APPLICATION OF AIR PHOTO INTERPRETATION TECHNIQUES TO PROBLEMS IN URBAN AND REGIONAL PLANNING

By

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PREFACE

This thesis is concerned with the application of air photo interpretation techniques to problems in urban and regional planning. An interpretation procedure is developed and demonstrated for the purpose of accomplishing responsive, comprehensive resource survey and management analysis in support of planning objectives.

I would like to take this opportunity to express my sincerest appreciation and gratitude for the assistance and guidance given me by the following persons:

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CHAPTER I

INTRODUCTION TO THE PLANNING PROBLEM

The United States is experiencing metropolitan expansion unparalleled in its history. This expansion results from: (1) a population explosion which is conservatively estimated to rise from a current level of 200 million to over 300 million by the year 2000; (2) a dynamic economy which is responsive to radical advances in all fields of technology; and (3) rapidly changing social attitudes and living-working habits on the part of a society which has more money, mobility, free time and education than at any time in history. To satisfy the physical requirements of this population explosion, rural land is being converted to urban use at a rate of more than 3,000 acres a day. The impact of this development, which is shaping the American landscape for years to come, is being felt today throughout metropolitan areas in terms of virtually every form of environmental pollution. Even if fully effective programs were to start immediately, which they will not, these problems would get much worse before they could be retarded and reduced. Of equal importance, and very much related to the problems of urban sprawl, are the literally explosive problems found in the urban core of the nation's metropolitan areas. Taken in total, the problems of the metropolitan region raise serious doubts as to society's ability to produce a viable living environment.

The challenge to planning, whether at the urban or regional level, is, therefore, to provide a physical and administrative framework which will provide for the most expeditious elimination of all forms of social-economic strain caused by pollution of the physical environment, and to provide for orderly, compatible growth and change throughout the metropolitan complex. It must be emphasized that the challenge to planning is not to promote a particular form of urban environment, but rather to create a sound, yet flexible, framework which allows a broad range of choice for every individual in the metropolitan society.

Potential Value of Air Photo Interpretation

It should be readily apparent that the problems of urban and regional planning are among the most complex faced by society. The complexity of planning problems infers the need for a method of investigation that will be fully comprehensive rather than merely a means of compiling masses of information from uncorrelated, isolated studies, each based on different sets of conditions, or even on different premises. It is essential that a planner be able to view the many facets of a planning problem at one time, to assess not only their individual characteristics and effects, but also their characteristics and effects as parts of a total system. This requirement implies a comprehensive information system capable of collecting, storing, retrieving, analyzing and disseminating information concerning every element of the system as well as the system as a whole. Following the assumptions that all physical planning problems are, or soon become, problems of engineering; and that all engineering problems are directly related to the physical environment in which they exist; and that all aspects of the physical environment can be displayed to some significant degree in a visual manner; then, dependent on the exposure of land form, the quality of photo coverage, and the experience and competence of the interpreter, an unlimited amount of significant information concerning the physical environment can be derived from air photos. Of particular significance are the following characteristics of air photo interpretation:

1. Information can be collected easily, quickly, reliably, and economically via air photos.
2. Information can be stored easily and permanently in air photos.
3. Information can be retrieved from air photos quickly, at any time, and by any number of interpreters.
4. Information can be analyzed at the convenience of the interpreter and to any degree of detail he desires. Information on an air photo is easily compared with information on other photos or with the actual area photographed.
5. Unlimited amount of information can be disseminated via an air photo. In this dissemination, information is presented in terms of the total diversity of its inter-relationships rather than as some statistical average.
6. Air photos allow unlimited perspectives of the physical environment.
7. Due to its permanence, information in an air photo is not lost by an interpretation failure, but remains available for unlimited re-interpretation.

8. Virtually any planner, provided he is competent in his field, can interpret and analyze air photos easily and effectively with only a very minimum amount of training.
9. Air photos are perhaps the most extensive, most responsive, most reliable, most economical, and most convenient resource survey and analysis tool available to a planner.

Previous Research and Development

The value of air photo interpretation has long been established in most of the fields of physical science. Virtually all geologists, soil scientists, foresters and agronomists appreciate the capabilities of air photo interpretation as applied to their fields; however, development of a similar appreciation by planners has been generally lacking, possibly due to the apparent lack of an appreciation for physical science that is evident in much metropolitan planning.

Early work of particular importance is that of Witenstein (1954-56) who used air photo interpretation to analyze physical structure (land-use/building-type/accommodation density) as a measure of social and economic factors in urban living. Green and Monier (1957-59) demonstrated the capability of air photo interpretation in evaluating the socio-economic status of urban residential areas. Wagner (1963) demonstrated via interpretation of sequence aerial photography the ability to accurately and economically evaluate land-use change in developing areas. Very recently NASA and the U. S. Geological Survey have jointly sponsored an extensive research program involving the use of remote sensing devices for interpretation purposes.

The objective of this thesis has been to develop a program for comprehensive resource survey and management analysis using air photo interpretation techniques and to demonstrate the application of those techniques to a wide range of urban and regional planning problems in the Sherman, Texas, metropolitan area.

Chapter II discusses a general program for a responsive, comprehensive urban and regional resource planning capability and presents an extensive interpretation outline supporting such a program. Chapter III presents representative applications of the air photo interpretation technique to urban and regional problems in the Sherman, Texas, metropolitan area. Chapter IV briefly summarizes the main text and offers proposals for continued research and development. Appendix A provides a more thorough discussion of fundamental air photo interpretation techniques. Appendices B through D provide background information concerning the geology, soils and hydrology of the Sherman, Texas, metropolitan area and represent the extent of information concerning these fundamental elements in the physical planning process that a planner _must_ understand, appreciate and account for at every stage in his work. Virtually all efforts of man are of secondary impact when compared to the regional impact of these basic elements of our physical environment; thus, whenever possible, planning should attempt to work _with_ these elements rather than _against_ them.

The main text has been advanced on the assumption that the reader, in addition to a full understanding of the various criteria required in urban planning, has a basic understanding of the material referenced in the appendices. If, however, this is not the case, it is recommended that the reader refer to the applicable appendices before continuing further in the main text.

CHAPTER II

AIR PHOTO INTERPRETATION AS A BASIS FOR COMPREHENSIVE RESOURCE SURVEY AND MANAGEMENT ANALYSIS

An understanding of the physical environment is essential in providing a framework for responsive, comprehensive urban and regional planning. In order to make decisions concerning the proper use of physical resources, planning objectives must be formed. These objectives should then be tested against:

1. Applicable social, economic, and physical environmental needs of the entire region. These needs should include those of plant and animal development as well as those of human development.
2. The characteristics of available physical resources. This evaluation should consider all resources, both developed and undeveloped, with respect to a hierarchy of needs ranging from local to regional.

These requirements suggest a need for a responsive, comprehensive capability for resource survey and management analyses. The survey must identify:

1. Relevant physiographic factors in the planning area.
2. Current use of resources.
3. Physical factors which significantly limit planning options.

The relationships observed between needs, resources and specific site conditions will reveal:

1. Where restraints exist for particular types of land use.
2. Where existing conditions create opportunities for particular types of land use development.
3. Where existing land use should be conserved because change would diminish the quality and extent of the asset it represents.
4. Where existing land use should be rehabilitated because the quality and extent of the asset it represents have been allowed to deteriorate to a point where it is potentially detrimental to the overall environment.
5. Where existing land use should be redeveloped because the quality and extent of the asset it once represented have been allowed to deteriorate to a point where it is detrimental to the overall environment.

Based on the results of such a survey, a hierarchy of land use priorities can be established to aid in the development of management policy for the allocation of land use needs among available resources. Such policy should thus ensure that both valuable and marginal physical resources are used in the most appropriate manner; that their assets are conserved where they have unique value; and that deficiencies are corrected where necessary. This policy must be based on the concept of introducing change and development to deficient areas which might otherwise be denied the resources necessary to correct their deficiency. At the operational level, planning must not become merely a rigid mapping of land use proposals developed at a particular point in time under premises tied to conditions existing to a large degree only during that point in time. Rather, planning must be tied to a policy framework that accommodates and guides a process of change. This approach will provide a wider range of site and location choices to all land users, more realistic accommodation of a step-by-step development process for the planning area, and, provided that explicit site plan and performance standards are developed and enforced, more effective regulation of the quality of development.

On the following pages are: (1) an outline for conducting a comprehensive resource survey using air photo interpretation techniques, and (2) an outline of potential application of air photo interpretation techniques to the management analysis stage of urban and regional planning.

In closing this chapter it must be emphasized that the planning process, in addition to being comprehensive, must be continuous; especially at present, since change is taking place at a rate greater than our ability to recognize and adequately accommodate it. Thus, there is a vital need for planning tools and methods which allow for flexible response to ever changing and growing needs.

COMPREHENSIVE RESOURCE SURVEY FOR URBAN AND REGIONAL PLANNING USING AIR PHOTO INTERPRETATION TECHNIQUES

I. Introduction to Study Area. Research non-photo reference material for data concerning:

A. General location

B. Climate

C. History

D. Basic socio-economic character

II. Topographic Analysis

A. Locate general elevated areas; estimate height

B. Locate general depressed areas; estimate depth

C. Locate primary drainage areas

D. Locate drainage system divides

E. Classify slopes within drainage areas as:

1. Flat (0-3%)

2. Moderate (3-7%)

3. Steep (7+%)

III. Natural Vegetation Analysis

A. Locate areas supporting natural vegetation

B. Locate areas of natural vegetation apparently being used for domestic purposes

C. Locate areas of vegetation which apparently have been artificially derived for non-agricultural purposes (conservation)

D. For each of the above areas, locate subareas of:

1. Forest
2. Brush
3. Grass

E. For each forest subarea, locate subdivisions according to:

1. Primary patterns of stands
2. Estimated densities of stands
3. Estimated heights of stands
4. Character of undergrowth
5. Broadleaf or needle-leaf tree type
6. Recent clearance and selective cutting
7. Probable species

F. For each brush subarea, locate subdivisions according to:

1. Primary patterns of stands
2. Estimated densities of stands
3. Estimated heights of stands
4. Recent clearance and selective cutting
5. Probable species

G. For each grass subarea, locate subdivision according to:

1. Mixture of trees and/or brush
2. Primary patterns of stands
3. Estimated densities of stands
4. Estimated heights of stands
5. Recent clearance
6. Probable species

IV. Hydrologic Analysis

A. Coastal Hydrology

1. Locate coastlines of large water bodies

2. Identify general coastline characteristics with respect to:

(a) Shape

(b) Probable depth along shore

(c) Distribution of beaches

(d) Land form along shore which modify coastline

3. For offshore areas:

(a) Locate features, disturbances, and tonal patterns on and in the water

(b) Locate areas of abrupt change in depth; estimate depths

(c) Locate submerged features near water surface

(d) Locate land forms which are temporarily or permanently exposed

4. For foreshore and backshore areas:

(a) Locate basic land form features

(b) Locate beach areas

(c) Locate bedrock areas

(d) Locate areas of active and stationary sand dunes

(e) Locate inlet and other coastal drainage features

(f) Locate old shorelines

B. Mainland Hydrology

1. Locate areas of natural permanent and seasonal surface water storage

2. Locate areas of artificial permanent and seasonal surface water storage
3. Locate water sheds for surface water storage areas
4. Locate first-order streams:
    (a) Locate water sheds for each stream
    (b) Prepare representative profiles and cross sections for each stream valley
5. Locate second and third order streams; locate water sheds and prepare stream profiles and cross sections as required by study
6. Determine the general directions of flow; locate points of sharp change in direction of flow or vertical change in stream
7. Locate and identify artificial drainage features; identify area drained
8. Provisionally locate areas with apparent underground drainage or water storage
9. After correlation with subsequent geologic and soils analyses:
    (a) Locate areas of probable ground water storage
    (b) Locate areas of probable recharge
    (c) Locate areas of probable discharge
10. Locate flood plains
    (a) Identify extent of recent flooding
    (b) Identify extent of maximum flooding

V. Geologic Analysis

A. Locate areas and points of rock outcrop

B. Locate areas where surface configuration appears to be controlled by bedrock near surface; estimate depth to bedrock

C. For the above areas:

1. Locate sand and gravel pits, quarries, open-pit mines, and mine-head installations

2. Locate subareas of probable:

(a) Sedimentary rock

(b) Igneous rock

(c) Metamorphic rock

3. Locate and identify significant structural features such as faults and fractures

D. For areas of apparently thick unconsolidated materials:

1. Locate sand and gravel pits

2. Locate areas of probable:

(a) Fluvial land form

(b) Marine and lacustrine land forms

(c) Aeolian land form

(d) Glacial land form

3. For each of the above:

(a) Locate areas primarily resulting from deposition

(b) Locate areas primarily resulting from erosion

(c) Locate and identify significant features

VI. Soil Analysis

A. Evaluate each area of unconsolidated material according to:

1. Physiographic location

2. Associated land form

3. Topographic position
4. Boundary conditions
5. Surface tone characteristics
6. Surface texture characteristics
7. Drainage pattern
8. Erosion features
9. Vegetation characteristics
10. Land use

B. Correlate the above evaluations and provisionally identify soil areas according to probable soil series, type, and phase

C. Compare characteristics of interpreted soils with characteristics of known or suspected areas of similar soil series, type, and phase

D. Finalize soil interpretations; assign associated engineering characteristics

VII. Land Use

A. Locate areas in agricultural use:

1. Cultivated areas:

(a) Being prepared for planting

(b) Under cultivation; identify crop

(c) Harvested

(d) In extensive use

(e) In intensive use

(f) Abandoned or idle

(g) In probable commercial development

2. Range areas;

   (a) Active; identify using animals

   (b) Abandoned or idle

   (c) In probable commercial development

B. Locate farmsteads and other farm structures

C. Locate probable property boundaries

D. Locate <u>regional</u> non-agricultural uses:

1. Locate population centers; determine size

2. Locate areas containing major transportation elements; identify:

   (a) Major transportation corridors

   (b) Major transportation nodes

   (c) Transportation lines connecting the nodes, determine capacity

   (d) General transportation pattern for the region

   (e) Major transportation terminals:

      (1) Determine terminal access characteristics

      (2) Determine if transportation service changes modes of transportation at terminal

   (f) Other major transportation elements

3. Locate major transportation elements which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate elements

4. Locate areas containing major utility systems; identify utility corridors containing:

   (a) Water supply systems

   (b) Waste disposal systems

(c) Storm drainage and flood control systems

(d) Energy distribution systems

(e) Communications networks

5. Locate areas containing major concentrations of military personnel and material:

(a) Fixed installations

(b) Temporary or mobile installations

(c) Function:

(1) Supports ground operations

(2) Supports airborne operations

(3) Supports naval operations

(d) Distinguish between elements of an installation; determine use

(e) Locate access to installations

(f) Locate community/support areas

(g) Locate military facilities which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate facilities

6. Locate areas containing major industrial elements <u>not</u> associated with a population center:

(a) For each industrial area:

(1) Locate individual factories or integral units

(2) Distinguish between older and newer parts

(b) For each individual unit, locate:

(1) Transportation access

(2) Storage areas for raw materials

(3) Power and heating plants

(4) Storage areas for finished products

(5) General flow of material through the unit

(c) Identify each industrial unit according to extraction, processing, or fabrication functions; locate those which are exploitive

(d) Classify use as intensive, intermediate, or extensive

(e) Locate industrial units which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate facilities

7. Locate major institutional facilities <u>not</u> associated with population centers; identify functions as:

(a) Civic or governmental administration

(b) Educational

(c) Health and welfare

(d) Public safety

8. Locate commercial centers <u>not</u> located within a population center:

(a) Regional shopping centers

(b) Farm markets

(c) Isolated rural commercial facilities

9. Locate non-farm residences <u>not</u> located within a population center

10. Locate regional recreation activities; identify function as:

(a) High density area

(b) General outdoor area

(c) Natural environment area

(d) Unique natural feature area

(e) Primitive area

(f) Historical or cultural area

E. Locate urban uses:

1. Transportation

(a) Locate areas containing any type of transportation element

(b) Locate major transportation corridors; identify function:

(1) Road system

(2) Railroad system

(3) Waterway system

(4) Pipeline system

(c) Locate major transportation nodes; identify function:

(1) Interchange

(2) Intersection

(3) Grade separation

(4) Transfer facility

(d) Locate transportation lines connecting the major transportation nodes; determine capacity:

(1) Number of lanes

(2) Number of tracks

(3) Width of waterway

(4) Probable diameter of pipe line

(e) Determine general transportation system patterns

(f) Locate major transportation terminals; identify function:

(1) Bus or truck terminals

(2) Railroad stations and yards

(3) Airports:

(a) General aviation

(b) Commercial

(4) Ports

(5) Pumping and receiving stations

(g) Determine terminal access characteristics

(h) Determine if transportation service changes modes at the terminal

(i) Determine conditon of transportation facilities

(j) Locate and identify other major transportation elements such as bridges and canal locks

(k) Locate major transportation elements which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate elements

2. Utility

(a) Locate areas containing any type of utility element

(b) Locate major utility networks; identify function:

(1) Water supply

(2) Waste disposal

(3) Storm drainage control

(4) Energy distribution

(5) Communications

(c) Locate and identify major nodes and lines associated with:

(1) Water supply:

(a) Water supply reservoirs

(b) Water pumping facilities

(c) Water treatment plants

(d) Elevated storage

(e) Ground storage

(f) Water mains

(g) Area served by mains

(2) Waste disposal:

(a) Sewage treatment plants

(b) Lift stations

(c) Sewer mains

(d) Area served by mains

(e) Open dumps

(f) Sanitary land fills

(g) Old car dumps

(h) Incinerators

(i) Disposal barges

(3) Storm drainage control:

(a) Storm sewers

(b) Flood retention facilities

(c) Catchment basins

(d) Area served by drainage control facilities

(e) Discharge areas

(4) Energy distribution:

(a) Power plants

(b) Steam heating plants

(c) Transformer stations

(d) Power lines

(5) Communications:

(a) Telephone/telegraph facilities

(b) Telephone/telegraph lines

(c) Radio/TV stations

(d) Navigation aid facilities

(d) Locate and identify other utility facilities

(e) Determine condition of utility facilities

(f) Locate utility elements which appear to be temporarily or permanently abandoned or idle; identify original function; locate alternate elements

3. Military

(a) Locate areas having any type of military activity

(b) Locate major concentrations of military personnel and material

(c) Identify installations as:

(1) Fixed

(2) Temporary or mobile

(3) In support of ground operations

(4) In support of airborne operations

(5) In support of naval operations

(d) Locate:

(1) Operational areas

(2) Training areas

(3) Administrative areas

(4) Communications and control areas

(5) Housing areas

(6) Material and maintenance support areas

(7) Community support areas

(8) Recreational areas

(e) Distinguish between new and older areas; determine condition of facilities

(f) Locate access to installation

(g) Locate military facilities which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate facilities

4. Industrial

(a) Locate areas containing any type of industrial activity:

(1) Restricted industrial parks

(2) Non-restricted industrial parks

(3) Unplanned industrial districts

(4) Isolated industrial units

(b) For each industrial area:

(1) Locate individual factories or integral units

(2) Distinguish between older and newer parts

(c) For each industrial unit:

(1) Locate transportation access:

(a) Truck

(b) Railroad

(c) Air

(d) Water

(e) Employee

(f) Truck parking

(g) Auto parking

(2) Locate storage areas for raw materials;

(a) Open storage

(b) Covered storage

(3) Locate power and heating facilities

(4) Locate storage areas for finished products:

(a) Open storage

(b) Covered storage

(5) Determine general flow of material through the unit

(d) Identify each industrial unit as:

(1) Extractive

(2) Processing

(3) Fabricating

(4) Exploitive

(e) Classify as light, restricted, medium or heavy

(f) Classify as intensive, intermediate, or extensive in use of land

(g) For extractive and exploitive units, locate the sources of material being used

(h) For all units, identify the material being produced

(i) Determine condition of structures:

(1) New and/or well maintained

(2) In need of maintenance

(3) In need of removal or replacement

(j) Locate industrial units which appear to be temporarily abandoned or idle; identify original use; locate alternate facilities

5. Institutional

(a) Locate areas containing any type of institutional activity; identify:

(1) Governmental administrative facilities:

(a) Local, county, state, federal offices

(b) Maintenance areas

(c) Court houses

(d) Post offices

(2) Civic and cultural facilities:

(a) Civic centers

(b) Libraries

(c) Museums

(d) Auditoriums

(e) Churches and related religious facilities

(3) Educational facilities:

(a) Colleges and universities

(b) Industrial and commercial training centers

(c) High schools

(d) Junior high schools

(e) Elementary schools

(f) Schools on church property

(4) Health and Welfare facilities:

(a) Hospitals

(b) Nursing homes

(c) Health institutions

(d) Welfare facilities

(e) Medical and dental clinics/centers

(5) Public safety facilities:

(a) Fire stations

(b) Police stations

(c) Detention facilities

(d) Natural disaster and fallout shelters

(b) Determine condition of institutional structures:

(1) New and/or well maintained

(2) In need of maintenance

(3) In need of removal or replacement

(c) Locate access and parking for all institutional facilities

(d) Locate institutional facilities which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate facilities

6. Commercial

(a) Locate areas containing any type of commercial activity

(b) Locate main business thoroughfares:

(1) Pattern of streets

(2) Changes in street capacity

(3) Access to commercial areas

(4) Capacity of business thoroughfares

(5) Traffic control on business thoroughfares

(c) Locate the Central Business District:

(1) Determine CBD land use:

(a) Retail

(b) Office

(c) Finance

(d) Entertainment

(e) Industrial

(f) Open

(2) Determine condition of structures:

(a) New and/or well maintained

(b) In need of maintenance

(c) In need of removal or replacement

(3) Determine traffic flow characteristics:

(a) Access to CBD

(b) Direction of flow through CBD

(c) Intersection/RR crossing control

(d) Street capacity in lanes

(4) Inventory parking:

(a) On-street

(b) Off-street

(d) Locate planned shopping districts, centers, and malls:

(1) Regional

(2) Community

(3) Neighborhood

(4) Access

(5) Parking

(6) Condition of structures

(e) Locate unplanned shopping areas according to the criteria described above

(f) Locate wholesale districts:

(1) Warehouse/covered storage

(2) Open storage

(3) Truck access and parking

(4) Condition of structures

(g) Locate isolated or miscellaneous commercial activities:

(1) Minor commercial strips along highways

(2) Gas stations

(3) Quick-stop markets

(4) Businesses located in homes

(5) Auto sales and service facilities

(6) Used car and trailer sales lots

(7) Junk yards

(8) Entertainment facilities

(9) Access

(10) Parking

(11) Condition of structures

(h) Locate commercial facilities which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate facilities.

7. Residential

(a) Locate areas containing any type of residential structure

(b) Locate neighborhood units:

(1) Street patterns

(2) Lot size

(3) Boundaries

(4) Non-residential elements:

(a) Schools

(b) Recreation

(c) Business

(d) Entertainment

(e) Churches

(f) Fire stations

(5) Determine access:

(a) Local streets

(b) Collector streets

(c) Arterial streets

(d) Pedestrian ways

(6) Locate:

(a) Single family unit areas

(b) Multi-family unit areas

(c) High rise apartments

(d) Trailer parks

(7) Determine condition:

(a) New and/or well maintained

(b) In need of maintenance

(c) In need of removal or replacement

(8) Locate transition areas:

(a) Between established residential areas

(b) Between non-residential areas and residential areas

(c) Between rural areas and residential areas

(d) Determine the direction of transition

(9) Locate residential structures which appear to be temporarily or permanently abandoned or idle

8. Recreation

(a) Locate areas containing any type of recreational activity

(b) Classify areas as serving a:

(1) Regional area

(2) Community area

(3) Neighborhood area

(c) Classify function as:

(1) High density

(2) General outdoor

(3) Natural environment

(4) Unique natural environment

(5) Primitive

(6) Historical or cultural

(d) Classify as:

(1) Active

(2) Passive

(e) Locate:

(1) Golf courses

(2) Trails and bridle paths

(3) Playing fields, stadiums and arenas

(4) Marinas

(5) Swimming beaches and pools

(6) Shooting ranges

(7) Zoos, aquariums and animal parks

(8) Access and parking

(f) For each neighborhood unit, locate:

(1) Play lots

(2) Community center/school

(3) Public swimming area, skating area, and play fields

(4) Pedestrian access

(5) Vehicle-pedestrian separation

(g) Determine condition of all recreation facilities

(h) Locate recreation facilities which appear to be temporarily or permanently abandoned or idle; identify original use; locate alternate facilities

9. Open

(a) Locate any areas in the urban region not in use for any type of cultural function:

(1) Land

(2) Water

(b) Locate:

(1) Agricultural lands

(2) Vacant or idle land

(3) Cemeteries

(4) Active or abandoned exploitive areas

(5) Flood plains

(6) Wooded areas

(7) Areas of steep slope

MANAGEMENT ANALYSIS APPLICATIONS OF AIR PHOTO INTERPRETATION

I. General Planning Applications

  A. Regional patterns of settlement and communications

    1. Investigation of factors causing coalescence of urban areas
    2. Investigation of central place hierarchy and other spatial theories on human settlement
    3. Investigation of the influence of major land forms on regional settlement patterns
    4. Investigation of relationships between changes in rural land use and urban growth
    5. Location of sites for new settlements
    6. Investigation of the influence of communications on regional development and change
    7. Investigation of physical factors causing growth, decay or stagnation in regional settlement patterns
    8. Investigation of the influence of federal installations and activities on regional settlement

  B. Historical evolution of the city

    1. Investigation of time-space relationships within the urban area using sequence photography
    2. Investigation of the influence of topography (and indirectly, geology), soils, drainage (and other hydrologic

factors), and lines of communication on the development of settlements

3. Investigation of basic changes in land use requirements using sequence photography

4. Investigation of the influence of changing modes of transportation on urban growth

5. Investigation of the influence of changes in base and service industry on land use patterns

C. Functional structure of the city

1. Investigate forces behind land use patterns. Test concepts such as the concentric, sector and multiple nuclei theories of urban land use

2. Investigate nature of transition areas; determine general forces, such as anticipation, which govern land use policy in transition areas

3. Investigate the economic base of a region or urban center; determine classification as manufacturing center, etc.; determine the influence of this classification on land use patterns

D. Social structure of the urban settlement

1. Investigate relationships between social patterns and:

   (a) Ecological situation

   (b) Dwelling condition and density

   (c) Local land-use characteristics

2. Investigate the possibility that recognition and analysis of particular land use patterns will directly and reliably identify certain critical, though dormant,

socio-economic problems so that recognition and corrective action can be made before the problems reach an explosive stage

II. Transportation Planning Applications

A. Investigate relationships between traffic generation and land use

B. Investigation of traffic flow characteristics

C. Parking analysis; investigate relations between walking distance from a parking area and various types of land uses

D. Engineering studies for maintenance and development of traffic facilities

E. Investigation of traffic control devices

F. Location of primary traffic corridors

G. Transportation site selection

H. Location of special transportation facilities such as scenic by-ways

I. Investigation of spatial distribution of traffic units at various times

J. Investigation of weak elements in a transportation system

K. Investigation of inter-relationships between various transportation modes

III. Utility Planning Applications

A. Engineering analysis for utility site and corridor selection

B. Investigation of relationships between land use and utility system requirements

C. Location of reservoir sites; investigation of multiple use potential

D. Location of critical land forms affecting the siting and operation of utility systems

E. Investigation of flood plains and flood plain management policies

F. Investigation of pollution and pollution control policies

G. Location and investigation of incompatible land uses involving utility systems or sanitation elements.

H. Investigation of service performance

IV. Military/Civil Defense Planning Application

A. Investigation of the effect of military installations and activities on surrounding civil land use

B. Investigation of actual or potential incompatible land-uses involving military activities, particularly with regard to air field approach zones

C. Investigation of the effectiveness of land use management within military areas

D. Location of structures suitable for Civil Defense shelters; determination of sites requiring development of shelters

E. Investigation of potential sites for military installations or activities, particularly where the area is inaccessible from the ground

V. Industrial Planning Applications

A. Site selection investigations

B. Location of industrial resources

C. Location of access to industrial resources

D. Investigation of basic land use requirements associated with industry

E. Investigation of incompatible land use practices involving industry

F. Investigation of access requirements of industrial facilities with respect to primary transportation systems

G. Investigation of the effect of industrial traffic on urban and regional transportation systems

VI. Institutional Planning Applications

A. Institutional site selection

B. Investigation of the influence of advanced educational facilities on the location of research-oriented industries

C. Investigation of beneficial and detrimental land use effects associated with institutions

D. Investigation of access and parking requirements

E. Determination of service area for fire stations, police stations, maintenance facilities, libraries, hospitals, schools, and post offices

F. Investigation of the distribution and service areas of religious institutions

G. Investigation of land use benefits or liabilities as related to concentrating or dispersing institutional facilities

H. Investigation of facilities or areas warranting historical preservation

VII. Commercial Planning Applications

A. Commercial site selection

B. Investigation of trade areas

C. Investigation of commercial land use density and distribution within a region or urban area

D. Investigation of the effect of satellite commercial centers on the Central Business District

E. Investigation of factors causing decay in the CBD

F. Investigation of incompatible land use practices involving commercial activities

G. Investigation of the possibility of recognizing particular land use patterns, such as highway strip commercial zones, which can be used as reliable indicators of detrimental land use

H. Investigation using sequence photography of the spread of decay caused by incompatible commercial land use

I. Investigation of blighted area or areas subject to explosive social instability

J. Use of photos for administrative purposes such as mortgage and fire risk appraisal, discreet appraisal and acquisition of real estate, and tax assessment

K. Investigation of the land use benefits or liabilities of various sized consolidated commercial units versus dispersed units

L. Investigation of the success of planned commercial areas versus unplanned areas

M. Investigation of the effectiveness of land use controls

VIII. Residential Planning Applications

A. Investigation of sites for individual dwellings or sites for subdivisions or whole suburbs

B. Investigation of areas likely to receive future population distribution to determine whether suitable land is available to support that growth

C. Investigation of residential patterns to determine relationships between status and physical environment :

1. Lot size
2. Traffic facilities
3. Sidewalks
4. Community support facilities
5. Density of land use
6. Land use mix
7. Condition of structure and grounds

D. Investigation of residential patterns to determine areas needing conservation, rehabilitation, or redevelopment policies

E. Investigation of the influence of suburban sprawl on access and trip time between residence, work, shopping and entertainment

F. Investigation of the quality and extent of neighborhood units; investigation of sites for potential neighborhood units

G. Investigation of land use patterns indicating potential explosive social problems

H. Evaluation of the effectiveness, from a land use viewpoint, of urban renewal projects

I. Investigation of the rates of change of neighborhood status

J. Investigation of relationships between development of new residential units and the decline of existing units, particularly the change of units from owner occupied to rental status

K. Investigation of relationships between development of new high density residential units and surrounding land uses; investigation of row house and garden apartment land use

L. Investigation of incompatible land uses involving residential units

IX. Recreational Planning Applications

A. Recreation site selection:

1. Regional use

2. Community use

3. Local or neighborhood use

B. Investigation of areas not suitable for intensive development as either active or passive recreation areas

C. Investigation of the service area of recreation facilities, particularly intensively developed community centers, zoos, etc.

D. Investigation of the sufficiency of recreation resources within a region or urban area

E. Investigation of recreation resources within blighted residential areas

F. Investigation of access to recreation areas

G. Investigation of acreage and distribution requirements for recreation facilities

H. Investigation of potential multi land-use schemes involving recreation facilities (i.e., flood plains, reservoirs, conservation areas, etc.)

I. Investigation of incompatible land use practices involving recreation resources

X. Open Space Planning Applications

A. Investigation of factors causing open space to be found in intensively developed areas

B. Investigation of land use practices in rural areas on the urban fringe

C. Investigation of the desirability of maintaining low intensity, open land use within urban areas:

1. Agriculture areas
2. Natural/conservation areas,
3. Recreation areas
4. Transportation areas
5. Storage areas
6. Areas allowing movement of air and admittance of light

D. Investigation of land taxation policies as they influence land use and change

E. Investigation of the effectiveness of land use control and reservation policies (i.e., policies, such as those of Oklahoma City, which are designed to insure the availability of adequate land for future expansion)

XI. NOTE: While this outline of potential applications of air photo interpretation is extensive, it is by no means complete. Potential applications are limited only by the experience of the planner and degree of analysis required.

