, and it may be cemented by silica or calcium carbonate. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not slake in water.

Hydrologic group--A grouping of soils for estimating the runoff potential on watersheds. The classification indicates the minimum rate of infiltration obtained from a bare soil at the end of individual storms occurring after the soil has had prolonged wetting and opportunity for swelling. Four groups are used:

Group A--Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of deep, well to excessively drained sands and/or gravel. These soils have a high rate of water transmission and have a low runoff potential.

Group B--Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of transmission.

Group C--Soils having slow infiltration rates when thoroughly wetted, consisting chiefly of (1) soils with a layer that impedes the downward movement of water, or (2) soils with moderately fine to fine texture and a slow infiltration rate. These soils have a slow rate of water transmission.

Group D--Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clay soils with a high swelling potential, (2) soils with a high permanent water table, (3) soils with a claypan or clay layer at or near the surface, and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

Indurated--A condition that exists in material that has become hardened by heat, pressure, and/or cementation. The indurated material cannot be softened by prolonged soaking in water.

Intake rate--The rate, usually expressed in inches per hour, at which rain or irrigation water enters the soil.

Lime (limy)--Chemically, lime is calcium oxide, but as the term is commonly used, it is also calcium carbonate and calcium hydroxide. When present in visible amounts it is also sometimes called "caliche" locally.

Mapping unit (unit, soil unit)--A kind of soil, a combination of kinds of soil, or land types, that can be shown at the scale of mapping for the defined purposes and objectives of the survey. Mapping units are generally designed to reflect significant differences in use and management.

Percent slope--The gradient of any particular slope expressed as the difference in elevation in feet between two points 100 feet apart horizontally. See slope classes.

Permeability, soil--The quality of a soil layer that enables water or air to move through it. The permeability of a soil may be limited by the presence of one nearly impermeable layer even though the others are permeable. Terms used to describe permeability are:

	<u>Inches per hour</u>
Very slow - - - - -	< 0.06
Slow - - - - -	0.06-0.20
Moderately slow - - - - -	0.20-0.6
Moderate - - - - -	0.6 -2.00
Moderately rapid- - - - -	2.00-6.0
Rapid - - - - -	6.0 -20.0
Very rapid- - - - -	> 20.0

Piping--Removal of soil material through subsurface flow channels or "pipes" developed by seepage of water.

Profile, soil--A vertical section of the soil from the surface through all its layers, including C horizons. Unless otherwise stated in this report it is the section from the surface to 60 inches or to bedrock.

Reaction, soil--The degree of acidity or alkalinity of a soil, expressed in pH values. A soil that has a pH of 7.0 is neutral in reaction because it is neither acid nor alkaline. In words, the degrees of acidity or alkalinity are expressed thusly:

	pH
Extremely acid - - - - -	Below 4.5
Very strongly acid - - - - -	4.5 to 5.0
Strongly acid- - - - -	5.1 to 5.5
Medium acid - - - - -	5.6 to 6.0
Slightly acid- - - - -	6.1 to 6.5
Neutral- - - - -	6.6 to 7.3
Mildly alkaline- - - - -	7.4 to 7.8
Moderately alkaline- - - - -	7.9 to 8.4
Strongly alkaline- - - - -	8.5 to 9.0
Very strongly alkaline - - - - -	9.1 and higher

Rough broken land--Land with very steep topography and numerous intermittent drainage channels, usually covered with vegetation.

Runoff, surface--Refers to the relative rate water is removed by flow over the surface of the soil. Rates are referred to as slow, medium and rapid.

Saline soil--A nonalkali soil that contains sufficient soluble salts to impair the growth of plants but that does not contain excess exchangeable sodium.

Saline-alkali soil--A soil having a combination of harmful quantities of salts and either a high alkalinity or high content of exchangeable sodium, or both, so distributed in the profile that the growth of most crop plants is reduced.

Sand--Individual rock or mineral fragments in soils having diameters ranging from 0.05 to 2.0 millimeters. Most sand grains consist of quartz, but they may be mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

Sediment yield--The quantity of solid materials, both mineral and organic, removed from its original site and transported, usually by water, but also by wind, ice, or gravity and deposited in another location.

Semiarid--A term applied to regions or climates where moisture is normally greater than under arid conditions but still limits the growth of most plants. Irrigation is usually required for crop production. The average annual precipitation in the area of this survey is from about 10 to 16 inches. (Contrast with subhumid and arid)

Shear strength--The internal resistance offered to shearing stresses. It is measured by the maximum shear stress, based on original area of cross section, that can be sustained without failure.

Shrink-swell (potential)--Susceptibility to volume change due to loss or gain in moisture content.

Silica--A constituent composed of silicon and oxygen. The essential material of the mineral quartz.

Silt--Individual mineral particles in a soil that ranges in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). Soil of the silt textural class is 80 percent or more silt and has less than 12 percent clay.

Slope classes--Groupings of slope gradients into named classes as follows:

Nearly level-0 to 2 percent; gently sloping-2 to 5 percent; moderately sloping-5 to 8 percent; strongly sloping-8 to 15 percent; moderately steep-15 to 30 percent; steep-30 to 60 percent; very steep-more than 60 percent.

Soil--The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Soil profile--A vertical section of the soil from the surface through all its horizons (layers). Thickness as usually mapped in the soil survey is to 60 inches or to bedrock.

Soil series--A subdivision of soils within a soil family having horizons similar in differentiating characteristics and arrangement in the soil profile except for texture of the surface horizon.

Soil associations--A group of defined and named soil units occurring together in a characteristic pattern over a geographic region.

Stones--Rock fragments larger than 10 inches in diameter.

Subhumid--A term used in this survey where moisture is more than under semiarid conditions and sufficient for good range herbage production. Natural vegetation is mostly mid and tall grasses and trees. Average annual rainfall ranges from about 16 to 30 inches. Contrast with semi-arid.

Subsoil--The B horizon of soils with distinct profiles. In soils with weak profile development the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow.

Substratum--Technically, the part of the soil below where the processes of soil formation are active; the parent materials. Generally, the characteristics of the material in this part of the profile are unlike those of the overlying material.

Surface soil or layer--The uppermost part of the soil ordinarily moved in tillage or its equivalent in uncultivated soil, about 3 to 8 inches in thickness. The plowed layer. The A horizon(s).

Swale--A slight depression in an area generally nearly level. These depressions are usually slightly more moist than the adjacent higher land and often have ranker vegetation due to additional water and the enrichment resulting from the washing down of the finer and richer part of the soil of the higher land about them.

Terrace (geological)--A nearly level or undulating plain, commonly rather narrow and usually with a steep front, bordering a river or lake.

Texture, soil--The relative proportions of sand, silt, and clay particles in a mass of soil. The different texture classes are commonly referred to in general terms as listed below:

Texture

Sands	)	coarse textured soils)
Loamy sands))
Sandy loam	)	moderately-coarse textured soils)	sandy
Fine sandy loam	)		soils
))
Very fine sandy loam))
Loam	)		loamy
Silt loam	)	medium textured soils	soils
Silt))
))
Clay loam))
Sandy clay loam	)	moderately-fine textured soils	loamy
Silty clay loam	)		soils
))
Sandy clay))
Silty clay	)	fine textured soils	clayey
Clay	)		soils

Underlying material--The soil layer(s) below the surface layer. Normally this would be the layers below about 6 to 10 inches in soils that do not have layers of clay accumulation.

Water table--The upper surface of groundwater or that level below which the soil is saturated with water.