CHAPTER III

REPRESENTATIVE APPLICATIONS OF AIR PHOTO INTERPRETATION TECHNIQUES: SHERMAN, TEXAS, METROPOLITAN AREA

Sherman, near Lake Texoma in north-central Texas, is the southern city in an expanding twin city industrial complex designated by the U. S. Census Bureau as the Sherman-Denison Standard Metropolitan Statistical Area. This complex is developing into the northern anchor of a line of metropolitan areas extending from Lake Texoma south through Dallas-Fort Worth, Waco, and Austin to San Antonio. This urban system, containing major concentrations of water, communications, industrial, human, technical and educational resources, is vital to the economic development of the Southwest.

In approximately 100 years Sherman has developed through stages as a pioneer settlement and a railroad and agricultural center to its current status as a modern, diversified industrial complex. While traditional industry and agriculture are still important elements in the area's economy, Sherman's future appears to be governed by its ability to attract and maintain research oriented industry. Base industries in this category are Texas Instruments, IBM, Johnson and Johnson and Kaiser Aluminum. Other major industries in the area are Anderson-Clayton, Hardwicke-Etter, Burlington Industries and Perrin Air Force Base. Oil and gas field production and tourism (Lake Texoma) are added economic benefits in the area. Sherman's growth is dependent on two related factors: (1) the immigration of people from rural areas, and (2) the location of base-type industry seeking sites which provide adequate water, communication, and personnel resources. It can be assumed that a very large majority of Sherman's future population will be attracted by new industrial development and that these immigrants (typically young, well paid, well educated, and very mobile) will have a profound influence on the character of the community. Thus, the only significant restriction on Sherman's growth potential appears to be the community's ability to manage its available resources so that the physical and socio-economic environments are conducive to attracting and holding industrial entrepreneurs and a productive population. All urban and regional planning must be directed towards this goal. This chapter is devoted to illustrating, through representative examples, how air photo interpretation can aid in this effort. While these illustrations are intended to show the comprehensive capability of air photo interpretation techniques, it is not the intention of this thesis to conduct a comprehensive urban and regional planning study for the Sherman area.

Materials and equipment used in these interpretations were: stereoscope; dividers and measuring devices; topographic charts of scales 1:125,000, 1:62,500 and 1:24,000; and black and white stereo pair aerial photography of scales 1:13,500 (provided by the U. S. Soil Conservation Service) and 1:1000 (provided by the Texas Highway Department).

Topographic Analysis

A comprehensive air photo interpretation study begins with an investigation of the basic topographic features of the study area. While each topographic feature will subsequently receive more specific analysis regarding its natural vegetation, hydrologic, geologic, soils, and land use characteristics, it is first necessary to become oriented with the region. Figure 1, a photo mosaic, and Figure 2, a topographic chart, illustrate the topography of the Sherman-Denison area. Study of these materials (with additional stereo photo study) reveals a generally rolling terrain, heavily eroded by a drainage system which locally drains to the east and southeast, but regionally drains northeast into the Red River. The planner is primarily interested in determining what influence topography has had on regional settlement patterns and local land use. Study of the Sherman-Denison area suggests that topography has had moderate to major influence on regional settlement patterns in that virtually all communities have developed on major drainage system divides.

There is an interesting, and somewhat unique, feature concerning the close similarity in size, age and location that exists between Sherman and Denison. Central Place Theory is a regional settlement theory which, in essence, states that each urban center is: (1) the nucleus of a ring of smaller communities (at a given radius) comprising its service area; and (2) an element in a similar, but much greater,

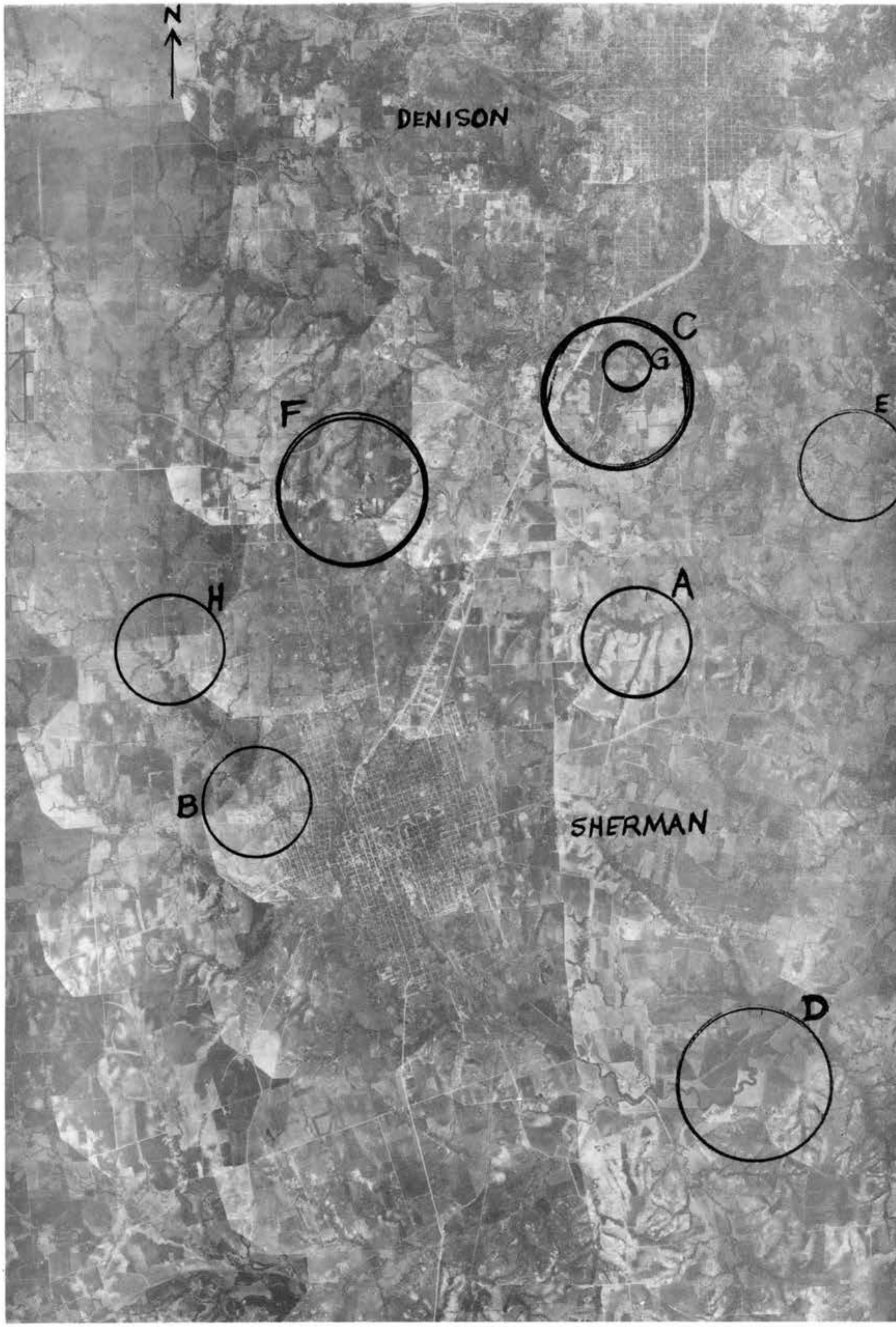

Figure 1. Sherman-Denison Topography

Figure 2. Sherman-Denison Topography

ring surrounding a larger community. This theory has been applied extensively and has been found generally valid in rural areas of the mid-west and southwest. According to this theory, either Sherman or Denison would have to become clearly subordinate in size and economy to the other community. However, this has obviously not been the case, and it is very probable that some unique and economically significant natural feature has been responsible.

Grayson County developed primarily as an agricultural area, and it was topographically and geographically logical that Sherman should develop as the center of that activity. Study of the settlement pattern in eastern Grayson County tends to support Sherman as a central place, except for its relation to Denison (which does not display central place characteristics). Thus, it would seem pertinent to investigate the natural resource characteristics of Denison to determine why it has been able to maintain an economic position generally equal to Sherman's. Denison developed as a railroad center, most likely because of: (1) readily available ground water suitable for locomotive use; (2) timber for ties (still an important industry in Denison); and (3) a desire on the part of railroad management to have a central place location in north-central Texas, but also to be able to control development of the community (which probably precluded their locating in Sherman and apparently caused them to compromise on a slightly offset position at Denison). Thus, as long as railroads were a very major industry in north-central Texas, Denison was able to support its position in relation to the "theoretically dominant" Sherman. However, in the past decade, Sherman has begun to transition from an agricultural central place to an even larger industrial central place. At the same time, the railroad industry has declined in Denison. Therefore, unless Denison can develop a new economic position based on some unique and economically significant natural resource, one would expect Denison to become increasingly an economic satellite of Sherman. If this is to be the case, it is essential that both urban and regional planning proceed accordingly.

Study of Figures 1 and 2 further suggests that, locally, topography has had only moderate influence on land use. Both Denison and Sherman display largely rectilinear street patterns. Denison has a customary north-south grid pattern, while Sherman's grid has a slightly north-northwest to south-southwest orientation which suggests some local topographic influence (most likely the boundary of the Austin chalk east of Post Oak Creek). Agricultural land and rural roads display relatively rectilinear patterns regionally; however, locally these elements display patterns indicating moderate to strong topographic influence. Railroads appear to be very responsive to topography, particularly near Denison where railroads follow paths influenced by topography while nearby roads appear little influenced by the same topography.

Topography will greatly influence industrial expansion in the Denison area. Industry customarily requires large, relatively flat sites; however, such sites are severely limited in the hilly terrain around Denison. If Denison's economic future is to depend on attracting base-type industry, then all available suitable sites must be inventoried and protected by some means of land use control.

Hydrologic Analysis

Referring again to Figures 1 and 2, it is noted that Sherman and Denison lie in the Choctaw Creek watershed; that the watershed is roughly defined by the communities (reading counter-clockwise from the north) of Denison, Pottsboro, Perrin Air Force Base, Dorchester, Howe, Tom Bean, Bells and Ambrose; that Choctaw Creek drains northeast to the Red River; and that local drainage in the metropolitan area is generally east and southeast to Choctaw Creek. Within the watershed, the drainage pattern is generally dendritic (tree-like), which suggests flat-laying, uniformly resistant rock, probably sedimentary. Choctaw Creek and all of its primary tributaries display recent flood plains and show evidence of severe sedimentation, a problem of growing concern to planners. In rural areas soil conservation measures (small dams, contour plowing) are in evidence; however, roughly fifty percent of the farm land does not appear to be protected by soil conservation measures and continues to erode. Such stream pollution and land waste can be observed in area A on Figure 1. This area still shows evidence of former field boundaries even though sheet and gully erosion have apparently caused the fields to be abandoned or converted to less intensive use.

In urban areas two factors are combining at an increasing rate to erode valuable land, increase stream sedimentation, and aggravate flood control problems. The first factor arises when construction sites are cleared of protecting ground cover, leaving exposed soils highly vulnerable to erosion. Secondly, once development takes place, the ground surface is usually much more impervious than previously, resulting in much greater surface water run-off rates. Thus, the greater volume and velocity of run-off couples with more vulnerable soil to greatly increase erosion and sedimentation. (The U. S. Soil Conservation Service estimates that, under such conditions as described above, as much as 80% of run-off may be sediment.) Only one of the many problems derived from sedimentation is the filling in and damming up of floodways, thus increasing the level of subsequent flood water.

Area B on Figure 1 and the western portion of Figure 3, West Sherman, illustrate sheet and gully erosion around developing residential areas west of Post Oak Creek. Sequence photography taken between 1957 and 1969 shows extensive growth in erosion features on the western slope plus greatly increased sedimentation in the bed of Post Oak Creek. It is pertinent that the two greatest floods on record for this stream took place within the past three years. Flood plain analysis is of two fold importance to the planner in that: (1) the location and extent of past and probable future floods must be determined and evaluated as they effect land use development (this application will be covered in a later section); (2) flood plains, provided they drain areas containing granular parent material, are often major sources of construction materials so vital to urban development. Areas D and E on Figure 1 illustrate two composite flood plains. Potential granular deposits can be identified by light soil tones in the bends of streams; abandoned channels; meander scrolls; tops of flood banks; and exposed sand bars where stream configuration has reduced velocity of the flow.

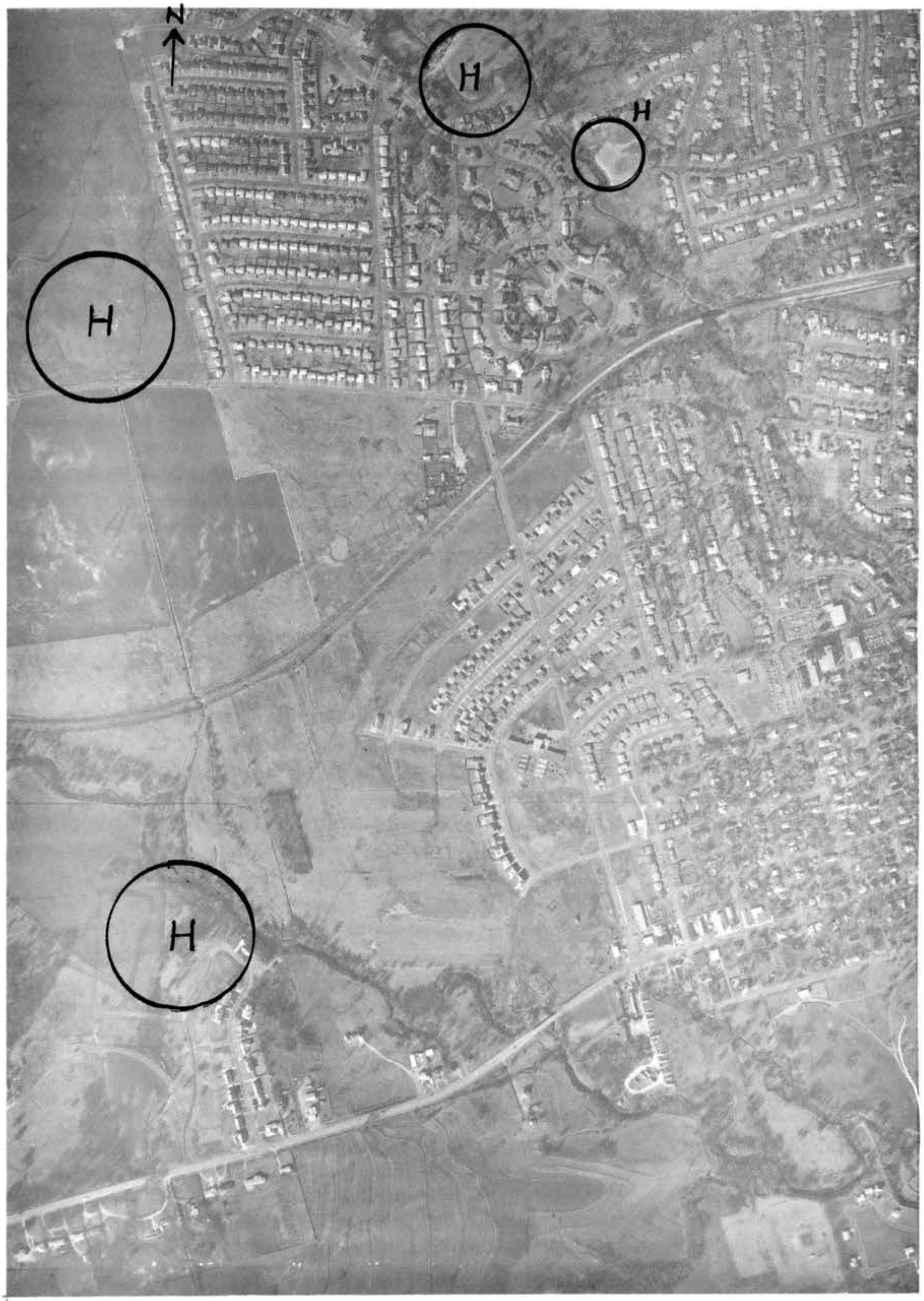

Figure 3. Urban Area Erosion

Geologic Analysis

As related in Appendix B, the geology of Grayson County is very significant and interesting; however, it is also very complex and it is expected that few planners will have the extensive geological education and experience necessary for photogeology. However, the planner can and must be familiar with basic geologic references for his study area; consequently, using a geologic reference such as the chart in Figure 4 as a guide, he may use air photos very profitably to familiarize himself with the area's basic geologic character and extent. Of particular concern are those geologic features directly influencing land use policy. Studying area C on the mosaic in Figure 1 and its large scale blow up in Figure 5, the planner will note: (1) a hilly topography with fairly sharp vertical slopes bordering a flood plain to the north; (2) a decrease in density of the local drainage pattern (i.e., fewer gullies); (3) a more rectilinear drainage pattern, in contrast to the surrounding dendritic pattern; (4) an increase in natural vegetation along slopes--apparently a moderately sized species of broadleaf tree; (5) an absence of cultivated fields along the bluff; and (6) a light tone in exposed areas along the bluff. Taken in total, these factors are usually indicative of a relatively thick, flat-laying sandstone formation. Comparing this evaluation with data relating to Figure 4 shows the formations in area C to be:[1]

1. Templeton member (Kwt), Woodbine formation, consisting of interbedded sandstone and shale, 75-95 feet thick.

Figure 4. Geologic Chart

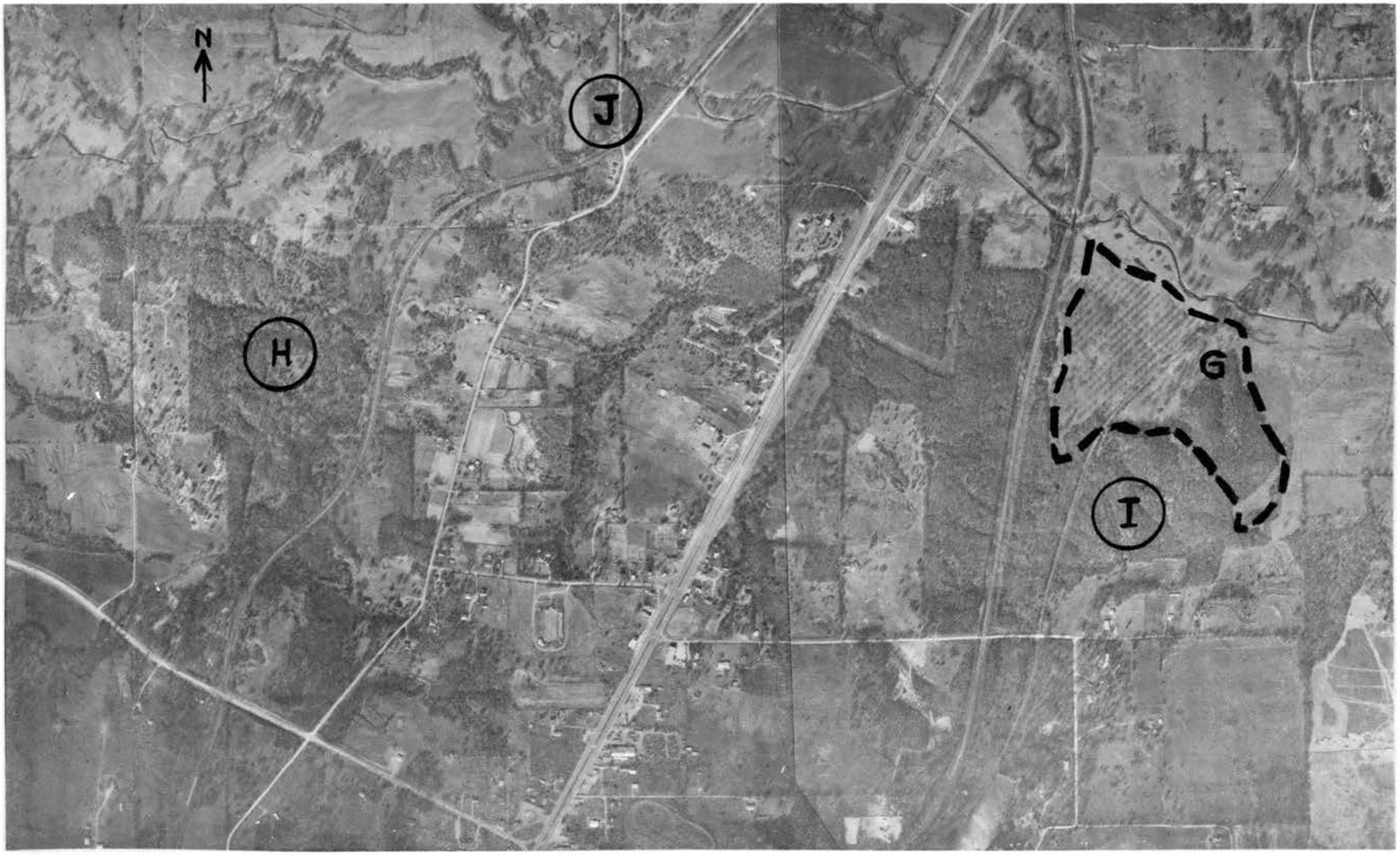

Figure 5. Woodbine (Sandstone) Outcrop

2. Lewisville member (Kwl), Woodbine formation, consisting of interbedded sandstone, shale and clay, 75-95 feet thick.

3. Red Branch member (Kwl), Woodbine formation, consisting of interbedded sandstone and shale, 25-80 feet thick.

4. Flood plain deposits (Qal)

Therefore, the air photo interpretation as sandstone was generally correct in area C. An important characteristic of sandstone is its porosity, which, when bounded by relatively impervious formations, makes a sandstone formation a major source of ground water. Appendix D bears out this fact, showing that the Woodbine formation is currently the principal aquifer for Grayson County and a main source of Sherman's domestic water.

Further investigation of interpretation materials reveals that area C is a major outcrop of the Woodbine formation, and is, therefore, of vital importance to the entire region as a recharge area for the Woodbine aquifer. Potential land uses for this area will be analyzed in detail later in this chapter.

Geologic analysis greatly expedites the search for construction materials. Old coastal plains, such as the Sherman-Denison area, are not generally good sources of construction materials; consequently, location and development of scarce granular resources are of great importance to the planner. In this region the two most likely sources of granular materials, aside from recent flood plains, are old fluvial terraces and the outcrop of sedimentary rock formations. Photo identification of rock outcrops has been demonstrated above; a second outcrop area can be viewed in area F on Figure 1. This area demonstrates the very light tone and evidence of quarry and gravel pit operation commonly associated with consolidated granular deposits. Northeastern Grayson County contains many remnants of fluvial terraces. Studying area G on Figured 1 and 5, the planner will note: (1) an orchard; (2) a flat, bench-like land form (in contrast to the surrounding hilly terrain); (3) a general absence of surface drainage; (4) and light soil tones. These features are indicative of a granular terrace. Further photo study tends to confirm this evaluation in noting that: (1) stream courses from the upland areas dissappear upon discharging onto the terrace; (2) drainage channels reappear on the lower lying flood plain at the base of the terrace; (3) short, steep, relatively V-shaped gullies (indicative of sandy gravel) dissect the eastern face of the terrace; and (4) braided channel markings (indicative of gravelly soil deposited by the stream that originally constructed the terrace) run along the terrace parallel to the stream valley.

Upon locating a granular deposit, engineering studies (both air photo and field) may be conducted to determine: (1) the quality and extent of the deposit; (2) the amount of site preparation required to begin excavation; (3) site access; and (4) haul road design. Evaluation of this data determines the economic use of the gravel material.

Soil Analysis

As related in Appendix C, soil is the product of climate, living organisms, parent materials, topography and time. Thus, to understand the significance of soils native to the Sherman-Denison area one must assimilate a vast amount of information relating to those five factors; this process, needless to say, can be exceedingly complex. However, the more intensively land is developed, the more important is a thorough understanding of related soils.

As related in Appendix C, the Department of Agriculture is conducting an extensive soil classification program; however, most of this mapping does not include urban and urban fringe areas. Second, there has been considerable difficulty in introducing standard classification procedures across the nation (primarily due to the time required to re-classify soil areas by field procedures), making it difficult to correlate various data. Third, urban development can radically change soil environment, causing the original, agriculturally-based soil classifications to become obsolete. It is therefore, essential that the planner have access to soils data which is meaningful to planning problems.

It has been found that a basic classification of soil can be reliably determined via air photo interpretation.

This interpretation is based on an evaluation of boundary, topographic, drainage, tone and land-use characteristics of soils as they appear on aerial photography.

As in the case with geologic analysis, comprehensive soil analysis via air photo interpretation is beyond the capability of most planners; however, the planner can use air photos in conjunction with other references as a means of determining soil information sufficient for most planning decisions. Later engineering analysis can be conducted by specialists (using both air photo interpretation and field checks) to determine more specific data.

<u>Boundary Conditions and Topography</u>

An understanding of the geologic history of an area's soils is essential in that it helps the interpreter determine a soil's parent material and recognize associated boundary and topographic features pertinent to soil classification.

As described in Appendix B, Sherman and Denison are situated on an ancient <u>coastal plain</u>. A complex history of submergence and emergence by the sea, combined with secondary erosion by streams and rivers, has left a relatively flat, though heavily dissected, land form composed of interbedded and intermixed sands, silts, and clays (which have largely consolidated into <u>stratified sedimentary rock formations</u>). In geologically recent times, streams have eroded the coastal plain creating <u>flood plains</u> which were, in turn, eroded by smaller streams forming new, lower flood plains below remnants of the old (which now appear as terraces).

Once the parent land form and material have been identified the interpreter can reduce the number of factors pertinent to soil classification down to a manageable level.

Drainage

Drainage pattern and gully plan, profile and cross section are perhaps the most important visual clues in classifying a specific soil area. Gullies are formed as the result of erosion by water runoff and serve as a reliable indicator of local surface soils. In general, fine grained silts and clays, being relatively impervious, have many gullies developed on their surface; whereas sands and gravels, being relatively permeable, have few or no gullies.

Using air photo interpretation surface soil can be classified generally as:

1. cohesive silty clays and clays having an elongated broad plan; a wide V-shaped cross section; and a low, uniform gradient (profile). These soils are commonly associated with lake beds, marine terraces and clay and shale formations. From an engineering standpoint, these soils are commonly highly impermeable (slow percolation rates), have high liquid and plastic limits (severe shrink-swell ratios), are highly corrosive (destructive to

utility lines), may have great depths to bedrock (poor foundations), may have high water table (susceptible to flooding), have poor bearing values (low traffic-supporting capacity), and are highly erodible (unstable cuts and fills).

2. moderately cohesive silts, silty loams and silty clay loams having U-shaped cross section; and a compound gradient. These soils are commonly associated with loess and alluvial formations. From an engineering standpoint, these soils are commonly poorly to moderately well drained, have moderate to high liquid and plastic limits, are moderately to highly corrosive, have great depths to bedrock (though are generally a good foundation if the water table is low), are one-sized in grain (requiring mixing with other materials for construction and traffic supporting purposes), and are moderately to highly erodible (unstable cuts and fills).

3. moderately cohesive sandy clays, sandy clay loam, clay loam, and loams having a U-shaped plan, a rounded U-shaped cross section, and a compound gradient. These soils are commonly associated with coastal plains and many bedrock outcrops. From an engineering standpoint these soils are commonly poorly to moderately well drained (dependent on their proximity to the water table), have moderate

to high liquid and plastic limits, are moderately to highly corrosive, have variable depths to bedrock (variable foundation capabilities), are moderately impermeable (moderate to slow percolation rates), and have poor to moderate traffic supporting capability.

4. non-cohesive sands, sandy loam, loamy sand, and gravels having a V-shaped plan; a V-shaped cross section; a very steep gradient when the soil is predominantly coarse material; and a very short, steep, uniform gradient when the soil is a well graded mix of sands and gravels. These soils are commonly associated with terraces. From an engineering standpoint these soils are generally moderately to well drained, have low to high liquid and plastic limits (slight to severe shrink-swell ratios), are moderately corrosive, may have great depths to bedrock (though are often good foundations), and have poor to moderate traffic supporting capabilities.

An absence of drainage patterns or gullies may indicate porous rocks, granular material or soluble rocks (limestone). In general, coarse textured (widely spaced channels) drainage patterns develop over pervious or massive formations, while fine-tectured drainage patterns develop over impervious, easily eroded formations where internal drainage is severely retarded.

Tone, Vegetation and Land Use

Tones are invaluable aids in establishing the extent of soils in a pattern, as even minute changes in a soil are usually reflected in its color or tone. However, the use of tones is limited to the study of relative differences in shades.

Vegetation is a reliable index of climatic conditions and the presence of water. In some cases, the presence or absence of certain types of vegetation will reliably establish the texture and permeability of the soil.

Land uses, such as quarries, gravel pits, certain agriculture, etc., give indications of a soil's character.

Figures 5 through 10 are provided to illustrate the soils associated with sedimentary rock outcrops, terrace and flood plains. Figure 11, a chart, correlates the areas represented by Figures 5 through 10. These analyses will be referred to in later land-use applications.

Figure 5 has earlier been used to illustrate the interpretation of a granular terrace (Area G) having an overburden consisting of sandy loam (soil consisting of a mixture of sand, clay or silt, and organic material) and loamy sand; and a sandstone outcrop (Areas H and I) having a thin layer of sandy soil. In addition, a composite flood plain (Area J) can be viewed across the top of the photo. This area can be interpreted as a deep formation consisting of mainly fine silts (in backwash areas of the covered flood plain) although coarse silts and sand can be expected along the meandering elements of the flood plain. Visual evidence of these granular deposits are the streaks of very light tone found along the levees and in the stream beds. The silts are identified by their dark tones and backwash locations.

Studying Figure 6, Northeast Sherman, one will recognize: (1) a rolling terrain; (2) roughly circular depressions; (3) intensive cultivation, except on the urban fringe where previously cultivated land has become idle; (4) a generally gray soil tone, except in the depressed areas which are very dark toned; and (5) erosion scars appearing as very light streaks. These features are indicative of a limestone formation (field data on this area shows it to consist of interbedded limestone, chalk and marl). Surface material derived from such a foundation can be interpreted as consisting of clay and silty clay overlaying a thick subsoil consisting of clay and marl. The short, shallow erosion scars and light tones suggest a resistant limestone or chalk formation. The engineering characteristics of these soils (using the criteria described in Appendix C) are high shrink-swell ratios, slow percolation rates, high corrosivity and low traffic supporting capability. They are rated as fair sources of topsoil and poor sources of borrow.

Figure 7, Southeast Sherman, reveals characteristics

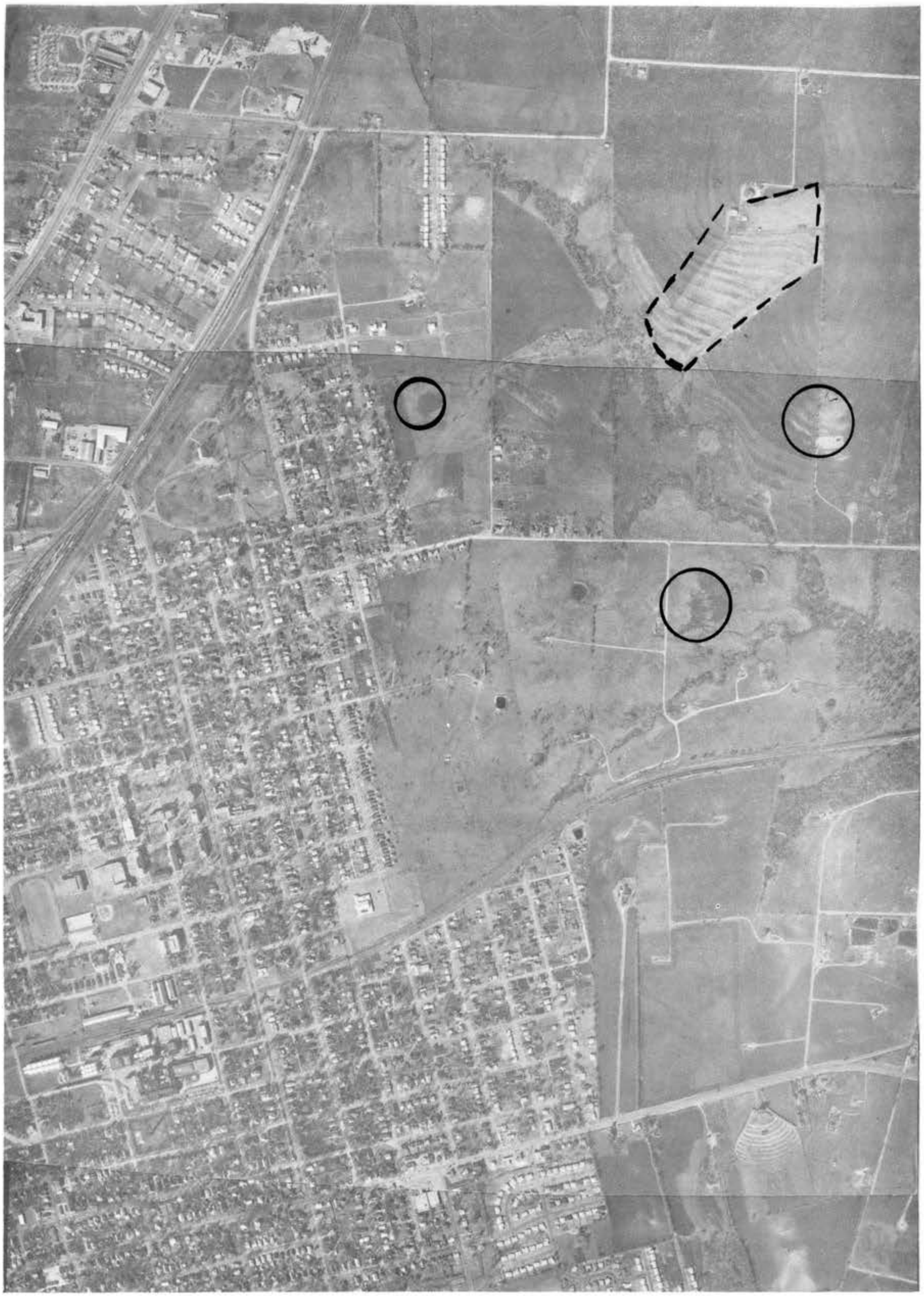

Figure 6. Soils, Northeast Sherman

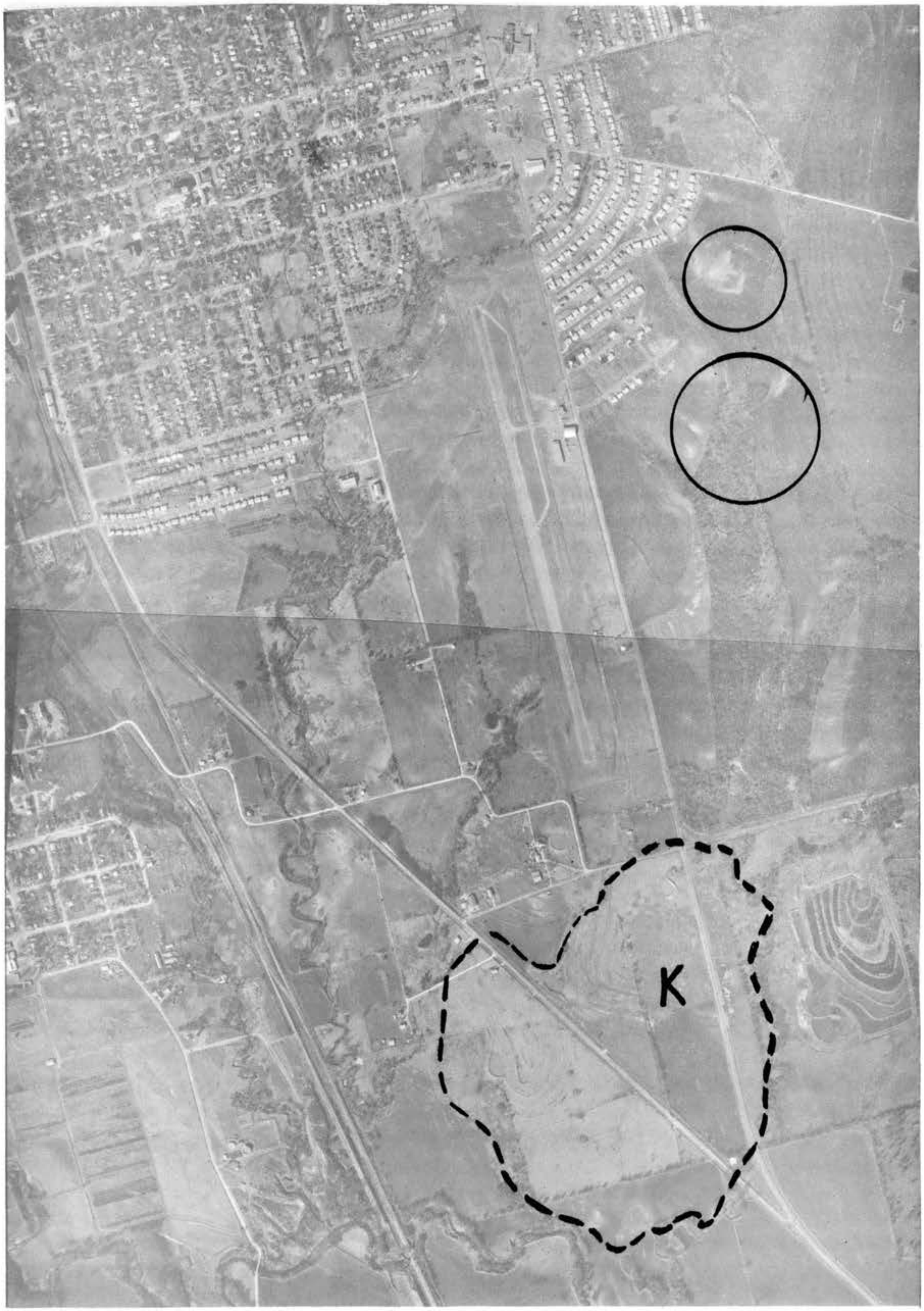

Figure 7. Soils, Southeast Sherman

Figure 8. Soils, Northwest Sherman

similar to those in Figure 6, suggesting an underlying limestone/chalk formation (note light colored erosion scars and sink holes in the upper right hand portion of the photo). However, tones are generally more even, suggesting a deeper overburden of clay and clay loam throughout the area. In area K, one notes a lightening of soil tone, indicating a more sandy loam. Engineering characteristics associated with these soils are severe shrink-swell ratios, slow percolation rates, high corrosivity and low traffic supporting capability. They are rated as good sources of topsoil and poor sources of borrow.

Figure 8, Northwest Sherman, reveals a variety of gully characteristics, suggesting a wide variety of soil types. The upper left of the photo (area A) shows evidence of well developed, gently curving dendritic drainage patterns indicative of a shaly area. Soils in this area are interpreted as sandy loams and clay loams. Their engineering characteristics are generally moderate shrink-swell ratios, slow percolation rates, high corrosivity, and low traffic supporting capability. They are rated as fair sources of topsoil and poor sources of borrow.

In the left center (area B) erosion scars, very light in tone, suggest an outcrop of limestone or chalk. In area C, dark, even tones on a composite flood plain suggests silty soil; however, in the stream bed at area D, there is evidence of extensive dredging for granular materials. Soils in area E present a very uniform dark tone, a lack of developed surface drainage, flat topography, and evidence of high water table -- all indicative of a frequently flooded plain.

Figure 9, Southwest Sherman, again gives extensive evidence of clay and clay loam soils. Areas A and B present erosion scars exposing light subsoil and rock near the surface. Dams at A, C, and D give evidence that the local soil is relatively impervious. A very dark tone in area E gives evidence of runoff infiltration onto the flood plain from relatively pervious upland. The engineering characteristics of these soils are generally high shrink-swell ratios, slow percolation rates, high corrosivity, low traffic supporting capability, frequent flooding (in the area at the right of the photo), and shallow depths to bed-rock in the upland areas. They are rated fair sources of topsoil and poor sources of borrow.

Figure 10 is an aerial photo of the planned interchange site between U. S. Highway 82 (presently under construction) and Farm Road 1417. The interchange site can be identified by turn-outs already constructed at point A. Study of background references (Appendices B and C) indicates that this area lies astride the transition zone between the outcrops of the Eagle Ford shale (generally west of highway) and the Austin chalk (generally east of highway). Study of Figure 10 reveals topographic, drainage pattern, and gully features common to those outcrops.

Areas denoted as B present gully features (U-plan,

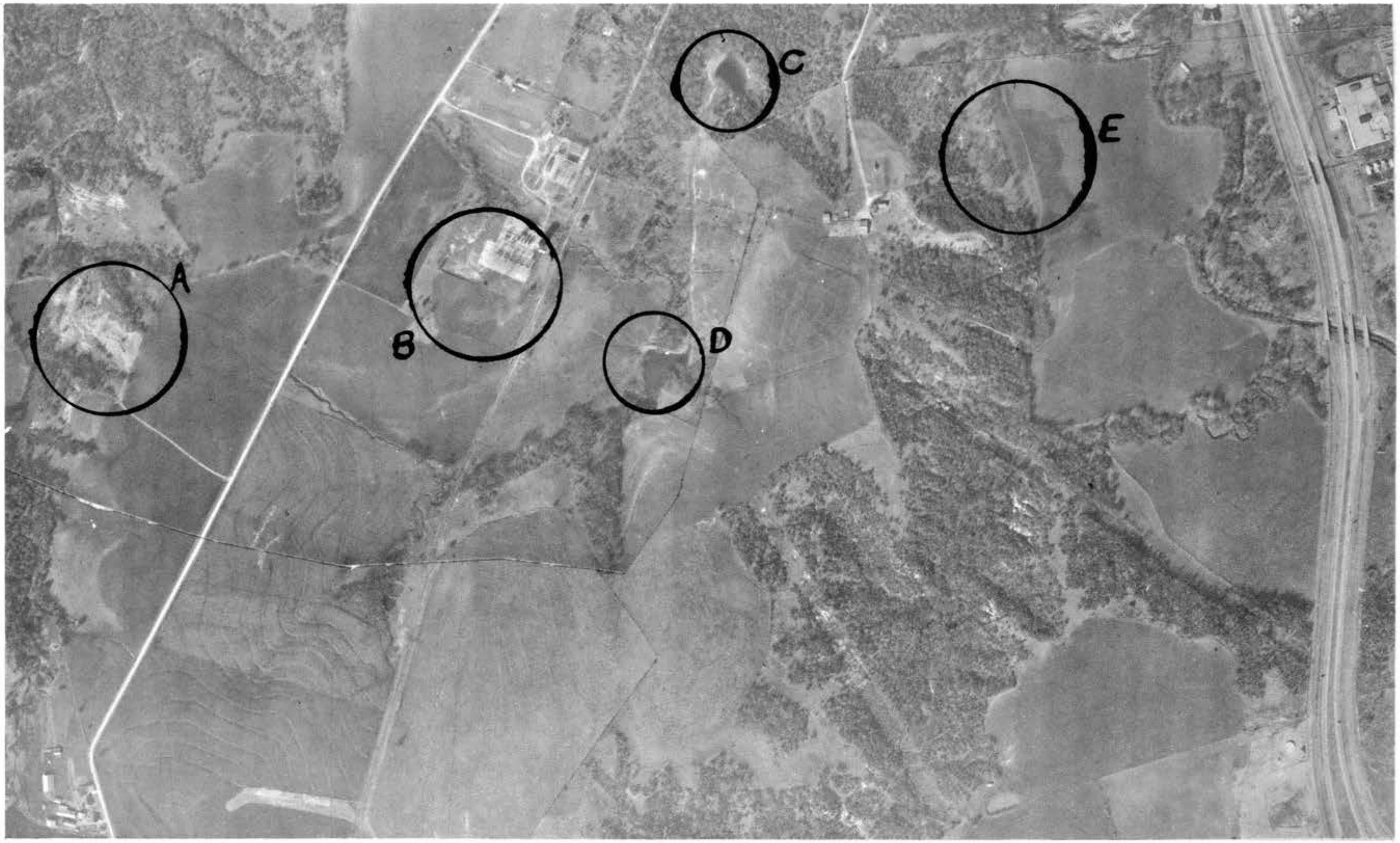

Figure 9. Soils, Southwest Sherman

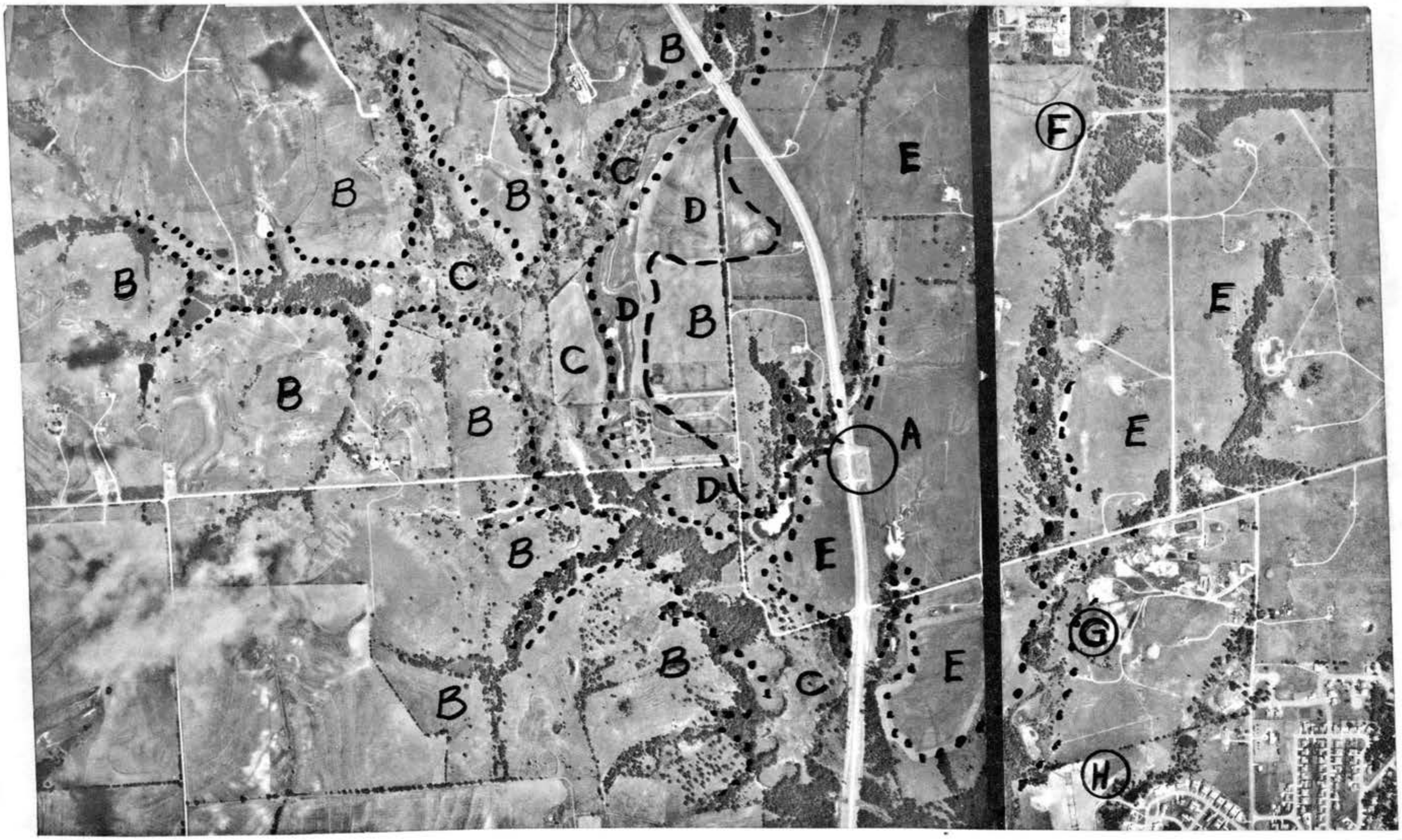

Figure 10. Soils, Highway Interchange Site

U-cross section, compound gradient) associated with clay loams (which are commonly derived from shale formations). The engineering characteristics of these soils are usually moderate to severe shrink-swell ratios, severe corrosivity, slow percolation rates and moderate traffic supporting capability. They are rated as good sources of topsoil and poor sources of borrow.

Area C represents recent alluvial soils, which because of the nature of soils in the watershed, are also clay loams. Engineering characteristics of these soils are generally similar to those of area B, with the exception that the lower soils are subject to frequent flooding and have higher corrosivity and shrink-swell ratings.

Soils in area D present streaked, light tones on their slopes and suggest a sandy loam with engineering characteristics similar, but generally less limiting than the clay loams. The farmstead in area D has apparently been located so as to take advantage of the best drained site in the area.

Areas denoted by D are relatively level and uniform in tone. The drainage pattern is more irregular than that to the west, but is still dendritic. Gullies display an elongated, broad plan and low, uniform gradient. Areas E, F and G present erosion scars of varying light tones. Taken together, these features are indicative of a massive clay formation such as those associated with the Austin chalk. The light erosion scars suggest chalk formations at varying

Figure 11. Photo Area Correlation

depths. Soils in this area can be interpreted as clays and silty loams. Their engineering characteristics consist of moderate to severe shrink-swell ratios and severe corrosivity ratings. In addition, they have variable, but generally poor, traffic supporting and percolation capabilities. They are rated as fair sources of topsoil and poor sources of borrow.

Land Use Analysis

Transportation

Study of Figure 12, a photo mosaic of the Sherman-Denison area, reveals major highway and railroad corridors passing east-west through Sherman and north-south through both Sherman and Denison.

The extensive network of individual railroad lines, indicating use of the area by an unusually large number of railroad companies, adknowledges the area's role as a major railroad center. The influence of the railroad is readily observed in both cities; however, the railroad land use in Sherman is much less than in Denison, supporting the latter's position as the predominant railroad center in the region. Railroad land use data is presented in Figure 13. Sherman has two relatively small yards (areas A and B), one for maintenance (northeast), another (downtown) for servicing local customers. Denison, on the other hand, uses

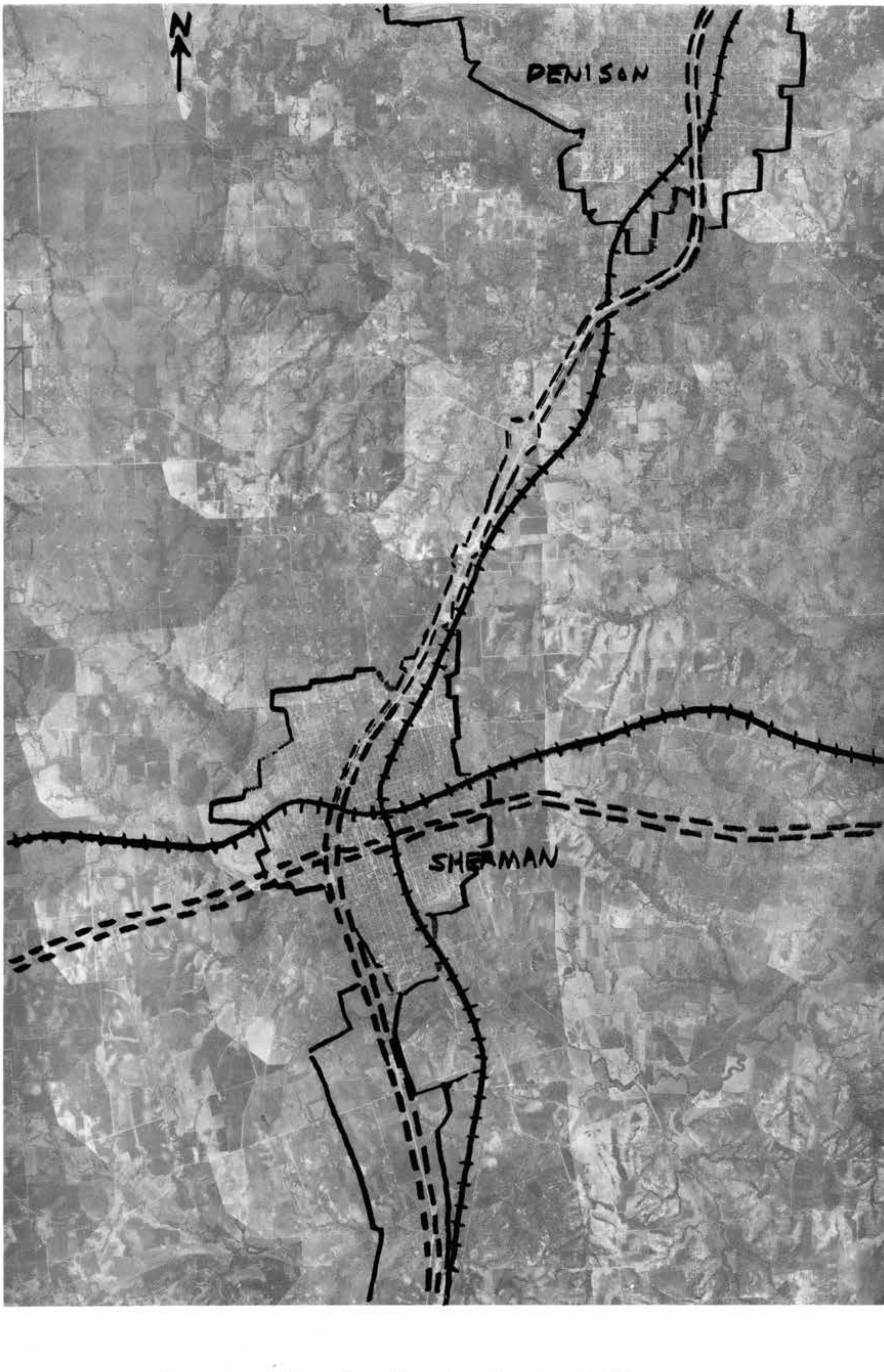

Figure 12. Regional Trans Patterns

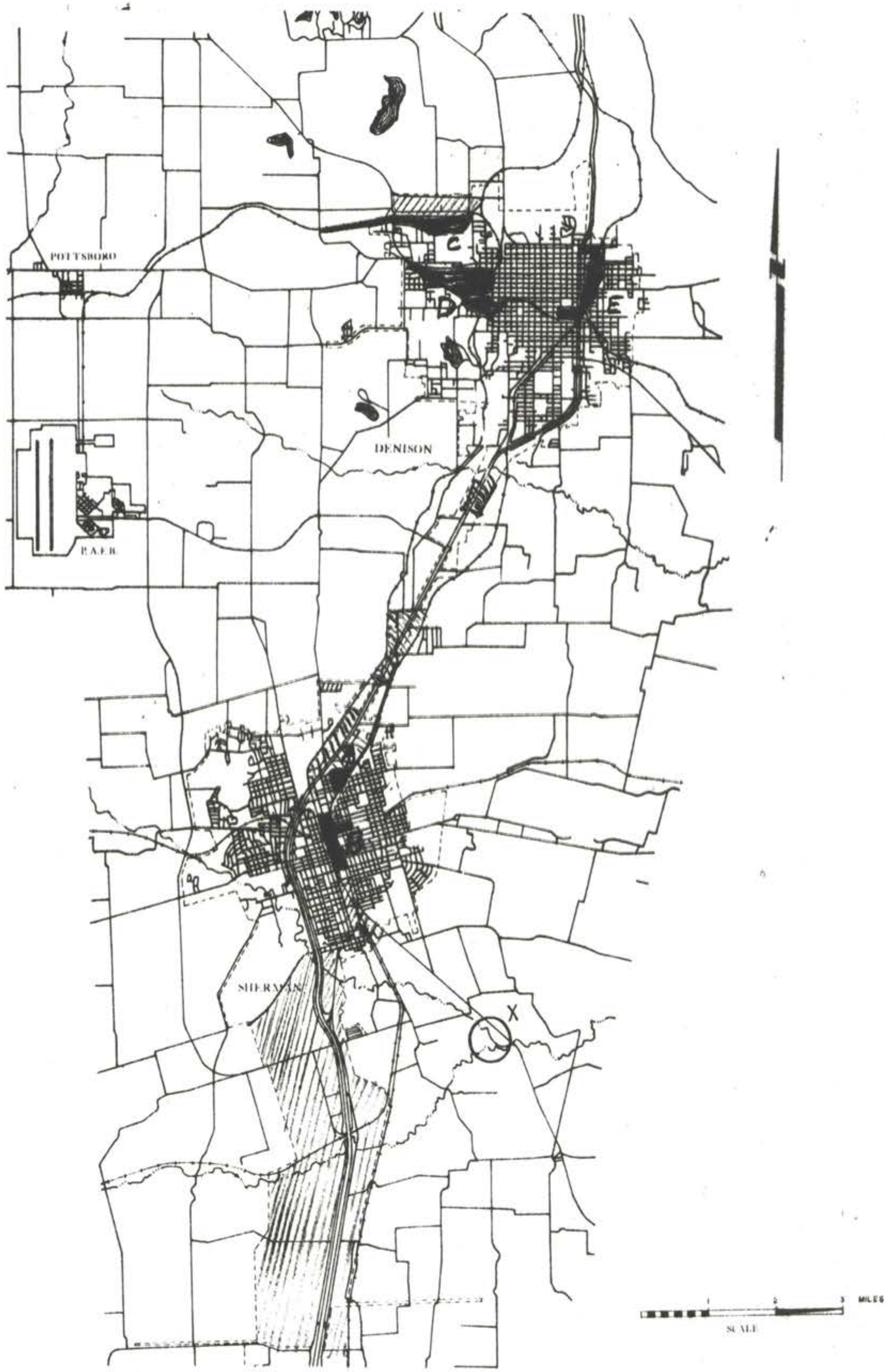

Figure 13. Industrial Land Use

apporoximately four times as much land for railroad uses. Three large yards (areas C, D and E) can be observed, all of which appear to have more of a maintenance function than a service function. Lack of maintenance along several lines indicates that they have been abandoned or are little used. As the railroad industry continues to decline in the Sherman Denison area, a major concern of the planner is: (1) to maintain an awareness of how declining railroad land use may be influencing other land use; and (2) how lands currently in declining railroad use can be best re-developed. Air photo interpretation aids in both problems by: (1) providing him with timely and accurate records of land use change; and (2) providing him with information concerning the physical environment which restricts planning options.

Study of Figure 12 reveals that the four-lane, divided highway running between Sherman and Denison, in addition to serving as a major interstate route, is having a major influence on land use along its corridor and appears to be causing highway-oriented (evidenced by extensive parking areas) commercial functions of the two cities to coalesce. While a prime goal of metropolitan planning is the development of sites and functions which can serve two or more urban centers, there are serious problems associated with unplanned coalescence. In this case, one can observe that, because there is unlimited access to the roadway, intensive development all along the corridor is beginning to cause traffic congestion which in turn, defeats the purpose of such a roadway. (Development concepts will be discussed later.)

The east-west highway running through Sherman is two-lane and probably intrastate in nature. Figure 14 illustrates the urban form Sherman would theoretically have if it were totally responsive to transportation land use. Such a theory suggests that urban development takes place according to isotims (time contours) reflecting driving time to the urban core via the most efficient traffic routes. It can be seen that Sherman responds to this theory to a considerable degree. Only areas in the northwest and southwest differ from the theoretical form. Study of Figure 12 (and Figures and) reveals that development in the southwest sector has been restricted because of a flood plain (which has only been restrictive because of the lack of economic importance of the western highway). The northwest sector has experienced more development than theorized, partially due to the influence of a secondary highway (FM 131). Of interest to the planner is the problem of determining what influence new traffic routes will have on urban form and land use. A correlation between theoretically derived isotims and physical restrictions (which can be easily determined by photo interpretation) can give a relatively reliable answer.

Figure 14, an aerial photo of southeast Sherman, pictures Sherman's community airport. Airport facilities and their influence on land use are critical planning problems.

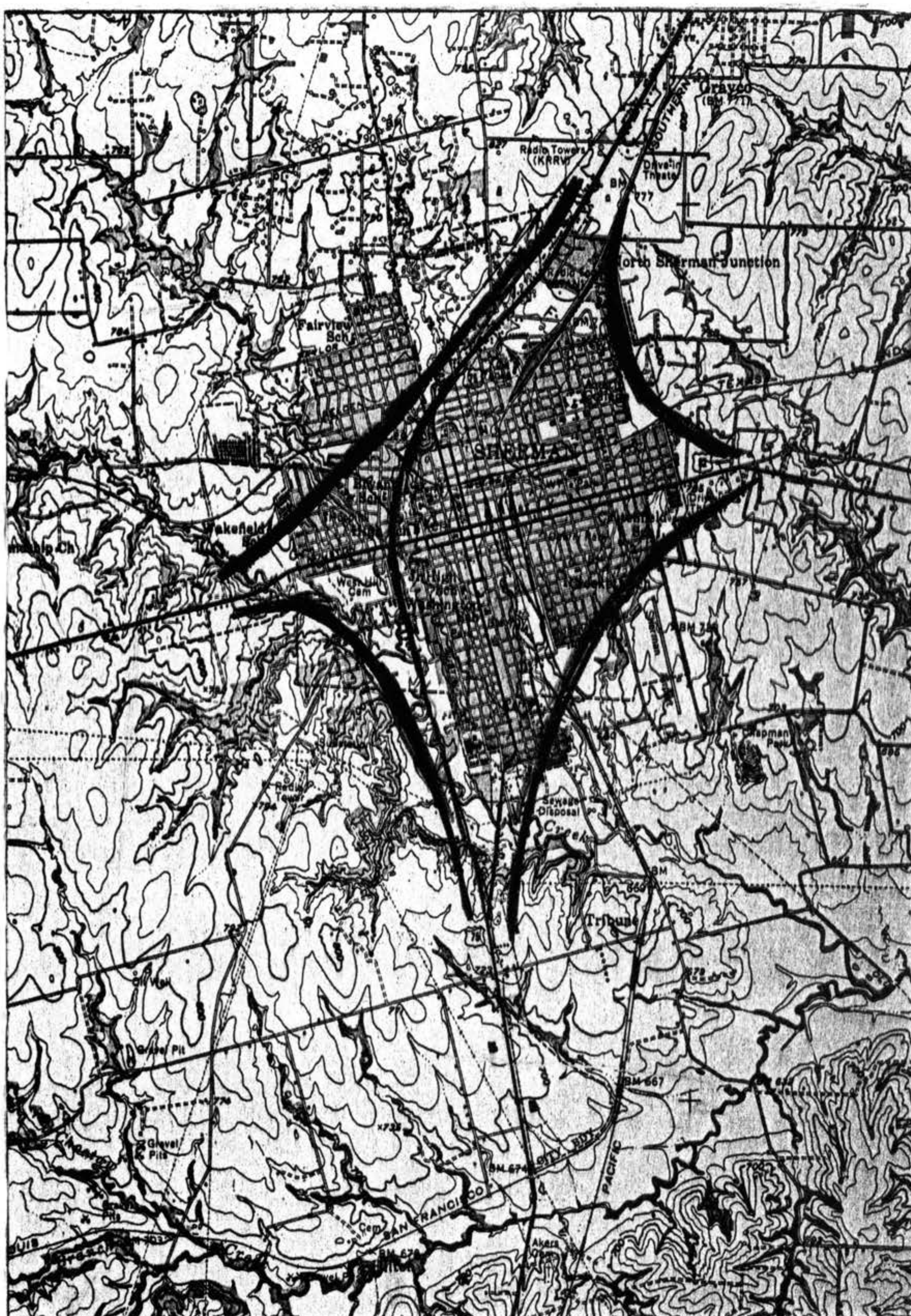

Figure 14. Transportation Influence on Urban Form

Studies by the Federal Aviation Administration have observed that an airport is a very important factor in attracting new industry to small and medium sized communities. Possibly because of the closeness of Dallas' Love Field, this observation has not been born out in Sherman; however, the community is very interested in developing a commercial and industrial air transportation capability. As revealed in Figure 14, even a very small airport takes up a great deal of land -- usually more land than can be afforded within an urban area. In addition, an airport is a very poor neighbor for many land uses. In this case, the hospital at A, the elementary school at B, the church at C, and all of the residential areas in the airport approach zone suffer from airport noise problems. (There is an additional safety hazard.) Though this airport is primarily used by general aviation, there will be an increasing demand for use by larger, more noisy aircraft unless another facility is provided. The planner may use air photos to great advantage in seeking a proper location for an airport. His first step is to determine how much land he needs for: (1) the air field; (2) supporting facilities and ground access; (3) approach zones (under which land use should be strictly controlled); and air space (with respect to other airports). The planner should next block out areas (residential areas, hospital zones, schools, etc.) which can afford no noise encroachment. He then may use topographic, soils, ground transportation, wind orientation, and other land use criteria

Figure 14. Sherman Airport

in determining a location for his airport. Whenever possible, he should give serious consideration to the use of existing airports (that meet his locational criteria) because few communities (of any size) can afford the proliferation of air traffic facilities. His next consideration should be the development of a multipurpose regional airport serving two or more communities.

Figure 15 illustrates the present thoroughfare plan for the Sherman-Denison area. Areas A through H represent existing or planned interchange locations in the thoroughfare system. Experience in other areas has shown that such interchanges are frequently subject to very intensive commercial and industrial development due to the convenient local and regional access such sites offer. This type of land development is already taking place in area C, where a regional shopping center is being constructed to take advantage of the soon-to-be constructed interchange between Highways 75 and 82. The development potential of area A will be studied in detail; however, areas B and D through H all possess some significant degree of development potential by virture of this transportation phenomena. At present, area C represents the most certain development potential, primarily because the area is already an established highway-oriented commercial sector. The interchange location will be very attractive to any regionally oriented enterprise.

Should plans to construct a by-pass Highway 75 north

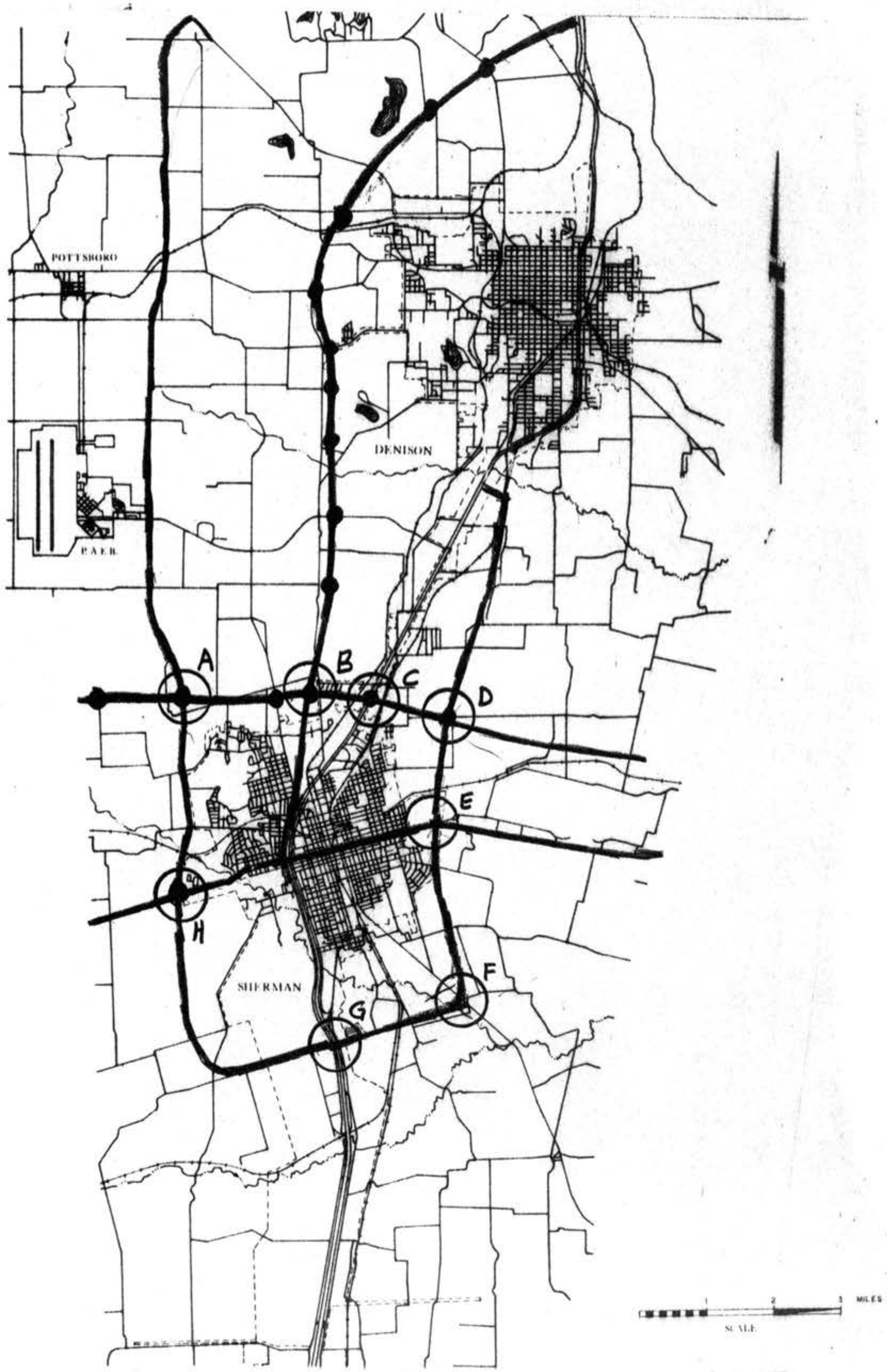

Figure 15. Thoroughfare Plan

of Sherman ever materialize, area B will have even greater development potential as a regional commercial center than area C. Before making the final decision on the location of this interchange, it is essential that an analysis be conducted to insure that the intensive development almost certain to follow can be properly supported without adversely effecting the land use balance of the area. Moving the location of the interchange or roadway only a small amount may have tremendous impact on the quality of development potential for the interchange area.

The current thoroughfare plan seems to give only secondary thought to the development requirements of East Sherman (there are reasons for this, such as the difficulty in providing utilities to some of the area, but such problems are of secondary importance in relation to the problem of establishing a balanced land-use program). Consequently, while areas D, E, and F presently show little or no development potential, they could and should become important elements in a more comprehensive development program for East Sherman. Area G is partially located in a well planned industrial complex south of Sherman. Major industries have already established themselves on the west side of Highway 75. Compatible institutional land-uses (fire station, highway department) have been established in the southeastern sector; however, small highway oriented businesses (in a generally deteriorated condition) and a small subdivision occupy the northeast sector. These land uses are not conducive to the proper development of this valuable land. A policy of re-development should be considered for the sector, particularly for the subdivision, even though it is in relatively good condition. The small businesses are apparently biding time until they can get a good price for their property; thus, it is only a matter of time before a more intensive non-residential land use develops in their place. This land use will make the subdivision increasingly susceptible to deterioration by the same forces of anticipation that are currently taking place with the small businesses. Such conditions often create economic and social liabilities for the community of sufficient magnitude to warrant taking corrective action at this early stage. (To a certain degree, this policy should be considered in all areas of changing land use. There are many means of conducting such a policy -- one means is that of taxing property according to its potential value rather than its present value.)

Area H represents a potential development sector at an existing interchange. Low intensity commercial development has already taken place in the area, but in an unplanned, uncoordinated manner which brings little economic benefit to the location. The topography of the site and a large health institution in the northeast sector limit the area's potential; however, residential land use is likely to develop around this area, creating a need for a local or community shopping center.

Continued surveillance of the planning area, using air photo interpretation techniques will allow the planner to keep track of problem areas such as those described above. He must continuously weigh existing land use with several potential land uses. Observing land use forces in action via air photos will be invaluable in this effort.

Utility

All urban development is dependent to a large degree on the availability of utility service. The planner can use utility planning as a major tool in controlling land use. Air photos, used in conjunction with projections of land use requirements based on expected population growth, can be used to determine: (1) service areas for utility systems; (2) corridors for lines; (3) sites for plants; (4) areas seriously limiting utility development; (5) maintenance condition and probable efficiency of above ground systems; and (6) areas requiring pollution control action.

Figure 16, an aerial photo of West Sherman, illustrates the use of air photo interpretation in determining service areas and corridors for a sanitary sewer system. Sewers (both sanitary and storm) should utilize drainage topography wherever possible. This topography can be easily determined in an air photo. Areas which can not use natural drainage features for sewer systems must have lift stations constructed to transfer sewage into another sewer system.

Drainage topography in the Sherman area does not

Figure 16. Sanitary Sewer System Analysis

severely restrict the siting of sewer systems; however, as noted under soils analysis, shrink-swell, corrosivity, and flooding characteristics must be carefully accounted for in all engineering design.

Air photo interpretation has proven to be an extremely valuable aid in pollution control. The planner can use air photos to locate existing and potential sources of pollution caused by sanitary, industrial and solid waste disposal practices. Study of area D in Figure 17 (Southeast Sherman) will reveal a sanitary fill operation located virtually on top of a major stream. This can be interpreted as an almost certain source of serious water pollution. Waste disposal sites can be readily located by air photo interpretation using drainage and soils criteria that protect against ground and surface water pollution. Further south (out of the photo, but located at area X on Figure 13) is Sherman's sewage treatment plant, another existing or potential source of serious water pollution. Pollution can often be detected on air photos by changes in water surface tones and patterns caused by the customarily warmer pollution.

Industrial

The survey and analysis of base-type industrial location is of vital importance to a community (particularly one which is heavily industrially-oriented) because it is commonly found that the following land use cycle takes place:

Figure 17. Sanitary Land Fill

(1) base industry locates with respect to existing (primarily natural) resources; (2) residential areas locate in support of habitat needs of industrial workers; (3) service industry (which includes all remaining land uses) locates in support of both the base industry and its workers; (4) the economic resource base is thus increased, attracting more base industry -- which causes a new development cycle. (A land use phenomena of vital importance to planning is that, the larger and more stable a community becomes, the more service industry-oriented it becomes.)

The industrial base of the Sherman-Denison area is illustrated on Figure 13. Sherman's south industrial area is extremely well planned, but the area still requires very thorough conservation and development policies. Of partiocular concern are transportation access (which can be observed as being particularly over-taxed in the Texas Instruments area), protection against incompatible land use, and waste control (which industries should individually or collectively provide for because community systems are seldom capable of handling industrial waste loads).

Figure 18 illustrates a zoned industrial area south of Denison on Highway 75 near Iron Ore Creek. Previous analysis of this area has revealed it to be a major outcrop area of the Woodbine (sandstone) formation and, consequently, of vital importance to the entire metropolitan area as a principal recharge area for that aquifer. Two land use restrictions must be enforced: (1) the ground water reserves must

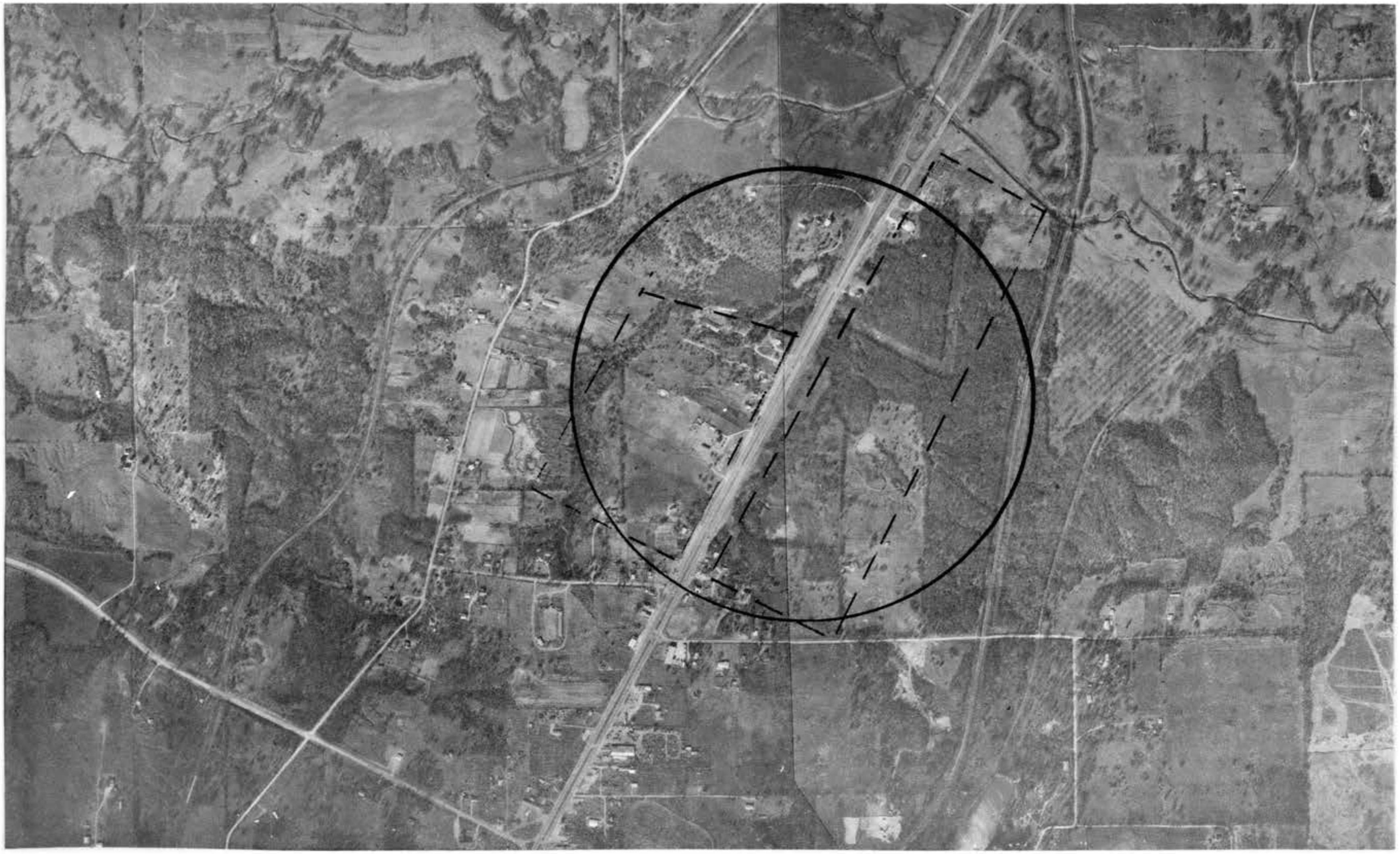

Figure 18. Iron Ore Creek Industrial Zone

not be polluted; and (2) the surface of the recharge area must remain highly pervious (in order to maximize re-supply of ground water). Either of these restriction is of sufficient importance to: (1) prohibit all but very low intensity land use (natural reserve,etc.); and (2) eliminate all existing intensive-type land use. (Because of the overlap that exists in all land use planning, industrial site evaluation will be illustrated at the end of this chapter in conjunction with other land uses.)

Institutional

Air photo interpretation can be used to great advantage in determining the distribution, classification, service areas, and influence of institutional land uses (schools, public and semi-public admisnistrative activities, fire stations, churches, libraries and post offices).

Study of Sherman area aerial photography taken between 1951 and 1959 reveals that schools have probably been the single most important influence on neighborhood development. Figure 19 illustrates existing school sites, their classification, and probable service areas. Figure 20, an aerial photo of Northeast Sherman, illustrates the proposed site (area A) of a new high school. Assuming that this school will generate residential growth of considerable magnitude, the planner should investigate the surrounding area's physical character to determine if the expected development can be supported. Soil and terrain analysis

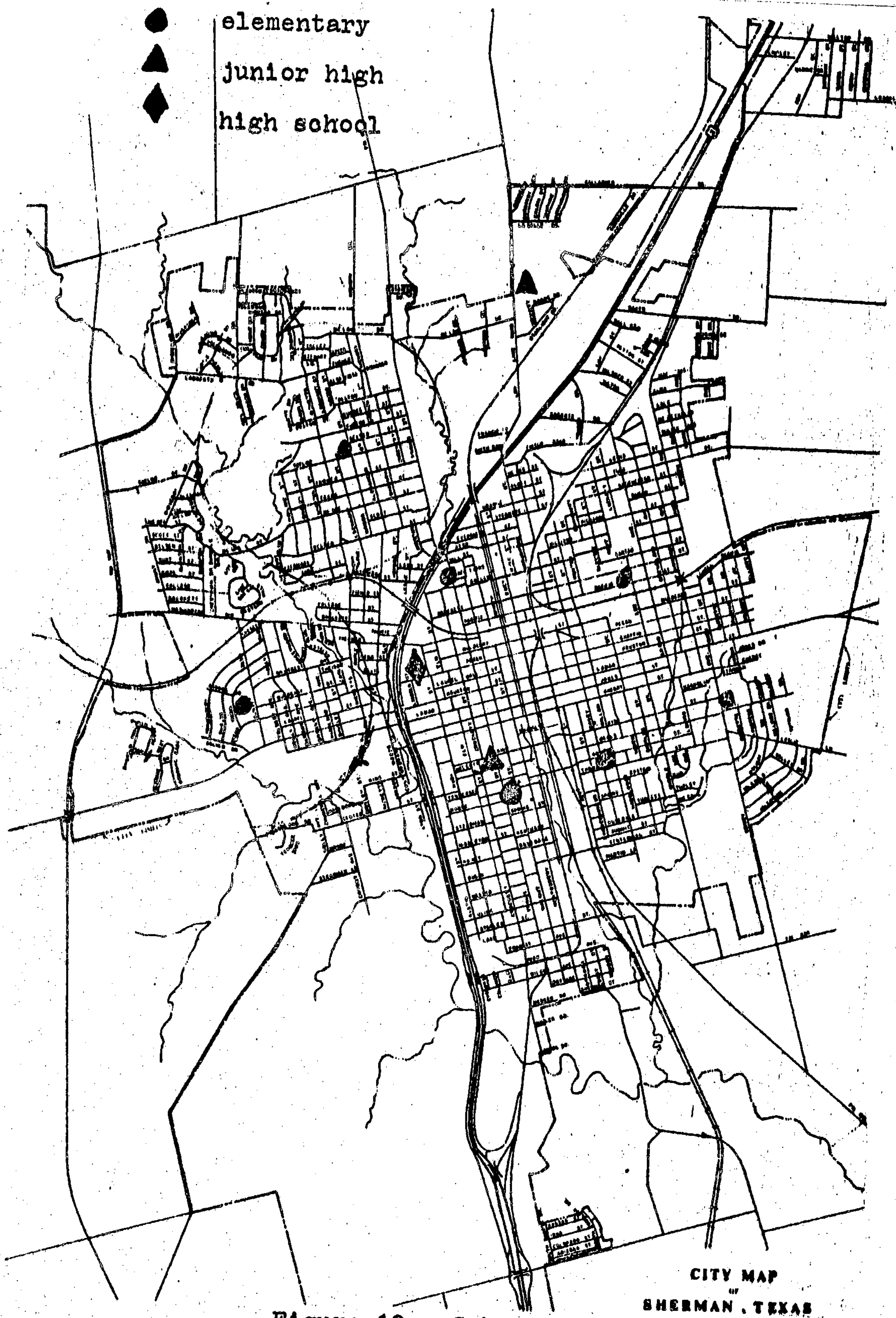

Figure 19. Schools

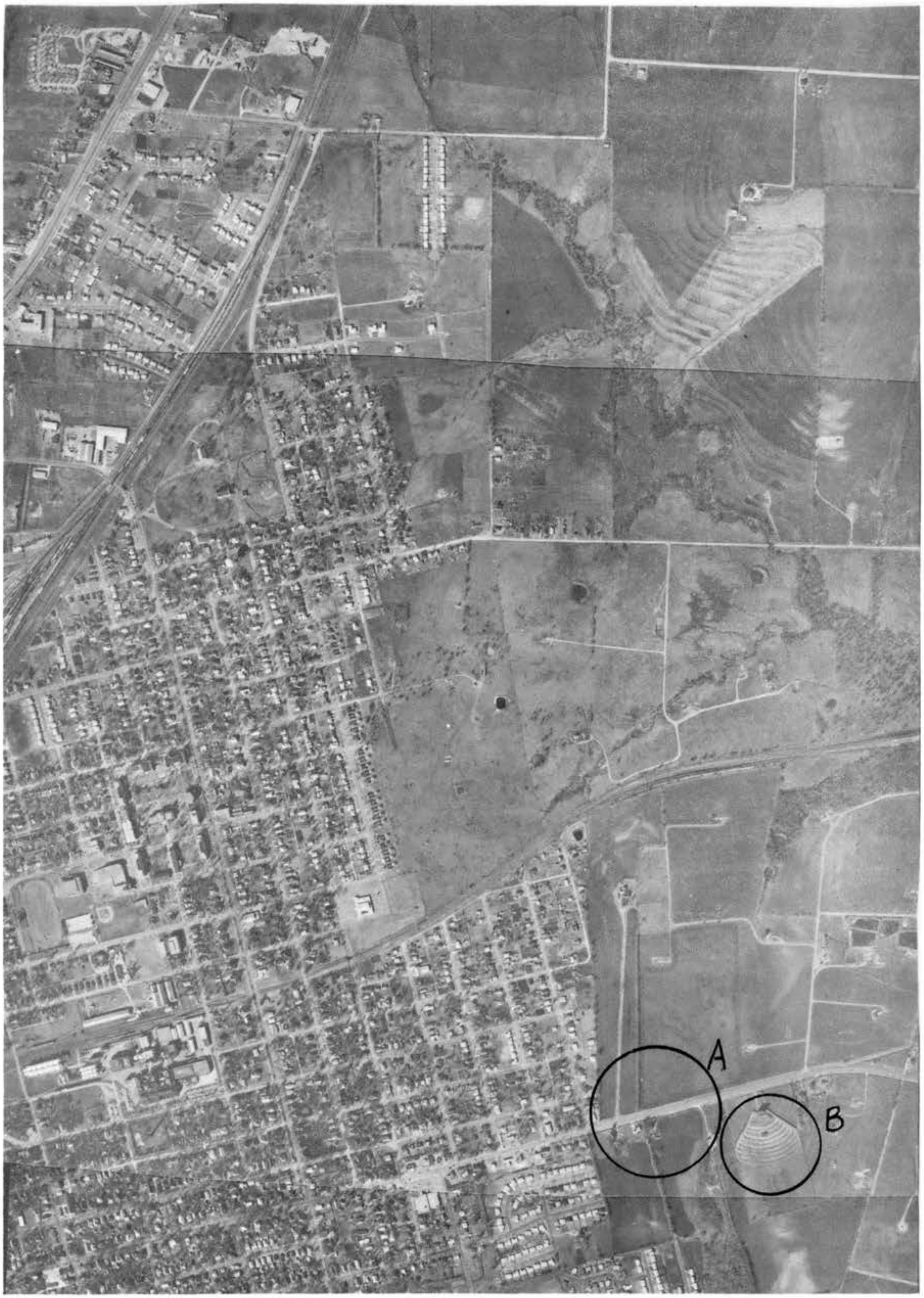

Figure 20. Proposed High School Site

have indicated this area to have serious limitations for any type of intensive development; however, most problems (utilities, drainage, shrink-swell, impermeability, erosion, corrosivity, and traffic support capability) can be managed through proper planning and engineering. Study of Figure 20 reveals several potential problems with respect to surrounding land use, such as a growing highway-oriented business strip along Highway 82 and a drive-in theater at B. As previously mentioned, this area is in the approach zone for the airport in southeast Sherman, making the proposed school and residential land uses potentially incompatible; however, it is more feasible to relocate the airport than the proposed land uses. Further analysis of Figure 20 reveals severe traffic access limitations for the high school site. Virtually all of the school's service area is west of the site, making the development of cross-town arteries a high priority of immediate concern.

Continued air photo investigation of this land use phenomena will reveal the space-time relationships that exist between the land use generator (in this case, the high school) and its surroundings.

Commercial

Figure 21 illustrates Sherman's Central Business District (CBD). Study of this photo allows the planner to readily determine the extent, access, land use and relative condition of the CBD. Figure 21 delineates the extent of

Figure 21. Sherman Central Business District

the CBD area and its inner core. The shape of the inner core again reflects the influence of transportation. The core is elongated in the north-south access, reflecting the predominant economic influence of old Highway 75; and is more constricted in the east-west axis, reflecting the lesser influence of Highway 82.

Study of Figure 23 reveals: (1) primary access routes (denoted by arrows), their capacity and direction of flow (many are one-way); (2) on-street parking, (such as at A), capacity, and extent of use; (3) off-street parking (such as at B), its location, capacity, extent of use and distance from shopping areas; and (4) covered off-street parking (areas C and D), its location, probable capacity and distance from customer destinations.

A problem of particular concern to the planner is that of locating parking facilities so that they are readily accessible from outside the CBD, and yet are centrally located within the CBD. In addition, multiple and time-staged use of parking facilities by several activities is a major goal.

Study of Figure 23 will allow the planner to determine, primarily by land use associations, probable uses of individual structures and areas. The large structure at A, by virtue of its shape, parking and proximity to several large athletic fields can be interpreted as a high school. The structures at B and C can, by virture of their extensive ground, prominent positions, and multi-story heights be

Figure 22. CBD Access/Parking

Figure 23. CBD Land Use

interpreted as municipal and county offices, respectively. Structures D and E, by virtue of their size, unique shapes and prominent positions can be interpreted as churches. The long, narrow buildings along the main business street (area F) can be interpreted as retail stores (the width of the structure indicating to a large degree the size or number of products sold). The structure at G can be readily identified as a railroad station; while that at H is, by virtue of its shape (particularly the shape of its roof), large size, extensive parking and detached location, a large grocery-chain store. The large structure at I, by virtue of its surrounding land use, size, and tell-tale ventilation stacks in its roof, can be interpreted as an industrial structure.

The condition of CBD structures can be readily determined from very large scale air photos (such as the 1:200 scale color photos being used in the Sherman-Denison Urban Transportation Study); however, even with smaller scale black and white photos, such as Figure 24, the planner, by associating various land use indicators, can determine areas requiring: (1) conservation; (2) re-habilitation; and (3) re-development. Study of Figure 24 suggests that CBD commercial activities located outside of area A are probably on the decline; consequently, their structures can, by virtue of their probable old age, be interpreted as in need of major repair or removal. Structures in area A, while their enterprises may be economically sound, are probably old and

Figure 24. CBD Condition

in need of extensive repair. Structures in area B, by virtue of evidence of recent construction, are relatively new and, thus, well maintained; however, a strict conservation policy is required because of their weak, off-set position from the CBD.

Area C is a relatively new, and apparently well maintained peripheral shopping center (located as a result of the nearby interchange). This area is challenging CBD land use; however, there is insufficient space, traffic access and control for it to be an efficient community center. A great danger exists that it will generate an extensive commercial strip to the CBD, further constricting access to the latter.

Residential

Studying Figure 25, West Sherman, the planner can easily detect patterns in residential areas which are indicative of their age, condition, approximate value, and the socio-economic status of their occupants. Areas designated as A reveal large structures, contoured street patterns, and large, well landscaped lots indicative of high value homes belonging to prominent citizens. Areas designated as B are relatively new, moderately large, well maintained homes, most likely occupied by persons of middle management economic status. Homes common to C areas are similar in status to B, except that the structures are older, smaller and showing need of minor repair. (These

Figure 25. Residential Area Analysis

areas will rapidly deteriorate if a strict conservation and rehabilitation policy is not followed.) D areas are still older residential areas requiring more extensive rehabilitation. E areas are fairly old (as evidenced by mature trees throughout the areas), small to moderate sized homes in need of selective or area wide removal. Area F is a trailer court, which, by virtue of its configuration and spacing between trailers, seems in moderately good condition. Area G is a new medium value subdivision. Due to its position on a flood plain it will require careful management attention.

Study of Figure 26 reveals several commonly imcompatible land uses in residential areas. A railroad across the top of the photo has been a major deterrent to residential development in area A; however, the same railroad has not restrained very high quality residential development in area B. A hospital complex in area C has had little noticeable restraint on residential development; however, access to the hospital is constrained by the residential sized streets in the area. A very serious situation exists in area D where a commercial strip is rapidly developing. In addition to the traffic congestion these developments cause, there is an additional deteriorating force on residential areas in the immediate area (primarily due to the anticipation phenomena discussed earlier). Areas E, F, G, H, and I are all subject to frequent flooding. Area E is a high quality subdivision which can probably recover from

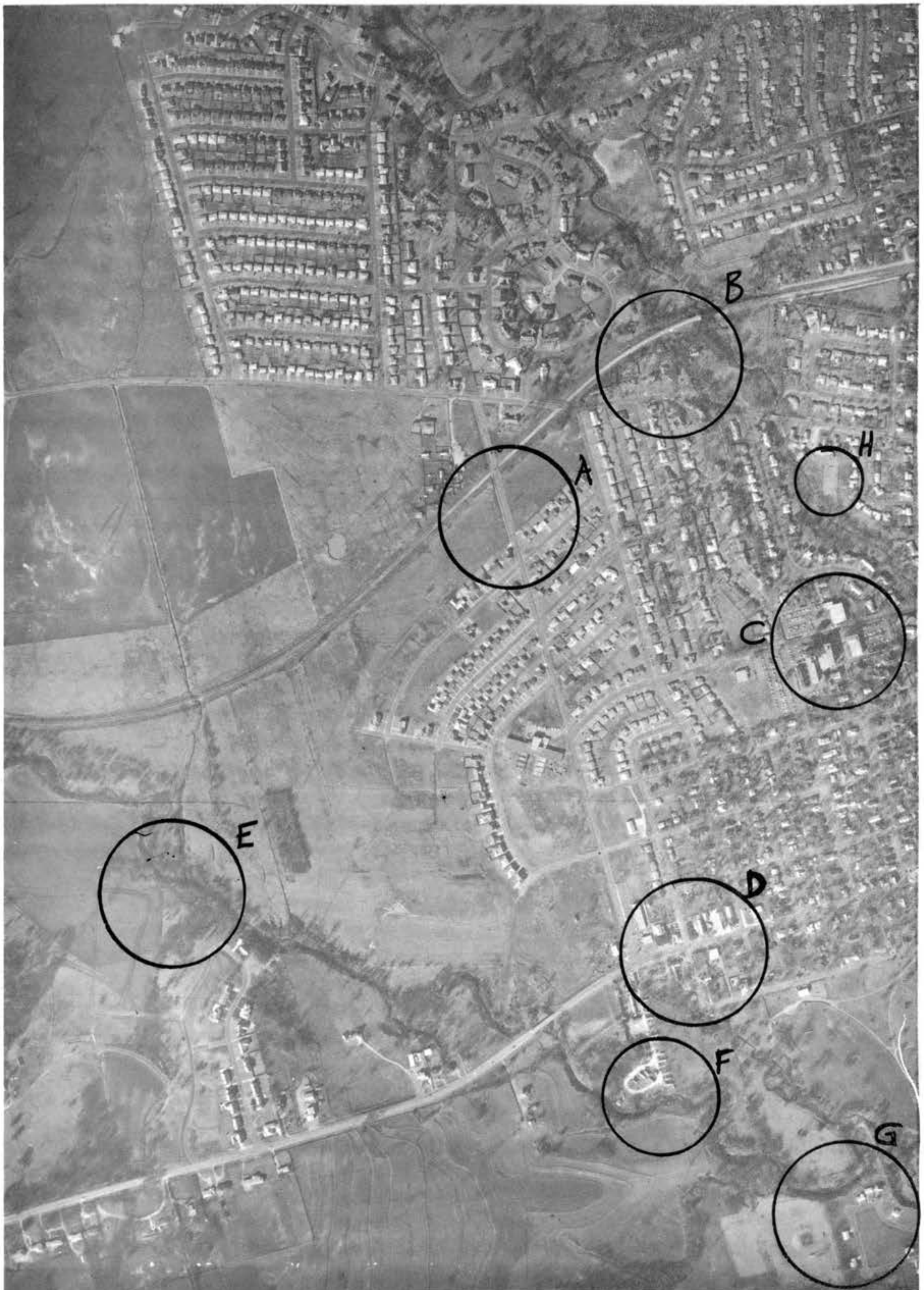

Figure 26. Residential Area Analysis

severe floods while its structures are still relatively new; however, the other areas will likely deteriorate rapidly as a result of frequent flooding.

Recreational

Air photo interpretation has received wide use as a means of inventoring recreation sites; however, metropolitan area requirements are primarily: (1) intensive play areas, picnic grounds, camping grounds, trails, and scenic drives. Recreation becomes increasingly important as society gains free time and mobility; also, as society becomes more urbanized, contact with the natural environment becomes more essential.

Recreational land use has an advantage in site selection over most other land uses in that it does not require intensive development. In particular, recreational functions can frequently be accommodated on land that can not be properly used for other purposes. An example of this practice is illustrated in Figure 27. As determined earlier, this site (the outcrop area of a principal aquifer) should not be used by any intensive-type land use; however, low intensity recreational land use would be acceptable. Study of Figure 27 reveals existing recreational land use in the form of a lake (area A), picnic ground, and further south (off the photo), a country club and golf course. The wooded ravines on either side of Highway 75 are both conducive to the development of natural areas with trails,

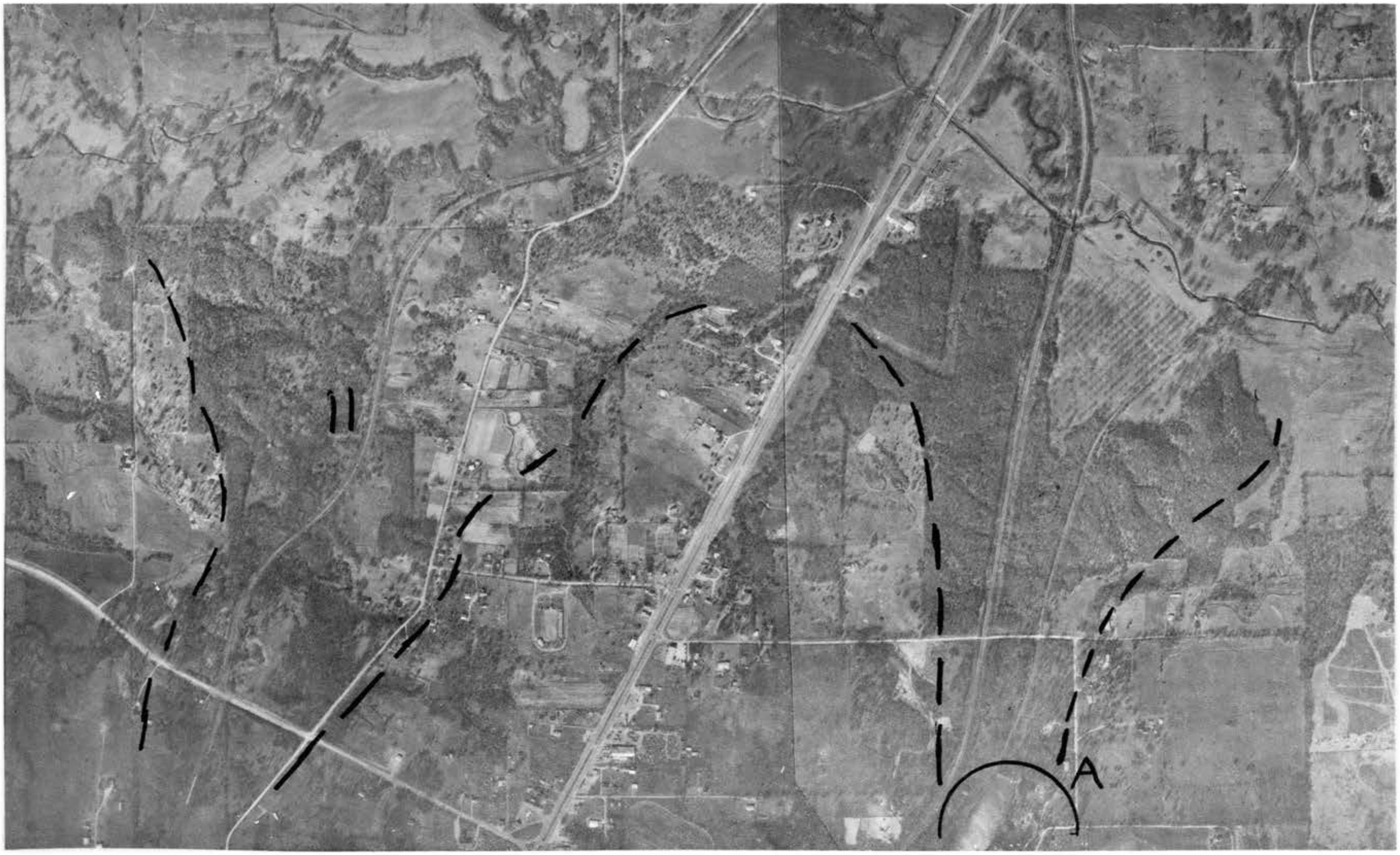

Figure 27. Recreation Site

bridle paths, small reservoirs and low density picnic and camping facilities. Roadways and structures should be held to a minimum and designed so as to minimize surface run-off. Urban recreational land use will be discussed in conjunction with open land use.

Open Land

Air photo interpretation aids the planner in determining which undeveloped areas should be: (1) reserved for open land use (floodway, recreation, agriculture, transportation and some very low intensity utility, industrial and commercial uses); and (2) planned for more intensive development.

The planner is particularly interested in getting multiple benefits from open land; specifically, many low intensity land uses can be supported on the extensive flood plains that exist in most urban areas.

The flood plain in area A of Figure 28 represents an open area which must be conserved because intensive development (in addition to being highly impractical) would greatly restrict the flow of flood waters, creating, in turn, greater flood damage upstream. Earlier soils analysis has indicated that, even if this site were geographically desirable for recreational use, the soils conditions would be very unsatisfactory. However, agricultural use of the land is both compatible and profitable. Because non-agricultural development limitations of this site are

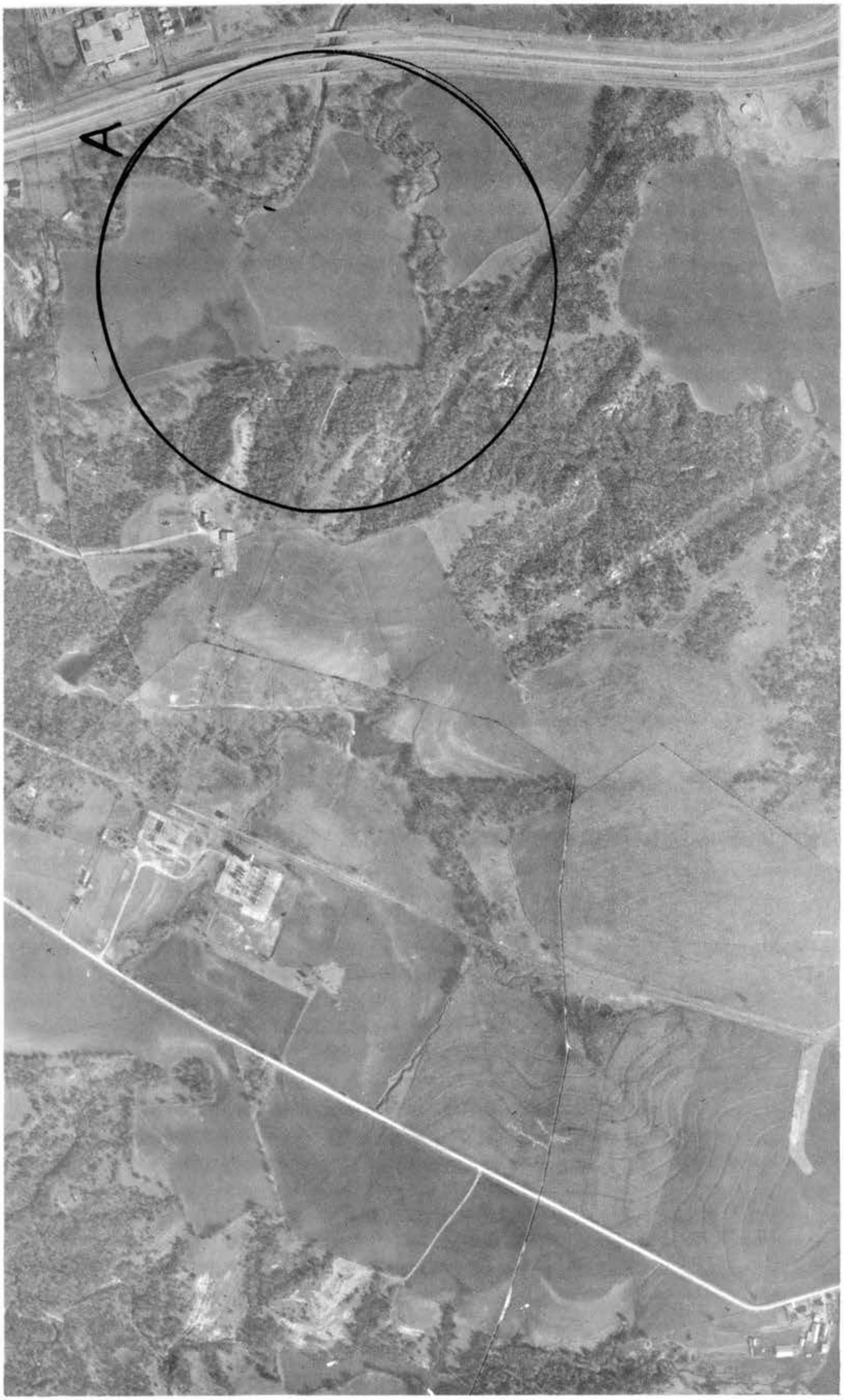

Figure 28. Open Land Use

fairly permanent, the planner should encourage the most intensive agricultural development possible on this land.

Figure 29 delineates several existing parks (A through I) and an extensive flood way system. Most of the parks have been situated along the floodways. Some (B and E) appear totally unusable as recreation facilities, while others are severely limited in size and access; (though a very extensive park has been developed at A). Air photo interpretation readily reveals the location of current floodways and the extent of past floods (the areas delineated). The floodways in the northeast and central areas are too narrow (wtih steep, highly erodible slopes) to be effectively developed for recreational or agricultural uses; however, the floodways in the northwest and south offer considerable opportunity for both uses. Particularly in the northwest, floodways can be developed into parkways which tie various neighborhood units together.

The second aspect of the planner's open land analysis is the location of sites for new, intensive development. As mentioned earlier, such development can be expected in the vicinity of highway interchanges.

Figure 30 illustrates the interchange site for Highway 82 and Farm Road 1417. The physical characteristics were discussed earlier under Soil Analysis. In that analysis it was determined that natural conditions in this area presented moderate to severe land use restrictions due to such soils engineering characteristics as: (1) moderate to high

Figure 29. Parkway System

Figure 30. Planned Development Zone

shrink-swell ratios; (2) moderate to high corrosivity; (3) slow percolation rates and moderately impermeable conditions (4) low to moderate traffic supporting capability; and (5) susceptibility to flooding in low lying areas. These soil characteristics place major restrictions on virtually every type of possible land use for the area; however, this does not mean that development is prohibitive. The ratings primarily are guides for determining: (1) how to take best advantage of natural conditions; and (2) what characteristics must be corrected or protected against in order to have safe and effective land use development. Each potential land use will be evaluated according to these guides:

1. Transportation. Traffic supporting capability can be corrected by several methods depending on transportation requirements. The ratings given apply primarily to unsurfaced roads, which are seldom used in urban areas; surfaced roads can be designed to correct for poor soil conditions. If the roadway must traverse a floodway, it may be necessary to design a bridge with piles extending to bedrock or sufficiently deep into the soil to support the bridge. In this area bridges or culverts should be constructed over all large gullies and stream beds because of frequent flooding conditions. The floodways should not be constricted any more than absolutely necessary.
2. Utility. High corrosivity ratings make cathodic

protection of underground utilities essential.

3. Industrial. Light and restricted industrial development must account for shrink-swell, corrosivity, and topography (area must be relatively level). Each of these problems can be managed in this area through proper engineering design. The sandy loam soils immediately west of FM 1417 (area A in particular) are slightly more suitable for large structures than the clay loam soils further west or the clays to the east. Heavy industry is severely restricted in this area due to soil characteristics, the close proximity of residential areas and building height limits in the Perrin AFB approach zone.

3. Commercial and Institutional. For large structures or complexes, the above industrial evaluation applies. Care should be taken not to constrict floodways, a restriction that considerably limits the amount of land development immediately west of the interchange.

4. Residential. Land use evaluation must consider two separate conditions: (a) the site is serviced by public utility systems, in which case this area's soils would present only moderate restrictions in the form of shrink-swell, surface drainage and corrosivity problems; and (b) the site is not serviced by public utility

systems, in which case this area's soils offer severe to very severe restrictions in the form of slow percolation rates and shrink-swell ratios as they effect septic tank systems.

5. Recreational. The soils and terrain of this area offer moderate restrictions on the development of intensive play areas, camping grounds, picnic sites and trails. Most serious restrictions arise from flooding, slow percolation in impermeable soils, and poor trafficability characteristics.

Using these individual land use capability ratings, the planner next attempts to establish priorities among competing demands. Considering only the soil capability ratings, it is noted that the area offers only slight to moderate problems for properly planned and engineered transportation, industrial, commercial, institutional and recreational development; however, moderate to severe restrictions are placed on residential development (primarily because this land use is not sufficiently intensive to afford the costs of correcting or protecting against problems associated with the soils and topography).

Further evaluation takes into account area wide land-use requirements and existing or expected trends. It is noted that residential developments are rapidly moving in this direction from Sherman; however, in addition to the above mentioned soils limitations, the planner notes that this area is very near a Perrin A.F.B. approach zone. Residential development in this area would be totally incompatible with existing land use. Many institutional land uses (schools in particular) would be similarly restricted. This analysis reduces potential development to transportation, industrial and commercial and recreational land uses. All of these uses are generally compatible with each other, provided proper codes and zoning regulations are enforced. In addition, these land uses are generally compatible with the Perrin approach zone, the oil fields and agricultural land uses existing in the immediate area. At this point a land use plan should be prepared and correlated with local zoning officials. This plan is not absolute, but it should not be changed unless it can be proven that such change is beneficial to the overall land use program of the area.

CHAPTER IV

SUMMARY

It is becoming increasingly apparent that urban and regional planning must become more responsive and more comprehensive. These requirements demand an information system which is capable of conveniently, rapidly, economically, and reliably collecting, storing, retrieving, analyzing and disseminating data pertinent to planning problems. Air photo interpretation provides these capabilities possibly more effectively than any other planning tool or procedure. In addition, air photo interpretation techniques can be readily learned and applied by any planner. The potential of air photo interpretation in urban and regional planning is limitless; however, its effectiveness is directly related to the planner's understanding of his field. It is in this latter area that much progress must be made; the planning profession has only begun to develop a comprehensive understanding of urban and regional settlement phenomena.

Proposals for Continued Research and Development

Development of Comprehensive Interpretation Techniques for all Forms of Remote Sensors

Intensive research is presently being conducted by government agencies, universities, and research-oriented industries in an effort to develop hardware and applications for the many forms of remote sensors. Of particular significance to urban and regional planning are infra-red sensors, K-Band radar sensors and color photography. Much effort is being applied towards the development of automated interpretation techniques; while such a capability is practical and invaluable in many areas of environmental science (particularly in natural resource inventory and pollution control) it is unlikely that it can be practically applied by the average planner. Rather, the planner should rely on his own ability to observe and evaluate the environment. In this regard, manual interpretation allows the air photo (or other remote sensing records) to be merely an extension of his ability to observe.

Development of Interpretation Keys

Resource survey and management analysis in urban and regional planning is very conducive to the use of interpretation keys. The keys can be of great assistance in allowing the planner to extend his experience and competence in identifying and evaluating environmental phenomena.

Development of Photo Depositories in Each Urban Center

At present several federal, state and local agencies use air photos for specific needs. In Sherman the Soil Conservation Service works with 1951 photos, the Soil Stabilization and Conservation Service works with 1956-1958 photos, and the Texas Highway Department works with 1965-1969 photos. Only the Highway Department uses color photography and none use other remote sensing materials. Each of these agencies, and numerous others, has a vital need for photo coverage taken over the years, taken at different scales, and taken in different mediums (panachromatic, color, infra-red, radar, and, possibly, laser). None of these agencies can individually afford to obtain and maintain such coverage; therefore, it is proposed that consideration be given to establishing a central depository for these materials and other reference materials pertinent to environmental planning, with the cost of the depository operation being distributed among all users. Implied in the establishment of such a depository is the policy that photo coverage be updated and expanded whenever economically feasible. In addition, it will be necessary to develop automated handling devices for storing, retrieving, viewing and disseminating (reproducing) photo materials.

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APPENDIX A

FUNDAMENTALS OF AIR PHOTO INTERPRETATION TECHNIQUES

Air photo interpretation can be defined as:[1]

> The utilization of systems, techniques, or processes for analyzing photographs that enables skilled scientific or professional personnel, by virtue of their individual experiences, to produce significant, reliable, and detailed information concerning the natural or cultural features of the area photographed and to determine or infer the factors that the observable presence, condition, or use of these features imply.

Air photo interpretation has been called a "tool science" in that it is essentially an analytical tool which can be used in an unlimited number of ways. The principal advantages of air photo interpretation are:

1. Its tecnhiques can be learned effectively with only a minimum of training by any person with a good background in natural science.
2. Its speed, timeliness and ability to record the total state of the area photographed at a partiqular instant in time.
3. Its expense, which when compared with conventional ground survey methods, is extremely economical.

Many of the above advantages stem from the unique characteristics of the aerial photograph, in particular:

1. The vantage point of an air photo is such that very large areas of the earth's surface can be viewed in a

single photo. When viewed stereoscopically, a three-dimensional terrain model is created for the interpreter.

2. The resolution of good quality aerial photography is much finer than that of the human eye; consequently, the photo is able to record objects which could not be detected by the human eye from the same vantage point.

3. The ability to perceive outside the visible spectrum allows the photograph to record objects and/or conditions which can not be seen by the human eye.

4. The reliability and geometric fidelity of an air photo provides an unbiased, infinitely detailed representation of all the objects and/or conditions being photographed.

5. The permanency of the air photo allows it to be viewed at the convenience of the interpreter and under conditions of his choosing.

6. The versatility of the air photo in that it can be used by an unlimited number of interpreters for an equally infinite number of analyses.

In general, applications of air photo interpretation techniques are limited only by the interpreter's imagination, his ability to obtain usable photography and his ability to exploit the information contained in the photo. The last factor is primarily dependent on the interpreter's background experience and analytic skill.

Air photo interpretation is but one division of a very complex photographic science. The effectiveness of air photo interpretation techniques is responsive to developments, products and limitations in most of the other divisions of photographic science. A prerequisite for competent interpretation is a fundamental understanding of the photographic process, of basic matter and energy relationships, of the atmosphere, and of aviation. The reader is referred to the references listed at the end of this appendix should information be desired concerning other divisions of photographic science. It should be remembered that the basic principles of air photo interpretation are unchanged, regardless of the types or character of materials, processing and equipment involved.

Aerial photography includes both image forming and non-image forming sensors. Both forms are important, and usually complementary, in comprehensive photo interpretation. While this paper is limited strictly to image forming sensors using the visible spectrum, attention is called to the existence of other sensor forms. These sensors, called collectively remote sensors, are defined as optical, mechanical, or electrical devices which record data relating to physical phenomena separated by some intervening distance from the recording instrument.[2]

Sensors are designed to be sensitive to radiations within a specified portion of the electromagnetic spectrum. The physical properties of electromagnetic waves within these different ranges result in different types of data and different data-gathering constraints for various sensors. These properties are summarized as follows:[3]

1. Sensors using visible light, record types of tonal and textural variation visible to the eye and produce an optical image or photograph. In the case of the conventional camera

a photograph is equivalent to an image; image, however, is a more general term because it refers to all visual representations of the object surface, irrespective of the way in which the visual representations are produced. At present, sensors utilizing visible light possess higher resolution capabilities than other operational systems since they discern variations of a smaller spatial extent.

2. Infrared sensors register the thermal emissions of objects by recording impulses of longer wavelength than those of visible light. The important difference between infrared sensors and visible light sensors is that radiation levels at different points within the object area are recorded electronically, not optically, to produce an image. Resolution is a function of the sensitivity of the original recording equipment. At present, resolution levels achieved by infrared sensors are not so high as for conventional systems; however, they are not limited to daylight, haze-free operation, and they possess some ability to penetrate clouds.

3. Microwave and radar sensors utilize still longer wavelength pulses. Essentially, they measure the roughness of the object surface, and by a sequence of operations similar to that for infrared sensors an electronic image is produced. Current imaging radars possess the poorest resolution capabilities among sensor types, but they compensate for this by the ability to cover from the same altitude much larger areas in one image than either of the other types of sensors. An important additional advantage is the ability to operate effectively both day and night under virtually all weather conditions.

The different properties of these sensors make it necessary to analyze their various capabilities to determine which sensor, or combination of sensors, can most effectively obtain data for a given problem.

There are two basic approaches one can take in interpreting air photos. The first, and most common, is referred to as "logical search." In this approach, the interpreter (who is usually a specialist in some field of natural science) begins by rapidly scanning the study area as a whole looking for probable indicators of objects or conditions in which he is interested. He disregards all information which is not likely to contain the desired information. Upon locating a probable indicator of the object or condition for which he is searching he conducts an intensive study to obtain whatever information he needs. This approach is fast and efficient when only a narrow range of information is required; however, it requires considerable experience and analytical skill on the part of the interpreter.

The second approach might best be referred to as "systematic search." It is less commonly employed because it takes more time and, to be effective, requires a fundamental understanding of the entire range of natural science by the interpreter. However, this approach is absolutely essential for any type of comprehensive analysis of an area. Because the purpose of this paper is to illustrate the application of air photo interpretation techniques to problems in comprehensive urban and regional planning only the "systematic search" will be described.

It is recommended that the steps in the interpretation sequence be:

1. A statement of the basic problem to be studied.
2. A delineation of the study area on a map.
3. A determination of photograph requirements. While the smallest usable scale photography, obtained with the film and filter combination, that provides the best subject/background contrast usually yields desired answers most economically in the "logical search" approach, rarely is one set of photos sufficient for the comprehensive analysis requiring the "systematic search" approach. Whenever possible it is advisable to obtain

photo coverage of the study area in large and small scale, for different seasons, and for different years (the latter is essential if detection of change is part of the problem). Interpretations should invariably be more accurate and complete when more than one set of photos is used. (Note: The entire United States has been photographed from the air at least once. Most of this photography is suitable for general photo interpretation problems. Most of the available coverage was flown for the U. S. Department of Agriculture and is commonly vertical, panachromatic-minus-blue film and filter combination and of scale 1:20,000 in a 9 inch square format. Other sources of photography are the U. S. Geological Survey, U. S. Forest Service, U. S. Coast and Geodetic Survey, NASA and the various state highway departments.)

4. Research of all available background information, such as topographic maps, soil maps, geologic maps, watershed studies, etc., which may be pertinent to the problem under study.

5. A study of any available photo interpretation keys which may be pertinent to the problem. This step is particularly important if the information to be extracted during the interpretation is to be based solely on the study of images.

6. Set up a work area and assemble materials and equipment. A great advantage of air photo interpretation is the flexibility available during this step. While many complex and costly instruments are used for special purposes, the essential elements of the interpretation can be conducted at any location with three simple and inexpensive items of equipment: a stereoscope, a colored pencil and a measuring device. Although stereo study is not absolutely necessary for all interpretation tasks it is essential whenever the significance of three-dimensional forms is critical. Stereo study permits the interpreter to see a minutely detailed, precisely accurate three-dimensional terrain model. An exaggeration of vertical distance is present in the stereo illusion; however, it helps to emphasize small but important differences in elevation and separates objects from their background.
7. Upon receipt of the photographic materials the interpreter orients himself with respect to the photos and locates each photo with respect to a map of the study area.
8. The photographs should be given a rapid preliminary examination under the stereoscope.
9. Objects and conditions of interest are detected in a systematic manner which depends on the nature of the problem; however, regardless of the specific nature, all subsequent identification results from a process

of classification according to size, shape, shadow, tone, texture, location and relationship to surrounding objects. During each of these evaluations it must be remembered that the ability of the human eye to detect and identify objects or conditions in an air photo ultimately depends on reflection differences between subjects and their backgrounds, which in turn relates back to a fundamental understanding of both natural and photographic science.

10. Intensive care must be exercised in identifying and evaluating regional and local patterns. This element is of particular importance to comprehensive analysis because it often will correlate several basic objects or conditions of interest. Regional patterns are only observable from an aerial vantage point; consequently, there may be little or no background data to aid in their identification. The interpreter should take care to differentiate all regular appearing patterns as these are virtually always indications of cultural activity. In most cases identification should proceed from general patterns to specific features and from the known to the unknown.

11. Interpretation should now extend beyond the photo reading stage that has just been described, and determine additional information concerning factors implied by the presence, condition or use of features

identified. It is usually basic that the interpretation proceed with an evaluation of probable geologic origin, landform, surface drainage, and erosion features, soil type and vegetation. This analysis should be transferred to mosaics of the study area (if available) or maps and studied for evidence of large scale regional trends. Subsequent to these evaluations come specialized evaluations peculiar to the problem under study. The application of specialized interpretation techniques to problems in urban and regional planning is covered extensively in the main body of this paper. Applications relating to other fields are discussed in detail in the references for this appendix.

12. At any point within this sequence, the interpreter may find it desirable or necessary to conduct a photo-planned field check or sampling survey for purposes of securing more reliable information or verifying and expanding the results of the interpretation. The amount of field work which will be necessary varies with the accuracy and intensiveness requirements of the study, the complexity of the area, the quality of the photos and the ability of the interpreter.

13. The detection, identification and interpretation stages each benefit greatly from the use of comparative analysis. Specifically, whenever possible the interpreter should compare:

(1) What is seen in the photos with the information contained on related maps.

(2) Photos obtained at different times in order to assess changes.

(3) Photos exposed at different portions of spectrum for more comprehensive understanding of the area.

(4) Black and white photos with color photos of the area in order to take advantage of the increased capability of the human eye to differentiate between colors.

(5) Photos of one area with those of other areas. It is often possible to use one photo as a "key" for another.

14. In summing up, the indicative weight of each element is compared with all others in such a way that a conclusion can be formed on the basis of convergence of evidence. The principle of convergence of evidence assumes that the interpreter has been able to recognize basic features and consider their arrangement in an areal context so that the most probable interpretations suggest themselves. Further intensive examination of the evidence should show a convergence towards but one of the probable interpretations.

After all conclusions have been correlated an analysis is presented in a report format which usually relies heavily on annotated photo mosaics and stereo-grams.

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APPENDIX B

GEOLOGY OF GRAYSON COUNTY, TEXAS[1]

Grayson County is situated in north-central Texas between latitudes 33°25' and 33°55' North, and longitudes 96°25' and 96°55' West and contains an area measuring approximately 927 square miles. The Red River and Lake Texoma (a 143,000 acre general purpose reservoir impounded by the Denison Dam on the Red River) form the north boundary of the county and the border between the states of Oklahoma and Texas. The county is bounded on the east by Fannin County and on the west by Cooke County. Denton and Collin counties border the county on the south. Sherman, the county seat, and Denison are the principle urban centers in the county.

Physiography

Grayson County, due to its position in the extreme northern reach of the West Gulf Coastal Plain, is a generally dissected region whose topography is largely determined by the character of its rock outcrops. Based on the regional character of these outcrops, north-central Texas has been subdivided into four physiographic regions or belts which generally coincide with basic geologic units of the area. These geologic units will be described in detail in subsequent sections. Figure 31 illustrates the general position of the four physiographic belts.

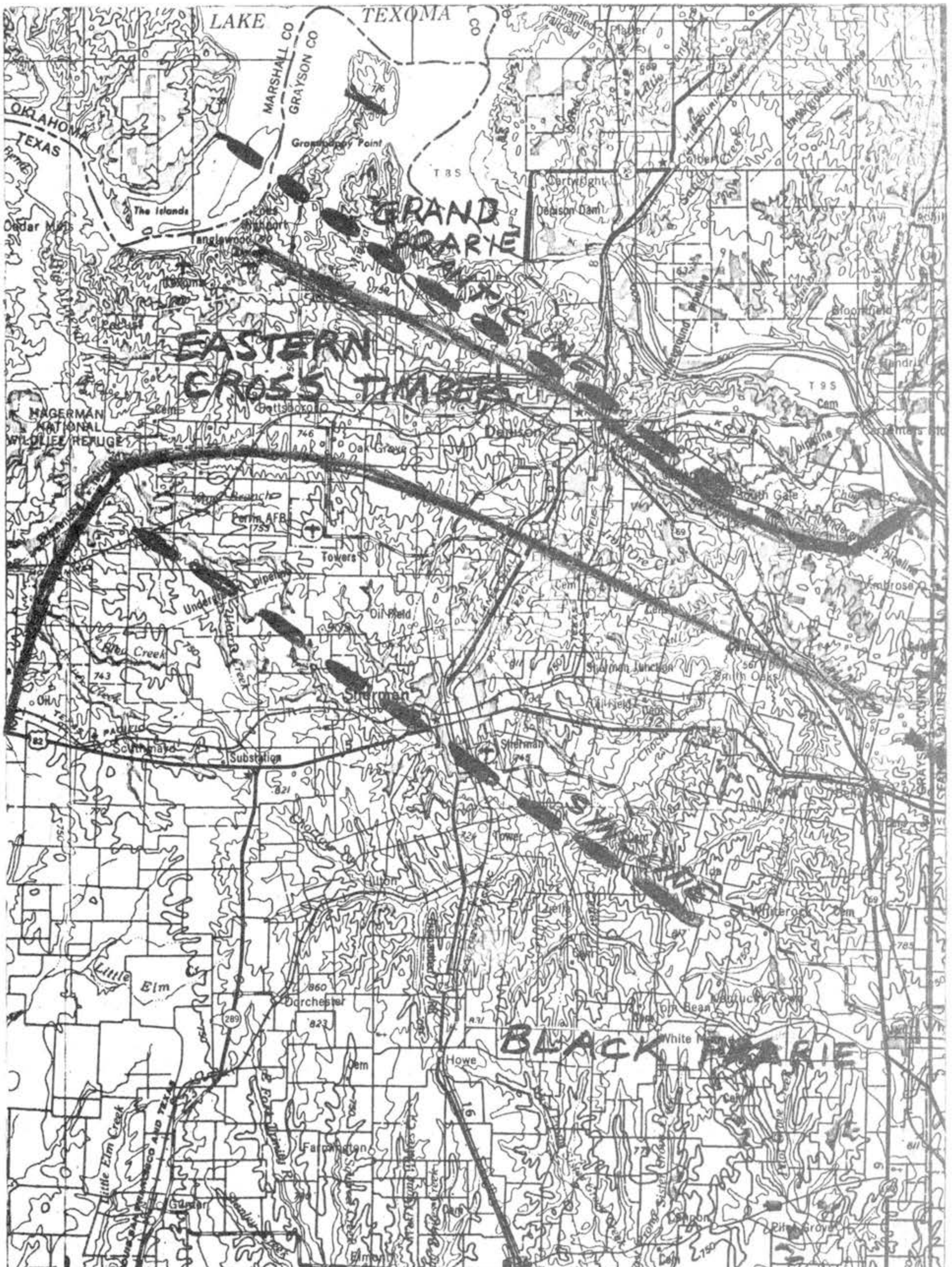


Figure 31. Grayson County Physiography

The Western Cross Timbers, occupying the outcrop areas of the Trinity group, is found only briefly in a narrow belt along the extreme northern reaches of the county. The belt intermittantly parallels the south shore of Lake Texoma and is characterized by a very rugged topography marked by deep, steep-walled ravines. The sandy soil typical of the formation supports a moderate growth of post oak and blackjack oak.

The Grand Prairie, occupying the narrow outcrop areas of the Washita and Fredricksburg groups in the northern part of the county, characteristically is a rolling upland formed by underlying limestone and marl. The resistant limestone forms a nearly flat surface or prairie, while the softer marl, exposed in slopes, creates significant erosion features by undercutting overlying limestone.

The Eastern Cross Timbers, generally coinciding with the outcrop area of the Woodbine formation, is a gently rolling sandy belt. The belt, averaging about 2 miles in width, extends from the southwest corner of the county northward through the county to the vicinity of the Big Mineral Arm of Lake Texoma, where it swings sharply eastward between Denison and Sherman to Bells near the Fannin County border. The western part of this belt is devoted to farming, while the northern part supports a moderate growth of post oak and blackjack oak.

The Black (or Blackland) Prairie, occupying the outcrop areas of the Eagle Ford shale and the Austin chalk, is characteristically a gently undulating to moderately rolling topography which covers roughly the southeastern three-fourths of the county. The area is extensively farmed.

Geologic History

Grayson County's position astride the transition zone between the North Central Plains and the West Gulf Coastal Plains creates a wide variety of unique geological and surface features which give evidence of the geologic history of this region. Figure 32, a Geologic Time Chart[2] describes the characteristics of the basic geologic eras and is offered as an aid to the following narrative.

During most of the Paleozoic era the area now occupied by Grayson County was part of a large sedimentary basin which received thick accumulations of marine deposits. Near the end of the Mississippian period and during the early part of the Pennsylvanian period, structural deformation created troughs and arches within the basin. Parts of the basin subsequently were deepened and faulted, and the basin continued to receive several thousand feet of sediments.

By Middle Pennsylvanian time the deeper parts of the basin were filled with sediments, in part, causing the seas to expand. A major crustal disturbance or orogeny during Middle Pennsylvanian time caused a general westward tilting of the land, causing the seas to move westward.

Uplift and erosion during the Mesozoic era tended to reduce the area to a flat surface or peneplain. Because of subsidence in the Gulf Coast geosyncline (a major depression in the earth's crust) during Middle and Late Mesozoic time, Cretaceous seas were able to submerge the area from the southeast. Sedimentation accompanying this

Figure 32. **Geological Time Chart**

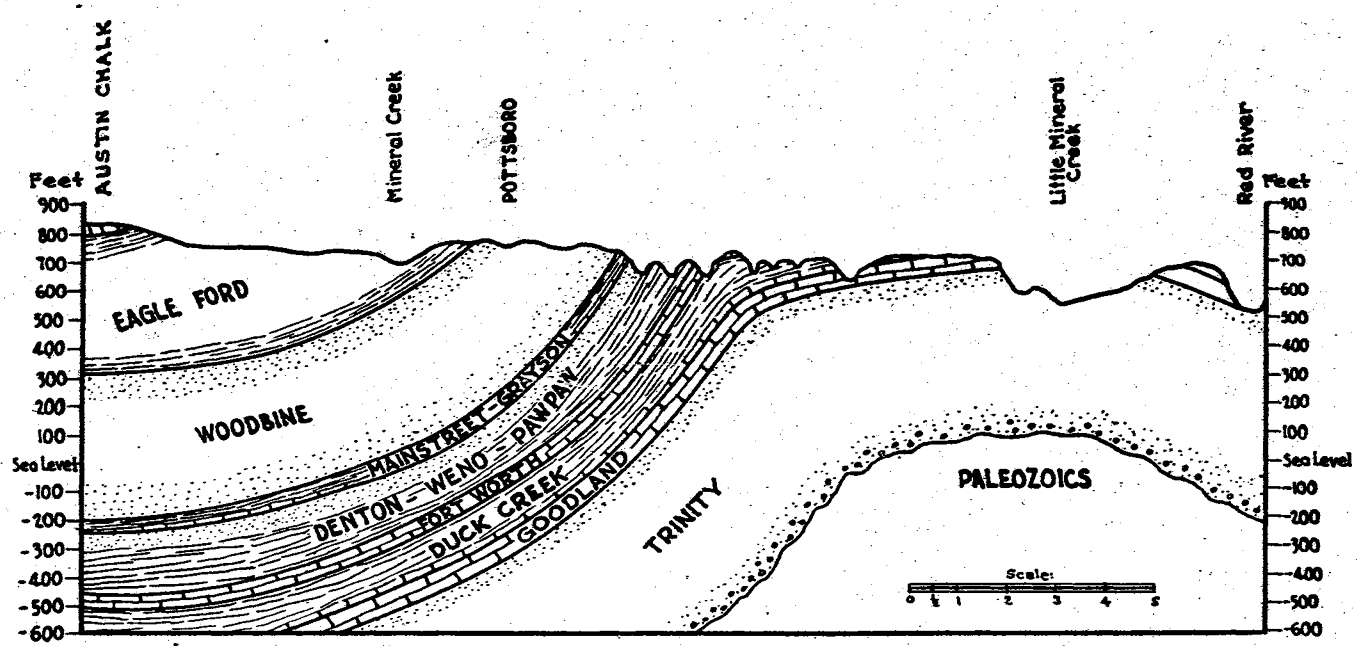
ERAS	PERIODS (OF TIME) or SYSTEMS (OF ROCK)	EPOCHS (OF TIME) or SERIES (OF ROCK)	APPROXIMATE TIME IN YEARS SINCE BEGINNING OF EACH	PHYSICAL & BIOLOGICAL FEATURES
CENOZOIC	QUATERNARY	RECENT	50,000	Development of modern man.
		PLEISTOCENE	1,000,000	Ice sheets over Europe and North America; appearance of early man.
	TERTIARY	PLIOCENE	12,000,000	Development of modern plants and animals; formation of mountains in western America.
		MIOCENE	30,000,000	Highest development of larger mammals; formation of mountains, including the Alps, Andes, and Himalayas.
		OLIGOCENE	40,000,000	Development of higher mammals.
		EOCENE (& PALEOCENE)	60,000,000	Rise to dominance of mammals; appearance of ancestral horse and primates.
MESOZOIC	CRETACEOUS		120,000,000	Extinction of dinosaurs; development of early mammals and flowering plants; deposit of chalk beds.
	JURASSIC		155,000,000	Appearance of flying reptiles and birds; dominance of dinosaurs; appearance of primitive mammals; abundance of coniferous trees.
	TRIASSIC		190,000,000	Appearance of dinosaurs; dominance of reptiles; appearance of cycadaceous trees.
PALEOZOIC	PERMIAN		215,000,000	Development of reptiles; decline of huge plants of the Carboniferous.
	CARBONIFEROUS PENNSYLVANIAN MISSISSIPPIAN		300,000,000	Age of coal; formation of coal beds from luxuriant plant life in warm, swampy forests; great fernlike trees; appearance of primitive conifers; abundance of insect life; first appearance of reptiles; development of amphibians.
	DEVONIAN		350,000,000	Age of the fish; appearance of primitive amphibians; development of primitive plant life on dry continents.
	SILURIAN		390,000,000	Appearance of scorpions, the first animals to live on land; extensive coral reefs.
	ORDOVICIAN		480,000,000	Floods and recessions of shallow seas; deposits of limestone, lead, and zinc ores; abundance of marine invertebrate life; appearance of a few primitive, fishlike vertebrates.
	CAMBRIAN		550,000,000	Shallow seas over much of the land; formation of sedimentary rocks; development of marine invertebrate life, including brachiopods, snails, sponges, and trilobites.
PRE-CAMBRIAN: PROTEROZOIC			1,200,000,000	Formation of mountains; deposits of iron ore; abundance of lime-secreting algae; appearance of sponges.
PRE-CAMBRIAN: ARCHEOZOIC			2,000,000,000	Great volcanic activity; formation of igneous rocks; some microscopic algae; probably some protozoa.

submergence resulted in the deposit on roughly 3600 feet of Cretaceous sand, shale, marl, chalk, and limestone of the Gulf and Comanche series. The seas withdrew at the close of the Cretaceous era and later structural deformation precipitated the Preston anticline (an arching fold), the Sherman syncline (a dipping fold or trough), and several associated crustal flexures now evident on the surface. Erosion of the emergent sea beds has been apparently continuous through the Quaternary and Tertiary periods of the Cenozoic era. Subsidence in the Gulf Coast geosyncline during Quaternary and Tertiary periods caused tilting toward the southeast, and accounts for the existing regional dip of the Cretaceous strata.

Many of the present topographic features of Grayson County, including stream terraces (now high above the valley flood plains) were formed during Pleistocene time. Continuous erosion during the Recent Epoch has formed extensive alluvial deposits along most drainage channels in the county. Figure 33 is a section through Grayson County which illustrates the deposits of the forementioned geologic eras.

Stratigraphy and Structure

The consolidated (sedimentary) rocks exposed in Grayson County consist of sand, clay, marl, chalk and limestone formed from deposits of the Cretaceous era. Within the county these formations have an estimated maximum thickness of about 3600 feet. Pleistocene and Recent Alluvium, consisting of sand, gravel, clay, and silt, is found along main drainage features, such as the Red River, Choctaw Creek, and the Big Mineral watershed.



Structure section across the Preston Anticline from a point on Red River, one mile northeast of Preston, southward through Pottsboro.

Figure 34. Geologic Section

The Cretaceous system of rocks is represented in Grayson County by formations of the Comanche series, which outcrop only in the northern part of the county, and formations of the Gulf series, which outcrop in most of the remainder of the county. The Comanche series includes the Trinity group and some rocks of the Washita and Fredricksburg groups. The Gulf series in Grayson County includes the Woodbine formation, the Eagle Ford shale, and the Austin chalk. The Cretaceous formations were apparently deposited on an unevenly eroded surface of Pennsylvanian rocks and have a regional southeasternly dip averaging approximately 33 feet per mile. This general dip in the Cretaceous strata is interrupted by two prominent folds in the county: the Preston anticline and the Sherman syncline. These folds, illustrated on Figure 31, have a major influence on the pattern of outcrops of the Cretaceous strata, causing the strata to be deflected to the southeast from their original northward and eastward strikes. The Preston anticline, an upwarp of about 1000 feet, begins in Southern Oklahoma and crosses into Texas in the vicinity of Preston Point on Lake Texoma and continues to the southeast past Denison until it becomes indistinct in Fannin County. The position of the axis of the anticline is evidenced in the Preston Point area by an outcrop of the Trinity group between outcrops of the Washita and Fredricksburg groups.

The Sherman syncline lies immediately to the south of, and roughly parallel to, the Preston anticline. The axis of the syncline trends southeastward through Gordonville and Sherman. The syncline is a wide, shallow, asymmetrical fold having a steep slope on the north and a gently dipping slope on the south. No major faults are observed at the surface in Grayson County, though a narrow outcrop of the Eagle Ford shale between Sherman and Denison is a suspected fault in view of the fact that no steep dips of strata are noted at the surface in that area. Faults having small displacements are noted in areas of outcrop of the Austin chalk. In the following description of rock units the symbols in parenthesis refer to the map symbols found on the geologic map illustrated in Figure 34.3

Pennsylvanian Rocks, Undifferentiated

Rocks of the Pennsylvanian period do not outcrop in Grayson County; however, they are generally formed directly below the Trinity group in the county and consequently influence the overlying strata. Pennsylvanian formations are found at depths ranging from about 600 feet in the northwestern part of the county to about 3600 feet in the southwestern part. These formations are characteristically sandy shale, limestone and sandstone, reach a maximum thickness of about 15,000 feet, and have a regional westward dip, which contrasts with the overlying Cretaceous beds which dip regionally to the south. (The Trinity sand is referred to by some geologists as Antlers sand.)

Cretaceous System

Comanche Series

The Comanche series, which includes the Trinity group, is the basal division of the Cretaceous system and was created by sediments deposited by an encroaching sea on an erodible land surface. The overlying Washita and Fredricksburg are distinguished by their cyclical type of deposition, evidenced by alternating beds of limestone, clay

Figure 34. Geologic Chart

and marl. This sequence of deposition reflects cyclic transgression and regression of seas over the area. In Grayson County the Comanche series ranges in thickness from 500 to 800 feet.

Trinity Group, Undifferentiated (Ka)

Throughout the Trinity period the Grayson County area apparently was near the edge of a sea which encroached upon the land from the southeast. Deposits laid down during this period consist chiefly of sand and minor amounts of clay and gravel. The Trinity group outcrops in massive beds in a narrow belt in the extreme northern parts of the county. The Trinity group erodes readily and, where overlain by Walnut clay and Goodland limestone, forms steep bluffs and deep ravines. Most of the outcrop of the Trinity in Grayson County is covered by a loose mantle of Red River alluvium or is submerged under the waters behind Denison Dam. The Trinity group characteristically begins with a basal conglomerate and transitions upward into a fine white to gray poorly consolidated sand in massive beds. The Trinity becomes deeply buried immediately to the southeast of its outcrop. At Sherman it is located approximately 1500 feet below the surface.

Fredricksburg Group (Kgw, Kki)

The Fredricksburg group overlies the Trinity group in Grayson County and includes, in ascending order, the Walnut clay, the Goodland limestone, and the Kiamichi formation. The thickness of the group ranges from 0 to 100 feet, increasing to the east and south. The strata of this group dip regionally to the southeast.

Walnut Clay (Kgw)

The Walnut clay overlies the Trinity group in an unconforming manner and outcrops in a narrow belt along the south shore of Lake Texoma. It consists of a black shale containing layers of shell breccia. The thickness of the formation ranges from about 8 feet near its outcrop to about 22 feet in southwestern Grayson County.

Goodland Limestone (Kgw)

The Goodland limestone overlies the Walnut clay conformably and outcrops in a narrow, north-facing escarpment extending along the south shore of Lake Texoma. The Goodland ranges in thickness from about 12 feet where it outcrops to about 40 feet in the southwestern part of the county. At its outcrop, the upper 8 feet of the formation is an extremely hard crystalline limestone, which weathers into thin fragments; the lower 4 feet is a chalky limestone.

Kiamichi Formation (Kki)

The Kiamichi overlies the Goodland limestone in a conformable manner. It outcrops in benches and terraces between the resistant Goodland limestone and the overlying Duck Creek formation. It averages 30 to 35 feet in thickness and consists predominantly of greenish clay, though the upper surface may consist of thin ledges of hard limestone containing an abundance of fossils.

Washita Group (Kdc, Kfw, Kd, Kwe, Kpp, Kms, Kgy)

The Washita group overlies the Fredricksburg group with apparent conformity. Included in this group, in ascending order, are the Duck Creek formation, Fort Worth limestone, Denton clay, Weno clay limestone, Pawpaw formation, Main Street limestone, and Grayson marl. The Washita group ranges in thickness from about 435 feet to about 550 feet, thickening in direction of dip but thinning southward along the strike. The group consists largely of alternating beds of limestone and marl but contains some sand near the top.

Duck Creek Formation (Kdc)

The Duck Creek formation overlies the Kiamichi with an apparent conformity; its outcrop extends across most of the northern part of the county. The formation ranges in thickness from about 90 to 130 feet; its thickness is generally uniform in the direction of dip to the southeast but decreases along the strike to the south. The Duck Creek consists chiefly of interbedded modular limestone and marl with the limestone weathering to form prominent ledges. In the lower 40 to 50 feet, the limestone and marl alternate in thin beds, with the thicker limestone beds predominating. In the upper 60 to 70 feet, the limestone beds become thinner and are separated by increasingly thicker beds of marl. The contact with the overlying Fort Worth limestone is gradational from marl to limestone. The lower parts of the Duck Creek contain an abundance of fossils.

Fort Worth Limestone (Kfw)

The Fort Worth limestone overlies the Duck Creek formation with apparent conformity and outcrops in northern Grayson County on the south slope of the Preston anticline. The area of outcrop is characterized by ridges and hills (cuestas) with a steep escarpment on the north and a long gentle slope to the south. The Fort Worth is about 60 feet thick near the outcrop and thickens in direction of dip to about 70 feet in the southeastern part of the county. The formation thins southward along the strike and is about 50 feet thick in the southwestern part of the county. The Fort Worth consists of limestone and marl in alternating beds which may be separated into three distinct units. The lower unit consists of about 15 to 20 feet of limestone and minor beds of marl. The middle unit, about 20 feet thick, is predominantly marl. The upper unit, about 15 to 20 feet thick, is chiefly limestone.

Denton Clay (Kd)

The Denton clay overlies the Fort Worth limestone with apparent conformity and outcrops in a narrow belt across the northern part of Grayson County. Near its outcrop the formation is about 60 feet thick, but thins in direction of dip to about 40 feet in the southeastern part of the county. The Denton consists largely of brownish-yellow clay and thick beds of hard light-colored sandstone. A bed of sandy shell agglomerate is characteristically found on its upper surface.

Weno Clay (Kwe)

The Weno clay (designated limestone by some geologists) overlies the Denton clay with apparent conformity. Its outcrop extends in a narrow belt across the northern part of the county. The formation ranges in thickness from about 110 to 135 feet and consists of dark gray to tan shaly clay, thin beds of sand, clay-ironstone concretions, and, in its upper levels, some hard sandstone and limestone beds.

Pawpaw Formation (Kpp)

The Pawpaw formation conformably overlies the Weno clay; its outcrop lies in a narrow belt in the northern part of the county. Locally, the Pawpaw forms a topography very similar to that of the Eastern Cross Timbers and may be mistaken for Woodbine formation. The Pawpaw is about 60 feet thick near its outcrop and thickens in the direction of dip to about 80 feet in the southeastern part of the county. The Pawpaw consists of reddish-brown clay in the lower levels and poorly cemented yellowish-brown sand in the upper levels. The sand at the top of the formation is typically in a massive bed 20 to 30 feet thick.

Main Street Limestone (Kms)

The Main Street limestone overlies the Pawpaw formation with apparent conformity and outcrops in conspicuous ledges of hard limestone in the northern part of the county. The thickness of the Main Street ranges from 11 to 15 feet in the outcrop area; however, unlike most of the other formations of this group, the Main Street thickens along the strike towards the south, reaching a thickness of about 25 feet in the southwestern part of the county. The Main Street consists of 1 or 2 foot beds of hard white or brownish-white crystalline limestone alternating with 1 to 6 inch beds of marl. Generally, the limestone is massive at the base of the Main Street formation, but becomes thinner near the top where marl beds predominate. Oxidation of pyrite in the limestone causes an iron-stained appearance.

Grayson Marl (Kgy)

The Grayson marl is the uppermost member of the Washita series and the Comanche group and outcrops in a narrow belt extending across the northern part of the county. The thickness of the formation averages about 15 to 20 feet near the outcrop and thickens to about 25 feet along the strike at the southern boundary of the county, though the formation thickens to about 50 feet in direction of dip to the southeast. Marl is derived from soft, calcareous deposits that are mixed with clays, silts and sands, often containing shells and organic remains. The Grayson marl typically consists of yellowish-brown fossiliferous, calcareous clay, bluish-gray marl containing many nodules of limestone, and thin beds of grayish limestone. The more prominent limestone beds near the base of the formation represent the gradation from the underlying Main Street limestone.

Gulf Series

Rocks of the Gulf series overlie rocks of the Comanche series in an unconformable manner and are represented in Grayson County by the Woodbine formation, the Eagle Ford shale and the Austin chalk. These sedimentary rocks dip to the southeast and reach a maximum thickness of about 1500 feet in Grayson County. The Gulf series outcrops in the southeastern three-fourths of the county and its rocks form the physiography for the Eastern Cross Timbers and the Black Prairie belts.

Woodbine Formation (Kwt, Kwl, Kwr, Kwd)

The Woodbine formation is the basal formation of the Gulf series in north-central Texas. The exact relationship of the Woodbine to the underlying rocks of the Comanche series has not been determined; however, the Woodbine apparently rests unconformably on the underlying Grayson marl, though the contact is obscure. It is possible that erosion may have removed late deposits of the Washita group in this area before deposition of the Woodbine. The Woodbine outcrop averages 6 miles in width in western Grayson County (where it forms the Eastern Cross Timbers belt) but narrows to less than 3 miles after it turns eastward near Pottsboro. The Woodbine formation thickens from about 410 feet near its outcrop to about 500 feet in the southeastern part of the county. The formation consists of medium to coarse crossbedded sand, much of which is unconsolidated, and laminated shaly clay. Beds of hard siliceous sandstone are scattered throughout the formation; locally, the outcrop is often covered with residual boulders of siliceous sandstone. Massive reddish sand beds are found in some places; however, the individual beds are highly lenticular and grade into clay within short lateral distances. In most parts of Grayson County the thickest sand beds are found at or near the base or in the upper third of the formation. The presence of alunite nodules may serve to identify the contact position between the Woodbine and the overlying Eagle Ford shale.

Eagle Ford Shale (Kef)

The Eagle Ford shale overlies the Woodbine in a conformable manner. Its outcrop pattern approximates that of the Woodbine, though the formation has two distinctly different directions of strike. An 8 mile-wide north-south outcrop turns sharply eastward near Pottsboro, continues in a narrow belt, 1/2 to 3 miles in width, and leaves the county near Bells. The outcrop of the Eagle Ford shale forms part of the Black Prairie and typically is a treeless prairie, though near Bells sandy layers in the upper part of the shale become prominent enough to support a wooded, sandhill topography. The Eagle Ford ranges in thickness from 440 to 480 feet in the uneroded parts of Grayson County. The formation consists largely of bluish-black shale and intermittent thin lenses and bands of hard limestone. Near the surface of the Eagle Ford are found sand layers and hard fossiliferous sandstone totalling about 15 to 20 feet in thickness.

Austin Chalk (Kau, Kg, Kec, Kbo)

The Austin chalk, overlying the Eagle Ford shale in an unconformable manner, is the latest Cretaceous formation in Grayson County. The formation underlies about one-third of the county; it forms a westward facing white escarpment which overlooks the broad plains formed by the Eagle Ford shale. The outcrop, mainly in the central and southeastern parts of the county, weathers to a black residual soil forming part of the Black Prairie belt. The maximum thickness of the formation in Grayson County is about 550 feet. The formation consists of chalk and limestone interbedded with layers of marl. The deeply buried rocks are bluish-gray, while those near the surface in the zone of weathering are chalky white. The base of the Austin chalk is typically marked by the presence of a conglomerate of fossils called "fish-bed."

Quaternary System

Pleistocene and Recent Series, Undifferentiated

Alluvium (Qt, Qt1, Qt2, Qt3, Qt4, Qal)

Alluvial deposits of Pleistocene and Recent time form flood plains and terraces in several parts of the county. Generally, the older alluvial deposits, which are typically represented by terraces located high above the present stream beds, are dissected and show the effects of varying degrees of erosion. In some areas the high-level terraces coalesce near junctions of streams and cap interstream divides. Associated with the high-level terraces are younger, lower lying deposits which form benches or broad terraces adjacent to existing streams. The lowest surfaces are flood plains stream bed of present streams. The Alluvium along each stream consists of sediments derived from rocks that outcrop within the drainage area of the stream. Streams draining shaly areas deposit Alluvium that consists chiefly of tight, impermeable material (Qt1, Qal); while streams draining sandy areas deposit Alluvium that consists chiefly of permeable materials (Qt2, Qt3, Qt4). Extensive deposits of sand and gravel are found near the mouth of Choctaw

Creek on the Red River. The thickness of the Alluvium in the county range from 0 to 60 feet.

FOOTNOTES

[1] This appendix is based on the following references: The Geology of Grayson County, Texas by Fred M. Bullard (1931); Ground-Water Geology of Grayson County, Texas, U. S. Geological Survey (1963); and The Geology and Geophysics of Cooke and Grayson Counties, Texas, The Dallas Geological and Geophysical Societies (1957).

APPENDIX C

GENERAL SOIL DATA, SHERMAN-DENISON, TEXAS

Soil is the product of climate, living organisms, parent materials, topography, and time. If the interaction of these five major elements has been identical in two given areas, the nature and characteristics of the soil in those two areas are identical. If, however, the interaction of these five elements has not been identical in the two areas, the soils in the two areas differ. Within very short distances the resulting soil differences may be extreme.

Soil Classification

A very comprehensive nationwide system of soil classification is followed in the United States. According to this sytem soils are placed in the following categories, in descending order: order, sub-order, great soil group, family, series, type and phase. Classes of the highest category are the zonal, intrazonal and azonal orders. The zonal order consists of soils with evident, genetically related horizons that reflect in their formation predominant influences of climate and living organisms. The intrazonal order consists of soils with evident, genetically related horizons that reflect the dominant influence of a local factor of relief or parent material over the effects of climate and living organisms. The azonal order is made up of soils that lack genetically related horizons, commonly because they are young, very steep, or have resistant parent material.

Persons requiring soil information for specific land use problems are primarily interested in data concerning soil series, type and phase. In the classification procedure soils that have profiles closely alike comprise a soil series. Except for different texture in the surface layer, all soils of one series have major horizons that are similar in thickness, arrangement, and other significant characteristics. (Each soil series is named for the locale where a soil of that series was first identified and mapped.) Many soil series contain soils that differ in texture of their surface layer and are accordingly divided into subgroups, called soil types, reflecting these differences in surface texture. Thus, within a series, all soils having a surface layer of the same texture belong to one soil type. However, some soil types vary so much in slope, degree of erosion, number and size of stones, or some other feature significantly affecting their use, that they are further subdivided into phases. The name of the soil phase indicates a feature that affects its management.

Development of a General Soil Map

The U. S. Department of Agriculture, primarily through the Soil Conservation Service, has for several years been engaged in an effort to map all soils in the United States. A primary goal in this effort is the general soil map. This document is used to illustrate soil patterns and associations that are useful to those persons who want a general idea of a region's soil patterns or who want to locate large areas suitable for some particular type of land use.

Soil scientists prepare general soil maps primarily through the use of air photo interpretation and field survey techniques. By study of changes in pattern, association, tone or color, texture and topographic structure the soil scientist is able to delineate the boundaries of major soil groups. These groups usually consist of soils of two or three soil series of close relationship. On the general soil map, even soil areas that are comparatively small reflect differences which are important in determining their use with respect to surrounding soil. Figure 35 is a general soil map for the Sherman-Denison area. Figure 36 is its soil legend.

The Soil Conservation Service has developed several guides for making comprehensive soil interpretation. Figure 37 presents criteria for interpreting:

1. Water Table (Supplement A)
2. Flood Hazard (Supplement B)
3. Productivity (Supplement C)
4. Depth to Hard Rock (Supplement D)
5. Traffic Supporting Capability (Supplement E)
6. Available Water Capacity (Supplement F)
7. Inherent Erodibility by Water (Supplement G)
8. Wind Erodibility (Supplement H)
9. Land Use Limitation Ratings (Supplement I)
10. Light Industry and Commercial Buildings (Supplement J)
11. Dwellings with Septic Tank Filter Fields (Supplement K)
12. Dwellings with Public or Community Sewage Systems (Supplement L)
13. Roadfill (Supplement M)
14. Topsoil (Supplement N)

15. Trafficways (Supplement O)

Figure 38 is a guide used for interpreting soils for recreational uses. Figure 39 consists of guides using soil corrosivity, percolation rate, permeability and shrink-swell characteristics as criteria in making soil interpretations for non-agricultural uses.

The Sherman office of the Soil Conservation Service is presently engaged in preparing a comprehensive soil survey which will result in soil interpretations for all land in Grayson County. The estimated completion date for this project is 1973.

Figure 35. General Soil Map

SOILS LEGEND[1/]

AUSTIN-EDDY SOILS (AEd)

Austin - dark grayish brown to grayish brown friable calcareous silty clay to clay surface, 10-14 inches thick, over brown to pale brown friable strongly granular highly calcareous silty clay to clay. Chalky marl or chalk at depths of about 15-30 inches. Gently sloping to moderately rolling (1-8% slopes).

Eddy - light brownish gray to gray very friable calcareous silty clay or clay containing many small fragments of chalky limestone, 3-15 inches thick, over soft chalky marl interbedded with white chalk or chalk fragments. Moderately sloping to undulating (4-8% slopes).

Approximate acreage[2/] - 50,000 (60% Austin; 30% Eddy; 10% other).

1/

Soil series shown are the dominant series in each delineation but smaller areas of other soils occur. Acreages and percentages shown are approximate. Percentages for the major series include similar soils. The scale of the map and the detail shown are not adequate for identifying the soils on a specific farm. The map is an advanced compilation subject to change as additional information is developed.

Figure 36. Soils Legend

2/

Nearest 1,000.

BOWIE-SAWYER SOILS (BoS)

Bowie - very pale brown acid sandy loam or loamy sand surface, 12-20 inches thick, over yellow or brownish yellow friable porous acid sandy clay loam, mottled with red and yellow in lower part. Nearly level to rolling (1-10% slopes).

Sawyer - grayish brown to pale brown acid fine sandy loam to loamy sand surface, 10-15 inches thick, over faintly mottled brownish yellow friable porous sandy clay loam grading into mottled pale yellow, red and light gray firm weakly blocky clay at depths of 25-35 inches beneath the surface. Nearly level to gently sloping (1-5% slopes).

Approximate acreage - 80,000 (35% Bowie; 25% Sawyer; 40% other).

CROCKETT-WILSON FINE SANDY LOAM (CrW)

Crockett - dark brown to yellowish brown friable acid sandy loam to clay loam surface, 7-12 inches thick, over yellowish brown and red mottled very firm and very plastic blocky acid clay. Surface soil very tight and crusty when dry. Calcium carbonate concretions below 50 inches. Nearly level to gently sloping (1-5% slopes).

Wilson - very dark gray to gray or grayish brown acid sandy loam to clay loam surface, 4-12 inches thick, over dark gray very firm blocky to massive neutral clay; alkaline to calcareous below about 30 inches. Surface soil very tight and hard when dry. Nearly level to gently sloping (0-4% slopes).

Approximate acreage - 45,000 (55% Crockett; 25% Wilson; 20% other).

ELLIS-CROCKETT SOILS (ECr)

Ellis - dark grayish brown to olive weakly granular to blocky firm neutral to alkaline clay surface, 4-12 inches thick, over olive very firm neutral to alkaline clay grading into pale olive or mottled yellow and light gray clay containing $CaCO_3$ concretions and shale fragments at 10-25 inches beneath the surface; surface crusty when dry. Gently to strongly sloping (3-12% slopes).

Crockett - dark brown to yellowish brown friable acid sandy loam to clay loam surface, 7-12 inches thick, over yellowish brown and red mottled very firm and very plastic blocky acid clay. Surface soil very tight and crusty when dry. Calcium carbonate concretions below 50 inches. Nearly level to gently sloping (1-5% slopes).

Approximate acreage - 63,000 (30% Ellis; 25% Crockett; 45% other).

EDGE-KIRVIN STONY FINE SANDY LOAM (EK)

Edge - grayish brown to pale brown acid fine sandy loam surface, 4-12 inches thick, over mottled red very firm compact blocky acid clay grading with depth through a mottled reddish brown to a brownish gray clay or sandy clay. Surface soil crusty and tight when dry. Nearly level to gently sloping (1-5% slopes).

Kirvin - light brownish gray to pale brown acid sandy loam surface, 9-14 inches thick, over red friable porous subangular blocky acid sandy clay becoming mottled with yellow at lower depths. Nearly level to undulating (1-8% slopes).

Approximate acreage - 23,000 (30% Edge; 30% Kirvin; 40% other).

GOWEN SOILS (G)

Gowen - dark grayish brown to grayish brown friable slightly acid to neutral sandy loam to clay loam surface, 8-16 inches thick, over dark gray friable porous massive acid to neutral clay loam stratified with fine sandy loam in places. Moderately well drained; nearly level floodplains.

Approximate acreage - 2,000 (80% Gowen; 20% other).

HOUSTON BLACK-AUSTIN CLAYS (HBA)

Houston Black - very dark gray to black crumbly and friable calcareous clay surface, 10-25 inches thick, over dark gray or olive gray firm weak subangular blocky calcareous clay, strongly calcareous mottled yellow and gray clay at 30-60 inches. Nearly level to gently sloping (1-4% slopes).

Austin - dark grayish brown to grayish brown friable calcareous silty clay to clay surface, 10-14 inches thick, over brown to pale brown friable strongly granular highly calcareous silty clay to clay. Chalky marl or chalk at depths of about 15-30 inches. Gently sloping to moderately rolling (1-8% slopes).

Approximate acreage - 144,000 (40% Houston Black; 40% Austin; 20% other).

HOUSTON BLACK-HOUSTON-AUSTIN SOILS (HBHA)

Houston Black - very dark gray to black crumbly and friable calcareous clay surface, 10-25 inches thick, over dark gray or olive gray firm weak subangular blocky calcareous clay, strongly calcareous mottled yellow and gray clay at 30-60 inches. Nearly level to gently sloping (1-4% slopes).

Houston - dark olive gray to dark grayish brown crumbly calcareous clay surface, 6-15 inches thick, over dark yellowish brown subangular blocky highly calcareous clay with yellow mottling in lower part - highly calcareous mottled yellow and gray clay (marl) at 20-36 inches. Gently sloping to undulating (4-8% slopes).

Austin - dark grayish brown to grayish brown friable calcareous silty clay to clay surface, 10-14 inches thick, over brown to pale brown friable strongly granular highly calcareous silty clay to clay. Chalky marl or chalk at depths of about 15-30 inches. Gently sloping to moderately rolling (1-8% slopes).

Approximate acreage - 23,000 (35% Houston Black; 20% Houston; 20% Austin; 25% other).

MINCO-WILSON SOILS (MW)

Minco - brown to dark brown friable slightly acid silt loam surface, 12-20 inches thick, over reddish brown friable porous neutral to alkaline silt loam or very fine sandy loam. Nearly level to gently sloping (1-5% slopes).

Wilson - very dark gray to gray or grayish brown acid sandy laom to clay loam surface, 4-12 inches thick, over dark gray very firm blocky to massive neutral clay; alkaline to calcareous below about 30 inches. Surface soil very tight and hard when dry. Nearly level to gentle sloping (0-4% slopes).

Approximate acreage - 14,000 (30% Minco; 20% Wilson; 50% other).

TARRANT-DENTON SOILS (TaD)

Tarrant - dark brown to dark grayish brown friable highly calcareous clay surface, 4-8 inches thick, over broken or partly weathered limestone or limestone bedrock at less than 12 inches beneath the surface; many limestone fragments on surface. Gently sloping to hilly (2-20% slopes).

Denton - very dark brown to dark grayish brown crumbly granular calcareous clay surface, 8-12 inches thick, over brown crumbly plastic strongly calcareous clay containing a few small hard $CaCO_3$ over substrata of limestone interbedded with soft marl, or broken fragments of limestone mixed with marl at depths of about 12-36 inches beneath the surface. Gently sloping (2-6% slopes).

Approximate acreage - 32,000 (35% Tarrant; 35% Denton; 30% other).

TRINITY-CATALPA SOILS (TC)

Trinity - very dark gray crumbly calcareous clay surface, 20-40 inches thick, over dark gray firm calcareous clay. Moderately well drained, nearly level floodplains.

Catalpa - dark grayish brown to dark brown friable calcareous clay or clay loam surface, 10-30 inches thick, over grayish brown friable granular calcareous silty clay or clay loam. Well drained; nearly level floodplains.

Approximate acreage - 11,000 (65% Trinity; 30% Catalpa; 5% other).

WILSON-CROCKETT CLAY LOAMS (WCr)

Wilson - very dark gray to gray or grayish brown acid sandy loam to clay loam surface, 4-12 inches thick, over dark gray very firm blocky to massive neutral clay; alkaline to calcareous below about 30 inches. Surface soil very tight and hard when dry. Nearly level to gently sloping (0-4% slopes).

Crockett - dark brown to yellowish brown friable acid sandy loam to clay loam surface, 7-12 inches thick, over yellowish brown and red mottled very firm and very plastic blocky acid clay. Surface soil very tight and crusty when dry. Calcium carbonate concretions below 50 inches. Nearly level to gently sloping (1-5% slopes).

Approximate acreage - 106,000 (35% Wilson; 35% Crockett; 30% other).

Supplement A

WATER TABLE

Definition: The upper surface of free water in a soil or underlying material. In some places an upper or perched water table is separated from a lower one by a dry zone. If water is above the surface it is called flooding.

Classes:

Depth		Duration*	
Deep	Deeper than 120 inches	Very brief	Shorter than 1 month per year
Moderately deep	60 to 120 inches	Brief	1 to 2 months per year
Moderately shallow	30 to 60 inches	Long	2 to 6 months per year
Shallow	15 to 30 inches	Very long	6 to 12 months per year
Very shallow	0 to 15 inches	Continuous	More than 12 months

*Duration of high water table is most severe when it occurs during the heavy use season. Duration may be more usefully expressed as a percentage of the use period. For example, a soil to be used for golf fairway might have a duration of 20 percent of the use period of 6 months.

Measurement: Observation of the level at which water stands (adequate time allowed for adjustment) in an unlined bore hole. A perched water level is observed when the deepening of the hole causes the water level in the hole to subside. The observations should be made at the time of the year when the soil is wettest. Normally in the southeast this is late winter or early spring.

Estimate: Without adequate water table observations, we must rely on estimates. The best estimates are based on the drainage class tempered with the judgement of experienced soil scientists.

Some approximate correlations are as follows:

Drainage class		Water table and duration
Well	approximates	Water table below 72 inches for more than 10 months per year
Moderately well	approximates	Water table below 30 inches for more than 9 months per year
Somewhat poorly	approximates	Water table below 15 inches for more than 8 months per year
Poorly	approximates	Water table below 15 inches for less than 6 months per year
Very poorly	approximates	Water table below 15 inches for less than 1 month per year

Reference: Proceedings of National Technical Work-Planning Conference of the Cooperative Soil Survey, Chicago, Illinois. March 25-29, 1963.

Supplement B

FLOOD HAZARD

Definition: Water from stream overflow, from runoff or seepage, standing or flowing above the soil surface.

Classes:

Frequency*		Duration	
None	Less often than once in 50 years	Extremely brief	Shorter than 2 days
Very infrequent	Once in 20 to 50 years	Very brief	2 to 7 days
Infrequent	Once in 5 to 20 years	Brief	7 days in 1 month
Frequent	Once in 1 to 5 years	Long	1 month to 6 months
Very frequent	More often than once every year	Very long	Longer than 6 months

Figure 37. Soils Interpretation Criteria

Measurement: Measurements should be accumulated according to Soils Memorandum SCS-40, April 27, 1961.

Estimate: Hydrological surveys from Geological Survey, Corps of Engineers, TVA, and other agencies give frequency and flow information on many streams. This information can be used in making the estimates.

*The time of year the floods occur should be noted. Flooding occurring at the time when use is heavy is more in those periods when use is light.

Supplement C

PRODUCTIVITY

Definition: Productivity as used here refers to the ability of the soil to produce adapted common crops under a reasonably high level of management. This level of management includes economically feasible fertilization, proper seed selection, cultural practices, and harvesting practices, but not irrigation. A soil may be productive, even though low in natural fertility, providing it is capable of responding to good management.

Properties important in determining soil productivity are:

1. Cation exchange capacity.
2. Effective root depth.
3. Available water capacity of the root zone (Effective root depth (in inches) times available water holding capacity (in./inch)).

Standards for making evaluations of productivity:

High:

1. Cation exchange capacity	More than 10me./100 grams of soil
2. Effective root depth	Deeper than 36 inches
3. Available water capacity of the root zone	Greater than 3.5 inches

Medium:

1. Cation exchange capacity	More than 3me./100 grams of soil
2. Effective root depth	Deeper than 10 inches
3. Available water capacity of the root zone	Greater than 2.5 inches

Low:

1. Cation excahange capacity	Less than 3 me./100 grams of soil
2. Effective root depth	Shallower than 10 inches
3. Available water capacity of the root zone	Less than 2.5 inches

Supplement D

Depth to Hard Rock

Definition: The depth of loose material to "rock which requires drilling and blasting for its economical removal." 1/

	Classes	Inches
vs	Very shallow 2/	Less than 10
s	Shallow	10 to 20
md	Moderately deep	20 to 36
d	Deep	36 to 50
vd	Very Deep	50 inches to 20 feet
rf	Rock free	More than 20 feet

1/ Glossary of Geology and Related Sciences, second edition, The American Geological Institute, Washington, D. C., 1960

2/ Descriptive terminology based on effective root depth classes (see Guide for Conservation Surveys, USDA, SCS, 1948).

Supplement E

TRAFFIC SUPPORTING CAPACITY

Definition: Traffic supporting capacity is the ability of the undisturbed soil to support moving loads and indicates the desirability of soil as subgrade material. It is commonly given as a group index of the AASHO classification system and is used for determining thickness of flexible pavement. The soil can also be evaluated for subgrade according to the Unified Classification system. Although the evaluation is based on undisturbed soil, the characteristics of disturbed soil (carefully compacted) are very similar.

Classes:

Evaluation of subgrade	AASHO group index 1/	Unified class 2/
Excellent	0	GW, SW, GP
Good	0-1	GM, SP, GC, SM
Fair	2-4	SC, ML, CL
Poor	5-9	OL, MH
Very poor	10-20	CH, OH
Not suited		Pt

1/ Hough, B. K., Basic Soils Engineering, the Ronald Press Co., New York, 1957, p. 380 and 388; also PCA Soil Primer, p. 37, 42, and 43.

2/ FHA 373, Engineering Soil Classification for Residential Developments, Rev. 11/61, column 4, table 3, p. 37.

Supplement F

AVAILABLE WATER CAPACITY

Definition: The difference between the amount of water in a soil at field capacity and the amount in the same soil at permanent wilting point, commonly expressed as the fractional inch of water per inch of soil.

Classes:

	Inches/inch
Very high	More than .20
High	.15-.20
Medium	.10-.15
Low	.05-.10
Very low	Less than .05

Measurement: Field capacity is approximated in the laboratory by the 1/3-atm. moisture percentage for very fine sandy loams and finer textured soils and by 1/10 atm. for fine sandy loams and coarser textures. The permanent wilting point is approximately by the 15-atm. percentage. Available water capacity in inches per inch can be calculated from the laboratory data as follows:

1/3 (or 1/10) atm. minus 15 atm. (expressed as decimals) X bulk density.

Estimate: In the absence of measured data, an estimate of available water capacity is useful. The following estimates of available water capacity seem likely for the family textural groupings:

	Inches/inch	Family textural groupings
Very high	More than .20	Fine silty
High	.15-.20	Coarse silty
Medium	.10-.15	Coarse loamy, fine loamy, fine clayey
Low	.05-.10	Sandy
Very low	Less than .05	Skeletal, fragmental

Research:

I. Data from Guy Smith at the National Technical Work Planning Conference, Chicago, Ill., 1963. Available water capacities were determined by the Beltsville soil survey laboratory on 222 samples. The samples were stratified by the textural classes used in family groupings.

	Available water capacity Percent
Coarse loamy	8
Fine loamy	8.6
Coarse silty	13
Fine silty	14
Fine	9
Very fine	11

II. In the left hand columns of table 1 are measurements of 414 samples from Tennessee. The determinations were made by T. J. Longwell, Soil Scientist, SCS. The texture was estimated. The moisture measurements were determined on sieved samples according to the procedure described in USDA Handbook No. 60. Bulk density was determined on 3 x 3" Uhland cores.

III. In the right hand column of table 1 are measurements made by the Lincoln Soil Survey Laboratory of 437 samples from central and southeastern states. The texture was determined by the pipette method. The moisture measurements were made on soil pieces according to the procedure desorption by K. K. Young, "A Method of Making Moisture Description Measurements on Undisturbed Soil Samples," Soil Science Society of America Proceedings 26:301, 1962. Bulk densities were obtained from the natural clod method on clods that were moistened by absorption to 30-cm. tension; the bulk density values are considered to be near what the material would have been at field capacity.

Table 1.--Available water capacity measurements for various soil textures.

Texture Class	University of Tenn.			Soil Survey Lab.
	Number samples	Range	Mean	Mean 1/
		In./in.	In./in.	In./in.
Sands	1	--	.02	
Loamy sands	5	.05-.10	.07	
Sandy loam	5	.10-.16	.12	
Fine sandy loam	11	.10-.24	.17	
Very fine sandy loam	3	.24-.28	.26	
Loam	22	.10-.23	.19	.14
Silt loam	153	.12-.36	.23	.19
Silt	2	.23-.29	.26	.24
Clay loam	19	.12-.21	.17	.12
Sandy clay loam	3	.13-.26	.21	
Silty clay loam	126	.11-.33	.20	.17
Sandy clay	3	.09-.24	.17	
Silty clay	24	.09-.31	.18	.14
Clay	37	.08-.21	.16	.15

1/ The standard deviations for estimates of available water capacity based on textural class average somewhat over 30 percent of the mean.

Supplement G

INHERENT ERODIBILITY (BY WATER)

Definition: Inherent erodibility (by water) is that property of the soil that contributes to the ease with which soil material is detached and transported by water. Erodibility factor (K value) is a useful measure of this property.1/ Slope, vegetative cover, and added plant nutrients, along with the precipitation characteristic, are important determinants of the rate of soil loss on a particular site, but are not considered as determinants of the inherent erodibility property.

Soil qualities important in determining inherent erodibility are:

1. Permeability of the soil and underlying material
2. Infiltration
3. Water holding capacity
4. Detachability
5. Ease with which particles are moved

1/ See "Soil Loss Estimation in the Southeast" or "Soil Loss Prediction for Arkansas, Louisiana, Mississippi, Oklahoma, and Texas."

Standards for making evaluations:

Slight	Soils with a K value of 20 or less
Moderate	Soils with a K value between 20 and 30
Severe	Soils with a K value between 30 and 40
Very severe	Soils with a K value above 40

Supplement H

WIND ERODIBILITY SOIL GROUPS IN THE SOUTHERN GREAT PLAINS FOR USE IN PREDICTING SOIL LOSSES BY WIND

Wind Erodibility Soil Group 1/	Predominant Soil Classes
1	Very fine, fine, and medium sand and dune sand.
2	Loamy very fine, fine, and medium sands.
3	Very fine, fine, medium, and coarse sandy loams.
4	Clays, silty clays (subject to granulation).
5	Loams, sandy clay loams, sandy clays.
6	Silt loams, clay loams.
7	Silty clay loams, silt.
8	Soils subject to wetness, stoniness, etc., and not subject to wind erosion.

1/ Group 1. Mostly dune sand; single grain structure; vegetation difficult to establish; not suitable for cropland.

Group 2. Mostly loamy sands; dry clod structure (as indicated by percentage of dry soil aggregates >0.84 mm. in diameter) is weak; requires a combination of intensive practices to control wind erosion.

Group 3. Mostly sandy loams; dry clod structure moderately stable; requires at least two measures to control wind erosion in regions with high and intermediate climatic factor.

Group 4. Mostly clays and silty clays; dry clod structure extremely variable due to contraction and swelling by freezing and thawing and wetting and drying; need a combination of at least two measures in regions with high and intermediate climatic factor.

Group 5. Mostly loams and sandy clay loams; dry clod structure quite stable; a combination of at least two measures is needed in a region with high climatic factor.

Group 6. Mostly silt loams and clay loams; dry clod structure stable; require a combination of at least two measures in a region with high climatic factor.

Group 7. Mostly silty clay loams; dry clod structure extremely stable; usually a single practice is sufficient to control wind erosion.

Group 8. Soils not suitable for crops because of wetness, stoniness, etc.

Supplement I

VALUES FOR RATING DEGREE OF LIMITATION OF SOILS FOR SPECIFIED USES

None to Slight	The soil has no limitation or no more than some limitation. The limitation is not serious and is easy to overcome.
Moderate	The soil has moderate limitation to use. The limitation needs to be recognized, but it can be overcome or corrected by means that in general are practical.
Severe	The soil has severe limitation. Use of the soil is questionable because the limitation is difficult to overcome.
Very severe	The limitation of the soil is so restrictive that its use is impractical.

Supplement J

LIGHT INDUSTRY AND COMMERCIAL BUILDINGS

Definition: This includes buildings other than residences that are used for stores, offices, and small industries, none of which are more than three stories high or require a presumptive bearing value of more than 6,000 pounds. It is assumed they have public or community sewage disposal facilities.

Properties important in evaluating the soils for this use:

1. Slope
2. Depth to hard rock
3. Water table
4. Flood hazard
5. Presumptive bearing value
6. Shrink-swell behavior
7. Corrosion potential

Guides for making evaluations of degree of soil limitations:
(The most limiting property determines the degree of limitation for the use.)

Slight
1. Slope less than 0 to 5 percent
2. Depth to hard rock, deeper than 36 inches
3. Water table below 30 inches for more than 6 months and always below 15 inches. Correlates approximately with well and moderately well drained soils.
4. Flood hazard, none
5. Presumptive bearing value, more than 6,000 psf.
6. Shrink - swell behavior, PVC less than 4 or shrinkage index less than 5
7. Corrosion potential, very low or low

Moderate
1. Slope, 5 to 12 percent
2. Depth to hard rock, 20 to 36 inches
3. Water table below 30 inches less than 6 months and below 15 inches more than 10 months. Correlates approximately with moderately well and somewhat poorly drained soils.
4. Flood hazard, none to infrequent
5. Presumptive bearing value, 2,000 to 6,000 psf
6. Shrink-swell behavior, PVC 4 to 6 or shrinkage index 5 to 7
7. Corrosion potential, moderate

Severe
1. Slope, more than 12 percent
2. Depth to hard rock, less than 20 inches
3. Water table below 15 inches less than 10 months. Correlates approximately with somewhat poorly drained soils.
4. Flood hazard, frequent and very frequent
5. Presumptive bearing value less than 2,000 psf
6. Shrink-swell behavior, PVC more than 6 or shrinkage index more than 10
7. Corrosion potential, high

Supplement X

DWELLINGS WITH SEPTIC TANK FILTER FIELDS

Definition: Dwellings of 3 stories or less that require septic tank soil-absorption systems as a method of disposing of sewage.

Guides for making evaluations: (The most limiting property determines the degree of limitation for the use.)

None to Slight
1. Percolation rate faster than 50 min./in.
2. Shrink-swell behavior, PVC less than 4 or shrinkage index less than 7.
3. Water table below 60 inches for 11months of the year and never above 30 inches. Correlates approximately with well-drained soils.
4. Flood hazard, none
5. Slope, 0 to 12 percent
6. Depth to hard rock deeper than 50 inches

Moderate
1. Percolation rate faster than 50 min./in.
2. Presumptive bearing value, 2,000 to 4,000 psf
3. Shrink-swell behavior, PVC 4 to 6 or shrinkage index 7 to 10
4. Water table below 60 inches more than 9 months of the year and always below 12 inches. Correlates approximately with moderately well drained soils.
5. Flood hazard, none
6. Slope, 12 to 25 percent
7. Depth to hard rock more than 50 inches

Severe

1. Percolation rate, 50 to 90 min./in.
2. Presumptive bearing value less than 2,000 psf
3. Shrink-swell potential, PVC more than 6 or shrinkage index more than 10
4. Water table deeper than 15 inches throughout the year. Correlates approximately with somewhat poorly drained soils.
5. Flood hazard, none or very infrequent
6. Slope, 12 to 25 percent
7. Depth to hard rock, 10 to 50 inches.

Very Severe

1. Percolation rate slower than 90 min./ in.
2. Water table below 15 inches for less than 12 months. Correlates approximately with most somewhat poorly drained soils, and with poorly drained and very poorly drained soils.
3. Flood hazard, infrequent to very frequent
4. Slope more than 25 percent
5. Depth to hard rock less than 10 inches.

Supplement L

DWELLING WITH PUBLIC OR COMMUNITY SEWAGE SYSTEMS

Definition: Dwellings of 3 stories or less that are serviced by a public or community sewage system.

Properties important in evaluating soils for this use:

1. Shrink-swell behavior
2. Water table
3. Flood hazard
4. Slope
5. Depth to hard rock

Guides for making evaluations: (The most limiting property determines the degree of limitation for the use.)

None to slight

1. Shrink-swell behavior, PVC less than 4 or shrinkage index less than 7
2. Water table below 30 inches for 6 months and never above 15 inches. Correlates approximately with moderately well drained soils.
3. Flood hazard, none.
4. Slope, 2 to 12 percent.
5. Depth to hard rock, deeper than 36 inches.

Moderate

1. Shrink-swell behavior, PVC 4 to 6 or shrinkage index 7 to10.
2. Water table below 30 inches for less than 6 months, and below 15 inches for more than 10 months. Correlates approximately with moderately well drained and somewhat poorly drained soils.
3. Flood hazard, none.
4. Slope, 12 to 25 percent.
5. Depth to hard rock, 20 to 36 inches.

Severe

1. Shrink-swell behavior, PVC more than 6 or shrinkage index more than 10.
2. Water table below 15 inches for more than 8 months. Correlates approximately with somewhat poorly drained soils.
3. Flood hazard, none or very infrequent.
4. Slope, more than 25 percent.
5. Depth to hard rock, less than 20 inches.

Very severe

1. Water table deeper than 15 inches for less than 8 months. Correlates approximately with poorly and very poorly drained soils.
2. Flood hazard, infrequent to very frequent.

Supplement M

ROADFILL

Definition: Material for building up road grades for supporting base layers.

Guides for making evaluations: (The most limiting property determines degree of limitation for the use.)

Good

1. Shrink-swell behavior, PVC less than 2 or shrinkage index less than 5
2. Traffic supporting capacity, good or excellent
3. Inherent erodibility, less than severe
4. Thickness of material at source, thicker than 6 feet

Fair

1. Shrink-swell behavior, PVC reading of 2 to 6 or shrinkage index 5 to 7.
2. Traffic supporting capacity, fair
3. Inherent erodibility, severe or very severe
4. Thickness of material at source, 2 to 6 feet

Poor

1. Shrink-swell behavior, PVC more than 6 or shrinkage index more than 7
2. Traffic supporting capacity, poor and very poor
3. Thickness ofmaterial, 1 to 2 feet

Unsuited

1. Traffic supporting capacity, unsuited
2. Thickness of material at source, less than 1 foot

Supplement N

TOPSOIL

Definition: Soil material useful for resurfacing areas where vegetation is to be established and maintained.

Properties important in evaluating soil material for this use:

1. Productivity
2. Coarse fragments
3. Thickness of the material at the source

Guides for making evaluations; (The most limiting property determines degree of limitation for the use.)

Good

1. Productivity, high
2. Coarse fragments, none
3. Thickness of the material at the source, more than 20 inches

Fair

1. Productivity, medium
2. Coarse fragments, none
3. Thickness of the material at the source, more than 6 inches

Poor

1. Productivity, low
2. Coarse fragments, more than 20 percent coarse fragments, as gravelly, channery, cobbly, or flaggy phases, or stoniness or rockiness.
3. Thickness of the material at the source, less than 6 inches

Supplement O

TRAFFICWAYS

Definition: This use is for low-cost roads and residential streets. The construction involves limited cut and fill and limited preparation of subgrade.

Properties important in evaluating the soils for this use:

1. Slope
2. Depth to hard rock
3. Water table
4. Flood hazard
5. Inherent erodibility
6. Traffic-supporting capacity

Guides for making evaluations of degree of limitations:
(The most limiting property determines the degree of limitation for the use.)

Slight

1. Slope, 0 to 12 percent
2. Depth to hard rock, deeper than 36 inches
3. Water table below 30 inches for more than 9 months and always below 15 inches. Correlates approximately with well-drained and moderately well drained soils.
4. Flood hazard, none to infrequent for less than 7 days
5. Inherent erodibility, slight or moderate
6. Traffic-supporting capacity, good or excellent

Moderate

1. Slope, 12 to 25 percent
2. Depth to hard rock, 10 to 36 inches
3. Water table below 15 inches for more than 8 months. Correlates approximately with somewhat poorly drained soils.
4. Flood hazard, less frequent than once every year for less than 7 days
5. Inherent erodibility, severe
6. Traffic-supporting capacity, fair

Severe

1. Slope, more than 25 percent
2. Depth to hard rock, shallower than 10 inches
3. Water table below 15 inches for less than 8 months. Correlates approximately with poorly and very poorly drained soils.
4. Flood hazard, more frequent than once every year or longer than 7 days
5. Inherent erodibility, very severe
6. Traffic-supporting capacity, poor or poorer

SOILS MEMORANDUM -

Re: SOIL SURVEYS - Guides for Recreational Interpretations

This memorandum outlines Service procedures for developing soil interpretations for recreational uses. It is not anticipated that all of these interpretations will be needed in all work units. Other interpretationsmay be developed as needed locally. Soil interpretations for recreational uses are prepared locally by soil scientists and other specialists familiar with the soils and conditions in the area. These interpretations are to be included in soil handbooks, technical guides, soil survey report manuscripts, and in other reports and publications as needed.

The attached guides are for : Picnic areas, intensive play areas, buildings in recreational areas, intensive camp areas, and for paths and trails.

These guides are to be used in evaluating each soil taxonomic unit to be grouped into soil limitation classes for the different recreational uses. It is recognized that interactions among some of the items listed in these guides may be of sufficient magnitude to change the soil limitation rating by one class. Soils, however, having the same soil name and occurring in the same land resource area normally should have the same rating.

The guides attached only provide for three soil groupings - slight, moderate, and severe. For some kinds of uses the soils may have a very severe limitation and should be so classified. For example, soils such as tidal and fresh water marshes, peat bogs, swamps, and the like are considered as having a very severe soil limitation for residential or service building sites and should not be grouped with soils classified as severe. These soils should be listed as a separate grouping. Usually only a few soil mapping units in a survey area will need to be classified as having a very severe soil limitation for a particular use. In some instances there may also be need for five or more soil limitation classes. In these instances a different range in the criteria used would be needed.

Soil Limitations for Building in Recreational Areas 1/

These soil ratings apply to seasonal and year-round cottages, washrooms and bath-houses, picnic shelters and service buildings. Suitability of the soil for supporting vegetation is a separate item to be considered in the final evaluation of selecting sites for these uses.

Ratings are on the basis of three classes of soil limitation - slight, moderate, and severe. These ratings provide preliminary information on soil suitability for this use. Detailed on-site investigations are usually required for the selection of a specific building site. Soils such as tidal and fresh water marsh, swamps, peat bogs, and the like are considered as having a very severe limitation and should not be grouped with soils classified as severe. These soils should be listed separately.

Degree of Soil Limitation

Items Affecting Use	None to Slight	Moderate	Severe 2/
Wetness hazard	Well and moderately well drained soils not subject to ponding. Over 4 feet to seasonal water table.	Well and moderately well drained soil subject to occasional ponding. Somewhat poorly drained not subject to ponding Seasonal water table 2-4 feet. 3/	Somewhat poorly drained soil subject to ponding. Poorly and very poorly drained. Seasonal water table less than 2 feet.
Flooding hazard	Soils not subject to flooding	---	Soils subject to flooding
Slope	0-6%	6-15%	15% +
Rockiness 4/	0	1	2,3,4, or 5
Stoniness 4/	0, 1	2	3,4,5
Depth to hard bedrock	>6 feet	3 - 6 feet 3/	<3 feet

For footnotes see next page.

Figure 38. Soils Criteria, Recreational Use

1/ For soil suitability for septic tank filter fields and for shrink-swell potential see National Guide (Soils Memorandum 53). Hillside slippage, frost heave, piping, loose sand, and low bearing capacity when wet are additional items not included in this rating that must be considered.

2/ Soils rated as having a severe soil limitation for individual cottage sites may be best from an aesthetic or use standpoint but they do require more preparation or maintenance for such use.

3/ These items are limitations only where basements and underground utilities are planned.

4/ Based on definitions in Soil Survey Manual, pp. 217-221.

Soil Limitations for Paths and Trails

This soil rating applies to areas that are to be used for trails, cross-country hiking, bridle paths, and nonintensive uses which allow for random movement of people. It is assumed that these areas are to be used as they occur in nature and little soil moved (excavated) for the planned recreational use. Soils such as swamps, marshes, peat bogs, and the like are considered as having a very severe limitation and are not included in this grouping.

Soils are rated on the basis of three classes for degree of soil limitation - slight, moderate, or severe. Ratings are based on soil features only and do not include other items that may be important in the selection of a site for this use. Soils rated as having severe soil limitations may be best from an aesthetic or use standpoint but they do require more preparation or maintenance for such use.

Degree of Soil Limitation

Items Affecting Use	Slight	Moderate	Severe
Wetness hazard 1/	Well and moderately well drained soils.	Well, moderately well drained soils subject to ponding and somewhat poorly drained soils.	Poorly drained and very poorly drained soils.
Flooding hazard 1/	Not subject to flooding	Subject to occasional flooding	Frequent flooding
Slope 2/	0-12%	12-20%	> 20%
Surface texture 3/	sl, fsl, vfsl, l Gravelly and nongravelly: moderately fine, moderately coarse, and coarse	sil, scl, cl, sc, ls	sic, c, loose sand All very gravelly soils.
Surface stoniness or rockiness 4/	Classes 0, 1, and 2	Class 3	Classes 4 and 5

1/ Season of use should be considered in evaluating these items.
2/ Soil erodibility is an important item to evaluate in rating this item. Some adjustments in slope due to climate may be warranted.
3/ In arid and subhumid climates some of the finer textured soils may be reduced one soil limitation class.
4/ Based on definitions in Soil Survey Manual, pp. 217-221.

Soil Limitations for Intensive Play Areas

These soil ratings apply to areas to be developed for playgrounds and organized games, as baseball, football, badminton, and the like. They are subject to intensive foot traffic. Areas selected for this use generally require a nearly level surface, good drainage, and a soil texture and consistence that gives a firm surface. The most desirable soils are also free of rock outcrops and coarse fragments. It is assumed that good vegetative cover can be established and maintained on areas where needed.

Rate use on the basis of three classes for degree of soil limitation - slight, moderate, and severe. Ratings are based on soil features and do not include other items that may be important in the selection of an area. Soils such as marsh, swamps, rock outcrops, and the like are considered as having a very severe limitation and should not be grouped with soils classified as severe.

See table on next page.

Degree of Soil Limitation

Items Affecting Use	None to Slight	Moderate	Severe
Wetness hazard	Well and moderately well drained soils with no ponding.	Well and moderately well drained soils subject to occasional ponding of short duration. Somewhat poorly drained soils.	Somewhat poorly subject to ponding and poorly, and very poorly drained soils. Too wet for use for periods of 1 week or more.
Flooding hazard	None	---	Soils subject to flooding.
Permeability 1/	Very rapid to moderate.	Moderately slow and slow.	Very slow.
Slope	0-2%	2-6%	6% +
Surface soil texture	sl, fsl, vfsl, l, and ls with text. B horizon free of coarse fragments.	cl, scl, sicl, sil, ls, and sand	sc, sic, c, organic soils and sand subject to blowing.
Depth to hard bedrock	5 feet +	2-5 feet 2/	Less than 2 feet
Stoniness 3/	Class 0	Classes 1 and 2	Classes 3 and 4
Rockiness	None	None	1, 2
Coarse fragments	0-15%	- - -	15% +

1/ In arid regions the degree of soil limitation imposed by soil permeability may be reduced by one class.
2/ This soil has a severe limitation if slope is greater than 2 %.
3/ As per definitions in Soil Survey Manual, pp. 217-221.

Soil Limitations for Picnic Areas Subject to Intensive Use

Soil ratings are on the basis of three classes for degree of soil limitation - slight, moderate, or severe. These ratings are based on soil features only and do not include other features as presence of trees or lakes which may affect the desirability of a site. Suitability of soil for supporting vegetation is a separate item to be considered in the final evaluation of selecting sites for these uses.

Degree of Soil Limitation

Items Affecting Use	None to Slight	Moderate	Severe
Wetness hazard	Well and moderately well drained soils not subject to ponding.	Well drained, moderately well drained soil subject to occasional ponding. Somewhat poorly drained not subject to ponding.	Poorly drained and very poorly drained soils. Somewhat poorly drained soils subject to ponding. Too wet for use for periods of 1 week or more.
Flooding hazard	None during season of use	May flood 1 or 2 times for short period during season of use.	May flood more than twice during season of use.
Slope	0-6%	6-15%	15% +
Surface soil texture	sl, fsl, vfsl, l and ls with textural B. Not subject to blowing.	cl, scl, sicl, sil, ls, and sand other than loose sand. 1/	sc, sic, c, organic and sand subject to soil blowing.
Stoniness 2/	Classes 0, 1, and 2	Class 3	Classes 4 and 5
Rockiness	Classes 0, 1 and 2	Class 3	Class 4

1/ In arid and subhumid climates fine textured soils may be classified as having a moderate limitation.
2/ See definition in Soil Survey Manual, pp. 217-221.

Soil Limitations for Intensive Camp Areas 1/

These soil ratings apply to areas suitable for tent and camp trailer sites and the accompanying activities for outdoor living. They are used frequently during the camping season. These areas require little site preparation and should be suitable for unsurfaced parking for cars and camp trailers and heavy foot traffic by humans or horses or vehicular traffic. The soils should be free of coarse fragments and rock outcroppings. Suitability of soil for supporting vegetation is a separate item to be considered in the final evaluation of selecting sites for these uses.

Rating guide: Soils such as swamps, marsh, rock outcrops, and the like are considered as having very severe limitation and should not be classified as severe. These soils should be listed in a separate grouping.

Degree of Soil Limitation

Items Affecting Use	None to Slight	Moderate	Severe
Wetness hazard	Well and moderately well drained soils with no ponding and with water table below 3 feet.	Moderately well drained soils with water table less than 3 feet and somewhat poorly drained soils with no ponding.	Well drained, moderately well drained and somewhat poorly, with occasional ponding of short duration and poorly, and very poorly drained soils.
Flooding hazard	None	- - -	Subject to flooding
Permeability 2/	Very rapid to moderate	Moderately slow and slow	Very slow
Slope	0-6%	6-15%	15% +
Surface soil texture	sl, fsl, vfsl, l, and ls with text. B horizon. Not subject to soil blowing	cl, scl, sicl, sil, ls, and sand other than loose sand	Organic, sc, sic, c, and sand subject to soil blowing.
Coarse fragments "10"	Less than 15%	15-50%	Over 50%
Stoniness or rockiness 3/	None	Classes 1 and 2	Classes 3 and 4

1/ Based on soil limitations during use season.
2/ In low rainfall areas soil limitations imposed by permeability may be reduced one class.
3/ For definitions see Soil Survey Manual, Pp. 217-221.

SOIL CORROSIVITY

Soil corrosivity correlates closely with physical, chemical, and biological characteristics and qualities of soil. Structural materials, such as metal or concrete pipe, corrode when buried in soil; and a given material will corrode in some soils more rapidly than in others. Corrosion differs with the general character of the soil. To be meaningful corrosivity must be given in relation to a specific structural material.

Untreated Steel Pipe

Corrosion of untreated steel pipe is a physical-biochemical process converting iron into its ions. Soil moisture is needed to form solutions with soluble salts in an environment having differential concentrations before the process can operate. This constitutes a corrosion cell. Any factors influencing the soil solution or the oxidation-reduction reactions taking place in the soil will influence the operation of the corrosion cell. Some of these factors are soil moisture content, conductivity of soil solution, hydrogen ion activity of soil solutions (pH), oxygen concentration (aeration), and activity of organisms capable of causing oxidation-reduction reactions. The corrosivity of soil for untreated steel pipe is commonly determined by (1) electrical resistivity or resistance to flow of current, (2) total acidity, (3) soil drainage, and (4) soil texture.

On the basis of data provided in the publication, "Underground Corrosion," table 99, page 167, Circular 579, U.S. Department of Commerce, National Bureau of Standards, the Service will use five soil corrosivity classes in making soil interpretations. These classes are as follows:

Very low. Somewhat excessive to excessively drained coarse-textured soils with very little clay in the control section of the soil. Water and air move through the soil rapidly to very rapidly. The total acidity is below 4.0 meq. per 100 g. of soil and resistivity at moisture equivalent (field capacity) is 10,000 ohms per cm. or greater (noncorrosive).

Low. Well drained soils with moderately coarse and medium-textured control sections. Imperfectly or somewhat poorly drained soils with coarse-textured subsoils. The soils are moderately to rapidly permeable. The total acidity ranges from 4.0 to 8.0 meq. per 100 g. of soil or electrical resistivity at moisture equivalent is 5,000 to 10,000 ohms per cm. (slightly corrosive).

Moderate. Well drained soils with moderately fine-textured control sections; moderately well drained soils with medium-textured control sections. Also included are imperfectly or somewhat poorly drained soils with moderately coarse-textured subsoils. Where the water table remains at the surface throughout the year, very poorly drained soils, including peats and mucks, are included. Permeability is moderately slow to slow. The total acidity ranges from 8.0 to 12.0 meq. per 100 g. of soil or electrical resistivity at moisture equivalent is 2,000 to 5,000 ohms per cm. (moderately corrosive).

High. Well and moderately well drained fine-textured soils, moderately well drained moderately fine-textured soils, imperfectly or somewhat poorly drained soils with medium and moderately fine-textured control sections, or poorly drained soils with coarse to moderately fine-textured control sections. Very poorly drained soils are included where the water table fluctuates within one foot of the surface sometime during the year. The total acidity ranges from 12.0 to 16 meq. per 100 g. of soil or electrical resistivity at moisture equivalent is 1,000 - 2,000 ohms per cm. (severely corrosive).

Very high. Imperfectly or somewhat poorly to very poorly drained fine-textured soils. Mucks and peats with fluctuating water tables are included. Total acidity is greater than 16 meq. per 100 g. of soil or electrical resistivity at moisture equivalent is below 1,000 ohms per cm. (very severely corrosive).

Single soil property or soil quality determinations tempered by the knowledge of other soil properties and qualities that affect corrosion are useful in placing soils in relative corrosivity classes. A study of soil properties in relation to local experiences with soil corrosivity will help the soil scientist and engineer in making soil interpretations for soil corrosivity. Special attention should be given to those soil properties that affect the access of oxygen and moisture to the metal, the electrolyte, the chemical reaction in the eletrolyte, and the flow of current through the electrolyte. If predictions are to be made of the soil corrosivity on steel pipe, it will be necessary to determine the corrosivity of each major soil horizon to a depth where the conduits are to be placed.

Concrete Conduits

Concrete conduits placed in soil materials deteriorate to varying degrees depending on (1) soil texture and soil acidity, (2) amount of sodium or magnesium sulfate present in the soil singly or in combination 1/, and (3) amount of sodium chloride in the soil. Three soil corrosivity classes will be used by the Service in making soil interpretations. These classes are described as follows:

Low. (1) Sandy and organic soils with pH $>$6.5 or medium and fine-textured soils with pH $>$ 6.0. (2) Soils with $<$1,000 parts per million of Na and/or Mg sulfate. (3) Soils with $<$2,000 parts per million of sodium chloride.

Moderate. (1) Sandy and organic soils with pH 5.5 to 6.5 and medium and fine-textured soils with pH 5.0 to 6.0. (2) Soils with 1,000 to 7,000 parts per million of Na and/or Mg sulfate. (3) Soils with 2,000 to 10,000 parts per million of sodium chloride.

1/ Adaptation of $NaSo_4$ and $MgSo_4$ ranges shown in engineering standards. SCS National Engineering Handbook, Chapter 5, table 5.2.

<u>High</u>. (1) Sandy and organic soils with pH 5.5 or less and medium and fine-textured soils with pH 5.0 or less. (2) Soils with more than 7,000 parts per million of Na and/or Mg sulfate. (3) Soils with more than 10,000 parts per million of sodium chloride.

<u>Related Problems</u>

Corrosion probability is greater for extensive installations that intersect soil boundaries or soil horizons than for installations that remain in one kind of soil or soil horizon.

Construction of buildings, paving, fill and compaction, surface additions, etc., that alter the soil permeability can increase corrosion probability by providing a differential oxidation cell that accelerates corrosion in the less permeable portion of the soil or the portion receiving less oxygen.

Mechanical agitation or excavation that results in nonuniform mixing of soil horizons may also accelerate the corrosion probability.

The use of soil corrosivity interpretations without considering the size of the metallic structure or the differential effects involved through use of different metals may lead to the wrong conclusions.

SOIL SHRINK-SWELL BEHAVIOR CLASSES

Shrink-swell behavior is that quality of the soil that determines its volume change with change in moisture content. Much damage to building foundations, roads, and other structures is due to shrinking and swelling of soils as a result of drying and wetting. The volume change behavior of soils is influenced by the amount of moisture change and amount and kind of clay present in the soil. Thus, knowledge of the kind and distribution of clay helps predict the behavior of the soil.

Methods in use for determining the shrink-swell behavior of soils are both quantitative and qualitative. The quantitative methods are the coefficient of maximum potential soil movement used by soil scientists, and the Shrinkage Index used by soil engineers 1/. The Shrinkage Index is defined as the difference between the Plastic Limit and the Shrinkage Limit. The qualitative method is related to the classes in the Unified Soil Classification System developed by the Corps of Engineers 2/. The following classes are used to help interpret soil maps for shrink-swell behavior 3/:

1/ "PCA Soil Primer," Portland Cement Association. 1962.
2/ "The Unified Soil Classification System," Technical Memorandum No. 3-357, Vol. 1, Waterways Experiment Station, U.S. Corps of Engineers, March 1963.
3/ Soil shrink-swell classes are based on the B horizon or control section. These interpretations apply to light structures three stories or less in height, roads, and to other similar types of structures.

Low. Generally includes soils with silt loam, loam, sandy loam, loamy sand, and sand textures with any kind of clay minerals and sandy clay loam with predominantly kaolinitic clays. These soils have a CMPM (coefficient of maximum potential soil movement) less than .010 and Shrinkage Indexes of less than 5. Unified ratings are usually ML or SM but a few soils have CL and SC ratings. The following are representative benchmark soils:

Gloucester	(SM) 1/	Norfolk	(CL)
Hanford	(ML)	Plainfield	(SM)*
Hiawatha	(SP)*	Tivoli	(SM)*
Lakeland	(SP-SM)	Valentine	(SM-SP)

Moderate. Generally includes soils with silty clay loam, clay loam, silty clay, sandy clay, and clay textures with predominantly kaolinitic clays; or heavy silt loam, light sandy clay, and silty clay loams with mixed clay minerals. These soils have a CMPM between .010 and .040 and Shrinkage Indexes of 5 to 7. Usually the soils in this grouping are those with kaolinitic clays with a CH rating or soils with mixed clay minerals with CL or ML ratings. The following are representative benchmark soils:

Aiken	(MH)	Hagerstown	(CH)
Cecil	(CH & CL)	Holdrege	(CL)
Dalhart	(SC)	Josephine	(ML)
Dunmore	(CH)	Mardin	(CL)
Fayette	(CL)	Miami	(CL)
Frederick	(CH)*	Muscatine	(CL)
Fullerton	(CH)		
Guernsey	(MH or CH)*		

High. Generally includes soils with clay loam, silty clay loam, silty clay, and clay textures with mixed clay minerals or montmorillinitic clays. These soils have a CMPM of .040 or greater and Shrinkage Indexes of more than 7. Usually these are soils with mixed or montmorillinitic clay minerals with CH ratings. The following are representative benchmark soils:

Beaumont	(CH)	Hoytville	(CH)
Blount	(CH)	Iredell	(CH)
Boswell	(CH)	Sharkey	(CH)
Fargo	(CH)	Springerville	(CH)
		Wabash	(CH)

1/ Unified Soil Classification of the finest textured horizon - tests made by the Bureau of Public Roads.

* Estimates made by engineers and soil scientists and included in published soil surveys.

SEPTIC TANK FILTER FIELDS

The septic tank filter field is a part of the septic tank soil absorption system for 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 the soil limitations. Three groupings are made: Slight, moderate, and severe.

Some factors important in determining the suitability of a soil for a filter field are (1) local experience and records of performance of existing filter fields, (2) permeability of the soil, (3) depth to consolidated rock or other impervious layers, (4) flooding, (5) ground water level, and (6) slope.

Performance of Existing Systems

Records or observations of correctly designed and installed septic tank systems that failed within a few years after installation are indicators of an unsuitable soil. Clues to watch for besides information from the homeowner, are rank vegetational growth, seepage, or odor in the vicinity of the absorption system.

Soil Permeability

Soils with moderate to very rapid permeability are rated as having a "slight" soil limitation. Soils with a permeability at the slower end of the moderate range (about 1.0 to 0.63 inches per hour) are rated as having a "moderate" soil limitation unless measured results or experience show a "slight" limitation. Soils with a permeability rate of less than 0.63 inches per hour are rated as having a "severe" soil limitation if used for a filter field.

Although soils with rapid permeability have slight soil limitations, it should be noted that a contamination hazard exists if water supplies, streams, ponds, lakes, or water courses are nearby (see coarse-textured soils). Very coarse-textured soils with very rapid permeability have moderate or severe limitations.

Soil Percolation Rate

Experience has shown that soils having percolation rates (1) faster than 45 minutes per inch function satisfactorily, (2) between 45 and 75 minutes per inch have moderate limitations, and (3) slower than 75 minutes per inch have severe limitations when used as filter fields for septic tanks.

Field percolation tests made by local health departments are usually conducted under a wide range of soil moisture conditions and, therefore, the results should be interpreted with caution. Results are reliable only if the soil moisture is at or near field capacity when the test is run. In fact, nearly impermeable soils on which filter fields have failed can give high percolation test results after periods of drought. In addition to soil properties that influence percolation rates, the biological activity in the soil may also influence the functioning of the filter field after it is in operation. In the absence of reliable data on percolation rates, estimates can be made from data on soil permeability. Because the methods of measuring percolation and permeability are different, the correlation between the two values is imperfect. Use the following rough correlation cautiously:

General Relationship of Soil Limitations to Permeability Classes and Percolation Rates

Soil Properties	Soil Ratings in Terms of Limitations		
	Slight	Moderate	Severe
Permeability class 1/	Rapid, moderately rapid, and upper end of moderate.	Lower end of moderate.	Moderately slow and slow. 2/
Hydraulic conductivity rate (Uhland core procedure)	More than 1.0 inch/hr.	1.0 to 0.63 inch/hr.	Less than 0.63 inch/hr.
Percolation rate (Post hole procedure)	Faster than 45.0 min./inch	45 to 75 min./inch	Slower than 75 min./inch

1/ Class limits are the same as those suggested by the National Soil Survey Work Planning Conference of the Cooperative Soil Survey.
2/ In arid or semiarid areas soils with moderately slow permeability may have a moderate limitation.

Ground Water Level
A seasonal water level should be at least 4 feet below the soil surface for soils rated as having a slight limitation 3/. Soils with water levels at 1-4 feet below the soil surface should be rated as having moderate or severe limitations, depending upon the frequency or duration of wetting. In the humid area of the United States, soil drainage classes provide clues to soil limitations. Well drained and most moderately well drained soils that are readily permeable have slight limitations. Somewhat poorly drained and some moderately well drained soils have moderate limitations. Poorly and very poorly drained soils have severe limitations.

Impervious Layers
Impervious layers including rock formations should be more than 4 feet below the bottom of the tile trench floor.

3/ Manual of Septic Tank Practice, U.S. Department of Health, Education, and Welfare, Public Health Service.

Creviced or Fractured Rock
Creviced or fractured rock without an adequate soil cover permits unfiltered sewage to travel long distances. At least four feet of moderately coarse or finer textured soil material should occur between the bottom of the tile trenches and such rock.

Coarse-Textured Soils
Coarse-textured soils (loamy sand, sand, and gravel) are relatively poor filtering materials. These soils permit unfiltered sewage to travel long distances. Ratings on the basis of permeability alone should be supplemented by a statement about the hazard of contaminating nearby water supplies.

Soils in Drainageways and on Flood Plains
Soils that flood have severe limitations even if the permeability rate is high and the ground water level is below four feet. Floodwaters interfere with the functioning of the filter field and carry away unfiltered sewage. In addition, areas subject to flooding are not suitable for home sites.

Related Problems
Slopes of less than 10 percent are the most desirable sites from the standpoint of construction and successful operation of the filter field. Mechanical problems of layout and construction increase with steepness of slope. Lateral seep or flow down-slope is a problem on sloping soils especially where bands of impermeable material occur in the 0-4 foot depth. Large rocks, boulders, and rock outcrops increase construction costs. On sloping soils the grade of the trench system cannot be maintained if the obstacle cannot be removed. Trench lines can be installed and grade maintained around these obstacles on nearly level soils.

Detergents in solution are readily transmitted through some soils and may contaminate ground water supplies. Sodium salts from water softeners and other sources tend to disperse the clay in the soil and reduce the effectiveness of the filter field.

SEWAGE LAGOON REQUIREMENTS AND THE CRITERIA USED IN EVALUATING SOILS FOR DEVELOPING LAGOONS

A sewage lagoon is a shallow lake used to hold sewage for the time required for bacterial decomposition. Sewage lagoons require consideration of the soil for two functions, (1) as a floor for the impounded area and (2) as material for the dam. The requirements for the dam are the same as for other embankments designed to impound water. There must be adequate soil material available that is suitable for the structure, and when properly constructed the lagoon must be capable of holding water with minimum seepage. The material should be free of coarse stone-size fragments (more than six inches in diameter) that interfere with compaction processes.

Material of the Unified Soil Classification groups GC, SC, and SM are most satisfactory 1/. The coarse groups with few of the fines (GW, GP, SW, and SP) have high limitations and are poorly suited. The groups consisting of soils high in organic matter (OL, OH, and Pt) also have severe limitations and are poorly suited. Soil material of the other Unified Classification groups (GM, CL, CH, ML, and MH) are suitable when properly compacted or if used in combination with soils classified as GC, SC, and SM.

Soil requirements for basin floors of lagoons are: (1) Effective sealing against seepage, (2) even surface of low gradient and low relief, and (3) little or no organic matter. Specifications for lagoons state that the liquid depth should be not less than two feet and generally not more than five feet, that the floor should be as level as possible, and that the materials for the basin floor should be sufficiently impervious to preclude excessive liquid loss 2/. The impervious soil material should be at least one foot thick. This is especially important where the water supply is from shallow wells since the well water may be contaminated. Using table 1 (attached) as a guide, the following items are to be considered in evaluating the degree of limitations for soils forming the lagoon impoundment site:

Soil Permeability

Soil Material at Reservoir Site

Soils classified in the Unified Soil Classification system are grouped into three classes according to their "degree of limitation" for a sewage lagoon site. The "slight" limitation class includes soils effective in functioning as well sealed basin floors and are low in organic matter. Soils in the "moderate" limitation class are those that require special practices or treatment to modify soil limitations so they qualify for use as sewage lagoons. Soils placed in the "severe" limitation class are those that are either very porous or high in organic matter and have severe soil limitations that normally prevent their use for sewage lagoons.

the thickness of suitable soil material generally need not be more than 36 to 60 inches. Surface runoff water must be kept from entering the lagoon. This is often difficult to avoid on steeper slopes.

Organic Matter
Moderate to high amounts of organic matter are unfavorable in the basin floor even though it is underlain by suitable soil material. They promote aquatic plant growth which is detrimental to proper functioning of the lagoon.

Coarse Fragments
Fragments more than six inches in diameter interfere with manipulation and compaction of the soil material in the process of smoothing the basin floor and are therefore undesirable in sewage lagoon sites.

Table I - Criteria for evaluating degree of soil limitation for sewage lagoons.

A.--Soil in place under embankment and impoundment.

Items to evaluate	Class definition and degree of limitation for lagoon basin floors			
Permeability	Less than .63 inch per hour--SLIGHT	.63 to 2.0 inches per hour--MODERATE	More than 2.0 inches per hour--SEVERE	
Depth to hard rock	More than 60 inches SLIGHT	36 to 60 inches MODERATE	20 to 36 inches SEVERE	Less than 20 inches VERY SEVERE
Slope and relief	Less than 2 percent SLIGHT	2 to 7 percent MODERATE	More than 7 percent SEVERE	
Organic Matter	Less than 2 percent SLIGHT	2 to 15 percent MODERATE	More than 15 percent SEVERE	
Coarse fragments less than 6 inches in diameter	Less than 50 percent by volume--SLIGHT to MODERATE	More than 50 percent by volume--SEVERE		
Coarse fragments more than 6 inches in diameter	Less than 3 percent 1/ of surface area SLIGHT	3 to 15 percent 1/ of surface area MODERATE	More than 15 percent 1/ of surface area SEVERE	
Soil material at 2/ reservoir site	GC,SC,CL,CH---SLIGHT	GM,ML,SM,MH---MODERATE	GP,GW,SP,SW,OL,OH,Pt---SEVERE	

1/ See Soil Survey Manual , page 217, for stoniness classes.
2/ Undisturbed soil underlying the embankment and impoundment.

B.--Soil as a source of embankment material.

For embankment construction	GC,SC,SM---SLIGHT	GM,CL,CH,ML,MH---MODERATE	GW,GP,SW,SP,OL,OH,Pt---SEVERE

APPENDIX D

HYDROLOGY OF GRAYSON COUNTY, TEXAS

The hydrologic cycle is an endless process of water circulation going on throughout the world. Almost all water is concentrated in the oceans. Energy from the sun converts some of this liquid water to gaseous water vapor. Additional warming causes the moisture-laden air to rise until cooling causes clouds to form. The clouds also contain fine dust, particles of sea salt, and other foreign matter. When clouds cool, rain drops form around these bits of foreign matter and fall to the earth. As they fall, they pick up carbon dioxide and other matter. Rain that falls on a land surface soaks in, runs off, or is picked up immediately by plants. Eventually, most water that falls on the earth's surface is converted to water vapor and returned to the hydrologic cycle. Figure 40 illustrates these elements of the hydrologic cycle.

Climate

Grayson County has a moist subhumid climate that is typically hot in summer and mild in winter. The mean annual temperature is 64°F. The mean July and January temperatures are about 84°F and 43°F, respectively. Freezing weather and snow are infrequent and generally of short duration. Precipitation averages approximately 40 inches annually and is fairly well distributed over the year. Rainfall is

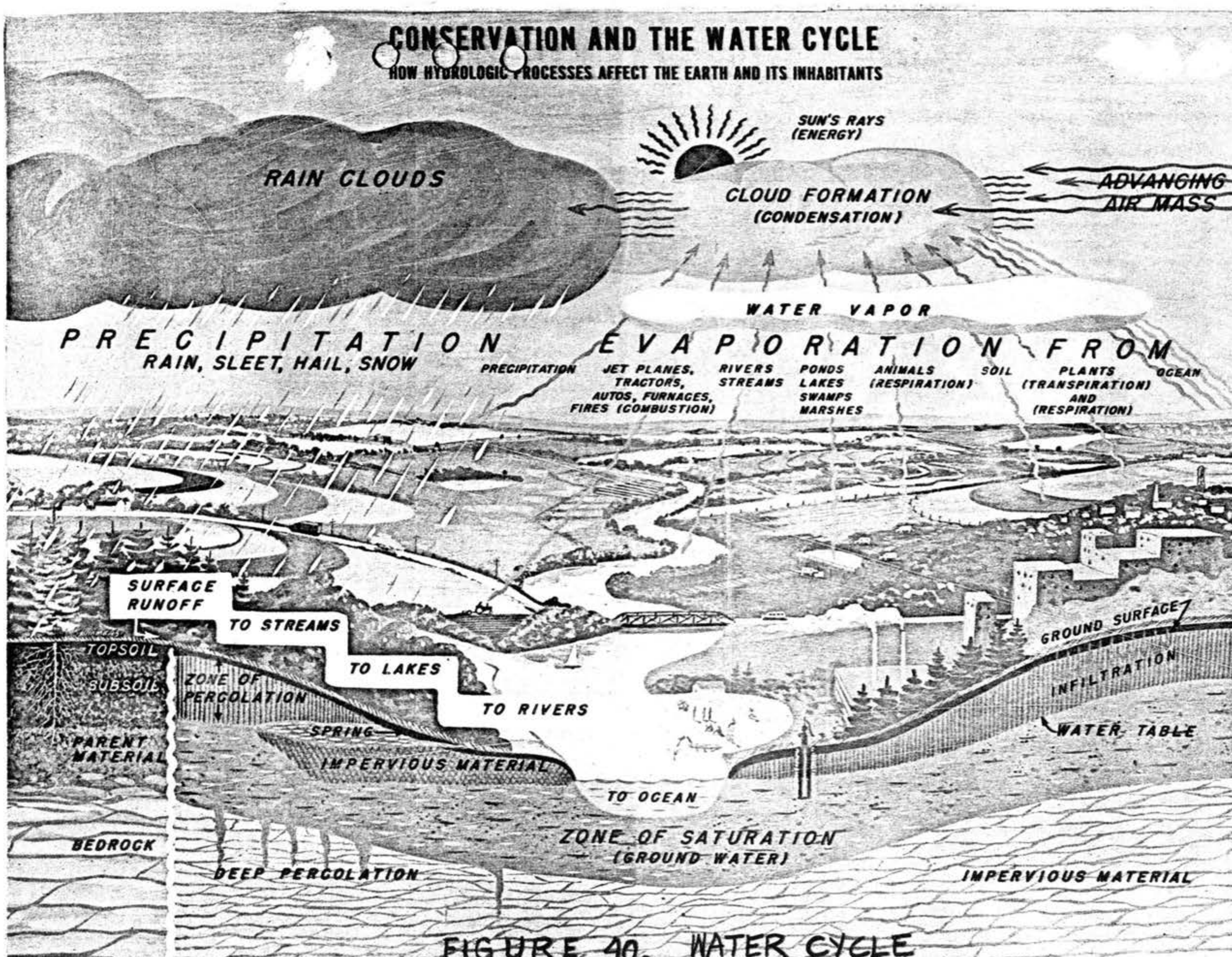


FIGURE 40. WATER CYCLE

greatest during April through June and is least from November through February. Heavy rains measuring 4 inches or more are not uncommon. Droughts sometimes occur in late summer, but are not of excessive duration. The average annual evaporation is about 74 inches, or roughly twice the annual average precipitation. Evaporation is greatest in late summer, the time when water demand is also greatest.

Topography

The altitude of Grayson County ranges from approximately 900 feet above sea level in an area about 5 miles west of Denison to approximately 500 feet along the Red River at the Fannin County line in the northeast; thus, maximum relief is about 400 feet. The area of greatest relief is in the vicinity of Lake Texoma, where erosion of Trinity sands has undercut overlying strata consisting of more resistant limestone and marl thus creating a very rugged topography.

The northern two-thirds of Grayson County slopes north and east to the Red River, while the southern third of the county drains south into the Trinity River watershed. The divide separating these two drainage systems is defined by a line passing near the towns of Whitesboro, Howe, Tom Bean, and Whitewright. Figure 41 illustrates the primary drainage features in Grayson County. Both Sherman and Denison lie north of the divide line and are consquently removed from the problems of the Trinity watershed as related to the Dallas-Fort Worth metropolitan complex.

Choctaw Creek, which heads about 6 miles southwest of Sherman, drains the northeastern part of the county, joining the Red River near the Fannin County line. Mineral Creek and other intermittent

Figure 41. Regioanal Drainage System

tributaries of the Red River drain the northwestern part of the county and empty into Lake Texoma. The southwestern area is drained by Range, Bush, and Little Elm Creeks, which empty into Lake Dallas in Denton County. Pilot Grove Creek, Sister Grove Creek and the East Fork of the Trinity River drain the southeastern area into Lake Lavon in Collin County.

Drainage in the Sherman area is governed by a ridge running northwest to southeast through the urban center. Areas to the west of this ridge drain south and southeast via Sand and Post Oak Creeks to Choctaw Creek. Surface drainage to the northeast of the ridge is generally to the Blue, Calf and Iron Ore Creek branches of the Choctaw. Figure 42 illustrates the primary drainage features in the Sherman area.

Surface Water

The primary source of surface water in Grayson County is Lake Texoma, a 141,000 acre multi-purpose reservoir impounded on the Red River by Denison Dam. 46,000 acres of this lake are included within the boundaries of Grayson County. Two small multipurpose reservoirs, Randell Lake and Waterloo Lake, are located in the Denison area. Numerous small erosion control dams are located throughout the county. Only Lake Texoma and Randell Lake are used for water supply. (Denison is permitted to draw 5,400 acre-feet annually from Randell Lake.)

The mineral content of Lake Texoma water contains excessive amounts of chloride, sulfates, and dissolved solids (salts) based on public health agency criteria for chemical quality of drinking water. Though it is possible to correct Lake Texoma's pollution problem

Figure 42. Sherman Drainage System

through comprehensive pollution control actions, both Sherman and Denison are seeking additional sources of water suitable for drinking, industrial, and agricultural use. Currently being considered is a project to dam across Big Mineral Arm of Lake Texoma in an effort to create 94,000 acre-feet of fresh water supply.

The critical importance of Lake Texoma to the future of North Texas (and southern Oklahoma) is indicated in recent proposals by the Texas Water Development Board that consideration be given to: (1) the diversion of surplus water in Lake Texoma to the Dallas-Fort Worth area; and (2) the development of a system which would be capable of transporting surplus water from the Mississippi River up the Red River into Lake Texoma where it could be staged on into the Texas Panhandle.

Ground Water[1]

Water Bearing Formations

In Grayson County, ground water is found principally in strata of the Woodbine formation and the Trinity group. The Woodbine and Trinity sands supply roughly two-thirds and one-third, respectively, of the county's ground water demand. These strata outcrop in northern Grayson County and underlie most of the eastern part of the county. Alluvial deposits northeast of Denison on the Red River yield small to moderate amounts of water, chiefly to domestic wells.

Occurrence and Movement

Rocks contain open spaces, called voids or interstices, which determine the hydraulic characteristics of the strata. While the capacity of a rock to hold water is determined by its porosity, its capacity to yield water is determined by its permeability. Below a certain level the permeable rocks are saturated with water under hydrostatic pressure. The upper surface of the zone of saturation is called the water table. Wells dug or drilled into the zone of saturation become filled with ground water to the level of the water table.

Artesian conditions exist where permeable strata pass between less permeable strata. Water enters the aquifer at its outcrop and percolates slowly down to the water table and then laterally down the dip of the water bearing strata beneath the overlying confining strata. The water exerts pressure against the confining strata, so that when a well is drilled through the confining strata the pressure is released and water rises above the level at which it is found. Artesian conditions prevail in Woodbine and Trinity stratas where they are overlain by impermeable strata.

The rate of movement of water through an aquifer depends upon its porosity, permeability, and hydraulic gradient. Ground water moves from areas of recharge to areas of discharge under the influence of gravity; however, the movement is generally very slow. The time necessary for water to move from the areas of recharge of the Trinity and Woodbine sands to Sherman would be measured in centuries. However, in local areas of heavy pumping, water moves from the surrounding areas toward the discharge point; thus, much of the present water movement in the Woodbine and Trinity sands is probably accelerating toward Sherman, where heavy pumping has brought about a large decline in the water levels.

Recharge

Recharge of ground water reservoirs results from the infiltration of water from precipitation on the outcrop of the formation, by seepage from lakes or other bodies of surface water, or by vertical or lateral movement of water from one underground reservoir to another. (This latter process is not a primary source of recharge but only incidental to underground water movement.)

Ground water in Grayson County is derived chiefly from precipitation on the outcrop of the water bearing strata. (The soil mantle and outcropping rocks of the Trinity and Woodbine strata provide an excellent facility for recharge of ground water.) Recharge is most effective during periods of long, heavy rainfall when the requirements of evaporation and transpiration are quickly satisfied, thus allowing the surplus water to run off or penetrate to the water table.

Water may enter the aquifer by infiltration from lakes impounded on its outcrop or by streams flowing over the outcrop (making pollution control of surface water vital). The Trinity strata receives some recharge from Lake Texoma where its outcrop is covered by lake waters (Lake Texoma, however, is a discharge area for Woodbine which outcrops above the lake surface.)

Discharge

Ground water discharge is both natural and artificial. Water in underground reservoirs is discharged naturally through springs and seeps, evaporation, transpiration by plants, underflow out of the county, and, in the artesian parts of the reservoirs, by upward movement of water through less permeable, confining strata. Ground water is discharged through springs and seeps wherever the land surface intersects the water table. Ground water is discharged by evapo-transpiration principally from the outcrop of the Woodbine and Trinity strata. Most of the water transpired is discharged by plants which obtain their water supply from the zone of saturation, and by cultivated plants. The discharge is greatest in areas of dense vegetation where the water table is close to the surface.

Before articifical development of ground water takes place, aquifers are virtually in a state of equilibrium, with the amount of recharge equalling the amount of discharge. Artificial discharge imposes new conditions on the stable system, and the discharge must be balanced by an increase in the amount of recharge, a decrease in the natural discharge, a loss of water from storage in the aquifers, or by a combination of these methods.

Use of Ground Water

Trinity and Woodbine water supplies the municipal and nearly all the industrial, domestic and agricultural needs of Grayson County; however, Denison, as mentioned previously, obtains its municipal supplies from Lakes Randell and Texoma.

Development

The ground water resources of the county are only partly developed. The amount of fresh water in transient storage in the Woodbine formation and the Trinity group is estimated to be about 25 million and 60 million acre-feet, respectively. Most of the water is not economically recoverable at present because of the great depth at which it occurs. However, relatively high artesian heads and large available drawdowns are favorable factors for future development. A factor limiting any large scale well development, however, is the volume of saturated fresh-water sand available in the area. The amount of fresh-water sand in the Trinity strata decreases northward, principally as a result of an increase in the salinity of the ground water near Lake Texoma. Consquently, in much of northern Grayson County, large developments of fresh ground water from the Trinity are not feasible. Large to moderate amounts of fresh water may be obtained from the Woodbine in areas where the amounts of saturated sand are greatest. The Woodbine has been developed near its maximum potential in the Sherman area due to heavy pumping over the past few decades; however, at a greater depth there are abundant fresh ground water resources in the Trinity strata.

Quality

The ground water in Grayson County is suitable for most purposes. The Trinity group generally yields soft water that has high bicarbonate and sodium contents. Water from the Woodbine is generally soft but may have a high iron content. The alluvial formations yield water which is suitable for most purposes.

FOOTNOTES

[1] This discussion on ground water is derived from Ground-Water Geology of Grayson County, U. S. Geological Survey Water-Supply Paper 1646, 1963.

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